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COMPREHENSIVE REVIEW ON *TERMINALIA CATAPPA*: TRADITIONAL USES, PHARMACOLOGICAL PROPERTIES, AND BIOACTIVE COMPOUNDS

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ABSTRACT

In this review article, we concentrate on *Terminalia catappa*, which is commonly referred to as Country almond, Indian almond, Malabar almond, sea almond, tropical almond, beach almond, and False kamani, also known as Badam, recognized for its medicinal properties. The Ayurvedic plant *Terminalia Catappa* belongs to the Combretaceae family. It exhibits various therapeutic medicinal properties, including Antimicrobial, Anthelmintic, Antibacterial, Anti-tumor and Antidiabetic activity. In this review, we will broadly discuss the pharmacological effects reported through various in-vitro and in vivo models.

KEYWORDS: *Terminalia catappa*, Indian almond, Pharmacological activities, Bioactive compounds, microscopic characteristics.

INTRODUCTION

Since ancient times, medicinal plants have been utilized to cure microbial infections and other illnesses in humans. Herbal remedies are still used today in India and other countries.

This is because plant-derived chemicals are less hazardous when used at low quantities and do not cause adverse effects when compared to commercially available synthetic medications.[1]

Terminalia catappa is regarded as one of the world's most significant medicinal plants. In several Indian states as well as other countries, it is utilized as folk medicine. It is popularly called as tropical almond or Indian almond.

Terminalia catappa Linn. belonging to family Combretaceae, originates from southeast asia. The generic name is derived from the latin word *terminalis*, which refers to the numerous leaves at the extremities of the stems. The Nut kernels of the tree can be eaten raw. *T. catappa* is a widely used herb in Ayurveda. The juice from its fresh leaves is used to make therapeutic lotion for leprosy and scabies, as well as to treat stomach aches and headaches.[2]

The plant is indigenous to the Indian subcontinent, which extends to the Pacific Islands via Southeast Asia, Northern Australia, and New Guinea.

Barbados Almond, Bastard Almond, Beach Almond, Bengal Almond, Catappa, Coastal Almond, Country Almond, Demerara Almond, False Kamani, Fiji Almond, Indian Almond, Ketapang, Java Almond, Malabar Almond, Malay Almond, Sea Almond, Singapore Almond, Story Tree, Talisay Tree, Tavola Nut, Tropical Almond, Water Almond, West Indian Almond, Umbrella Tree, Atafa, Fijian almond, and India almond are some of the other common names for the plant.[3]

Phytochemical studies on several components of the plant genus *Terminalia* have been conducted extensively. Therefore, the purpose of this review is to present a comprehensive list of the phytochemical components of *Terminalia* that have been reported in the literature along with their distinctive features. *Terminalia's* biological activities and pharmacological features have also been summarized based on scientific research.

Botanical description[2]

The tree grows to a height of 35 meters, with an erect, symmetrical crown and horizontal branches. Its branches are typically grouped in layers. The leaves are big, measuring 15-25 cm long and 10-14 cm wide, ovoid, lustrous dark green, and leathery. The trees are monoecious, bearing separate male and female blooms on the same tree.

Both have a diameter of 1 cm, lack petals, with white to greenish colour. The fruit is a drupe that is 5-7 cm long and 3-5.5 cm wide. It has a single seed and is first green, turning yellow, and then red when it ripens. When the fruit is fully ripe, the seed within is edible.

Taxonomical classification of *Terminalia catappa* Linn[4]

Table No. 1: Taxonomical classification.

Domain	Eukaryote
Kingdon	Plantae
Subkingdom	Tracheobionta
Super division	Spermatophyta
Division	Angiospermae
Phylum	Charophyta
Clade	Eudicots
Class	Dicotyledons
Subclass	Rosidae
Order	Myrtales
Family	Combreraceae
Genus	*Terminalia* L.
Species	*Terminalia catappa* L.

(Fig.1. Leaves)

(Fig.2.Fruits)

(Fig.3. Flowers)

(Fig.4.Seeds)

Table no. 2: Vernacular names of *Terminalia catappa* Linn.[3]

Sanskrit	Ingudi, Taliphala, Badam
Hindi	Jangli-badam, Desi-badam, Badam
English	Indian Almond tree
Bengali	Badam
Telugu	Badamu
Gujrathi	Ingudii, Badamalili
Malayalam	Ketapag
Marathi	Badam, Bengali Badam, Jangli badam
Oriya	Desiyobadamo
Kannada	Kaadubaadaami, Naatibaadaami, Naadubaadaami, Tavasa
Tamil	Nattu-vadam, Saraparuppu, Vatha-Kottai, Natttuvadumi, Vadumai
Assamese	Kath-badam
Others	Atafa, Bengal Almond, Country Almond,

Description

Macroscopic Characters[4]

The almond tree has a spreading fibrous near-surface lateral root system, despite the fact that it is generally deep-rooted in sand. The tree produces a red, high-quality, elastic, cross-grained timber that seasons well and functions smoothly. At 12 hosts, the wood's viscosity ranges between 450 and 720 kg/m³.

Microscopic Characters[4]

The anatomical characteristics revealed that the pores were widespread and solitary, and the axial parenchyma cells are primarily paratracheal, aliform, and confluent.

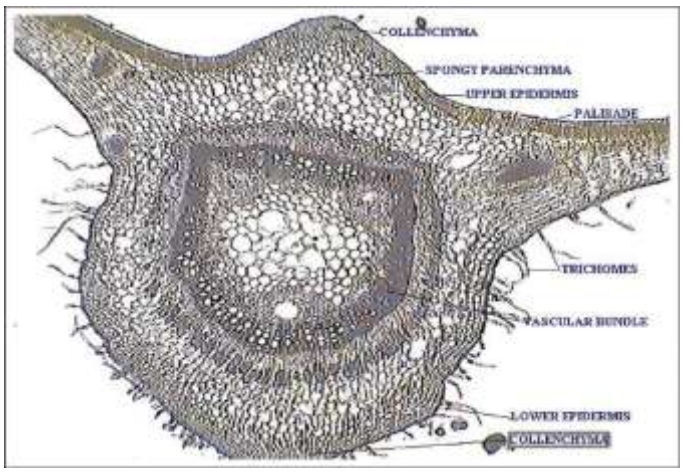

Figure no. 5: Microscopic features of plant leaf sections.

MORPHOLOGY

Leaves

The leaves are single, alternating obovate leaves with short petioles, spirally grouped at the branch terminals, 15-36 cm long, 8-24 cm broad, dark green above, pale underside, leathery, and glossy(fig.1). Before falling, leaves turn a vivid scarlet, dark red, dark purplish red, or yellow. During the winter, especially after a heavy rain, leaves fall off swiftly and are replaced with shiny, silky, purple new foliage.[5]

Flowers

Flowers are tiny (4-6 mm [0.16-0.24 in] wide), white or cream-colored, five-lobed, and grouped on long (8-25 cm) (3.2-10 in) axillary spikes. They are male and have a somewhat disagreeable fragrance. The bulk of the blooms on a spike are male, with a few bisexual flowers at the base (fig.3).[5]

Plants often begin blooming and fruiting at a short age, such as within 2-3 years of planting, however this varies by location and genotype. *T. catappa* solely produces male flowers.[6]

Fruits

T. catappa fruits are firm, green-red, spherical and flattened, egg-shaped, with two ridges, but no wings. The fruits are similar to other drupe fruits in the Rosaceae and Anacardiaceous families, including plum, apricot, peach, cherry, ova, and mango. It contains a membrane epicarp, a succulent mesocarp, and a fibrous endocarp, which encloses the seed and draws fruit flies. When unripe, this fruit is green, but when mature, it changes to yellow or red.(fig.2)

The fruit has a huge edible nut inside that resembles a real almond.

Inside the fruit, seeds are covered in fiber and separated into two pieces, namely Inside the fruit, seeds are covered in fiber and separated into two pieces, namely the seed coat and the umbilical cord.[7]

Seeds or Nuts

The kernel tastes like almonds and may be eaten either raw or roasted. (fig.4) Sun-dried kernels produce 34-54% bland, yellow, semi-drying oil that is edible but turns turbid when left undisturbed. The oil is mostly used for cooking.[5]

Trunk

The trunk of the tree is rough, brownish, and have fissured bark with a diameter of 55-155 cm.[5]

Bark

The bark has small fissures and ranges in colour from grey to dark grey-brown. The slightly flaky bark peels off in straight or curved scales along the lines of continuous vertical fissuring and discontinuous horizontal fissures, giving the impression of a grid.[6]

Rooting habit

The trees often have a spreading, fibrous, near surface.[6]

Phytochemistry

This plant contains a variety of phytochemicals, such as flavonoids (isovitexin, vitexin, isoorientin, rutin), triterpinoids (ursolic acid, 2á, 3â, 23-trihydroxyurs-12-en-28 oic acid), and

tannins (punicalagin, punicalin, terflavins A and B, tergallagin, tercatain, chebulagic acid, geranin, granatin B, corilagin).[8]

Table no. 3: various chemical constituents present in different parts of *Terminalia catappa*.

Parts of Plant	Chemical constituents
Leaves	*T. catappa* leaf includes 1-degalloyl-eugeniin, 2,3-(4,4',5,5',6,6'-hexahydroxy-diphenoyl)-glucose, chebulagic acid, corilagin, gentisic acid, geraniin, granatin-b, kaempferol, punicalagin, punicalin, quercetin, tercatain, terflavin-a, terflavin-b, and tergallagin.[9]
Leaves	Reddish brown leaves contain flavonoid apigenin 6-c-(2- galloyl)- L-Dglycoside, apigenin 8-c-(2- galloyl)- L-D-glycoside, isovitexin, vitexin, isoorienthin, rutin and tannin; gallic acid, ellagic acid, puricalagin, punicalin.[9]
Fruits	The fruit of *T. catappa* includes the following: beta-carotene, cyanidin 3-glucoside, ellagic and gallic acids, glucose, pentosans, tannin, and corilagin.[10]
Seeds	The *T. catappa* seed includes the following nutrients: arachidic acid, ascorbic acid, carbs, beta-carotene, fat, fiber, iron, kilocalories, phosphorus, potassium, protein, riboflavin, stearic acid, thiamin, and water.[10]
Nuts	The *T. catappa* Nuts includes the following nutrients: Phosphorus, carbs, crude fat, magnesium, calcium, iron, zinc, sodium, manganese, vitamins A, C.[10]
Bark	*T. catappa* bark contains (+)-catechin, (-)-epicatechin, 3,3',4-tri-o-methyl-ellagic acid, 3,3'-di-o-methyl-ellagic acid, arjunolic acid, arjunolic acid-28-o-beta-d-glucoside, beta-sitosterol, beta-sitosterol, betulinic acid, daucosterol, ellagic acid, leucocyanidin, oleanolic acid, oxalic acid, and tannin.[9]

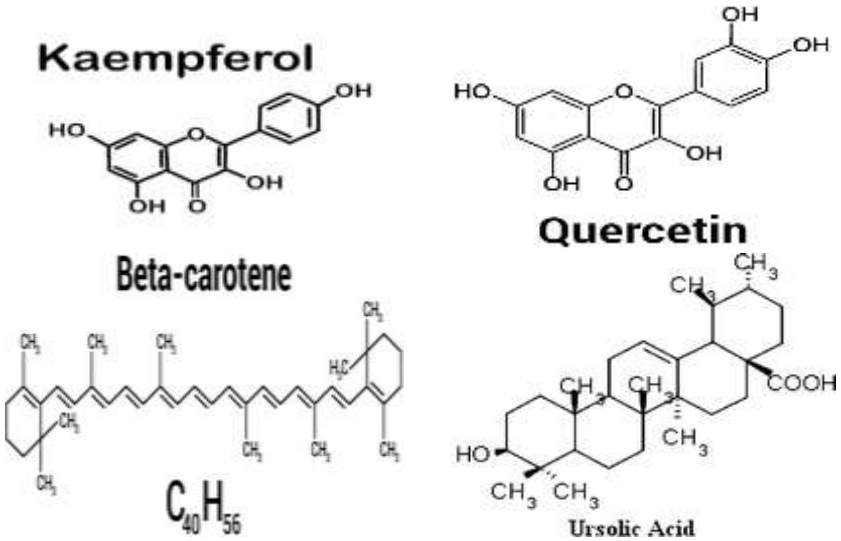

Figure no. 6: Various bioactive constituents present in different parts of *Terminalia catappa*.

Table no. 4: Phytochemical screening of the *Terminalia catappa*.[16]

Phytochemicals	Leaf				Stem bark				Fruit			
	PE	CF	ME	AQ	PE	CF	ME	AQ	PE	CF	ME	AQ
Alkaloids	+	+	+	-	-	-	-	-	-	-	-	-
Saponins	-	-	+	-	-	-	+	-	-	-	+	-
Terpenoids	+	+	+	-	+	+	+	-	+	+	+	+
Phlobatannins	-	-	-	-	-	-	-	-	-	-	-	-
Glycosides	+	+	-	-	+	+	-	-	+	+	-	-
Steroids	+	+	-	-	+	-	-	-	-	-	+	-
Flavonoids	-	-	+	+	-	-	+	+	-	-	+	+
Tannin	-	+	+	+	-	+	+	+	-	-	+	-
Phenol	-	+	+	+	+	+	+	-	-	-	+	+

Key: (+) = Present, (-) = Absent,

PE = Petroleum ether extract, CF = Chloroform extract,

ME = Methanol extract, AQ = Aqueous extract

Pharmacological Activity[23]

Antifungal activity

The extracts of *T. catappa* in methanol and methylene chloride shown efficacy against Phytophthoraparasitica, Aspergillus fumigatus, Sclerotium rolfsii, Rhizoctoniasolani, and Pythiumultimum. The effort is contrasted with the common antibiotic, Clotrimazole. The extracts showed how growth inhibitory effort works in a cure-dependent way.[4]

Anthelmintic activity

T. Catappa leaf extract was tested for antihelmintic activity against Trichostrongyluscolubriformis, Cooperiacurticei, and Haemonchuscontortus, and it was proposed that *T. Catappa* leaves might operate as an implicit antihelmintic agent. The discovery of SC- CO2 extracts of *T. Catappa* leaves did not produce mutagenicity at the Boluses examined while exhibiting powerful antimutagenicity and were more cytotoxic to lethal hepatoma cells than to normal liver cells is noteworthy and warrants further investigation.[5]

Antiviral activity

Terminalia catappa leaf extract contains punicalin and punicalagin, which suppressed HIV replication in infected H9 cells with little cytotoxicity. Additionally, it inhibited pure HIV reverse transcriptase with ID50 values of 8 and 5 µM. Chebulagic acid and punicalin inhibite the binding of recombinant HIV viral protein gp120 (rgp120) to its normal cellular receptor, CD4. The fruit of *T. catappa* includes ellagic acid, which has anti-HIV activity.[5]

Antidiabetic Activity

To study the possible anti-diabetic properties, aqueous and cold extracts of *Terminalia catappa* Linn (Combretaceae) leaves were tested on fasting blood sugar levels and serum biochemical analysis in diabetic rats treated with alloxan. All *Terminalia catappa* extracts demonstrated considerable anti-diabetic effect at dosage levels one-fifth of their fatal doses. Concurrent histological observations on the pancreas of these mice revealed regeneration by aqueous and cold extracts that had previously been necrosed by alloxan. *Terminalia catappa.* Linn. Leaf Extracts in Alloxan-Induced Diabetes Rats. Alloxan administration (150 mg/kg, i.p.) produced a 1.5-fold rise in fasting blood glucose levels that lasted three weeks. Three weeks of daily extract treatment resulted in a dose-dependent reduction in blood sugar levels of 25-62%. The impact tends to peak after 15 days of treatment and is sustained during the third week.[8]

Hypoglycemic activity

Terminalia catappa Linn (Combretaceae) leaves were examined in both normal and alloxan-induced diabetic rats. Each leaf extract [90% ethanol (ET), 70% ethanol (ETWT), and 70% acetone (ACWT)] was tested for its effect on blood glucose levels in glucose-overloaded rats. The most effective extract (ETWT) was evaluated for hypoglycemic activity in normal fasting rats as well as antihyperglycemic activity in alloxan-induced diabetic rats. 70% ethanol extract (300 mg/kg/day) shown strong antihyperglycemic efficacy in glucose-loaded rats and alloxan-induced diabetic rats, with significant improvements in body weight, protein, albumin, and hemoglobin levels, as well as reductions in blood glucose and urea. Based on these findings, we interfere that *T.catappa* has good glucose-lowering properties when supplied to alloxan-induced diabetic rats.[8]

Anti-depressant

Research indicated that the hydroalcoholic extract of *T. catappa* has an antidepressant effect. The usage of TC extract was shown to successfully reverse CMS-induced alterations in hippocampal neurotransmitter concentrations as well as levels of AchE, cortisol, monoamine oxidase, and BDNF. The extract was shown to modulate monoamine neurotransmitters, BDNF, cortisol, and AchE levels, as well as repair oxidative damage, hence reducing depression-induced stress.[13]

Antiaging activity

T. catappa also has anti-aging effects. The TC hydrophilic extract has been shown to bind together DPPH-free radicals and protect erythrocytes against AAPH-induced hemolysis. Furthermore, *T. catappa* suppresses collagenase activity while increasing type I procollagen protein production, which is necessary for skin suppleness and preventing aging. *T. catappa* has been shown to reduce the production of MMP-1, -3, and -9, which are connected to skin aging and wrinkle development, by inhibiting ERK, JNK, and p38 activation. These findings suggest that *T. catappa* might possibly be used as an anti-aging agent.[13]

Anticancer activity

The anticancer activity of Terminalia catappa plant ethanolic extract (TCE) was investigated in the current study using the SW480 CRC model cell line. In this context, the effects of TCE on the proliferation, apoptosis, and migration of SW480 cells were investigated using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay, Annexin V/PI flow cytometry, and scratch tests. Furthermore, quantitative real-time PCR was used to assess changes in the expression of genes implicated in these processes, including as Bax, Bcl-2, Caspase 3, Caspase 8, Caspase 9, MMP-13, miR-21, and miR-34a.[14]

ACE inhibitory activity

The ability of Brazilian *Terminalia catappa* plants to inhibit angiotensin converting enzyme (ACE) was used to assess their potential antihypertensive efficacy in vitro. A total of 44 plants from 30 different families were examined. Plants were chosen for their widespread usage as antihypertensives and/or diuretics. *Terminalia catappa* has substantial ACE inhibition rates.[15]

Immunomodulator

The presence of phenolic chemicals in ETCB may explain its immunomodulatory and anti-inflammatory properties. Ellagic acid has been shown in studies to be antioxidant and anti-inflammatory, whilst gallic acid has been shown to be antibacterial, antiviral, anti-inflammatory, and antioxidant. Catalamine is a lesser-known chemical that has been linked to neuroprotective properties.[17]

Wound healing Property

A crack is the loss or breaking of the live apkins' cellular and functional capabilities. The development of synthetic antibacterial drugs to treat injuries was hampered by drug resistance

and toxicity. Several stores with efficient pharmacological conditioning may provide healthier, necessary therapies for injuries. It was claimed that applying *T. catappa* ointment to the crack resulted in a 97 percent reduction in crack area when compared to the control and betadine ointment as the conventional treatment. *T. catappa* ointment quickly promotes epithelization, implying that these excerpts produce significant crack-mending effort.[18]

Antioxidant Activity

T. Catappa leaf extract with antioxidant activity significantly decreased mitomycin C-convinced micronuclei. It also prevented lipid peroxidation (LPO) and hydrogen peroxide conformation induced by TPA in mortal mononuclear leukocytes in a cure-dependent way. Ellagic acid was detected in the extracts by HPLC analysis. The insulated ellagic acid exerted significant antioxidant activity in the test methods employed.[19]

Antimicrobial Activity

Terminalia catappa extracts were manipulated to include certain secondary metabolites. All of the pieces obtained in this experiment suggest the presence of resin. An ethanol extract, petroleum ether, chloroform, and ethyl acetate all performed well in a steroid presence test. Waterless and ethanolic *T. Catappa* leaf extracts have antibacterial properties against S. Typhi, E. coli, S. aureus, and P. Aeruginosa. The antibacterial assays of n-hexane, chloroform, and ethyl acetate fragments revealed a good effect against the bacterial isolates tested.[20]

Antiparasitic activity

The dried leaves of *Terminalia catappa* contain a range of attention of this finding were utilized to determine performance conditioning against tilapia infections. Trichodina, a fish ectoparasite, were eradicated at 800 ppm, according to the results.[21]

Hepatoprotective activity

Terminalia catappa L. leaves have been proven to protect against acute liver damage caused by several hepatotoxins, although the active components and processes are unknown. The purpose of this work was to describe the protective effects of the chloroform fraction of the ethanol extract of *T. catappa* leaves (TCCE) against carbon tetrachloride (CCl4)-induced hepatotoxicity in mice, as well as to examine changes in interleukin-6 (IL-6) expression levels.[22]

Anti tumor Activity

Terminalia catappa leaf extract has anti-tumor efficacy against Ehrlich ascites-induced cancer in mice. The methanolic extract of *T. catappa* was shown to have a strong reaction against ehrlich ascites-induced cancer cells only at higher concentrations. 75mcg and 100mcg yielded 100% fatality. The methanolic leaf extract had a concentration-dependent cytotoxic impact on EAC cells.[23]

Toxicology

Studies on the toxicity of *T. catappa* extract on rats during treatment indicate that the tested doses are safe to eat and do not have any negative effects. However, more research is necessary to confirm the safety of *T. catappa* extract for human consumption before it can be widely recommended. It is also important to research the dose, duration of usage, and any possible interactions with other drugs or medical conditions. Prior to adopting any herbal supplements or other therapies, it is always advised to speak with a healthcare provider.[13]

Pharmacological activity and its Extraction[3]

Table no. 5: Various pharmacological activities from different parts of *Terminalia catappa*.

Part of Plant	Pharmacological activity	Extraction
Leaves	Antibacterical activity	Aqueous and ethanolic
	Anthelmintic activity	Crude extract
	Antidiabetic activity	Aqueous and cold extract
		Methanolic extract
	Antioxidant activity	Aqueous extract
		Methanolic extract
	Antitumor activity	Aqueous extract
		Supercritical CO_2 extract
		Water extract
		Methanolic extract
	Antiviral activity	Water extract
		Ethanolic extract
	Hepatoprotectivity activity	Ethanolic extract
	Hypocholesterolemic activity	Ethanolic extract
		Chloroform
	Immunomodulatory activity	Chloroform
Fruit	Antidiabetic activity	Petroleum ether, methanol and aqueous extracts
	Antiviral activity	Petroleum ether, methanol and aqueous extracts
	Anti-inflammatory activity	Aqueous extract

	Hypocholesterolemic activity	Ethanolic extract
Bark	Antibacterial activity	Aqueous ethyl acetate and hexane extract
	Antifungal activity	Aqueous ethyl acetate and hexane extract
	Anti-inflammatory activity	Aqueous extract
	Wound healing	Chloroform
Dried roots	Antibacterial activity	Petroleum ether, chloroform and methanol extracts
Wood	Antibacterial activity	Aqueous ethyl acetate and hexane extracts
	Anti-inflammatory activity	Aqueous extract
Herb	Antitumor activity	Hot water extract
	Wound healing activity	Ethanolic extract

CONCLUSION

The current literature study focuses on the phytopharmacological properties of *Terminalia catappa.* It has been noticed that this old tree is commercially, medicinally, and environmentally significant; in addition, the multicoloured corridors of this tree are enriched in bioactive motes.

As a result, a comparable collection of knowledge about the medicinal products and pharmacological exertion of this factory will be valuable to the exploration community, which is seeking for the creation of a natural, safe, and factory-rested source of medicine for various mortal illnesses. More in-depth research can help to generate scientifically confirmed herbal medicines from this implicit manufacturing source.

The pharmacological studies on *T. catappa* confirm the plant's enormous potential for the treatment of a variety of ailments. More research and clinical studies are needed to enhance the utilization of *T. catappa* for future generations.

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Conflict of interest: There are no potential conflicts of interest to declare.

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