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Artocarpus heterophyllus (Jackfruit): An Overview

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ABSTRACT
Artocarpus heterophyllus (Syn. Kathal) belonging to family Moraceae is an integral part of common Indian diet and is freely available in Indian and adjoining continents, its medicinal properties are also mentioned in Ayurveda. The plant is reported to possess antibacterial, anti-inflammatory, antidiabetic, antioxidant and immunomodulatory properties. *Artocarpus heterophyllus* is an important source of compounds like morin, dihydromorin, cynomacurin, artocarpin, isoartocarpin, cyloartocarpin, artocarpesin, oxydihydroartocarpesin, artocarpetin, norartocarpetin, cycloartinone, betulinic acid, artocarpanone and heterophylol which are useful in fever, boils, wounds, skin diseases, convulsions, diuretic, constipation, ophthalmic disorders and snake bite etc.
KEY WORDS: *Artocarpus heterophyllus*, Moraceae, Phytochemistry, Pharmacological activities.

INTRODUCTION

The *Artocarpus heterophyllus* is a species of tree of the mulberry family (Moraceae) is known by other names jackfruit (Eng.), Kathal, Panas (Hindi), Kanthal (Beng.), Palaa (Tamil), Phanas (Guj & Mar) & Chakka (Malayalam). It is native to Western Ghats of India, Malaysia and also found in central and eastern Africa, south-eastern Asia, the Caribbean, Florida, Brazil, Australia, Puerto Rico and many Pacific Islands (1). It is a large, evergreen tree, 10-15m in height, indigenous to the evergreen forests at altitude of 450-1,200m and cultivated throughout the hotter parts of India. Stem of this plant is straight rough whereas bark is green or black, 1.25cm thick, exuding milky latex, leaves broad obovate, elliptic, decurrent, glabrous, entire inflorescence solitary axillaries, cauliforous and ramflours on short leafy shoots. Male head is sessile or on short peduncles receptacles, sometimes born on the ultimate twing, Female head are oblong ovoid receptacle, syncarpus, cylindrics (2). Seeds are separated horny endocarpus enclosed by sub-gelatinous exocarpus (1mm thick) oblong ellipsoid in nature. The sweet yellow sheaths around the seeds are about 3–5 mm thick and have a taste similar to that of pineapple, but milder and less juicy (3).

Jackfruit (*Artocarpus heterophyllus* Lam) produces heavier yield than any other tree species, and bear the largest known edible fruit (up to 35 kg). The jackfruit tree has several uses. Flakes of ripe fruits are high in nutritive value; every 100 g of ripe flakes contains 287-323 mg potassium, 30.0-73.2 mg calcium and 11-19 g carbohydrates (4). In Bangladesh, it is commonly referred to as "poor man's food" as it is cheap and plentiful during the season. The nutritious seeds are boiled or roasted and eaten like chestnuts, added to flour for baking, or cooked in dishes. The tree is also known for its durable timber, which ages to an orange or reddish brown color, with anti-termite properties (5). The leaves and fruit waste provide valuable fodder for cattle, pigs and goats. Jackfruit wood chips yield a dye, which is used to give the famous orange-red color to the robes of Buddhist priests. In addition, many parts of the plant, including the bark, roots, leaves and fruits have medicinal properties (6).

It requires a soil which is well drained but moist, with a ph of 4.3 to 8.0 and with medium soil fertility. The optimum temperature is 19 to 29^{0}C, altitude at approx. 1600 meters above sea level and the annual rain fall between 1000 and 2400 mm (7).

Taxonomical classification (8)

Kingdom	:Plantae-- planta, plantes, plants, vegetal
Subkingdom	:Tracheobionta -- vascular plants
Division	:Magnoliophyta -- angiosperms, flowering plants, phanérogames
Class	:Magnoliopsida -- dicots, dicotylédones, dicotyledons
Subclass	:Hamamelidae
Order	:Urticales
Family	:Moraceae -- mulberries
Genus	:Artocarpus – breadfruit
Species	:*Artocarpus heterophyllus* Lam.

Parts used:

Apart from whole plant, seeds, fruits, bark, root, leaves and latex are also used.

Synonyms: (9)

Artocarpus brasiliensis Gomez., *Artocarpus heterophylla* Lam., *Artocarpus maxima* Blanco, *Artocarpus philippinensis* Lam., *Polyphema jaca* Lour., *Soccus arboreus major* Rumph., *Artocarpus integra* (Thunb.), *Artocarpus integrifolia* L.f., *Artocarpus integrifolius* auct., *Artocarpus integer* auct.

Ayurvedic Description

Sanskrit name	:Panasa Synonyms: Atibrhatphala
Properties	:**Rasa:** Madhura, kasaya (unripe fruit); **Guna:** Snigdha, guru, picchila; **Virya:** Sita; **Vipaka:** Madhura

Actions	:Vatapittahara, kaphavardhaka, balaya, sukraprada, tarpana, durjara, Seeds- Vrsya, baddhavitkara, mutrala
Therapeutic uses	:Klibata, durbalya, raktapitta, varna

Growth & Distribution

Artocarpus heterophyllus grows rapidly in early years, up to 1.5 m/yr (5 ft/yr) in height, slowing to about 0.5 m/yr (20 in/yr) as the tree reaches maturity (10). Jackfruit has been cultivated since prehistoric times and has naturalized itself in many parts of the tropics, particularly in Southeast Asia, where it is today an important crop of India, Myanmar, China, Sri Lanka, Malaysia, Indonesia, Thailand and Philippines. It is also grown in parts of Africa, Brazil, Surinam, Caribbean, Florida and Australia. It has been introduced to many Pacific islands since post European contact and is of particular importance in Fiji, where there is a large population of Indian descent.

MORPHOLOGY

Size and form

Jackfruit is a medium size, evergreen tree that typically attains a height of 8–25 m (26–82 ft) and a stem diameter of 30–80 cm (12–32 in). The canopy shape is usually conical or pyramidal in young trees and becomes spreading and domed in older trees. The tree casts a very dense shade. Heavy side branching usually begins near the ground. All parts of the tree exude sticky white latex when injured.

Flowers

This species is monoecious, having male and female inflorescences (or "spikes") on the same tree. Male and female spikes are borne separately on short, stout stems that sprout from older branches and the trunk. Male spikes are found on younger branches above female spikes. Male spikes are dense, fleshy, cylindrical to club shaped, and up to 10 cm (4 in) in length. Flowers are tiny, pale green when young, turning darker with age. Female flowers are larger, elliptic or rounded, with a tubular calyx. The flowers are reportedly pollinated by insects and wind, with a high percentage of crosspollination.

Leaves

Leaves are dark green, alternate, entire, simple, glossy, leathery, stiff, large (up to 16 cm [6 in] in length), and elliptic to oval in form. Leaves are often deeply lobed when juvenile and on young shoots.

Fruit

Jackfruit has a compound or multiple fruit (syncarp) with a green to yellow brown exterior rind that is composed of hexagonal, bluntly conical carpel apices that cover a thick, rubbery, whitish to yellowish wall. The acid to sweetish (when ripe) banana flavored flesh (aril) surrounds each seed. The heavy fruit is held together by a central fibrous core. Fruits are oblong cylindrical in shape, typically 30–40 cm (12–16 in) in length.

Seeds

Seeds are light brown, rounded, 2–3 cm (0.8–1.2 in) in length by 1–1.5 cm (0.4–0.6 in) in diameter, and enclosed in a thin, whitish membrane. Up to 500 seeds can be found in each fruit. Seeds are recalcitrant and can be stored up to a month in cool, humid conditions (11).

PHYTOCHEMISTRY

The *Artocarpus heterophyllus* contains various chemical constituents as several flavones colouring matters, morin, dihydromorin, cynomacurin, artocarpin (Fig.2), isoartocarpin, cyloartocarpin, artocarpesin, oxydihydroartocarpesin, artocarpetin, norartocarpetin, cycloartinone and artocarpanone (12). The heart wood on analysis yields moisture 6.7%, glucosides 38.0%, lipids 0.7%, albumin 1.7% and cellulose 59.0 % (13). The plant also contains free suger (sucrose), fatty acids, ellagic acid and some essential Amino acids like Arginine, Cystine, Histidine, Leucine, Lysine, Metheonine, Theonine, Tryptophan etc. (14). Bark from main trunk contains betullic acid and two new flavone pigments, cycloheterophyllin ($C_{30}H_{30}O_7$) (15). Triterpenic compounds like cycloartenyl acetate, cycloartenone are also reported (16). Heterophylol (Fig.1) a phenolic compound with novel skeleton was obtained from *Artocarpus heterophyllus* (17). There is only 3.3% tannin in the bark, which is occasionally made into cordage or cloth. The leaves and stem show the presence of sapogenins, cycloartenone, cycloartenol (Fig.4), β-sitosterol (18) and tannins, they show estrogenic activity. A root contains β-sitosterol (Fig.7), ursolic acid, Betulinic acid (Fig.3) and cycloartenone (19).

Jacalin, the major protein from the *Artocarpus heterophyllus* seeds, is a tetrameric two-chain lectin combining a heavy chain of 133 amino acid residues with a light *β* chain of 20–21 amino acid residues. It is highly specific for the *O*-glycoside of the disaccharide Thomsen–Friedenreich antigen (Gal*β*1–3GalNAc), even in its sialylated form. This property has made jacalin suitable for studying various O-linked glycoproteins, particularly human IgA1 (20). Jacalin's uniqueness in being strongly mitogenic for human $CD4^+$ T lymphocytes has made it a useful tool for the evaluation of the immune status of patients infected with human immunodeficiency virus HIV-1 (21). Two novel 2', 4', 6'-trioxygenated flavanones, heteroflavanones A and B were isolated from the root bark of *Artocarpus heterophyllus*. Their structures were elucidated as 5-hydroxy-7,2', 4',6'-tetramethoxyflavanone and 8-(γ,γ-dimethylallyl)5-hydroxy-7,2',4',6'-tetramethoxyflavanone (22, 23). Three phenolic compounds were characterized as artocarpesin [(5,7,2',4'-tetrahydroxy-6-(3-methylbut-3-enyl) flavone], norartocarpetin (5,7,2',4'-tetrahydroxyflavone) and oxyresveratrol (Fig.6) (trans-2,4,3',5'-tetrahydroxystilbene) by spectroscopic methods and through comparison with data reported in the literatures (24). The anti-inflammatory effects of these isolated compounds were evaluated by determining their inhibitory effects on the production of proinflammatory mediators in lipopolysaccharide (LPS)-activated RAW 264.7 murine macrophage cells. These three compounds exhibited potent anti-inflammatory activity (25). The composition of carotenoids of *A.heterophyllus* is carotenes β-carotene, α-carotene, β-zeacarotene, α-zeacarotene and β-carotene-5, 6-epoxide and a dicarboxylic carotenoid, crocetin were identified (26).

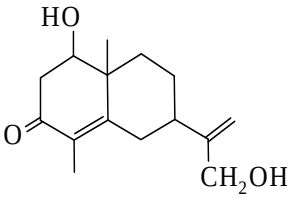

Fig.1 Heterophyllol

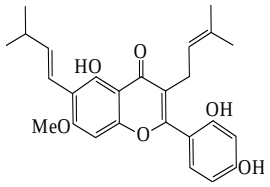

Fig.2 Artocarpin

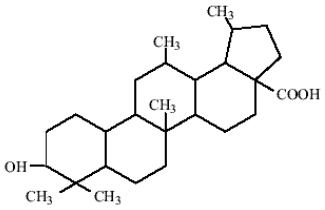

Fig. 3 Betulinic acid

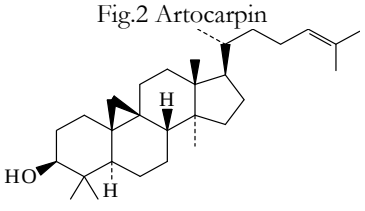

Fig.4 Cycloartenol

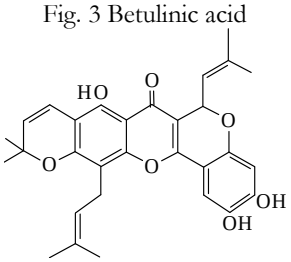

Fig.5 Cycloheterophylline

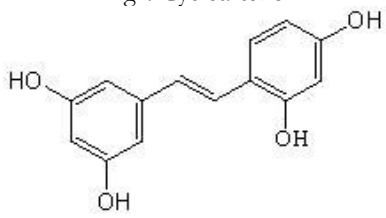

Fig.6 Oxyresveratrol

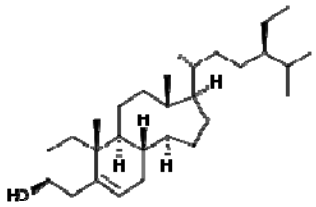

Fig. 7 β-Sitosterol

Traditional uses

The leaves are useful in fever, boils, wounds and skin diseases. The young fruits are acrid, astringent, and carminative. The ripe fruits are sweet, cooling, laxative, aphrodisiac and also used as a brain tonic. The seeds are, diuretic, and constipating. The wood is nervine, antidiabetic, sedative and is useful in convulsions (27). The latex is useful in dysopia, ophthalmic disorders and pharyngitis and also used as antibacterial agent (28). The ash of Jackfruit leaves is used in case of ulcers. The dried latex yields artostenone, convertible to artosterone, and a compound with marked androgenic action. Mixed with vinegar, the latex promotes healing of abscesses, snakebite and glandular swellings (29). The root is a remedy for skin diseases and asthma. An extract of the root is taken in cases of fever and diarrhoea. The bark is made into poultices. Heated leaves are placed on wounds. The wood has a sedative property and its pith is said to be abortifacient. Latex is used as an anti-inflammatory agent (30).

PHARMACOLOGY

Although a lot of pharmacological investigations have been carried out based on the constituents present in it but a lot more can still be explored and utilized in a therapeutic manner. A summary of the findings of some of these studies is presented below.

Anti-inflammatory Effect

Artocarpus heterophyllus Lam is a large evergreen tree cultivated throughout Southeast Asia for its fruits. Its leaves and roots have been used for medicinal purposes. The aim of this work was to study the *in vitro* anti-inflammatory effects of phenolic compounds isolated from the ethyl acetate extracts of the fruits of *Artocarpus heterophyllus*. Three phenolic compounds were characterized as artocarpesin [5,7,2',4'-tetrahydroxy-6-(3-methylbut-3-enyl) flavone] (1), norartocarpetin (5,7,2',4'-tetrahydroxyflavone) (2), and oxyresveratrol [trans-2,4,3',5'-tetrahydroxystilbene] (3) by spectroscopic methods and through comparison with data reported in the literatures. The anti-inflammatory effects of the isolated compounds (1- 3) were evaluated by determining their inhibitory effects on the production of proinflammatory mediators in lipopolysaccharide (LPS)-activated RAW 264.7 murine macrophage cells. These three compounds exhibited potent anti-inflammatory activity. The results indicated that artocarpesin (1) suppressed the LPS-induced production of nitric oxide (NO) and prostaglandin E 2 (PGE 2) through the down-regulation of inducible nitric oxide synthase (iNOS) and cyclooxygenase 2 (COX-2) protein expressions. Thus, artocarpesin (1) may provide a potential therapeutic approach for inflammation-associated disorders (31).

Antioxidant Effect

The antioxidant properties of prenylflavones, isolated from *Artocarpus heterophyllus* Lam., were evaluated in this study. Among them, artocarpine, artocarpetin, artocarpetin A, and cycloheterophyllin diacetate and peracetate had no effect on iron-induced lipid peroxidation in rat brain homogenate. They also did not scavenge the stable free radical 1, 1-diphenyl-2-picrylhydrazyl. In contrast, cycloheterophyllin (Fig. 5) and artonins A and B inhibited iron-induced lipid peroxidation in rat brain homogenate and scavenged 1, 1-diphenyl-2-picrylhydrazyl. They also scavenged peroxyl radicals and hydroxyl radicals that were generated by 2, 2'-azobis (2-amidinopropane) dihydrochloride and the Fe3+-ascorbate-EDTA-H2O2 system, respectively. However, they did not inhibit xanthine oxidase activity or scavenge superoxide anion, hydrogen peroxide, carbon radical, or peroxyl radicals derived from 2,2'-azobis(2,4-dimethylvaleronitrile) in hexane. Moreover, cycloheterophyllin and artonins A and B inhibited copper-catalyzed oxidation of human low-density lipoprotein, as measured by fluorescence intensity, thiobarbituric acid-reactive substance and conjugated-diene formations and electrophoretic mobility. It is concluded that cycloheterophyllin and artonins A and B serve as powerful antioxidants against lipid peroxidation when biomembranes are exposed to oxygen radicals (32).

Antifungal Effect

Two novel chitin-binding lectins from seeds of *Artocarpus* genus were described, one from jackfruit and one from breadfruit. They were purified from saline crude extract of seeds using affinity chromatography on chitin column, size-exclusion chromatography and reverse-phase chromatography on the C-18 column. Both are 14 kDa proteins, made up of 3 chains linked by disulfide bonds. The partial amino acid sequences of the two lectins showed they are homologous to each other but not to other plant chitin-binding proteins. Thus, they cannot be classified in any known plant chitin-binding protein family, particularly because of their inter-chain covalent bonds. Their circular dichroism spectra and deconvolution showed a secondary structure content of beta-sheet and unordered elements. The lectins were thermally stable until 80 degrees C and structural changes were observed below pH 6. Both lectins inhibited the growth of *Fusarium moniliforme* and *Saccharomyces cerevisiae*, and presented hemagglutination activity against human and rabbit erythrocytes. These lectins were denoted jackin (from jackfruit) and frutackin (from breadfruit) (33).

Sexual behaviour

According to medicinal plants text of Sri Lanka, roasted seeds of *Artocarpus heterophyllus* Lam. (Family: Moraceae) has aphrodisiac activity. However, some reproductively active young men in rural areas of Sri Lanka claim that consumption of these seeds few hours prior to coitus disrupts sexual function. Because of these two conflicting claims, it was thought useful to scientifically investigate the effects of *A. heterophyllus* seeds on male sexual function and fertility. This was done using a seed suspension in 1% methylcellulose (SS) in rats. In a sexual behaviour study using receptive female rats, an oral administration of 500 mg/kg dose of SS markedly inhibited libido, sexual arousal, sexual vigour and sexual performance within 2 hr. Further, the treatment induced a mild erectile dysfunction. These antimasculine effects on sexual function were not evident 6 hr post treatment indicating rapid onset and offset of action. Further, these actions on the sexual behaviour was not due to general toxicity, liver toxicity, stress or reduction in blood testosterone level but due to marked sedative activity. In a mating study, SS failed to alter ejaculating competence and fertility. These results suggest that *A. heterophyllous* seeds do not have aphrodisiac action, at least, in rats (34).

Immunomodulatory effect

Jacalin, the major protein from the jackfruit (*Artocarpus heterophyllus*) seeds, is a tetrameric two-chain lectin (molecular mass 65 kDa) combining a heavy chain of 133 amino acid residues with a light β chain of 20–21 amino acid residues. It is highly specific for the *O*-glycoside of the disaccharide Thomsen–Friedenreich antigen (Galβ1–3GalNAc), even in its sialylated form. This property has made jacalin suitable for studying various O-linked glycoproteins, particularly human IgA1. Jacalin's uniqueness in being strongly mitogenic for human $CD4^+$ T lymphocytes has made it a useful tool for the evaluation of the immune status of patients infected with human immunodeficiency virus (HIV)-1. The abundance of source material for the production of jacalin, its ease of purification, yield and stability has made it an attractive cost-effective lectin. It has found applications in diverse areas such as the isolation of human plasma glycoproteins (IgA1, C1-inhibitor, hemopexin, 2-HSG), the investigation of IgA-nephropathy, the analysis of O-linked glycoproteins and the detection of tumours (35).

Antidiabetic Effect

Investigations were carried out to evaluate the effects of hot-water extract of *Artocarpus heterophyllus* leaves on the glucose tolerance of normal human subjects and maturity-onset diabetic patients. The extracts of *Artocarpus heterophyllus* significantly improved glucose tolerance in the normal subjects and the diabetic patients when investigated at oral doses equivalent to 20 g/kg of starting material (36).

Antibacterial Effect

The crude methaolic extracts of the stem and root, barks, stem and root heart-wood, leaves, fruits and seeds of *Artocarpus heterophyllus* and their subsequent partitioning with petrol, dichloromethane, ethyl acetate and butanol gave fractions that exhibited a broad spectrum of antibacterial activity. The butanol fractions of the root bark and fruits were found to be the most active (37).

Anthelmintic Effect

The shoots revealed nematicidal activity against various nematodes *viz., Rotylenchulus reniformis, Tylenchorhynchus brassicae, Tylenchus filifofmis* and *Meloidogyne incognita* (38).

Inhibition of melanin biosynthesis

A series of prenylated, flavones based polyphenols, compounds 1-8, and were isolated from the wood of *Artocarpus heterophyllus.* These compounds, which have previously been shown not to inhibit tyrosinase activity, were

found to be active inhibitors of the in vivo melanin biosynthesis in B16 melanoma cells, with little or no cytotoxicity. To clarify the structural requirement for inhibition, some structure-activity relationships were studied, in comparison with related compounds lacking prenyl side chains. Our experiments indicate that both prenyl and OH groups, as well as the type of substitution pattern, are crucial for the inhibition of melanin production in B_{16} melanoma cells (39).

Allergy to jackfruit

Jackfruit allergy has been reported just once. It is unknown whether this food allergy is caused by direct sensitization or cross-sensitization to pollen allergens. Jackfruit allergy can be added to the list of birch pollen-related food allergies. Increased consumption of this fruit will result in a rise in allergic reactions (40).

Some chemical constituents isolated from *A. heterophyllus*

Six prenylflavonoids, including two new compounds, have been isolated from the root, bark of *Artocarpus heterophyllus*. The new prenylflavones have been characterized as 8-(γ,γ-dimethylallyl)-5,4'-dihydroxy-7,2'-dimethoxyflavone and 3,3'-di-(γ,γ-dimethylallyl)-5,7,2',5'-tetrahydroxy-4'-methoxyflavone, respectively (41).

A new natural Diels-Alder-type adduct, artonin X, along with two known Diels-Alder type adducts, were isolated from the bark of *Artocarpus heterophyllus* (42).

In an investigation emission and Fourier transform infrared spectra of the jackfruit seed, in powdered form, were recorded. Analysis of the emission spectrum confirms the presence of two hitherto undetected elements, manganese and magnesium. The Fourier transform infrared spectrum reveals the presence of some specific functional groups, attributed to the different bands present in the spectrum (43).

PESTS AND DISEASES

In southwestern and southern Asia, boring insects seem to be the major pests of jackfruit. These include *Indarbela tetraonis, Batocera rufomaculata*, *Margaronia caecalis,* and *Ochyromera artocarpio*. In India the main insect pests are the shoot boring caterpillar (*Diaphania caesalis*), mealybugs (*Nipaecoccus viridis*, *Pseudococcus corymbatus*, and *Ferrisia virgata*), spittle bug (*Cosmoscarta relata*) and jack scale (*Ceroplastes rubina*). In southern China, the fruit stem is susceptible to damage from the larvae of the longicorn beetles *Aprona germarri*, *Pterolophia discalis*, *Xenolea tomenlosa asiatica*, and *Olenecamptus bilobus*. The caterpillars of leaf webbers (*Perina nuda* and *Diaphania bivitralis*), aphids (*Greenidea artocarpi* and *Toxoptera aurantii*), and thrips (*Pseudodendrothrips dwivarna*) are minor problems. Important diseases of jackfruit are pink disease (*Pelliculana* [syn. *Corticum*] *salmonicolor*); stem, fruit, and male inflorescence rot caused by *Rhizopus artocarpi*; and leafspot due to *Phomopsis artocarpina*, *Colletrotrichum lagenarium*, *Septoria artocarpi*, and other fungi. Gray blight (*Pestalotia elasticola*), charcoal rot (*Ustilana zonata*), collar rot (*Rosellinia arcuata*), and rust (*Uredo artocarpi*) occur on jackfruit in some regions.

In a recent study it was found that wood boring insects include *Elaphidion mucronatum*, *Nyssodrysina haldemani*, and *Leptostylopsis terraecolor* various scales and mealybugs may attack stems and fruit. Diseases include *Rhizopus* fruit rot (*Rhizopus artocarpi*), gray mold (*Botrytis cinerea*), root rot (*Pythiumsplendens*,*Phytophthora* sp., *Fusarium* sp., and *Rhizoctonia* sp.), and leaf spotting by fungi (*Gloeosproium* sp. and *Phyllosticta artocarpi*) also affect the plant (44).

CONCLUSION

Considering the easy availability of *Artocarpus heterophyllus* in our country and that almost all the parts of the plant, including wood & latex possess curative properties, it seems that still there is a scope for scientific studies to fully exploit its medicinal properties to support the traditional claims as well as ,exploring some new and promising 'leads'. This review is an effort to compile all major information on its phytochemical as well as pharmacological profile published till now.

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