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, Parvatia*), 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.
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                                      |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|
| **B. aristata** | In Raithal locality of Uttarkashi (Uttaranchal), India, *Rasaut*- a popular medicine prepared for eye disorders from the roots of *B. aristata*                                                                                   | Kirtikar and Basu, 1935; Anonymous, 1948; Hayashi, 1950; Küpeli et al., 2002; Uniyal, 1964 |
|              | In Kumaon region of India, the decoction of root bark from *B. aristata* and *B. asiatica* 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 *B. aristata* is used in piles, gastric disorders and other allied complaints by Tibetan people and the plant is known there as *Kershuen*                                                            | Chauhan et al., 1978/79                        |
|              | Local inhabitants of DehraDun district of Uttaranchal, India use *B. aristata* as fish poison                                                                                                                                | Jain and Suri, 1979/80                         |
|              | Used in snake and scorpion bite by the tribal’s in Uttarakhand, India                                                                                                                                                        | Mittre, 1981                                   |
| **B. asiatica** | 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                      |
| **B. lycium** | In Lahul province of HP, India, *B. lycium* and *B. pachyacantha* fruit is used medicinally for stomachache. The twigs are important in ceremonials of Priests and Lamas. In the Burial ceremony, barberry nails are used. For Losar (New Year) celebrations barberry wood and buck wheat straw is used. | Koetz and Walter, 1979                         |
|              | In Rajouri district of Jammu, India, fruits of *B. lycium* are used as coagulant, branches made into broom for removing husk from grains                                                                                           | Virjee et al., 1984                            |
| **B. petiolaris** | In Kumaon region of Uttarakhand hills, India, the flowers of *B. petiolaris* are mixed with spinach, mashed and taken as salad                                                                                            | Bhargava, 1959                                 |
| **B. tinctoria** | Todas of Nedimand tribes, Nilgiris, India, grind the roots of *B. tinctoria* 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                                  |
| **B. wallichiana** | *B. wallichiana* 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 te 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
--- | --- | ---
*B. jaeshkeana* | Root extract of *B. jaeshkeana* and *B. kumaonesis*, 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, menorrhrea, jaundice and skin diseases by the local tribes | Gaur et al., 1976

*B. vulgaris* | 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 *B. vulgaris* 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

*B. holstii* | 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                  |
|---------------------|---------------|------------|----------------------------------------|---------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Cardiovascular activity | *B. darwinii* | Stem bark  | Methanol extract                       | *In vitro* acetyl cholinesterase inhibition assay                                                                           | Habtemariam, 2011          |
|                     | *B. aristata* | Root       | Aqueous-methanol extract               | Ovari-ectomized rats                                                                                                       | Yogesh et al., 2011        |
|                     |               | Root bark  | Hydro-alcoholic extract                 | Guinea pigs                                                                                                                 | Fang et al., 1986          |
|                     |               | Root bark  | Hydro-alcoholic extract                 | Guinea pigs                                                                                                                 | Wang et al., 1987          |
|                     | *B. lycium*   | Root       | Isolated Berberine                     | Microelectrode techniques were used for intracellular recordings of the transmembrane 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          |
|                     | *B. orthobotrys* | 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            |
|                     | *B. chitria*  | Root bark  | Isolated Berberine                    | Guinea pigs                                                                                                                 | Xiong and Fang, 1989       |
|                     | *B. chilensis*| 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           |
|                     | *B. paraspecta*| Root     | Aqueous extracts                      | Chorio allantoic membrane (CAM) assay and *In vitro* 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     | *B. aristata*  | Root                                | Aqueous methanol extracts              | Rats                                                                                                                          | Akhter et al., 1977         |
|                                | *B. vulgaris*  | Roots                               | Ethanol extract                        | Carrageenan- and zymosan-induced paw edema                                                                                  | Invanovska and Philipov, 1996 |
|                                |                | Root bark                           | Methanol extract                       | Carrageenan-induced edema and Serotonin-induced edema                                                                     | Yeilada and Küpeli, 2002   |
|                                | *B. crataegina*| Root bark                           | Isolated Berberine                     | Cell proliferation and activation of NF-κB. The protein levels of ICAM-1, TGF-β1, 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| *Berberis* 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       | *B. integerrima*| 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 | *B. vulgaris* | Fruits                               | Aqueous extract                        | Isolated guinea-pig ileum                                                                                                   | Shamsa et al., 1999         |
| Anti-microbial activity        | *B. vulgaris*  | Root                                | Isolated Berberine                     | Intestinal loop model                                                                                                        | Sack and Frochlich, 1982    |
|                                | *B. chitria*   | Root                                | Water soluble & alcoholic extract      | Antimicrobial                                                                                                               | Dobhal et al., 1988         |
|                                | *B. heterophylla* | Leaves, stems and root              | Aqueous extracts                       | *In vitro* assay on Gram-positive and Gram-negative bacteria, fungi and different *Candida* species                      | Freile et al., 2003         |
|                                | *B. aetnensis* | Root and Leaves                     | Ether, Ethanol and Chloroform extracts | *In vitro* 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 | Berberis sp.   | Root       | Isolated Berberine chloride              | Rats                                                          | Chan, 1977 |
|                      | B. integerrima | Root bark  | Isolated Berberine                       | CCl₄ induced toxicity model                                   | Jamshidzadeh and Niknahad, 2006 |
|                      |                | Root bark  | Isolated Berberine                       | TNF-α, COX-2 and iNOS in CCl₄ induced toxicity               | Domitrović et al., 2011 |
|                      | B. aristata,   | crude extract | Ethanol extract                      | amoebic liver abscess in golden hamsters and in immune modulation studies | Sohni and Bhatt, 1996 |
|                      | B. aristata    | crude extract | Ethanol extract                      | *In vitro* amoebicidal activity against *Entamoeba histolytica* | Sohni et al., 1995 |
| Anti-cancer activity | Berberis sp.   | Root       | Isolated berberine                      | Activity on AP-1 using a reporter gene assay in human hepatoma cells | Fukuda et al., 1999a,b |
|                      | B. amurensis   | Root bark  | Isolated Berbamine                     | Apoptosis of Gleevec-sensitive and -resistant Ph’CML cells    | Xu et al., 2006 |
|                      | B. koreana     | Root bark  | Water extract                          | Human cancer cell lines A549, AGS, MCF-7 and Hep 3B           | Qadir et al., 2009 |
| Hepato-carcinoma     | Berberis 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 Bax/Bcl-2 gene expression ratio | Chueh and Lin, 2012 |
| Antipyretic activity | Berberis sp.   | Root       | Isolated Berberine sulfate              | In vivo model on rats, dog, rabbit and guinea pig             | Sabir et al., 1978 |
| Immuno-stimulant activity | Berberis sp. | Root bark  | Isolated Berbamine                     | I.P. injection of berbamine in mice inoculated with influenza virus | Li and Sui, 1986 |
|                      | B. koreana     | fruit      | Aqueous Extract                        | Immunoassays                                                  | Qadir et al., 2008 |
| Fertility related activity | B. vulgaris   | 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       | *B. chitria*    | 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            | *Berberis* sp.  | Roots      | Isolated Berbamine                       | Colorimetric estimation of (MDA) malonaldehyde formation method and ESR-spin trapping technique.                              | Ju and Han, 1990                |
| Anti-diabetic activity           | *B. vulgaris*   | Fruits and roots | Aqueous ethanol extract                  | Rats                                                                                                                     | Rajaei et al., 2011; Meliani et al., 2011 |
| Urolithiasis                     | *B. vulgaris*   | 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 | *B. aristata* | 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 bio-active 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). Histological 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*

![Sindamine](image)

![Kararakoramine](image)

![Punjabine](image)

![Gilgitine](image)

Table 3: Phyto constituents of various *Berberis* species

| Species   | Isolated active principals                                      | Plant parts | Reference                      |
|-----------|------------------------------------------------------------------|-------------|--------------------------------|
| *B. aristata* |                                                                 |             |                                |
|           | • Karachine ($C_{26}$H_{27}O_{5}N), melting point 146-148 °C      | Roots       | Blasko et al., 1982; Potdar et al., 2012 |
|           | • Taxilamine                                                     |             |                                |
| *B. asiatica* |                                                                 | Leaves & Root | Chatterjee, 1952; Chandra and Purohit, 1980 |
|           | • Berberine, Palmitine, jatrohirine, colunbamamine, tetrahydropalmitine, berbamine, oxyberberine and oxyacanthine |             |                                |
| Species          | Isolated active principals                                                                                                                                                                                                 | Plant parts | Reference                                                                                                                                                   |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| *B. chitria*     | • A new aporphine base-o-methyl corydine N-oxide, along with berberine; palmitine, jatrorrhizine and oxyacanthine  
• Benzene extracts yielded henriciacontane, 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-trimethoxy dibenzo [a, g] quinoliziaium chloride dihydrate) consists of 4 fused rings.  
• Berlambine lambertine, berbamunine, 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                                                                                                                   |
| *B. lycium*      | • 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_{38}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 *in vivo* oxidation of bis benzylisoquinoline precursor in incorporating three diaryl ether bridges.  
• (+) - Kara-koramine C_{25}H_{27}O_3N, 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                                                                                                                                         |
| *B. pachycantha* | • 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 picate 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                        |
|-----------------|-------------------------------------------------------------------------------------------|-------------------|----------------------------------|
| *B. concinna*   | • Berberine and Palmitine were isolated as tetrahydro derivatives.                         | Stem bark         | Tiwari and Masood, 1977; 1978    |
|                 | • Alkaloid 9, 9-dimetyltetracosan-6 - one Me(CH2)4COCH2CH2CMe2(CH2)4Me                         |                   |                                  |
|                 | • 1, 4-Bis (2 - hydroxy-5-methylphenyl)-butan-1, 4-dione (I) (a ketone).                     | Stem bark         | Tiwari and Masood, 1979; Majumdar and Sah-<br>ha, 1978 |
|                 | • A new ketone -7 methyltetracosan - 6 - one (II), along with berberine                     |                   | Vereskovskii and Sapiro, 1985    |
|                 | • Anthocyanins -cyanidin, pelargonidin, petunidin, peonidin and delphinidin aglycons bounded with glucose and rutinose. |                   |                                  |
| *B. corearia*   | • 8 pigments that were identified with the percentage of the total carotenoids are β-carotene, 0.8; β-carotene 5-7; lutein 39.0; zea xanthin, 8.6; chrysanthenaxanthin, 7.6; flavoxanthin 11.7; auroxanthin 5.7; capsanthin 1.9 and there were two unidentified fractions constituting 15.2 %. | Fruits            | Wierzchowski and Budicz, 1969; Parlamarchulk et al., 1973; Suau et al., 1998 |
|                 | • 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. |                   |                                  |
| *B. vulgaris*   | • 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; Berbamaine 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            | Wierzchowski and Budicz, 1969; Parlamarchulk et al., 1973; Suau et al., 1998 |
| *B. kawakamii*  | • Berberine - C6H6 adduct mp. 124- 6 °C; isotetrandrine mp. 179-81 °C; jatrorrhizine; berberine; shobakunine and magnolosine picate mp 224- 6 °C (decomposition) | Roots             | Tsang-Hsiiumg and Lu, 1960       |
| *B. minget-sensis* | • Berbamine -C6H6 adduct mp 125-7 °C; a new base mp 240-2 °C; isotetrandrine mp 179-81 °C; oxyberberine mp 199-201 °C; berberine and shobakunine | Roots             | Tsang-Hsiiumg and Lu, 1960       |
| *B. calliobotrys* | • New dimeric aporphine benzylisoquinoline- Khyberine pakistanamine, 1-0-methylpakistanine, pakistanine, chitriline and kalashine. | Roots             | Hussain and Shamma, 1980         |
| *B. orthobotrys* | • A new dimer kalashine together with the pakistanamine and pakistazine. 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 pakistazine, together with small amounts of 1-0 methyl kalashine and (+) armparvining | Roots             | Hussain and Shamma, 1980         |
| Species         | Isolated active principals                                                                                                                                                                                                 | Plant parts | Reference                        |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------------------------|
| B. umbellata    | • An alkaloid C\textsubscript{20}H\textsubscript{20}O\textsubscript{3} mp 108-110 °C and was characterized as 2, 5-Bis (2-methoxy-5-methylphenyl) furan (I)                                                                 | Roots       | Masood and Tiwari, 1981            |
| B. brandisiana  | • A new alkaloid (+) - berbamine-2-β-N-oxide (C\textsubscript{37}H\textsubscript{40}N\textsubscript{2}O\textsubscript{7}) along with berbamine, palmitine, (+) berberine, thalifoline, (+) reticline, (+) apoglaziovine, (+) isoboldine and (+) isotetrandrine. | Aerial part | Hussain et al., 1986               |
| B. pseudo-umbellata | • Berberine and palmitine as the major and the bisbenzylisoquinoline alkaloid oxyoaanthine and O-methyl oxyacanthine as minor bases                                                                                      | Aerial part | Pant et al., 1986                 |
| B. floribunda   | • 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           |
| B. laurina      | • Two new alkaloid diastereomer (absolute configuration+) (5) of O-methyl thalicerine (++) (5), which is O-methyl iso-thalicerine (1) and other is lauberine (III a),                                                                 | Roots       | Falco et al., 1969; 1968; Krets, 1956 |
| B. baluchistanica | • Free base baluchistanamine mp. 122-124 °C.  
• Phenolic aprophine benzylisoquinoline alkaloid pakistanine C\textsubscript{37}H\textsubscript{40}O\textsubscript{6}N\textsubscript{2} mp. 156 and first known proaporphine benzylisoquinoline alkaloid pakistanamine C\textsubscript{38}H\textsubscript{42}O\textsubscript{6}N\textsubscript{2} mp. 158-162 °C. | Roots       | Shamma et al., 1974; 1972          |
| B. amursensis   | • Berbamine (as C\textsubscript{6}H\textsubscript{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               |
| B. thunbergii   | • Two picrates - jatrorrhizine picrate mp. 217-20 °C monoflorine picrate mp. 224-5 °C                                                                                                                                                                                                 | Roots       | Tomita and Kikuchi, 1956          |
| B. tschonoskyana | • Oxyacanthine, 2.40, 206-8 °C Obamegine (C\textsubscript{18}H\textsubscript{19}O\textsubscript{3}N), 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\textsubscript{28}H\textsubscript{29}O\textsubscript{2}N), 0.40, - , 178-180 °C; Jatrorrhirine 1.12, 214-15 °C - ; magnoflorine, 3.11, 3.11, - 231 – 2 °C; Shobakanine, 0.93, 138-40  
• Another alkaloid obamegine (C\textsubscript{38}H\textsubscript{38}O\textsubscript{2}N\textsubscript{2}) mp. 164-6 °C was isolated from the same species                                                                                                     | Stem & Roots | Tomita and Kugo, 1956               |
| B. koreana      | • Berberine; Palmitine; Oxyacanthanine; Berbamine                                                                                                                                                                           | Stem & Leaves | Pavel, 1965                        |
| B. tabiensis    | • A bisbenzyltetrahydroisoquinoline alkaloid Tabienine mp. 124 -127 °C                                                                                                                                                     | Stems       | Quevedo et al., 2008               |
### Species Isolated active principals Plant parts Reference

| Species | Isolated active principals | Plant parts | Reference |
|---------|-----------------------------|-------------|-----------|
| B. colletioides | • 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 |
| B. waziristanica | • 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.

### Acknowledgement

Authors are thankful to the Director, CSIR-NBRI for providing all the facilities. They are also thankful to Dr. KN Nair for his contribution in language check in this review.

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