

Review article:

A REVIEW ON BIOLOGICAL AND CHEMICAL DIVERSITY IN *BERBERIS* (BERBERIDACEAE)

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ABSTRACT

Berberis is an important genus and well known in the Indian as well as European systems of traditional medicine. It is used since ancient times for curing eye disease, fever, jaundice, rheumatism, vomiting during pregnancy, kidney and gall bladder stones and various other ailments due to the presence of biologically active alkaloid berberine. Action of the root extracts of few species are believed to be as powerful as quinine in the treatment of malarial fever.

A plethora of literature pertaining to the taxonomy, biology, chemistry, traditional and ethnic uses of *Berberis* in different countries and indigenous cultures was collected by both offline (library, journals, textbooks etc.) and online mode (electronic search of available databases). In addition to this, books on traditional medicine and ethno pharmacological knowledge were also referred to extract ancient uses of *Berberis* in different traditional medicine systems. Most of the folklore, traditional and ethno botanical claims about *Berberis* species were validated by broad spectrum *in vitro* and *vivo* pharmacological studies. The present article summarizes its usage in eye and liver disorder, fever, kidney and gall stones along with anticancer activity.

This comprehensive review will not only help researchers for further evaluation but also provide substantial information for future exploitation of species to develop novel herbal formulations.

Keywords: *Berberis*, berberine, pharmacology, ethno botany

INTRODUCTION

The genus *Berberis* has an important place in various traditional systems of medicine worldwide for their efficacious medicinal properties. The ancient Ayurvedic literature of India records uses of *Rasaut* (*Ras* = juice; *out* = frothing and foaming when boiling; hence *Rasaut* means concentrated juice), an extract of either stem or root of *Berberis* sp. The specific uses of *Rasaut* for curing eye diseases and indolent ulcers earned a great fame. In the British Pharmacopoeia, the alkaloid berberine- the active principle in several species of *Berberis* and *Mahonia*, has been

incorporated for its successful use in the treatment of oriental sore.

The roots of *Berberis* species are employed as an anti-periodic, diaphoretic and antipyretic, and its action was believed to be as powerful as quinine. The bark is used as a tonic and anti-periodic. This plant is also well proven for cardio vascular, hepato-protective, antimicrobial and anti-cancerous activities. Hence, a review of genus *Berberis* has been done to put all its activities, ethno botanical claims, pharmacological action along with chemistry. The scientific information compiled in this review is gathered by extensive

search of several electronic databases viz. SCOPUS, Google scholar, NOPR, Pub med, Elsevier, ACs, Medline plus, Web of science, etc. Additionally, the library search and ancient medicinal treatises/text books were also referred for gathering information on the traditional uses of *Berberis*. The review of *Berberis* was also done with an end in view of identifying the knowledge gaps in traditional uses, pharmacological studies, toxicity profiling, clinical trials and other relevant research in this medicinally important genus. Previous reviews on individual species of *Berberis* are available, but a comprehensive update on the entire genus is still lacking. This review will help researchers to identify the latent and patent potentials of *Berberis* and explore further studies on the biological and chemical properties of various species of this genus.

TAXONOMIC HISTORY OF *BERBERIS*

Berberis belongs to the family Berberidaceae, which was first established by A.L. Jussieu in 1789 as 'Berberides' and was considered one of the most primitive families of Angiosperms having a high number of disjunction or discontinuous genera. There is a general agreement among botanists (Kumazawa, 1938; Hutchinson, 1959; Airy Shaw, 1966; Takhtajan, 1969; Meacham, 1980; Nowicke and Skvarla; 1981) that the genera of Berberidaceae are not closely related but are separable into 4 distinct families, namely Lardizabalaceae (*Decaisnea*, *Holboellia*, *Parvattia*), Nandinaceae (*Nandina*), Podophyllaceae (*Podophyllum*) and Berberidaceae (*Berberis*, *Mahonia*, *Epimedium*). Berberidaceae was placed in the order Ranales (Bentham and Hooker, 1862). Several other works (Takhtajan, 1969; Cronquist, 1968) placed it in the order Ranunculales, while one worker (Hutchinson, 1959) included this family under a separate order Berberidales.

First taxonomic account of the family Berberidaceae for the Indian subcontinent (Hooker and Thomson, 1875) included six genera and 17 species. A revision of the genus *Berberis* was made by Schneider during 1905 and 1908 and recorded 13 new species and one variety from Indian region. Subsequently (Schneider, 1942) a monograph of section *Wallichianae* was published in which he recognized 71 species in 8 subsections. Chatterjee (1953) included 68 species of *Berberis*, 11 species of *Mahonia*, one species of *Epimedium* and two species of *Podophyllum*. In a survey (Ahrendt, 1941/45) the *Berberis* spp. from Bhutan, Assam, South Tibet, Upper Burma and Northwest Yunnan and later (Ahrendt, 1961) published a detailed revision of *Berberis* and *Mahonia* species. He included 52 species with 43 infra specific categories under *Berberis* and 11 species under *Mahonia* from the Indian region. It was again revised by including one new species (*B. victoriana*) from the Indian region (Chamberlain and Hu, 1985). Jafri (1975) while dealing with the Berberidaceae for the *Flora of West Pakistan* included only one species of *Mahonia* and 15 species of *Berberis* from Kashmir region. In a more recent study (Rao and Hajra, 1993) while revising the family for the *Flora of India* included 54 species of *Berberis*, one species of *Epimedium* and 13 species of *Mahonia* from the present political boundaries of India.

Singh et al. (1974, 1978) discussed the significance of epidermal structure and leaf architecture in the taxonomy of Berberidaceae. They have studied hardly 5-6 species of the family. Palynologically only five species of *Berberis* have been studied (Nair, 1965) and chromosome numbers in only nine species with five infraspecific categories of *Berberis* and three species of *Mahonia* have been reported (Kumar and Subramaniam, 1986). Some commercially important *Berberis* spp. from Indian region is shown in Figure 1.



B. aristata



B. asiatica



B. lycium



B. chitria

Figure 1: Some important species of genus *Berberis* collected from India

ETHNOBOTANICAL AND TRADITIONAL USES

There has been an increasing interest towards the scientific study of human-plant interaction in the natural environment among the botanists, social scientists, anthropologists, practitioners of indigenous systems of medicine. Jain (1981) undertook intensive field study among tribes of central India and devised methodology for ethno-botany, particularly in the Indian context. Different species of genus *Berberis* are used ethno botanically and medicinally by various tribes and in different traditional medical systems. A detailed pharmacognostic study of some common Himalayan *Berberis* species has been

done by Srivastava et al., 2001, 2004, 2006, 2010; Singh et al., 2009, 2012; Srivastava and Rawat, 2013, 2014. The ethno botanical uses of *Berberis* by different tribal communities in India and some other countries are provided in Table 1.

PHARMACOLOGICAL ACTIVITIES OF *BERBERIS* SPECIES

Berberis has diverse pharmacological potential. Various pharmacological activities of the *Berberis* species make them an important part of polyherbal formulations for the treatment of several diseases and disorders (Figure 2, Table 2).

Table 1: Ethno botanical uses of different species of *Berberis*

Species	Ethno botanical Information	References
<i>B. aristata</i>	In Raithal locality of Uttarkashi (Uttaranchal), India, <i>Rasaut</i> - a popular medicine prepared for eye disorders from the roots of <i>B. aristata</i>	Kirtikar and Basu, 1935; Anonymous, 1948; Hayashi, 1950; Kùpeli et al., 2002; Uniyal, 1964
	In Kumaon region of India, the decoction of root bark from <i>B. aristata</i> and <i>B. asiatica</i> is used for curing eye troubles and boils. A sauce is also prepared from its acidic flower buds	Shah and Joshi, 1971
	The decoction of the root of <i>B. aristata</i> is used in piles, gastric disorders and other allied complaints by Tibetan people and the plant is known there as <i>Kershuen</i>	Chauhan et al., 1978/79
	Local inhabitants of DehraDun district of Uttaranchal, India use <i>B. aristata</i> as fish poison	Jain and Suri, 1979/80
	Used in snake and scorpion bite by the tribal's in Uttaranchal, India	Mitre, 1981
<i>B. asiatica</i>	Inhabitants of Assam, India, use root extract with butter for the treatment of bleeding piles. About 2 ml of the extract of its root is taken with butter daily for two weeks	Bhattacharjee et al., 1980
<i>B. lycium</i>	In Lahul province of HP, India, <i>B. lycium</i> and <i>B. pachyacantha</i> fruit is used medicinally for stomachache. Roots yield a yellow dye for textiles. The twigs are important in ceremonials of <i>Priests</i> and <i>Lamas</i> . In the <i>Burial ceremony</i> , barberry nails are used. For <i>Losar</i> (New Year) celebrations barberry wood and buck wheat straw is used.	Koetz and Walter, 1979
	In Rajouri district of Jammu, India, fruits of <i>B. lycium</i> are used as coagulant, branches made into broom for removing husk from grains	Virjee et al., 1984
<i>B. petiolaris</i>	In Kumaon region of Uttaranchal hills, India, the flowers of <i>B. petiolaris</i> are mixed with spinach, mashed and taken as salad	Bhargava, 1959
<i>B. tinctoria</i>	Todas of Nedimand tribes, Nilgiris, India, grind the roots of <i>B. tinctoria</i> with water and administer it for stomachache, especially in the treatment of worms. Bark is used for stomach disorders of Buffaloes, along with butter. Fruits are eaten by Kotas of Kollimalai	Abraham, 1981
<i>B. wallichiana</i>	<i>B. wallichiana</i> is used by the tribes of various ethnic groups like Nishi, Apatani, Hill-Miri, Adi, etc. of Subansiri district of Arunachal Pradesh, India. A bunch of spines is used for tattooing on chin and forehead. The tattoo locally called <i>te</i> is significant and is a traditional custom. Skin is pricked with spines. A mixture of rice starch and root is applied on the wound. The rice starch pierces the skin and the root gives the colour	Pal, 1984

Species	Ethno botanical Information	References
<i>B. jaeshkeana</i>	Root extract of <i>B. jaeshkeana</i> and <i>B. kumaonesis</i> , commonly called as Kingora and Jhuri respectively in Garhwal Himalayas, India, used as an astringent, diuretic, blood purifier and alternative. It is also used in eye disorders, menorrhoea, jaundice and skin diseases by the local tribes	Gaur et al., 1976
<i>B. vulgaris</i>	Berries are used for sore throat and fever. Poultice of pounded root or bark used for sore throat	Speck, 1998
	Cold and compound decoctions of berries are taken in fever	Tantaquidgeon, 1928
	Decoction of leaves taken three times a day for jaundice	Carr and Carlos, 1945
	Bark and root is used for ulcerated gums and sore throat	Chandler et al., 1979
	Roots of <i>B. vulgaris</i> are boiled in water and decoction is used in both human and cattle for the treatment of internal injuries and also used for tanning skin	Chaudhary et al., 1980
<i>B. holstii</i>	African endemic species in northern Malawi. Leaves and stem bark infusion is used for coughs, malaria, stomachache, sexually transmitted infections and pneumonia	Maliwichi-Nyirenda, 2011

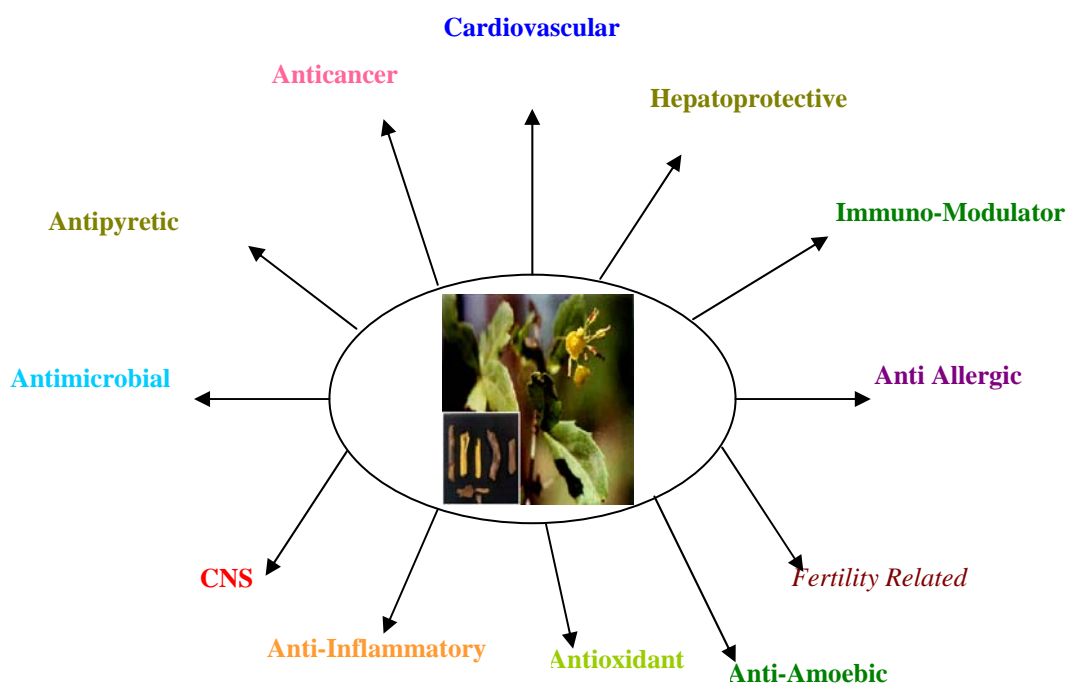


Figure 2: A broad spectrum of pharmacological activities of *Berberis*

Table 2: Pharmacological activities of various *Berberis* species

Activity	Source/species	Plant part	Type of extract/ fraction/ Isolate tested	Experimental procedures/animals/ organism studied/type of study	References
Cardio vascular activity	<i>B. darwinii</i>	Stem bark	Methanol extract	<i>In vitro</i> acetyl cholinesterase inhibition assay	Habtemariam, 2011
	<i>B. aristata</i>	Root	Aqueous-methanol extract	Ovari-ectomized rats	Yogesh et al., 2011
	<i>B. lycium</i>	Root bark	Hydro-alcoholic extract	Guinea pigs	Fang et al., 1986
		Root bark	Hydro-alcoholic extract	Guinea pigs	Wang et al., 1987
		Root	Isolated Berberine	Microelectrode techniques were used for intracellular recordings of the trans-membrane electrical potentials on canine cardiac purkinje and ventricular muscle fibers and on rabbit atrial fibers	Neto, 1993
		Root	Isolated Berberine	Guinea pigs	Wang et al., 1993
	<i>B. orthobotrys</i>	Root bark	Isolated Berbamine	Guinea pigs	Li et al., 1985
		Root bark	Isolated Berbamine	Rabbits & Rats	Fang et al., 1986
		Root bark	Isolated Berbamine	Guinea pigs	Li et al., 1991
		Root bark	Isolated Berbamine	Guinea pigs	Li et al., 1986
	<i>B. chitria</i>	Root bark	Isolated Berberine	Guinea pigs	Xiong and Fang, 1989
	<i>B. chilensis</i>	Root bark	Total Alkaloid	Electrical activity of frog cardiac pacemaker cells	Morales et al., 1989
		Root bark	Total Alkaloid	Guinea pigs	Morales et al., 1993
		Root bark	Isolated Berberidine and Tetrahydroberberine	Rat muscles	Han et al., 1990
	<i>B. paraspecta</i>	Root	Aqueous extracts	Chorio allantoic membrane (CAM) assay and <i>In vitro</i> bovine aortic endothelial cells (BAECs) culture and crystal violet assay	Wang et al., 2004

Activity	Source/species	Plant part	Type of extract/fraction/ Isolate tested	Experimental procedures/animals/organism studied/type of study	References
Anti-inflammatory activity	<i>B. aristata</i>	Root	Aqueous methanol extracts	Rats	Akhter et al., 1977
	<i>B. vulgaris</i>	Roots	Ethanol extract	Carrageenan- and zymosan-induced paw edema	Invanovska and Philipov, 1996
	<i>B. crataegina</i>	Root bark	Methanol extract	Carrageenan-induced edema and Serotonin-induced edema	Yeilada and Küpeli, 2002
		Root bark	Isolated Berberine	Cell proliferation and activation of NF- κ B. The protein levels of ICAM-1, TGF- β 1, iNOS and FN in rat MCs by Western blot	Jiang et al., 2011
		Root bark	Isolated Berberine	LPS- and IFN- γ -induced neuro-inflammation in microglia cells	Chen et al., 2012
		Root bark	Isolated Berberine	Nitric oxide (NO) expression and high-mobility group box 1 (HMGB1) release in lipopolysaccharide (LPS)-induced macrophages.	Lee et al., 2013
Central Nervous System activity	<i>Berberis</i> sp.	-	Isolated Berberine	Behavioral effects in conscious cats and mice, Pento barbitone sleeping time, Amphetamine toxicity, Pain threshold	Shanbhag et al., 1970
Anti-convulsion activity	<i>B. integerrima</i>	Root	Methanol extract, and hydromethanolic, and chloroform fractions	Pentylenetetrazole (PTZ) and maximal electroshock (MES)-induced seizure models	Hosseinzadeh et al., 2013
Anti-histaminic and anti-cholinergic activity	<i>B. vulgaris</i>	Fruits	Aqueous extract	Isolated guinea-pig ileum	Shamsa et al., 1999
Anti-microbial activity	<i>B. vulgaris</i>	Root	Isolated Berberine	Intestinal loop model	Sack and Frochlich, 1982
	<i>B. chitria</i>	Root	Water soluble & alcoholic extract	Antimicrobial	Dobhal et al., 1988
	<i>B. heterophylla</i>	Leaves, stems and root	Aqueous extracts	<i>In vitro</i> assay on Gram-positive and Gram-negative bacteria, fungi and different <i>Candida</i> species	Freile et al., 2003
	<i>B. aetnensis</i>	Root and Leaves	Ether, Ethanol and Chloroform extracts	<i>In vitro</i> assay on Gram positive and Gram negative bacteria	Musumeci et al., 2003

Activity	Source/species	Plant part	Type of extract/fraction/ Isolate tested	Experimental procedures/animals/organism studied/type of study	References
Hepato protective activity	<i>Berberis</i> sp.	Root	Isolated Berberine chloride	Rats	Chan, 1977
	<i>B. integerrima</i>	Root bark	Isolated Berberine	CCl ₄ induced toxicity model	Jamshidzadeh and Niknahad, 2006
		Root bark	Isolated Berberine	TNF- α , COX-2 and iNOS in CCL ₄ induced toxicity	Domitrović et al., 2011
	<i>B. aristata</i> ,	crude extract	Ethanol extract	amoebic liver abscess in golden hamsters and in immune modulation studies	Sohni and Bhatt, 1996
	<i>B. aristata</i>	crude extract	Ethanol extract	<i>In vitro</i> amoebicidal activity against <i>Entamoeba histolytica</i>	Sohni et al., 1995
Anti-cancer activity	<i>Berberis</i> sp.	Root	Isolated berberine	Activity on AP-1 using a reporter gene assay in human hepatoma cells	Fukuda et al., 1999a,b
	<i>B. amurensis</i>	Root bark	Isolated Berbamine	Apoptosis of Gleevec-sensitive and -resistant Ph ⁺ CML cells	Xu et al., 2006
	<i>B. koreana</i>	Root bark	Water extract	Human cancer cell lines A549, AGS, MCF-7 and Hep 3B	Qadir et al., 2009
Hepato-carcinoma	<i>Berberis</i> sp.	Root	Isolated Berberine	Anticancer actions in hepatocellular carcinoma SMMC-7721 cells	Li et al., 2013
		Root	Isolated Berberine	MMP-1 and MMP-9 mRNA expressions by real-time PCR	Kim et al., 2012
		Root	Isolated Berberine	Streptozotocin-induced apoptosis in mouse pancreatic islets through down-regulating <i>Bax/Bcl-2</i> gene expression ratio	Chueh and Lin, 2012
Antipyretic activity	<i>Berberis</i> sp.	Root	Isolated Berberine sulfate	In vivo model on rats, dog, rabbit and guinea pig	Sabir et al., 1978
Immuno-stimulant activity	<i>Berberis</i> sp.	Root bark	Isolated Berbamine	I.P. injection of berbamine in mice inoculated with influenza virus	Li and Sui, 1986
	<i>B. koreana</i>	fruit	Aqueous Extract	Immunoassays	Qadir et al., 2008
Fertility related activity	<i>B. vulgaris</i>	Leaves and bark	Acetone extracts	In-vivo effect on uterus of guinea pig, cat and rabbit	Aliev and Yuzbashinskaya, 1953

Activity	Source/species	Plant part	Type of extract/ fraction/ Isolate tested	Experimental procedures/animals/ organism studied/type of study	References
Fertility related activity	<i>B. chitria</i>	Roots	Isolated Palmitine	Administered orally to dogs for 60 days to check the impairment of primary and secondary spermatocytes and elongated spermatids (Stages IV-VIII).	Gupta and Dixit, 1989
Anti-oxidant activity	<i>Berberis</i> sp.	Roots	Isolated Berbamine	Colorimetric estimation of (MDA) malonaldehyde formation method and ESR-spin trapping technique.	Ju and Han, 1990
Anti-diabetic activity	<i>B. vulgaris</i>	Fruits and roots	Aqueous ethanol extract	Rats	Rajaei et al., 2011; Meliani et al., 2011
Urolithiasis	<i>B. vulgaris</i>	Root bark	Aqueous methanol extract	Animal model of urolithiasis, developed in male Westar rats by adding 0.75 % ethylene glycol in drinking water.	Jyothilakshmi et al., 2013; Bashir and Gilani, 2011
Osteolytic and Hypercholesterolemic	<i>B. aristata</i>	Root	Berberine	Rats	Zhou et al., 2012; Rahigude et al., 2012; Dong et al., 2011; Huang et al., 2012

CHEMICAL DIVERSITY IN *BERBERIS*

Isoquinoline alkaloids are the major bioactive constituents in *Berberis* (Figure 3). Berberine is a major representative of the protoberberine alkaloids which are a structural class of organic cations, characteristically yellow, having four linked benzene rings with a nitrogen atom joining two rings pairs, and modified via two oxygen atoms at each end. A vast array of alkaloids has been isolated from various *Berberis* species, among which, berberine, berbamine, Palmitine, jatrorrhizine and isotetrandrine are the most common ones (Figure 4).

The histological distribution of berberine has been well studied; alkaloids of *Berberis* are located chiefly in the cortical tissues of the roots and stems. The bark of old roots contains the highest concentration of alkaloids. In the upper parts of the stem, concentration is low and in young leaves alkaloids could not be detected (Greathouse and Rigler, 1940; Greathouse and Watkins, 1938). Histo-

logical distribution of berberine, umbellatine and nepiotime has also been examined in Indian species of *Berberis* (Chatterjee, 1952; Chatterjee et al., 1954). Mean value of berberine content for young actively growing shoots is 0.04 % and for young parenchymatous roots is 1.41 %. Thus there is a progressive increase in the berberine content of the plants with an increase in age.

Chemical analysis of the traditional preparation 'Rasaut' from Punjab market showed 1.67-4.26 % total alkaloid. The yield of Rasaut from *B. lycium* was found to be 15.4 % w/v and contained about 9.4 %w/v berberine (Anonymous, 1948).

Berberine exists in three tautomeric forms (I-III) in solution. Later on, these tautomeric structures and the evidence for the existence and structures of the ammonium (I) and pseudo-base form (II) were established (Anonymous, 1967). Chemical diversity of various *Berberis* species is illustrated in Table 3.

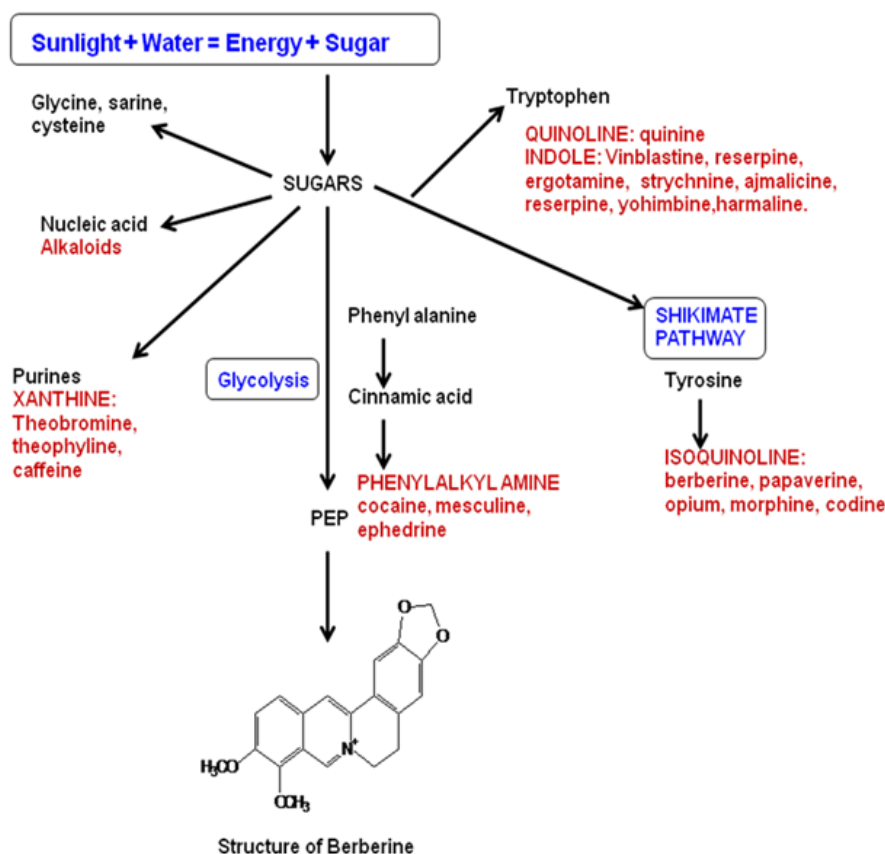


Figure 3: Biosynthetic pathway of Berberine and allied alkaloids

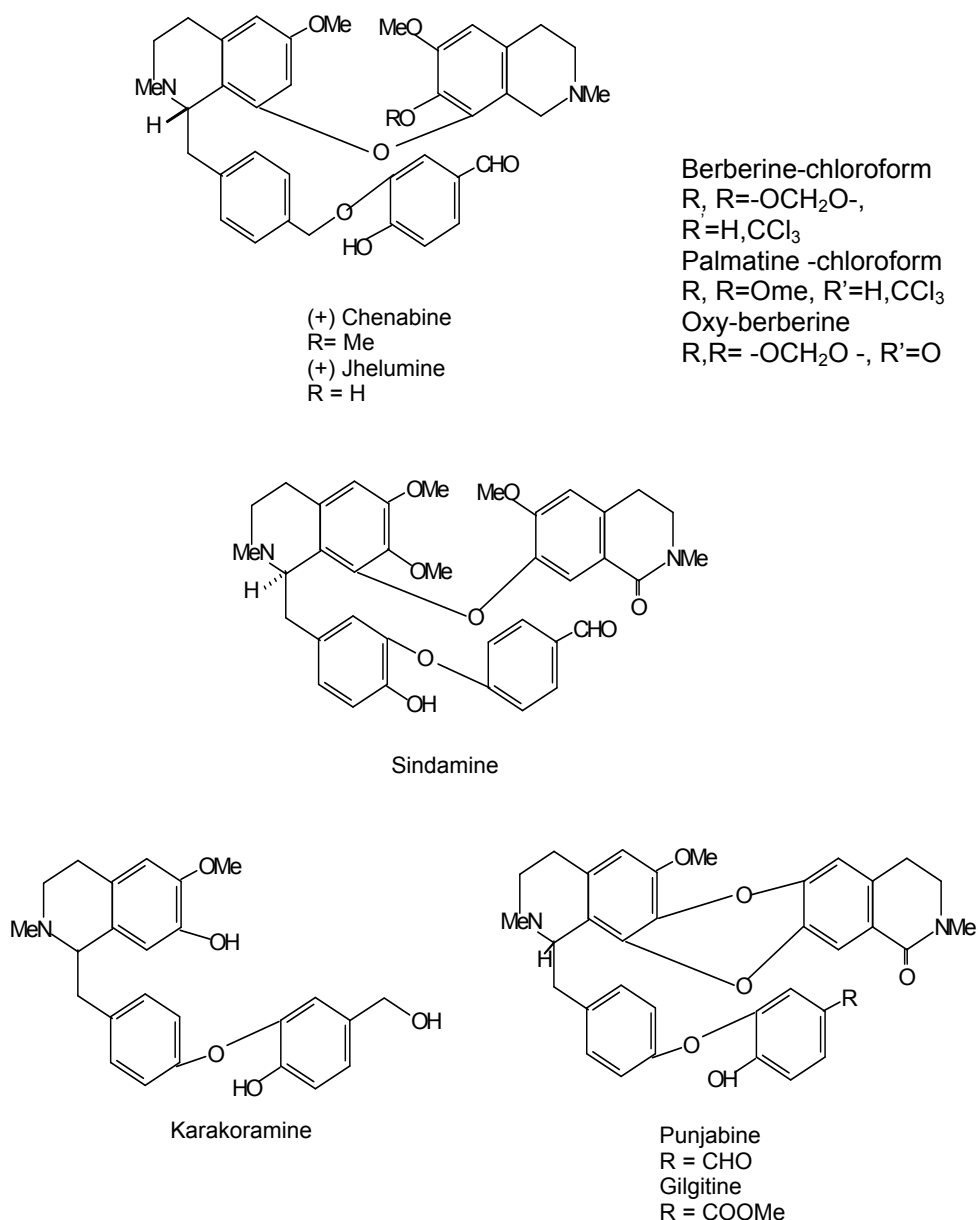


Figure 4: Some other important active principles of *Berberis*

Table 3: Phyto constituents of various *Berberis* species

Species	Isolated active principals	Plant parts	Reference
<i>B. aristata</i>	<ul style="list-style-type: none"> Karachine ($C_{26}H_{27}O_5N$), melting point 146-148 °C Taxilamine 	Roots	Blasko et al., 1982; Potdar et al., 2012
<i>B. asiatica</i>	<ul style="list-style-type: none"> Berberine, Palmitine, jatrorrhine, colunbamamine tetrahydropalmitine, berbamine, oxyberberine and oxyacanthine 	Leaves & Root	Chatterjee, 1952; Chandra and Purohit, 1980

Species	Isolated active principals	Plant parts	Reference
<i>B. chitria</i>	<ul style="list-style-type: none"> • A new aporphine base-o-methyl corydine N-oxide, along with berberine; palmitine, jatrorrhizine and oxyacanthine • Benzene extracts yielded hentriacontane, triacontane, cetyl alcohol, β-sitosterol, β-sitosterol, dihydro kaempferol, quercetin, and oleic, steric, palmitic and linoleic acids. • Alcoholic extract revealed 5 alkaloidal components of which three closely related alkaloids separated and named as chitrian A, B, C. • Water extract revealed the presence of glucose, fructose and rhamnose • Dihydropalmitine N-oxide (I) jatrorrhizine detected from its chloride (5, 6-dihydro 3-hydroxy-2, 9, 10-trimethoxyl dibenzo [a, g] quinolizinium chloride dihydrate) consists of 4 fused rings. • Berlambine lambertine, berbamine, berberine, berbamine, yuziphine (a new alkaloid), columbamine, palmitine and hydroxyacanthine. • Umbellatine, berberine and berbamine 	Roots	Bhakuni et al., 1968; Hussain and Shoeb, 1958; Ghosh et al., 1993; Yasupov et al., 1990; Ali and Khan, 1978
<i>B. lycium</i>	<ul style="list-style-type: none"> • Three new alkaloids-baberine, melting point 152 °C ($C_{19}H_{21}NO_3$), berbericine hydrochloride, mp. 199 °C ($C_{20}H_{17}NO_4Cl$) and berbericine hydroiodide, m.p. 205 °C ($C_{21}H_{22}NO_4I$). • Two artefact alkaloids berberine-chloroform, palmitine-chloroform along with oxyberberine • Umbellatine, berberine and berbamine was also identified in the roots of same species • Berberine chloride • Three new seco-bisbenzylisoquinolines (+)-sindamine (monophenolic base) $C_{37}H_{38}O_8N_2$; (-) -Punjabine (Secodimer Monophenolic base) $C_{35}H_{32}O_7N_2$; (-) - Gilgitine (Secodimer monophenolic base) $C_{36}H_{34}O_8N_2$. • Punjabine and gilgitine are the first secodimeric alkaloids derived from <i>in vivo</i> oxidation of bis benzylisoquinoline precursor in incorporating three diaryl ether bridges. • (+) - Kara-koramine $C_{25}H_{27}O_5N$, monophenolic (+) chenabine $C_{37}H_{40}O_7N_2$ and diphenolic (+) - jhelumine $C_{36}H_{38}O_7N_2$ (more polar than chenabine) 	Roots	Ikram et al., 1996; Miana, 1973; Datta et al., 1976; Leet et al., 1983; 1982
<i>B. pachycantha</i>	<ul style="list-style-type: none"> • Oxyacanthine, mp. 212-14 °C, oxyberberine, mp. 200-1 °C; berbamine-C_6H_6 adduct, melting point 124-6 °C; isotetrandrine mp. 180-2 °C; jatrorrhizine mp. 217-20 °C (decomposition); magnoflorine picrate mp 217-23 °C and isodide mp. 228-30 °C. • Two anthocyanin pigments were isolated and identified as polar gonidin - 3 glucoside and cyanidin - 3 glucoside. 	Roots	Tomita and Yong, 1960; Du and Francis, 1974

Species	Isolated active principals	Plant parts	Reference
<i>B. concinna</i>	<ul style="list-style-type: none"> Berberine and Palmitine were isolated as tetrahydro derivatives. Alkaloid 9, 9-dimethyltetracosan-6 - one $\text{Me}(\text{CH}_2)_4\text{COCH}_2\text{CH}_2\text{CMe}_2(\text{CH}_2)_{14}\text{Me}$ 	Stem bark	Tiwari and Masood, 1977; 1978
<i>B. corearia</i>	<ul style="list-style-type: none"> 1, 4-Bis (2' - hydroxy-5'-methylphenyl)-butan-1, 4-dione (I) (a ketone). A new ketone -7 methyltetracosan - 6 - one (II), along with berberine Anthocyanins -cyanidin, pelargonidin, petunidin, peonidin and delphinidin aglycons bounded with glucose and rutinose. 	Stem bark Fruits	Tiwari and Masood, 1979; Majumdar and Saha, 1978 Vereskovskii and Sapiro, 1985
<i>B. vulgaris</i>	<ul style="list-style-type: none"> 8 pigments that were identified with the percentage of the total carotenoids are β -carotene, 0.8; β -carotene 5-7; lutein 39.0; zeaxanthin, 8.6; chrysanthemaxanthin, 7.6; flavoxanthin 11.7; auroxanthin 5.7; capsanthin 1.9 and there were two unidentified fractions constituting 15.2 %. Tannin (5.56), carbohydrates (5.82). Organic acids (3.69), Mn (7.20) and pectic substances (0.48) percent and Vitamin C 156.50 mg. Thalifoline mp.195-197 °C; ⁸-Oxyberberine mp. 191-193 °C, Chilenine mp. 135°-137 °C, Baluchistanamine mp. 115-118 °C, Tejedine mp.132-134 °C, Obaberine mp.136°-138 °C. Isotetrandrine mp 171-174 °C, Oxycanthine mp. 205-208 °C, Berbamine mp.145-147 °C, Aromoline mp. 166-169 °C, Obamegine mp. 197°-198 °C, Thaligrisine mp. 120-122 °C, Jatrorrhizine Chloride mp. 203-205 °C, Palmitine Chloride 201-202 °C. Berberine Chloride mp.202°-206 °C. 	Fruits Root bark	Wierzchowski and Budicz, 1969; Parlamarchulk et al., 1973; Suau et al., 1998
<i>B. kawakamii</i>	<ul style="list-style-type: none"> Berberine - C₆H₆ adduct mp. 124- 6 °C; isotetrandrine mp. 179-81 °C; jatrorrhizine; berberine; shobakunine and magnolosine picrate mp 224- 6 °C (decomposition) 	Roots	Tsang-Hsiumg and Lu, 1960
<i>B. minget-sensis</i>	<ul style="list-style-type: none"> Berbamine -C₆H₆ adduct mp 125-7 °C; a new base mp 240-2 °C; isotetrandrine mp 179-81°; oxyberberine mp 199-201 °C; berberine and shobakunine 	Roots	Tsang-Hsiumg and Lu, 1960
<i>B. calliobotrys</i>	<ul style="list-style-type: none"> New dimeric aporphine benzylisoquinoline- <i>Khyberine</i> pakistanamine, 1-0-methylpakistanine, pakistanine, chitraline and kalashine. 	Roots	Hussain and Shamma, 1980
<i>B. orthobotrys</i>	<ul style="list-style-type: none"> A new dimer kalashine together with the pakistanamine and pakistanine. Kalashine is the first aporphine benzylisoquinoline known to be substituted at C-H Acid catalyzed rearrangements of pakistanaminein 3 N-HCl leads to 1-0-methyl pakistanine, together with small amounts of 1-0 methyl kalashine and (+) armaparine 	Roots	Hussain and Shamma, 1980

Species	Isolated active principals	Plant parts	Reference
<i>B. umbellata</i>	<ul style="list-style-type: none"> An alkaloid $C_{20}H_{20}O_3$ mp 108-110 °C and was characterized as 2, 5-Bis (2'-methoxy-5'-methylphenyl) furan (I) 	Roots	Masood and Tiwari, 1981
<i>B. brandisiana</i>	<ul style="list-style-type: none"> A new alkaloid (+) - berbamine-2'-β-N-oxide ($C_{37}H_{40}N_2O_7$) along with berbamine, palmitine, (+) berberine, thalifoline, (+) reticuline, (+) apoglaziovine, (+) isoboldine and (+) isotetrandrine. 	Aerial part	Hussain et al., 1986
<i>B. pseudo-umbellata</i>	<ul style="list-style-type: none"> Berberine and palmitine as the major and the bisbenzyisoquinoline alkaloid oxyaoanthine and O-methyl oxyacanthine as minor bases 	Aerial part	Pant et al., 1986
<i>B. floribunda</i>	<ul style="list-style-type: none"> Oxyacanthine, berbamine, berberine, epi-berberine, palmitine, dihydrocoridaline, jatrorrhizine and coulambine. This species appears to be the first instance of bearing epi-berberine 	Roots	Chatterjee et al., 1953
<i>B. laurina</i>	<ul style="list-style-type: none"> Two new alkaloid diastereomer (absolute configuration-+) (5) of O-methyl thalicberine (++) (5), which is O-methyl iso-thalicberine (1) and other is lauberine (III a), Two new phenolic alkaloid which have been named espinine (I a) $C_{36}H_{40}N_2O_6$ m.p. 123-5, R_f. 0.08 and Espinidine (I d) $C_{37}H_{42}N_2O_6$ R_f. 0.15. Extracts of <i>B. laurina</i> roots yielded only 0.536 % Et_2O solution alkaloid hydrastinine 	Roots	Falco et al., 1969; 1968; Krets, 1956
<i>B. baluchistanica</i>	<ul style="list-style-type: none"> Free base baluchistanamine mp. 122-124 °C. Phenolic arophine benzyisoquinoline alkaloid pakistanine $C_{37}H_{40}O_6N_2$ mp. 156 and first known proaphorphine benzyisoquinoline alkaloid paki-stanamine $C_{38}H_{42}O_6N_2$ mp. 158-162 °C. 	Roots	Shamma et al., 1974; 1972
<i>B. amursensis</i>	<ul style="list-style-type: none"> Berbamine (as C_6H_6 adduct) mp. 124-6 °C; a new phenolic tertiary base mp. 190-1 °C; hydroxy berberine mp. 197-9 °C; jatrorrhizine and shobakunine. Berberine, ferulic acid and vanillinic acid 	Stem & Roots	Tomita and Kugo, 1955
<i>B. thunbergii</i>	<ul style="list-style-type: none"> Two picrates - jatrorrhizine picrate mp. 217-20 °C monoflorine picrate mp. 224-5 °C 	Roots	Tomita and Kikuchi, 1956
<i>B. tschonoskyana</i>	<ul style="list-style-type: none"> Oxyacanthine, 2.40, 206-8 °C Obamegine ($C_{18}H_{19}O_3N$), 1.00, 164-6 °C, 98-90; oxyberberine, 0.20, 197-90 °C, a new tertiary non phenolic base, 0.01, 89-92 °C, Obaberine ($C_{20}H_{23}O_4N$), 0.40, -, 178-180 °C; Jatrorrhizine 1.12, 214-15 °C - ; magnoflorine, 3.11, 3.11, - 231 - 2 °C; Shobakanine, 0.93, 138-40° Another alkaloid obamegine ($C_{36}H_{38}O_6N_2$) mp. 164-6 °C was isolated from the same species 	Stem & Roots	Tomita and Kugo, 1956
<i>B. koreana</i>	<ul style="list-style-type: none"> Berberine; Palmitine; Oxyacanthine; Berbamine 	Stem & Leaves	Pavel, 1965
<i>B. tabiensis</i>	<ul style="list-style-type: none"> A bisbenzyltetrahydroisoquinoline alkaloid Tabienine mp. 124 -127 °C 	Stems	Quevedo et al., 2008

Species	Isolated active principals	Plant parts	Reference
<i>B. cole-tioides</i>	<ul style="list-style-type: none"> Pronuciferine N-oxide, the first naturally occurring proaporphinoid alkaloid with an N-oxide functionality, along with the parent compound Pronuciferine 	Roots	Fajardo et al., 2009
<i>B. waziri-stanica</i>	<ul style="list-style-type: none"> Berberine mp.253 °C, Oxyberberine mp. 199-200 °C, Karachine mp.146 -148 °C, Corydaldine mp. 173 °C, N-Methylcorydaldine mp. 121 °C, N-methyl-6, 7-Dimethoxy-isoquinoline mp. 215 - 217 °C, Aromoline mp. 178 - 180 °C, Pakistanine mp. 154 -156 °C, Waziristanine mp. 182 °C 	Root bark	Hussain, 1992

CONCLUSION AND FUTURE PROSPECTIVE

During the last few decades there has been an increase in the study of medicinal plants and their traditional use in different parts of the world. Reports of the folk medicine followed by critical scientific evaluation have given to the world newer sources as corrective, preventive and upto some extent curative measures in various diseases. *Berberis* species are among the most important traditional herbs with a vast array of pharmacological activities. The present review summarizes the taxonomic, ethno-botanical, pharmacognostic, photochemical and pharmacological claims of *Berberis* species. Literature on Phyto-chemistry reveals that the species are rich in alkaloids, of which biologically active 'Berberine' is the major and potential one.

This review is a comprehensive documentation of various species belonging to this genus and their therapeutic potentials in the present context. Previous pharmacological studies on *Berberis* and its isolated alkaloids revealed more potential towards cardio vascular, hepato-protective, antimicrobial and anticancer activities. Recent trend in research on *Berberis* species, however directed the workers to focus more towards oncology, toxicological studies and clinical trials. This review will be useful for researchers to approach the newer avenues by exploring varied pharmacological activities like anti diarrheal, antispasmodic, anti malarial, etc.,

which in turn will be more beneficial in developing myriads of scientifically validated herbal formulations containing naturally occurring biodynamic compounds.

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