Bergenia ligulata : A Brief Overview

***Shabnam Kumari Thakur[1], N V L Suvarchala Reddy V[2], Renushri Kurva [3], Rachana B [4], Tulasi O[5].**

Gokaraju Rangaraju College of Pharmacy, Department of Pharmacology, Osmania University, Hyderabad, Telangana-500090, India

Corresponding author: *Shabnam Kumari Thakur

Assistant Professor,

Department of Pharmacology,

Gokaraju Rangaraju College of Pharmacy,

Hyderabad,

Telangana-500090, India.

ABSTRACT

Bergenia ligulata Wall., widely recognized in Ayurvedic medicine as Paashanbheda—a term meaning "stone breaker"—is a highly valued medicinal herb renowned for its potential to dissolve urinary and kidney stones. It is also one of the notable examples of a controversial drug due to its varying identification in different traditional sources.Phytochemical research has uncovered a diverse range of bioactive constituents in B. ligulata, including coumarins, flavonoids, benzenoids, lactones, carbohydrates, tannins, phenols, and sterols. These compounds contribute to the plant's broad therapeutic applications. Extracts and isolated molecules from this species have demonstrated multiple pharmacological effects, such as antiurolithic, antiviral, antioxidant (free radical scavenging), antidiabetic, liver-protective (hepatoprotective), diuretic, fever-reducing (antipyretic), antitumor, antibacterial and antifungal, anti-inflammatory, anti-implantation, cardioprotective, and antioxaluria (reducing oxalate levels in urine).A key compound, bergenin, is believed to play a major role in many of these therapeutic actions. The aim of this review is to gather and present the current knowledge surrounding B. ligulata, covering its botanical characteristics, traditional applications, phytochemistry, biological effects and pharmacopeial standards.

Keywords: Bergenia ligulata, phytochemistry, microscopic features, antioxidant, pharmacological activities, traditional uses.

INTRODUCTION

Bergenia ligulata [family Saxifragaceae], known locally as 'Pashanbheda' is a perennial herbaceous medicinal plant, and in the western Himalayan region, it is an endangered plant species according to the IUCN. In the past, this plant's rhizomes were used for treating diabetics, for dissolving kidney stones and for dissolving gallbladder stones, and for pulmonary infection, cough and cold. The methanolic extract of B.ligulata was evaluated for phytochemical screening using standardized methods. The phytochemical analysis showed that the plant extract is a rich source of secondary metabolites such as alkaloids, coumarins, phenols, flavonoids, benzenoids, tannins, saponins, lactones and terpenoids, which make this plant a valuable medicinal herb with broad-spectrum pharmacological activities like antioxidant, antiviral, antibacterial, diuretic, antipyretic, anti-inflammatory, antioxaluria and antidiabetic activities. In India, the majority of the population utilizes plant-derived medicine to meet their medical and health care demands. Natural medicines are becoming increasingly popular because they are viewed as green medicine that is always assumed to be non-toxic. Therefore, in vitro micropropagation plays an important role in producing high-quality plant-based medicines. It is essential to develop a reliable in-vitro micropropagation protocol for the commercially important medicinal plant species for rapid regeneration and production of high-quality plant chemicals (secondary metabolites) so that there should be a continuous supply of healthy plant material to the pharmaceutical industry for the production of medicinally important drugs sustainably. The in-vitro micropropagation techniques are successfully developed for conservation of genetic material/germplasm of various medicinally important plant species throughout the Himalayas, including Aconitum violaceum, Origanum vulgare, Berberis aristata, Aconitum ferox and Nardostachys jatamansi. The in-vitro propagation for several endangered medicinal plants has already been established. These include such as Thymus persicus, Siphonochilus aethiopicus and Celastrus paniculatus. There are a number of difficulties that can arise during the process of tissue culture, like discoloration of media and browning of explant. In the present study, we developed a simple and effective technique for in vitro micropropagation of B. ligulata using leaf disc explants for mass multiplication [1].

Figure 1. Bergenia ligulata

PLANT PROFILE

Bergenia ligulata Wall belonging to family Saxifragaceae is popularly known as a 'stone flower/stone breaker'. It is also known as *Saxifraga ligulata* Wall.

Vernacular names

Assamese: Patharkuchi

Bengali: Himasagara, Patharchuri, Patrankur

Gujarati: Pakhanbheda, Pashanbheda

Hindi: Dakachru, Pakhanabhed, PakhanabhedaPatharcua, Silparo, Silpbheda

Kannada: Alepgaya, Hittaga, Hittulaka, Pahanbhedi, Pasanberu

Kashmiri: Pashanbhed

Malayalam: Kallurvanchi,Kallurvanni, Kallorvanchi

Marathi: Pashanbheda

Mizoram: Khamdamdawi, Pandamdawi

Oriya: Pasanbhedi, Pashanabheda

Punjabi: Batpia, Dharposh, Kachalu, Pashanbhed

Sanskrit: Ashmabheda,Nag

Tamil: Sirupilai

Telugu: Kondapindi, Telanurupindi

Urdu: Kachalu, Pakhanabheda [2].

GEOGRAPHICAL DISTRIBUTION:

1. Indian Himalayas

The plant is native to the Western and Eastern Himalayan regions and is distributed widely across:

- Jammu and Kashmir
- Himachal Pradesh (notably in Kullu, Chamba, Lahaul-Spiti)
- Uttarakhand
- Sikkim
- Darjeeling (West Bengal)

These regions offer an altitude range of 1500–3000 meters, which provides a cold climate and moisture-rich soil suitable for the plant’s growth.

2. Northeastern India

In addition to the Himalayas, *Bergenia ligulata* is also found in:

- Assam

- Meghalaya (especially in Khasi Hills)

3. Neighbouring Countries

The plant also naturally grows in adjacent Himalayan territories including:

- Nepal
- Bhutan
- Pakistan
- Tibet (China)

It prefers rocky and limestone-rich soils, which are abundant in these regions.

Global Occurrence

Outside South Asia, the plant is known to be cultivated or found in:

- China (as part of traditional Chinese medicine)
- Some parts of Central Asia

However, its wild and natural growth is largely restricted to the Himalayan mountain belt [3].

HABITAT:

It is mostly found in temperate regions of the Himalayas from Kashmir to Bhutan and in the Khasi Hills at 1,500 m (4,900 ft) elevation.

It is often found on rocky slopes and in stone crevices.

BOTANICAL DESCRIPTION:

Kingdom: Plantae- Plants

Subkingdom: Tracheobionta-Vascular plants

Superdivison: Spermatophyta- Seed plants

Division: MagnoliphytaFloweringplants

Class: Magnoliopsida- Dicotyledons

Subclass: Rosidae

Order: Rosales

Family: Saxifragaceae- Saxifrage family

Genus: Bergenia Moench- elephant ear

Species: Bergenia ligulata (Wall.)

Synonyms: Bergenia ciliata (Haw.) Sternb., Megasea ciliata (Haw.), Saxifraga ciliata (Haw) [4].

MORPHOLOGY

Habit- Pashanabheda is much branched perennial herb

Root- Red in colour and 2-5 cm thick

Stem- Short thick, fleshy and procumbent

Leaves- Ovate, 12 to 25 cm in diameter, sessile, ban rounded at the apex, fringed with short hairs.

Flowers- White, pink or purple in colour and flowering occurs in April and May. Flowers are 3 cm in diameter forming a cymose panicle.

Fruit- Drupes, orange or red in colour

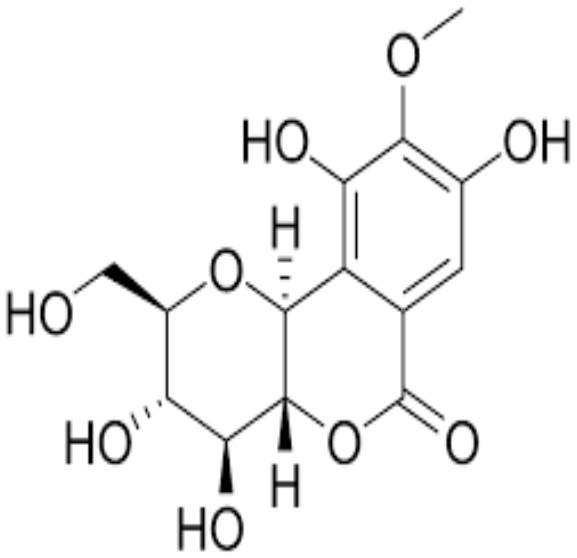
Rhizome- Transversely cut pieces of dried rhizome will be up to 6 cm long and 1-2 cm in diameter. External surface is reddish brown in colour, wrinkled or irregularly shriveled, bearing leaf scales in the upper part and root scars below [5].

MICROSCOPIC FEATURES

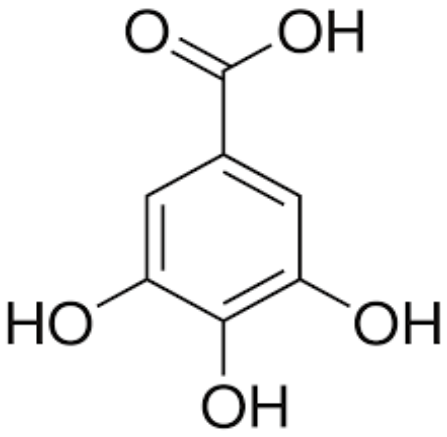
Transverse section of the rhizome shows cork divided into two zones; outer and inner. Outer zone is with few layers of slightly compressed and brown coloured cells whereas inner zone is multilayered consisting of thin walled, tangentially elongated and colourless cells. Cork is followed by single layered cambium and two to three layers of secondary cortex. Cortex consists of a narrow zone of parenchymatous cells containing a number of simple starch grains whereas most of cortical cells contain large rosette crystals of calcium oxalate (CaC2O4) and starch grains. Endodermis and pericycle are absent whereas vascular bundles arranged on a ring. Cambium is present as continuous ring composed of two to three layers of thin walled, tangentially elongated cells. Xylem consists of fibres, tracheids, vessels and parenchyma. Centre is occupied by large pith composed of circular to oval parenchymatous cells containing starch grains with CaC2O4 crystals similar to those found in cortical region. Vessels with simple pits have perforation plates on one end or at both ends and tracheids have helical thickenings [6-8].

PHYTOCHEMISTRY

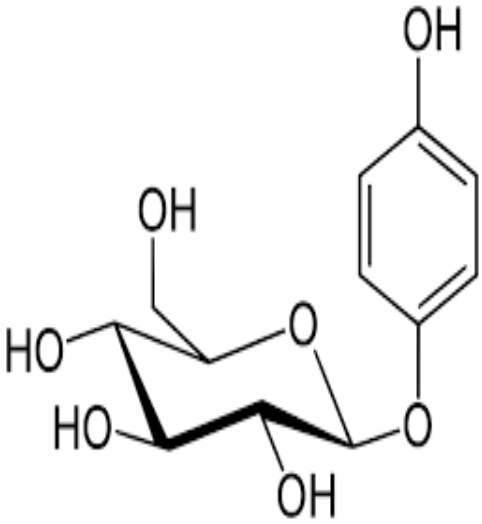
It consists of major phenolic compound ‘bergenin’ (nearly 0.9 %) and other phenolic compounds in minor amount. Phenolic compounds includes (+)- afzelechin, [29] leucocyanidin, gallic acid, tannic acid, methyl gallate, (+)-catechin, (+)-catechin -7-O-ß-D-glucopyranoside, 11-Ogalloyl bergenin28; a lactone- Paashaanolactone. It also contains sterols viz., sitoindoside I, ßsitosterol and ß-sitosterol-D-glucoside, glucose (5.6 %), tannin (14.2-16.3 %), mucilage and wax. Rhizomes of B. ligulata showed a presence of different chemical entities like; Coumarins: bergenin, 11-0-galloyl bergenin, 11-O-P-hydroxybenzoyl bergenin; 11-O-brotocatechuoyl bergenin, 4-0-galloyl bergenin; Flavonoids: (+) afzelechin, avicularin, catechin, eriodictyol-7-O-β-Dglucopyranoside, reynoutrin; Benzenoids: arbutin, 6-O-P-hydroxy-benzoyl arbutin, 6-Oprotocatechuoyl arbutin; 4-hydroxy benzoic acid; Lactone: Idehcxan-5-olide, 3-(6’-O-P-hydroxy) [9].



BERGENIN



GALLIC ACID



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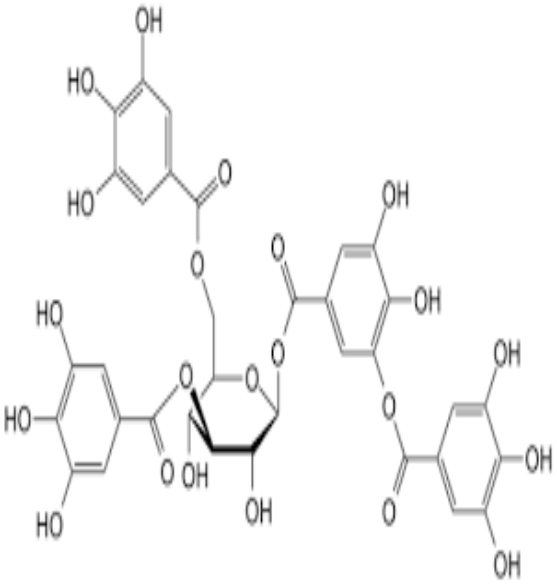

TANNIC

BIOACTIVE COMPOUNDS OF BERGENIA LIGULATA

Part used	Chemical constituents
Root/Rhizome	Bergenin Gallic acid Tannic acid Arbutin Catechin *β*-Sitosterol Stigmasterol Afzelechin 1,8-Cineole Isovaleric acid Terpinen-4-ol (*Z*)-asarone Leucocyanidin Methyl gallate Sitoinoside I *β*-Sitosterol-d-glucoside Avicularin Eriodictyol-7-*O*-*β*-d-glucopyranoside Reynoutrin 11-*O*-Galloylbergenin Pashaanolactone Catechin-7-*O*-glucoside Coumarin 11-*O*-*p*-Hydroxybenzoyl bergenin 11-*O*-Protocatechuoyl bergenin 4-*O*-Galloylbergenin 6-*O*-*p*-Hydroxybenzoyl arbutin Hexan-5-olide Quercetin *β*-Sitosterol-d-glucoside [10].

TRADITIONAL USES:

1. the roots of B. ligulate possess cooling, laxative, analgesic, abortifacient, aphrodisiac properties and used in treatment of vesicular calculi, urinary discharges, excessive uterine haemorrhage, diseases of the bladder, dysentery, menorrhagia, splenic enlargement and heart diseases[2].

2. It is also considered absorbent and given in dysentery. In Sind (Pakistan), the root is rubbed down and given with honey to children when teething. In IndoChina the leaves are ground in a mortar and the juice is used for earaches [11].
3. Hot water extract has been applied externally for boils and also used topically for the treatment of ophthalmia[12].
4. In India dried roots of B. ligulata have been used externally for cuts, boils, wounds and burns; its oral infusion for the treatment of dysentery while its rootstock has also been used as masticator by human adults [13].
5. Decoction of fresh roots of B. ligulata is taken orally by human adults to treat urinary disorders, stomach disorders and urogenital complaints [14].
6. The paste of root Pashanabheda is given as an antidote for opium poisioning [15].
7. In Nepal, about 10 g of rhizome paste or juice of B. ligulata has been taken orally by human adults with the molasses, twice a day for 3-4 days as an anthelmentic for the expulsion of roundworms and also for the treatment of cold [16].
8. Thick leaves of Bergenia ligulata are used in Chinese Medicine to stop bleeding, treat cough, dizziness, hemoptysis, and asthma, and to strengthen immunity [17].
9. The rhizome extract is traditionally used to strengthen capillary walls, which is beneficial in stopping bleeding after abortions, alleviating excessive menstruation, and addressing cervical erosion. This hemostatic property underscores its value in managing various gynecological conditions [5].

PHARMACOLOGICAL ACTIVITY:

1. Anti-inflammatory:

Anti-inflammatory activity of B. ligulata was determined according to the method described by Winter and colleagues. Briefly, 0.1 ml of 1% carrageenan solution, prepared by suspending 100 mg carrageenan in 10 ml normal saline solution, was injected into the left hind paw of rat. The swelling (oedema) produced by carrageenan injection was measured by measuring the increase in paw volume every hour for three hours using a plathysmometer (Ugo Basile, Italy). The percent inhibition was calculated as follows: Vc – Vt / Vc x 100, where Vc is the volume of edema measured in the hind paw, and Vt is the volume of edema in the drug treated group. Volume of edema was derived by taking the difference in the volume of left hind paw receiving carrageenan injection minus the volume of right hind paw, which was not injected with carrageenan.

Evaluation of the anti-inflammatory activity measuring carrageenan-induced paw edema is one of the widely used pharmacological methods. It measures the ability of a compound to reduce local oedema produced by injecting carrageenan in rat hind paw. The formation of oedema is the result of a synergism between various inflammatory mediators that increase vascular permeability and/or mediators that increase the flow of blood. It is a biphasic event. The early phase is observed around 1h after carrageenan injection and is attributed to the release of histamine and serotonin. In the late phase, molecules such as prostaglandins are released. In this study, aqueous and 50% ethanolic extracts of the rhizomes of Bergenia ligulata are reported to attenuate the inflammatory response as determined by pharmacological and biochemical measurements. The treatment significantly decreased the inflammation as can be seen. The activity level of succinate

dehydrogenase (SDH), which has been reported to rise in inflammation, decreased in rats receiving the extract treatment. SDH is a key inner mitochondrial membrane enzyme linked with the energy yielding citric acid cycle in living cells. An increase in SDH would mean an increased supply of ATP to liver and possibly other tissues including the inflamed tissue. In this study, evidence is provided in animal model to demonstrate the role of aqueous as well as 50% ethanolic extract of B. ligulata in inflammation and as antibacterial agent. Oral administration of the extract at a dose level of 1 gm/kg bw showed anti-inflammatory and free radical scavenging activity as evaluated using pharmacological and biochemical parameters. The effect was studied on biochemical parameters reportedly perturbed in inflammation. While the extract treatment could alleviate the level of succinate dehydrogenase and xanthine oxidase, which increase in inflammation, the level of superoxide dismutase increased following the treatment with the extract as well as the diclofenac. Role of oxygen free radicals/peroxides was evaluated by measuring lipid peroxidation and glutathione. Treatment with the extract could significantly decrease the enhanced level of lipid peroxidation in inflammation, and increased the level of glutathione. Further, the antibacterial activity of various fractions was tested in vitro using cultures of Escherichia coli, Baccillus subtilis, and S. aureus, and the fractions were found to be antibacterial [18].

2. Diuretic activity

The ethanolic extracts of root of Bergenia ligulata were assessed for diuretic activity in albino rats that was compared with standard drugs. For evaluation of the diuretic activity Lipschits method, was used. It was done by measuring the volume of urine collected at the end of 5 hrs and Na+, K + and Cl - concentration in urine. The ethanolic extract of the roots of Bergenia ligulata was found to produce significant activity. The extracts of Bergenia ligulata root were studied in the presence of artificial reference urine (ARU) and human urine (HU) the growth behaviors of CHPD crystals grew within the rings. The addition of aqueous extract of B.ligulata to the calcium chloride in the supernatant solution modified the diffusion process and hence the periodic precipitation and the number of liesegang rings. The maximum length of the crystals was reduced due to inhibition produced by the addition of aqueous extract of B.ligulata the HU aqueous extract (AE) of B.ligulata contained a large number of salts and organic molecule. And their complex formation may have promoted the effect on growth of CHPD crystals. But when they are added separately to CaCl2 they inhibit the growth of crystals. This suggests that these solutions separately inhibit the growth of crystals in in–vitro condition. But mixing with HU (humane urine) changes their behavior markedly. The diuretic nature of AE/B.ligulata seems to be important in the remedy rather than their inhibitive nature [19].

3. Anti-pyretic

The ethanolic (95%) extracted of roots, rhizomes and leaves and aqueous extract of whole plant of Bergenia ligulata Wall in yeast induced fever in albino rats of wistar strain were assessed for antipyretic activity.51 The yield of semisolid mass (w/w) was obtained as ethanol extract of roots (13.36%), ethanol extract of rhizomes (15.12%), ethanol extract of leaves (11.02%) and aqueous extract of whole plant (09.21%). Acute toxicity studies were carried out for all the extracts of Bergenia ligulata Wall on healthy swiss albino mice of body weight 25-35g by using Up and Down or Stair case method. The suspension of all the extracts of

Bergenia ligulata Wall was prepared in 5% gum acacia and employed for assessment of antipyretic ligulata were assessed for antipyretic activities in albino rats that were compared with standard drug. The assessment of Antipyretic activity was carried out using Brewer‟s Yeast induced pyrexia method in wistar rats. Rectal temperature was recorded at a time interval of 0, 30 min, 1 hr, 2 hr, 3 hr after drug administration for evalution of antipyretic activity the ethanolic extract of the roots of Bergenia ligulata was found to produce significant antipyretic activity [20].

4. Cardio protective

The present study was designed to investigate the cardioprotective effects of bergenin on isoproterenol-induced myocardial infarction in rats. Bergenin and atenolol were administered through intraperitoneal (i.p.) injection to Sprague Dawley (SD) rats in separate experiments for five (5) days. At the end of this period, rats were administered isoproterenol (80 mg/kg s.c.) to induce myocardial injury. After induction, rats were anaesthetized to record lead II ECG, then sacrificed, blood was collected to analyze cardiac marker enzymes, and a histopathological study of the heart tissues was also performed. Pretreatment with bergenin showed a significant decrease in ST-segment elevation, deep Q-wave, infarct size, and also normalized cardiac marker enzymes (cTnI, CPK, CK-MB, LDH, ALT, and AST), particularly at 3 mg/kg, as compared to isoproterenol treated group. Our findings revealed, for the first time, the use of glycoside bergenin as a potential cardioprotective agent against the isoproterenol-induced MI in rats [21].

5. Anti-Tumor

This study aimed to investigate the chemical composition of methanolic and aqueous extracts of *Bergenia ligulata* rhizome and assess their anticancer activities against various cancer cell lines. The investigation entailed Gas chromatography-mass spectrometry (GC-MS) for phytochemical analysis, the MTT assay for cytotoxicity assessment, and DAPI staining for nuclear morphological analysis. GC-MS analysis revealed 45 phytochemical constituents in methanol extract and 35 in aqueous extract, with each extract containing six major phytoconstituents. Dihydro-3-methylene-5-methyl-2-furanone (α-Methylene-γ-valerolactone), oleic acid, and n-Hexadecanoic acid were identified as the common constituents in both the extracts. The cytotoxic evaluation demonstrated potent antiproliferative effects of both extracts against tested cancer cells and biocompatibility with HEK-293 cells. Additionally, methanolic and aqueous extracts induced nuclear fragmentation and condensation in T24 cells. These findings underscore the presence of diverse phytoconstituents in *B. ligulata* and suggest its potential as a natural anticancer agent. Further research is warranted to explore the anticancer activities of the main bioactive compounds in *B. ligulata* rhizome extracts and to elucidate their possible molecular mechanism of action in different cancers [22].

6. Anti-oxidant

Antioxidant activity is the efficiency of an active molecule to decrease free radical production and scavenge ROS, repairing, as well as inhibiting, injuries occuring due to the degradation and oxidation of biomolecules and other molecules. BER(Bergenin) manifests its antioxidant action by reducing free radical formation and scavenging the various ROS

formed. This action of BER has been observed via a strong scavenging effect on DPPH (2,2-diphenyl-2-picryl hydrazyl free radical) in the literature. It also prevents lipids peroxidation.

Rastogi et al. reported the good antioxidant effect of BER and Nazir et al. illustrated that bergenin pentacetate (a peracetate derivative of BER) isolated from *Bergenia stracheyi*, displayed higher DPPH radical scavenging activity [23].

7. Anti-microbial

The aim of the present study was to investigate the antimicrobial and synergistic potential of solvent fractions and major phytocompound of B. ligulata against bacterial and fungal pathogens. The antimicrobial and synergistic potential of the solvent fractions (Petroleum ether, chloroform, ethyl acetate, and remaining aqueous) of methanolic extract of B. ligulata rhizome and major phytocompound bergenin were investigated by agar well diffusion and broth microdilution method. Major Phytocompound bergenin was quantified in solvent fractions of B. ligulata by HPTLC and HP-LC method Molecular docking of bergenin was done by AutoDock vina with bacterial and fungal targets. Drug likeness and ADME screening was done with help of molinspiration and swissADME servers. Ethyl acetate sub-fraction of B. ligulata showed the highest antimicrobial activity against bacterial and fungal strains with zone of inhibition 13, 13, 14, 13 mm against Escherichia coli, Staphylococcus aureus, Candida albicans MTCC 277 and ATCC 90028 respectively. The MIC of ethyl acetate sub-fraction against E. coli, S. aureus, C. albicans MTCC 277 and ATCC 90028 was 31.25, 250, 62.5, 62.5 μ g mg−1 respectively. Bergenin major phytocompound of B. ligulata also showed the antimicrobial activity with MIC 250 μ g mg−1 against all the selected bacterial and fungal strains. Quantification of bergenin showed that ethyl-acetate sub fraction (17.6 μ g mg−1 and 112 μ g mg−1 measured through HPTLC and HPLC, respectively) is rich in bergenin content. The bergenin content recovered in ethyl acetate sub-fraction is 38.2%. Bergenin showed good interactions with bacterial and fungal targets and follows all parameters of drug likeness. Conclusions: Solvent fractions of B. ligulata and major phytocompound Bergenin can be used as a bioenhancer of antibacterial and antifungal agents to treat drug resistant pathogens [24].

8. Bone healing

Suh and research group studied the BER (Bergenin) effect on osteoblasts (MC3T3-E1). BER therapy potentially raised the synthesis of osteocalcin, action of alkaline phosphatase, synthesis of collagen fibers, and cells mineralization. Moreover, BER therapy remarkably suppressed the transcription factor 6 activation and MG (methylglyoxal) autophagy. The outcomes represented that BER may have good efficacy when it comes to functions of osteoblastic cell. MG is the main precursor for the synthesis of AGEs (advanced glycation end products). Pretreating cells (MC3T3-E1) with BER inhibited the formation of protein adduct induced by MG. BER suppressed the soluble receptor for the interleukin, AGE (sRAGE), superoxide, and ROS making induced by MG. In addition, in the presence of MG, BER enhanced heme oxygenase-1 glutathione, nuclear factor erythroid 2-related factor 2 levels, and glyoxalase I activity. The findings showed that BER may be a good bioactive for the management of diabetic osteopathy.Bone mesenchymal stem cells (BMSCs) are vital applicants for the regeneration of bone. Hou and his research group examined the potential of BER on the BMSCs osteogenesis, and an in vitro study showed that BER augmented osteoblast-specific markers and suppressed the adipocyte-specific markers. These outcomes

presented that BER enhanced the differentiation of osteogenic of BMSCs, at least partly via SIRT1 activation [25].

9. Anti-urolithic effect of Bergenia ligulata rhizome

The crude aqueous-methanolic extract of Bergenia ligulata rhizome (BLR) was studied using in vitro and in vivo methods. BLR inhibited calcium oxalate (CaC2O4) crystal aggregation as well as crystal formation in the metastable solutions and exhibited antioxidant effect against 1,1-diphenyl-2-picrylhydrazyl free radical and lipid peroxidation in the in vitro. BLR caused diuresis in rats accompanied by a saluretic effect. In an animal model of urolithiasis, developed in male Wistar rats by adding 0.75% ethylene glycol (EG) in drinking water, BLR (5–10 mg/kg) prevented CaC2O4 crystal deposition in the renal tubules. The lithogenic treatment caused polyuria, weight loss, impairment of renal function and oxidative stress, manifested as increased malondialdehyde and protein carbonyl contents, depleted reduced glutathione and decreased antioxidant enzyme activities of the kidneys, which were prevented by BLR. Unlike the untreated animals, EG intake did not cause excessive hyperoxaluria and hypocalciuria in BLR treated groups and there was a significant increase in the urinary Mg2+, instead of a slight decrease. These data indicate the antiurolithic activity in Bergenia ligulata mediated possibly through CaC2O4 crystal inhibition, diuretic, hypermagneseuric and antioxidant effects and this study rationalizes its medicinal use in urolithiasis [4].

10. Anti-Diabetic

Plants belonging to the genus *Bergenia* play a crucial role in reducing the hyperglycemic condition. Rigorous studies on animal models revealed that *B. ligulata* possesses strong anti-diabetic activity. Another possible mechanism of anti-diabetic action of *B. ligulata* may be attributed to its bioactive compound (+)-afzelechin, which acts as an inhibitor of α-glucosidase enzyme, as ascertained by enzyme inhibition assay. The inhibition of α-glucosidase enzyme has been found to be effective in the treatment of hyperglycemia by delaying the absorption of carbohydrates in rat small intestines.

Diabetes mellitus has several etiologies and is characterized by high blood glucose level resulting from the destruction of pancreatic beta cells, defects in insulin secretion, and abnormalities in insulin receptors. Diabetes can also trigger other diseases such as cardiovascular diseases, neuropathy, retinopathy, and nephropathy. *B. ligulata* extract may stimulate the pancreatic islet cells and increase insulin secretion to maintain normal blood glucose levels . Afzelechin from *B. ligulata* extract exhibited anti-diabetic activity by inhibiting the enzymatic action of α-glucosidase, thus delaying the absorption of dietary carbohydrates in the small intestine and reducing postprandial hyperglycemia and hyper-insulinemia. Similarly, (-)-3-O-galloylepicatechin and (-)-3-O-galloylcatechin isolated from *B. ligulata* have demonstrated inhibitory effects against porcine pancreatic α–amylase, which also delays the absorption of glucose in the intestine. Anti-diabetic mechanism of *B. ligulata*. Plant extract stimulates the pancreatic islet cells and increases insulin secretion for maintaining normal blood glucose levels. (+) afzelechin, a compound of *B. ligulata*, inhibits the enzymatic action of alpha-glucosidase, thus delaying the absorption of dietary carbohydrate in the small intestine and reduces postprandial hyperglycemia and hyper-insulinemia. Additionally, compounds such as (-)-3-O-galloylepicatechin and (-)-3-O-

galloylcatechin from *B. ligulata* inhibit pancreatic α-amylase and delay the absorption of glucose in the intestine [26].

11. WOUND HEALING

For a long time, several parts of the Indian ethnomedicinal plant "*Shorearobusta"* have been conventionally employed for various disorders, such as burns and wounds, by various tribal communities. The animals treated with the fractions (5%) and extracts presented potential minimization in the wound area (96.41% and 96.55%), with faster epithelialisation, whereas the isolated constituents ursolic acid and Bergenin heal the injury more rapidly. Furthermore, the hydroxyproline content, granuloma tissue weight, and tensile strength of the incision wound were potentially enhanced by both the compound(s). Moreover, as per tissue histology outcomes, isolated compound(s) presented entire epithelialization with enhanced collagenation, comparable to povidone-iodine [27].

12. Hepatoprotective activity

The administration of ethanolic root extract of *B. ligulata* to albino Wistar rats at a dose range of 25–35 g/kg body weight for 10 days exerted hepatoprotective activity, which was assessed by measuring the levels of serum glutamate pyruvate transaminase (SGPT), serum glutamate oxaloacetate transaminase (SGOT), serum alkaline phosphatase (ALP), and total bilirubin. All these parameters were significantly lower in the *B. ligulata*-treated group as compared to standard drugs.Several studies have demonstrated the hepatoprotective activity of *B. ligulata*, although the mechanism of action is poorly understood. The antioxidant properties and cellular restoration capacity of the plant may play significant roles in the recovery of damaged liver tissues. Free radicals such as hydroxyl radicals, hydrogen peroxide, superoxide radicals, and lipid peroxide are predominant in liver diseases. These free radicals are normally generated during the biochemical process of the body or due to exposure to different environmental toxicants or pathological states. Excess amounts of free radicals generate oxidative stress that alters the membrane structure and damage other important components of the cell including lipids, proteins, and nucleic acids. The bioactive compounds of *B. ligulata* may exert hepatoprotective activity through antioxidant and free-radical scavenging properties. Similarly, it can normalize increased Kuffer cells number and lymphocytic infiltration in infected mice. In Wistar albino rats, *B. ligulata* root extract ameliorated carbon tetrachloride (CCl_4)-induced liver damage along with a reduction in the level of alkaline phosphatase (ALP), total bilirubin level, SGPT, and SGOT. The major bioactive component of *B. ligulata*, i.e., bergenin, might be responsible for the hepatoprotective properties of the plant. Bergenin at doses of 50, 100, and 200 mg/kg body weight showed a strong hepatoprotective effect when administrated orally for 7 successive days in CCl_4-induced liver damage in rats. The administration of bergenin subsequently normalizes the increasing serum enzymatic activities of alanine/aspartate aminotransferase, sorbitol dehydrogenase, and γ-glutamyltransferase in CCl_4-treated rats in a dose-dependent manner. In contrast, the recuperation of the activities of glutathione S-transferase and glutathione reductase was also reported. Additionally, bergenin can prevent the elevation of hepatic malondialdehyde formation and the depletion of reduced glutathione content in the liver of CCl_4-intoxicated rats [28, 29].

Pharmacopeial standards

1)Pharmacognostic Standards

- Macroscopic Characteristics
- Microscopic Features

2) Physicochemical Parameters

- Loss on Drying: Not more than 9% w/w, indicating the moisture content in the plant material.
- Total Ash: Not more than 15% w/w, representing the total mineral content.
- Acid-Insoluble Ash: Not more than 1.5% w/w, indicating the presence of silica and other acid-insoluble substances.
- Water-Soluble Ash: Approximately 0.3% w/w, reflecting the amount of water-soluble minerals.
- Alcohol-Soluble Extractive: Around 13.9% w/w, denoting the amount of constituents soluble in alcohol.
- Water-Soluble Extractive: Approximately 15.9% w/w, indicating the constituents soluble in water.

3) Phytochemical Constituents

Bergenia ligulata contains several bioactive compounds, including:

- Bergenin: A C-glucoside of 4-O-methyl gallic acid, known for its anti-inflammatory and antiurolithiatic properties.
- Gallic Acid: An antioxidant and anti-inflammatory agent.
- Catechin: A flavonoid with antioxidant properties.
- Tannic Acid: Known for its astringent and antimicrobial activities.
- β-Sitosterol: A phytosterol with potential cholesterol-lowering effects.

4) Analytical Standards

- High-Performance Thin-Layer Chromatography (HPTLC): Used for the identification and quantification of bergenin and other constituents.
- High-Performance Liquid Chromatography (HPLC): Employed for precise quantification of bergenin, ensuring consistency and quality in herbal preparations.

5) Adulteration and Substitutes

Due to its high demand, *Bergenia ligulata* is sometimes adulterated with or substituted by other plants like *Aerva lanata*, *Bryophyllum pinnatum*, and *Ammania buccifera*. Such substitutions can lead to variations in therapeutic efficacy. Therefore, proper identification through morphological, microscopic, and chemical analyses is crucial [30,31].

Discussion

Bergenia ligulata is a well-known medicinal plant used traditionally in Ayurvedic and Unani systems of medicine. Its rhizomes and roots are rich in bioactive compounds like bergenin, gallic acid, catechin, and tannins, which contribute to a wide range of pharmacological activities. These include antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, antiurolithiatic (stone-dissolving), antipyretic, and antidiabetic properties. The review highlights how *Bergenia ligulata* has been extensively studied for its role in treating kidney stones due to its ability to inhibit calcium oxalate crystal formation. It also discusses the plant's potential in modern medicine as a source of phytochemicals that could be developed into drugs with fewer side effects compared to synthetic options. Despite its promising bioactivities, there is a need for further research focusing on its molecular mechanisms, clinical trials, dosage standardization, and potential toxicities to validate its therapeutic use.

Conclusion

Bergenia ligulata is a potent medicinal herb with a wide spectrum of pharmacological benefits, particularly in the management of urolithiasis and inflammation. Its rich phytochemical profile supports its traditional uses, and it holds promise for the development of natural therapeutic agents. However, comprehensive scientific studies and clinical evaluations are necessary to confirm its efficacy and safety for widespread use in modern medicine.

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