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Review Article

A Comprehensive Review on Therapeutic Properties of *Bombax ceiba*

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ABSTRACT

Plants have played a significant role in traditional medicine for treating a wide range of human ailments. Among the many medicinal herbs used in Unani medicine, *Bombax ceiba* Linn. has been employed for centuries. This herbaceous plant is renowned for its impressive height, reaching approximately 150 feet. It can be found in temperate and tropical regions of Australia, Africa, and, Asia with occurrences in India at altitudes of up to 1500 meters. The indigenous communities and forest dwellers extensively utilize various components of this plant, including the root, flower, gum, leaf, prickles, stem bark, fruit, seed, and heartwood, to address diverse diseases. Ethnobotanical research reveals that *Bombax ceiba* Linn. is effectively employed in the treatment of ailments such as diarrhea, boils, wounds, leprosy, acne, and various other skin conditions. Furthermore, it has been used as an anthelmintic since ancient times. Through scientific investigations, the presence of numerous beneficial properties has been confirmed in different parts of this plant, thus validating its traditional medicinal use. These properties include hypotensive, antioxidant, pain-relieving, anti-inflammatory, antipyretic, antiangiogenic, antioxidant, antibacterial, antidiabetic, hepatoprotective, anticancer, and anti-helicobacter pylori properties.

INTRODUCTION

Throughout history, nature has been an invaluable source of therapeutic agents, leading to the discovery of groundbreaking drugs derived from natural origins [1]. India, often referred to as the "Botanical Garden of the world," is renowned for its abundant variety of therapeutic plants. These plants have played a crucial role in advancing material medica, contributing significantly to human well-being and promoting a healthy, disease-free life [2, 3]. The preservation of our health is of utmost importance, and India holds a significant position in this regard. With its rich traditions in medicine and culture, India has a profound legacy of utilizing medicinal plants that continues to be respected even in modern times. The old systems of medicine in India, like Ayurveda, Unani, and Siddha, are vital in maintaining the well-being of individuals [4]. Plants have long been recognized for their remarkable biochemical capabilities and have been integral to the field of phytomedicine for centuries [4]. Different parts of plants, including bark, leaves, flowers, roots, fruits, and seeds, serve as potential sources of natural compounds with medicinal properties [1]. In the tropical regions of India Silk Cotton Tree, scientifically known as *Bombax ceiba*, holds significant importance as a medicinal plant. This tall deciduous tree exhibits a straight buttressed trunk and expansive branches. According to Ayurveda, *Bombax ceiba* is renowned for its proven medicinal properties and finds

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applications in numerous formulations. Virtually every part of this plant possesses medicinal value, with the roots and flowers being particularly noteworthy for their efficacy in treating various ailments [2]. Belonging to the Bombacaceae family, *Bombax ceiba* Linnaeus is a notable species among approximately 26 species and nearly 140 pantropical classes. It is usually referred to as Semal, Simbal, Simul, Indian kapok, Katsavar, Indian *bombax*, or Red Silk cotton tree. In India, it can be found at altitudes of up to 1500 meters. This tree thrives in both dry and moist deciduous forests, as well as in the vicinity of rivers, particularly in peninsular India. *Bombax ceiba* prefers well-drained soils, especially deep sandy loams, and is characterized as a fast-growing species that requires ample sunlight. It flourishes in regions with annual rainfall ranging from 50 to 460 centimeters, which is evenly distributed throughout the year [3]. *Bombax ceiba* is a deciduous tree that can reach heights of up to 45 meters. Its trunk is straight and is supported by buttresses measuring 1-2 meters in height. The bark has a gray color with white mottling and is approximately 20-30 mm thick. The branches are arranged horizontally in a whorled pattern. The leaves are alternately arranged and have a digitately-compound structure with small lateral stipules. The central axis of the leaf, known as the rachis, is smooth and measures 12-25 cm in length. The leaflets, usually 5-7 in number, are elliptic or elliptic-obovate in shape, with dimensions of 10-20 x 2-6 cm. The leaf margins are smooth, and the entire leaf surface is free from hairs [5]. The flowers of *Bombax ceiba* are bisexual and have a dark crimson color. They are large, with a diameter of 6-7 cm, and can appear individually or in clusters of 2-5 flowers. The calyx, which forms the outer part of the flower, has a bell-shaped structure, and its lobes measure about 3-4 x 3 cm. The outer surface of the calyx is smooth, while the inner surface is covered in silky hairs. The petals, numbering 5, are fleshy and elliptic-obovate, with measurements of 8.5-18 x 3.5-5 cm. The tree produces a substantial number of stamens, ranging from 65 to 80, which can reach lengths of 3-7.5 cm. The ovary is conical and covered in fine hairs, and it contains 5 compartments with numerous ovules. The style, the elongated part of the female reproductive structure, is longer than the stamens [6-8]. The fruit of *Bombax ceiba* is a capsule that measures 8-10 x 3 cm. It has a cylindrical shape and is covered in soft, tomentose hairs. As it matures, the capsule turns blackish and becomes glabrous. Inside the fruit, numerous seeds are present. These seeds are pyriform (pear-shaped), smooth, and have a dark brown color. They are surrounded by a distinctive white cotton-like material [5, 7].

Bombax ceiba Morphology

According to ethnobotanical surveys and traditional systems of medicine like Ayurveda, various parts of semal, including seeds fruits, roots, leaves, bark, flowers, and gum, have been identified for their medicinal properties. The Semal tree is a tall deciduous tree that can reach heights of up to 40 meters. It features horizontally spreading branches, and the young stems are adorned with hard prickles. The bark of the tree displays a grey-brown or silver-grey color and is adorned with sharp conical prickles. The leaves are large, spreading, and possess a smooth texture. They consist of lanceolate leaflets, typically numbering 3-7, with smooth margins. The flowers are abundant and characterized by their red color. They appear when the tree is leafless and are distinguished by multiple stamens arranged in 5 bundles, each containing 9 to12 stamens, along with an internal bundle of 15 stamens. The fruits resemble capsules, are brown in color, and can reach lengths of up to 15 millimeters. They contain numerous black seeds that are smooth and can vary in color, ranging from black to grey. These seeds are enveloped in extended white wool, which has an uneven obovoid shape, a smooth and oily texture, and is densely covered in silky hair. Additionally, the tree produces a gum known as semul gum, which ranges in color from light brown to opaque or dark brown [2, 4].

Figure 1: *Bombax ceiba* tree in bloom, showcasing its vibrant flowers during the months of April to May

The seeds of *Bombax ceiba* are rich in essential amino acids. The gum obtained from *Bombax ceiba* upon hydrolysis yields various sugars and derivatives. The gum can be used as a substitute for gum tragacanth. Methylated *Bombax ceiba* gum, upon hydrolysis, produces different methylated sugars. Extracts of *Bombax ceiba* flowers and their solvent fractions have undergone physicochemical and preliminary phytochemical screening using standard tests [8, 9].

Bombax as Antioxidant

Bombax ceiba, is a medicinal plant belonging to the Bombacaceae family [10]. The plant extracts of B. ceiba have been studied for their antioxidant, anti-inflammatory, and antibacterial properties. They have shown potential in managing diabetes and hyperglycemia. While certain parts

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of B. ceiba flowers are consumed in Thai culture, limited research has been conducted to explore their biological and pharmacological effects. Chemical analysis of B. ceiba leaf and flower extracts has revealed many flavonoids, saponins, tannins, terpenoids, and cardiac glycosides. Notably, the flower extracts exhibit significant concentrations of total phenolics and flavonoids. In vitro studies have demonstrated the antioxidant and anti-diabetic activities of the flower extracts, which contain phytochemicals such as anthocyanin, rutin, quercetin, and apigenin [11]. In recent years, various chemical-based tests have been developed and modified to detect antioxidant activities. Primary antioxidants play a vital role in inhibiting oxidation by interrupting chain reactions and neutralizing free radicals. Secondary antioxidants act as metal chelating agents, helping to restore primary antioxidants and stabilize singlet oxygen. These tests have diverse applications in evaluating antioxidant properties [12]. Flavonoid compounds, known as secondary natural antioxidants, have been found to exhibit stronger inhibitory effects on glucosidase and amylase compared to acarbose in vitro. The flavonoids and phenolics present in B. ceiba flower extracts have the potential to suppress the activity of glucosidase and amylase, which could aid in the management of diabetes. Additionally, a 50/50 ethanolic extract of B. ceiba stem bark and flowers has shown hypoglycemic effects, with mangiferin being attributed to the reduction of fasting blood glucose levels [12]. Nitrite, a highly toxic compound found in high levels in leafy and root vegetables, can have adverse effects such as methemoglobinemia through the oxidation of hemoglobin [13]. In a specific study, B. ceiba extract exhibited excellent scavenging properties against nitric oxide radicals. Phenolic compounds, particularly flavonoids, are known not only as scavengers of free radicals but also for their ability to stabilize nitric oxide, peroxynitrite, and reactive oxygen species during lipid peroxidation [14].

Bombax as Anti-Inflammatory

Chronic inflammation is associated with conditions like gastritis, rheumatoid arthritis, atherosclerosis, inflammatory bowel disease (IBD), and cancer. Excessive production of free reactive nitric oxide (NO) by inducible NO synthase (iNOS) can contribute to inflammatory disorders and autoimmune diseases like rheumatoid arthritis. Compounds that inhibit the overproduction of NO are often referred to as anti-inflammatory drugs. However, synthetic anti-inflammatory drugs available in the market can have significant toxic side effects and may lead to a recurrence of inflammation upon discontinuation [15]. Plants provide a diverse range of secondary metabolites with potential anti-inflammatory activity, targeting various molecular pathways. Exploring the anti-inflammatory properties of natural products offers a promising approach to developing new drugs with reduced risks of side effects [16]. *Bombax malabaricum*, a plant species, has been found to exhibit significant antifungal activity against the fungus responsible for ringworm infections when extracted from its leaves. Catechutannic acid is present in the bark gum of this plant, while mangiferin, an antioxidant and analgesic compound, has been isolated from its leaves. The roots of the plant contain several compounds, and the root bark is a source of lupeol, β-sitosterol, isohemigossypol-1-methyl ether, and 7-hydroxycadalene [16, 17].

Bombax as Antibacterial

The antibacterial activity of methanol extracts from *Salmalia malabarica* was found to be potent against multi-drug resistant strains such as *Salmonella typhi*, *Staphylococcus aureus*, *Micrococcus luteus* (Gram-positive), *Escherichia coli*, and *Pseudomonas aureginosa* (Gram-negative) bacteria [18]. The N-hexane and methanol extracts of *Bombax malabarica* flowers also exhibited significant antimicrobial activity. Gram-positive bacteria including *S. aureus*, *Bacillus cereus*, *E. coli*, and *Vibrio cholerae* showed high susceptibility to the methanol extract of *B. malabarica* flowers. Furthermore, the extract demonstrated antifungal activity against *Cryptococcus neoformans* but did not exhibit effectiveness against *C. albicans* [19]. In the case of *Bombax ceiba* extracts, certain fractions showed greater susceptibility against bacterial strains such as *B. subtilis, S. aureus, E. coli, P. aeruginosa*, as well as fungal strains *A. niger and C. albicans*. The bark extract in different solvents exhibited susceptibility against *A. niger and C. albicans*, with ethanol showing the highest activity followed by acetone and aqueous extracts. However, petroleum ether and chloroform extracts did not show any effect. *E. coli* showed the highest sensitivity among the tested microbes, with a larger zone of inhibition observed in the carbon tetrachloride fraction compared to the n-hexane and chloroform fractions [17].

Hepatoprotective Activity

The aqueous extract of *B. malabarica* has shown protective effects against CCl4-induced hepatotoxicity. Specifically, the xylem of the stem and root play a role in protecting the liver from histological changes associated with CCl4-induced damage, such as fatty degeneration, cell necrosis, ballooning necrosis, lymphocytes, and Kupffer cell aggregation. Mangiferin, isolated from *B. malabarica*, has also been found to alleviate liver damage caused by CCl4. Furthermore, mangiferin has been shown to reverse alterations in liver biochemical markers induced by antitubercular medicines (Isoniazid and Rifampicin) and paracetamol, although it does not have an impact on liver histology [20]. Excessive and chronic alcohol consumption can lead to severe liver injury. The therapeutic effects of aqueous methanol extract from *Bombax ceiba*

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(Bombacaceae) on liver steatosis were investigated in a study that lasted eight weeks and involved seven groups. One group served as the control, while the other six groups were subjected to various conditions. One group was fed a fatty diet, another received ethanol and a high-fat diet, and each group was administered the same dose of fluvastatin (2 mg/kg/d). Another group received oral administration of BCE extract (200 mg/kg/d), and the final group did not receive any treatment. The BCE extract contributed to weight loss and enhanced hepatic function in alcohol-induced liver injury. The extract significantly reduced malondialdehyde (MDA) levels and increased hepatic antioxidants. Furthermore, it led to a significant decrease in triglycerides (TG), LDL (LDL), and total cholesterol (TC) levels. Histopathological analysis revealed that BCE treatment reversed alcohol-induced fatty alterations. Phenolic compounds and flavonoids present in BCE possess anti-alcoholic, anti-steatosis, anti-inflammatory, and antioxidant properties, which contribute to its therapeutic potential [21].

Anticancer Activity

The antiproliferative activity of diethyl ether (DE) and light petroleum (PE) extracts from *Bombax ceiba* flowers was assessed against seven human cancer cell lines, including ACHN, COR-L23, A549, Caco-2, Huh-7D12, and C32 [22-25]. Both DE and PE extracts displayed strong inhibition of tumor cell viability, particularly against ACHN cells, in a dose-dependent manner. The IC50 values for PE and DE were determined as 45.5 µg/mL and 53.2 µg/mL, respectively [26]. Flavonoid-rich extracts obtained from *B. ceiba* flowers were screened for their impact on fatty acid synthase (FAS) in various cancer cells [23]. FAS is known to be overexpressed and hyperactive in certain cancers. The *B. ceiba* extract exhibited significant inhibition of FAS activity across different cancer cells. Among the tested cells, N87 gastric cancer cells exhibited the lowest FAS activity, while A549 lung cancer cells showed the highest. The flavonoid-rich extract demonstrated inhibitory effects on FAS with a minimum inhibitory concentration of 247.98 µg/mL, using A549 cells [26]. The methanolic extract of *B. ceiba* demonstrated minimal cytotoxicity in the Vero cell line based on a mitochondrial activity assay [24]. The anticancer potential of the methanol extract from *B. ceiba* root was evaluated using a brine shrimp lethality bioassay, with vincristine sulfate as the standard cytotoxic agent. The LC50 (50% mortality) and LC90 values for the crude extract were determined as 3.90 µg/mL and 150.0 µg/mL, respectively [25]. Additionally, the methanolic extract of *B. ceiba* leaves exhibited antioxidant activity and showed significant enhancements in neutrophil adhesion, carbon clearance from blood, delayed-type hypersensitivity (DTH) response, and protection against cyclophosphamide-induced myelosuppression. The extract also demonstrated increased cell death in the HL-60 cell line, as observed through the MTT assay. Furthermore, elevated caspase-3 activity and an increase in the sub-G1 population were observed in the presence of the methanolic extract of *B. ceiba* leaves [26].

Anti-Diabetic Activity

Shamimin, obtained from the leaves of *Bombax ceiba* at a dosage of 500 mg/kg, has been identified as a hypoglycemic agent in rats [27]. The hydromethanolic (2:3) extract of *Salmalia malabarica* sepals demonstrated a significant reduction in Fasting Blood Sugar and Glycated Hb (HbA1C) levels in STZ-induced diabetic rats. This extract also restored the activity of specific carbohydrate metabolic enzymes and countered the hyperactivity of glucose-6-phosphatase in the liver and skeletal muscle, which were impaired due to STZ induction. Moreover, the extract alleviated elevated oxidative stress levels and restored SGOT and SGPT levels [28]. The n-hexane fraction of this hydromethanolic extract also exhibited significant hypoglycemic and hypolipidemic effects. Additionally, the n-hexane fraction increased serum insulin levels and hemoglobin concentration while decreasing glycated hemoglobin levels. This fraction was also found to be beneficial in preserving the islets of Langerhans in diabetic rats [29]. Certain compounds present in *Bombax ceiba*, such as quercetin and epicatechin, were identified as potent inhibitors of the α-glucosidase enzyme, with inhibitory rates of 50.5% and 48.3%, respectively [30]. Furthermore, glucosylxanthone derived from the plant has been investigated as a potential target for new anti-diabetic medication, particularly due to its inhibitory effect on DPPIV. In silico binding studies revealed that glucosylxanthone and its analogues exhibited comparable binding activity to FDA-approved medicines and other compounds under research. Inhibiting DPPIV could lead to increased serum Glucagon-like Peptide-1 (GLP-1), resulting in a net hypoglycemic effect. Additionally, the aqueous (at a dose of 100 mg/kg) and ethanolic (at a dose of 200 mg/kg) extracts of *Bombax malabarica* bark demonstrated beneficial effects in alloxan-induced diabetic rats [30]. The anti-diabetic activity observed of the extract could be attributed to the antioxidant properties induced by compounds such as isoorientin, vitexin, isomangiferin, quercetin, hexoside, mangiferinisovitexin, and nigricanside [31]. In a study conducted on the therapeutic potential of a standardized extract derived from *Bombax ceiba* leaves (BCE) was investigated in rats with type 2 diabetes mellitus (T2DM) [32]. The administration of BCE resulted in a significant decrease in fasting blood glucose levels and improved oral glucose tolerance in T2DM rats. These findings highlight the excellent hypoglycemic

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effects of BCE in rats with type 2 diabetes [33, 34].

Anti-Obesity Activity

Bombax ceiba Linn. has a rich traditional history of being used to address various ailments, including diarrhea, dysentery, digestive disorders, diabetes, and imbalances of the three doshas (tridoshas). It is recognized for its positive effects on digestion and its ability to modulate insulin, leptin, and integrin signaling by stimulating PTP-1B. This stimulation results in increased fatty acid synthase (FAS) activity, which can contribute to obesity [33]. The powdered root of *B. ceiba* has demonstrated significant effects in modifying coronary risk factors, such as atherogenic lipids, fibrinogen, and oxidative stress, in individuals with ischemic heart disease. Its antioxidant activity is attributed to its high phenolics and tannins content [33]. In a study conducted on male Wistar albino rats, the anti-obesity efficacy of *Bombax ceiba* Linn. was investigated using a high-fat diet-induced obesity model. After ten weeks of being fed a high-fat diet, the rats developed experimental obesity. From the 7th to the 10th week, the rats were orally administered a dose of 100 mg/kg of *B. ceiba* extract and 50 mg/kg of gemfibrozil. Significant result shows in this study. However, treatment with *B. ceiba* extract and gemfibrozil effectively reduced these obesity-induced alterations. Notably, *B. ceiba* extract at doses of 200 and 400 mg/kg exhibited stronger effects compared to the conventional medicine. The study suggests that the methanolic extract of *Bombax ceiba* Linn. stem bark may have anti-obesity potential against high-fat diet-induced obesity in rats by modulating FAS and PTP-1B signaling pathways [34].

Gastrointestinal Effects

The antidiarrheal properties of the methanolic extract derived from *Bombax buonopozense* leaves were investigated. The extract was evaluated for its effects on diarrhea, enteropooling, and intestinal transit in rats. *Bombax buonopozense* demonstrated a reduction in diarrhea, enteropooling, and intestinal motility in the tested rats. The estimated oral LD50 (median lethal dose) in mice was approximately 5000 mg/kg. These results suggest that the methanolic extract of *B. buonopozense* leaves contains active compounds traditionally used in Nigerian herbal medicine for the treatment of diarrhea [35, 36]. *Bombax ceiba* is renowned for its beneficial effects on gastrointestinal and urogenital disorders. Both the leaf and stem branches of *B. ceiba* exhibit ACE inhibitor, antifungal, and anticholinesterase activities [37].

Anti-Acne Effect

Bombax ceiba Linn. is widely utilized in the formulation of various cosmetics and skin preparations, finding its place in skincare products targeting skin issues like acne, pimples, and skin infections. Among its various parts, the thorns of the plant are particularly valued for their ability to combat acne and are employed in numerous acne-specific skincare formulations. An example of such a formulation is the "Himalayas" anti-acne cream, where *Bombax ceiba* Linn. plays a prominent role as a key ingredient (Jain and Verma). In an ethnopharmacological study conducted among tribal groups in Pakistan's North-West Frontier Province, the use of *B. ceiba* was recorded for treating skin ailments and traditional cosmetics. The bark of *B. ceiba* was ground and topically applied to address concerns like pimples, carbuncles, and boils [38]. *Salamalia malabarica* Schott. and Endl, commonly known as the thorn of *B. ceiba*, have also been employed in the treatment of facial acne. The alcoholic extract derived from the bark and thorns of *S. malabarica* demonstrated potent anti-acne activity against Propionibacterium acne, with a minimum inhibitory concentration (MIC) of 250 µg/ml, surpassing the MIC of the standard clindamycin. The leaf extract showed an MIC value of 500 µg/ml. Furthermore, all three extracts exhibited a reduction in P. acne-induced granulomatous inflammation in rats. The thorns of *S. malabarica* are an essential component of the polyherbal formulation "Acne-N-Pimple Cream" by Himalaya, recommended for managing acne vulgaris. Clinical observations of the cream revealed a significant decrease in the number of blackheads, whiteheads, inflamed pustules, and overall inflammation, indicating its effectiveness and safety in managing acne vulgaris [39].

CONCLUSIONS

Bombax ceiba, commonly known as *B. ceiba*, has a diverse and extensive traditional history of medicinal use. This traditional knowledge has been validated by scientific investigations, further supporting the plant's therapeutic potential. Moreover, considering its ecological and economic significance, it is crucial to emphasize the importance of conserving *B. ceiba* from an ecological standpoint. Throughout history, *B. ceiba* has been utilized in the treatment of a wide range of ailments. It has been employed for conditions such as dysentery, menorrhagia (excessive menstrual bleeding), various skin problems, hemorrhoids, snakebites, scorpion stings, boils, leucorrhoea (vaginal discharge), internal bleeding, calculus affections (stones in the body), chronic inflammation, ulcers in the bladder and kidneys, gonorrhea, hemoptysis (coughing up blood), influenza, enteritis (intestinal inflammation), pulmonary tuberculosis, cystitis (bladder inflammation), and bleeding piles.

Authors Contribution

Conceptualization: HMJ, BR, SS
Writing-review and editing: SN, NK, ZI, SAI HMJ

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Conflicts of Interest

The authors declare no conflict of interest.

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