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Review Article

Reviewing the Recent Advancements of *Terminalia arjuna*, the Guardian of the Heart

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ABSTRACT

Terminalia arjuna is a remarkable medicinal herb known for its antioxidant, cholesterol-lowering, blood pressure-regulating, and antidiabetic properties. Since ancient times, medicinal plants have served as vital sources of therapeutic agents for treating various human diseases. In India, traditional medical systems such as Ayurveda, Siddha, and Unani have long utilized *Terminalia arjuna* for its healing potential. This evergreen tree, belonging to the Combretaceae family, is widely distributed across the Indian subcontinent. Extensive experimental and clinical studies have demonstrated that the bark of *T. arjuna* possesses anti-ischemic, antihyperlipidemic, and antioxidant activities. Its therapeutic efficacy is attributed to the presence of bioactive phytoconstituents, including triterpenoids, flavonoids, glycosides, tannins, phenolic compounds, and arjunolic acid. Research findings highlight its strong cardioprotective and antioxidant potential. The present review provides a comprehensive overview of the phytochemical composition, pharmacognostic features, pharmacological activities, and clinical significance of *T. arjuna*, with particular emphasis on its role in managing cardiovascular disorders.

INTRODUCTION

Medicinal plants play a vital role in healthcare, serving as essential sources of raw materials for both traditional and modern medicine. Despite advances in synthetic pharmaceuticals, a significant portion of the global population continues to prefer herbal remedies for treatment [1]. The vast array of bioactive compounds derived

from natural sources has attracted growing interest from the scientific and pharmaceutical communities. Recent studies on medicinal plants primarily aim to revalidate ancient therapeutic effects through cellular and molecular investigations.

Terminalia arjuna, commonly known as Arjuna, is one such remarkable medicinal herb that has been

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valued for centuries for its efficacy in treating various cardiac ailments. In traditional medicine, it is utilized not only for managing heart disorders but also for promoting wound healing and treating ulcers. Moreover, it exhibits antibacterial, antioxidant, antimutagenic/anticarcinogenic, and hypolipidemic activities [2–7]. The plant has shown potential benefits in addressing obesity, hypertension, and hyperglycemia, and its bark has been extensively studied for its therapeutic role in cardiovascular diseases.

Research indicates that *T. arjuna* enhances antioxidative defense mechanisms, thereby protecting hepatic and renal tissues from oxidative stress induced by carbon tetrachloride (CCl₄) [8]. In recent years, nanoparticles synthesized using species from the *Terminalia* genus have gained considerable attention due to their diverse applications in medicine, catalysis, materials science, and energy research [9–11].

The bark powder of *T. arjuna* is reported to possess a wide spectrum of pharmacological activities, including anti-ischemic, antioxidant, cardioprotective, hypocholesterolemic, antimicrobial, antifungal, anti-inflammatory, immunomodulatory, and antinociceptive properties. The presence of flavonoids in the bark contributes significantly to its antioxidant and anti-inflammatory potential, helping the body combat free radicals—major contributors to chronic diseases [12–14].

2. PROFILE OF TERMINALIA ARJUNA

2.1. Habitat and Distribution: *Terminalia arjuna* is a perennial, evergreen tree belonging to the family Combretaceae (Figure i, a). It typically grows at altitudes ranging from 20 to 30 meters above sea level. The species is widely distributed throughout the Indian subcontinent, particularly in states such as Uttar Pradesh, Bihar, Madhya

Pradesh, West Bengal, Maharashtra, and Odisha. It commonly thrives along riverbanks and near dry riverbeds.

Beyond India, *T. arjuna* is also found in several other tropical regions, including Sri Lanka, Bangladesh, Malaysia, Indonesia, and Kenya [15–18].

The tree is known by various vernacular names: Arjuna (common name), Arjun (Hindi), Sadado (Gujarati), Marudhu (Tamil and Malayalam), Tella Maddi (Telugu), Sadaru (Marathi), Arjhan (Bengali), and Neer Matti (Kannada) [19].

2.2. Ethnopharmacology and Phytochemistry

(a) Stem Bark: The stem bark of *Terminalia arjuna* is externally smooth with a pinkish-gray appearance, while the inner surface is soft, velvety, and reddish in color (Figure 1, b).

The bark contains a rich array of phytochemical constituents, including:

- **Triterpenoids:** arjunin, arjunic acid, arjungenin, arjunolic acid, and terminic acid [20–21].
- **Glycosides:** arjunetin, arjunoside I, arjunoside II, arjunaphthanoloside, and terminoside A [22–23].
- **Flavonoids:** arjunone, arjunolone, baicalein, luteolin, quercetin, gallic acid, ethyl gallate, kaempferol, pelargonidin, and oligomeric proanthocyanidins.
- **Tannins:** punicallin, punicalagin, pyrocatechols, terchebulin, terflavin C, castalagin, casuarinin, and casuariin.
- **Phytosterols:** β -sitosterol.
- **Minerals and trace elements:** calcium, copper, aluminum, magnesium, silica, and zinc [20–21].



b) Roots: The roots of *Terminalia arjuna* are large and buttressed, providing strong anchorage and stability, especially in rocky regions and along riverbanks where the tree commonly grows (Figure 1, c). The primary bioactive compounds found in the roots include:

- **Glycosides:** arjunoside I, II, III, and IV, along with 2,19-dihydroxy-3-oxo-olean-12-en-28-oic acid-28-O- β -D-glucopyranoside.
- **Triterpenoids:** arjunic acid, arjunolic acid, oleanolic acid, and terminic acid.
- **Phytosterol:** β -sitosterol [24–28].

(c) Leaves: The leaves of *T. arjuna* are simple, leathery (coriaceous), and usually sub-opposite in arrangement. They have an oblong or elliptic shape with margins that are often crenulated, and the apex is either shortly acute or obtuse. The upper surface appears light to dark green, while the underside is pale brown (Figure 1, d). The main active phytochemicals present in the leaves include flavonoids, alkaloids, tannins, steroids, oxalic acid, and various phenolic compounds.

(d) Fruits: The fruits of *T. arjuna* are drupe-shaped, ovoid, fibrous, and woody with a smooth surface. Each fruit typically bears five distinct, hard, wing-like ridges that are oblique and curve upward (Figure 1, e). The key phytochemical constituents of the fruits are glycosides and flavonoids (notably luteolin), while the seeds contain cardenolides.

(e) Flowers: The plant produces small, white, bisexual flowers that are sessile and arranged in short axillary spikes or terminal panicles (Figure 1, f) [25].



(a) *T. arjuna* tree



(b) *T. arjuna* bark



(c) *T. arjuna* roots



(d) *T. arjuna* leaves



e) T. arjuna fruits



(f) T. arjuna flowers

Figure 1: Various parts of Terminalia arjuna tree

2.3. Uses of Terminalia arjuna

Terminalia arjuna has been extensively used in traditional medicine, particularly in Ayurveda, Unani, and Siddha systems, for its broad range of therapeutic effects. The bark, leaves, and fruits of the tree are known for their diverse medicinal properties.

1. **Cardiovascular Health:** The bark of T. arjuna is primarily used as a cardioprotective and cardiotonic agent. It helps strengthen the heart muscles, regulate blood pressure, and improve circulation. It is widely prescribed for angina, hypertension, heart failure, and other cardiac ailments.
2. **Antioxidant and Anti-inflammatory Effects:** The rich presence of flavonoids and tannins in the bark provides potent antioxidant properties that help neutralize free radicals and reduce oxidative stress. These effects contribute to the prevention of atherosclerosis and other degenerative diseases.

3. **Lipid-lowering Activity:** T. arjuna is known to reduce total cholesterol, LDL, and triglycerides while increasing HDL levels, thus supporting healthy lipid metabolism.
4. **Antimicrobial and Antifungal Activity:** Extracts of T. arjuna have demonstrated antibacterial, antifungal, and antiviral effects against several pathogenic microorganisms.
5. **Wound Healing and Skin Care:** The bark extract exhibits astringent and healing properties, promoting tissue regeneration and helping treat wounds, ulcers, and skin disorders.
6. **Liver and Kidney Protection:** Its hepatoprotective and nephroprotective effects help safeguard the liver and kidneys from toxin-induced damage.
7. **Antidiabetic and Anticancer Potential:** Recent studies suggest that T. arjuna possesses antidiabetic and anticancer properties, attributed to its bioactive compounds that modulate oxidative and inflammatory pathways.

3. EXPERIMENTAL STUDIES

Terminalia arjuna possesses significant therapeutic potential, particularly in the management of cardiovascular diseases. Numerous preclinical and clinical studies have been conducted to scientifically evaluate and substantiate its medicinal efficacy, with extensive documentation and discussion available in the literature.

3.1. Effects on the Cardiovascular System: Clinical and experimental studies have demonstrated that Terminalia arjuna exhibits significant cardioprotective properties. In one clinical trial, twelve patients suffering from chronic congestive heart failure—primarily due to idiopathic dilated cardiomyopathy—were administered 500 mg of an aqueous bark extract of

T. arjuna every eight hours. The treatment was well-tolerated, producing marked improvement in the symptoms and clinical signs of heart failure, along with an enhanced quality of life.

Another study involving ninety-three patients with idiopathic and ischemic dilated cardiomyopathy reported that participants receiving 500 mg T. arjuna capsules every eight hours showed notable improvement in both systolic and diastolic cardiac functions, as well as overall functional capacity, when compared to those on standard therapy alone [29].

Pharmacological investigations revealed that T. arjuna bark possesses chronotropic, inotropic, and diuretic properties [22]. In an experimental rabbit heart model (Langendorff preparation), the aqueous extract significantly increased coronary blood flow [30]. These findings were further supported by research on in-situ frog hearts, hypodynamic frog hearts, and isolated perfused rabbit hearts, where the extract enhanced myocardial contractility, increased coronary perfusion, and induced bradycardia [31]. The observed positive inotropic effect is believed to be mediated by the high calcium content in the plant [32].

Further studies using isolated rat atria confirmed the inotropic activity of the aqueous bark extract [33]. Additional experiments revealed that this activity was modulated in the presence of cocaine and propranolol, indicating possible involvement of adrenergic mechanisms [34]. From T. arjuna roots, a novel compound—16,17-Dihydroneridienone, 3-O-D-glucopyranosyl-(1→6)-O-D-galactopyranoside—has been isolated, exhibiting cardiotonic properties [35].

Experiments using isolated rabbit hearts showed that administration of aqueous bark extract maximized coronary flow at a concentration of

1024 µg/mL [36]. In animal studies, particularly in dogs, intravenous, intracerebral, and intravertebral administration of both aqueous and alcoholic extracts produced a dose-dependent reduction in blood pressure and heart rate. Specifically, a 70% hydroalcoholic bark extract demonstrated hypotensive and bradycardic effects, though the exact underlying mechanism remains unclear [37].

3.2. Antioxidant Effect: Administration of 30 mg of Terminalia arjuna stem bark suspension orally to rats with isoproterenol-induced myocardial ischemia, followed by treatment with Abana, demonstrated a protective effect against cardiac damage [38]. Studies have shown that the dried and powdered bark of T. arjuna enhances the levels of natural antioxidants in the heart and protects myocardial tissue from oxidative stress caused by ischemia–reperfusion injury [39].

Furthermore, alcoholic extracts of T. arjuna were reported to upregulate myocardial heat shock protein 72 and boost endogenous antioxidant defenses in rabbit hearts, offering significant cardioprotection against oxidative damage resulting from ischemic-reperfusion stress [40]. The bark's bioactive phytoconstituents also provide protection against oxidative damage induced by sodium fluoride and carbon tetrachloride, primarily due to their strong antioxidant potential. The ferric reducing antioxidant power (FRAP) assay confirmed that ethanol extracts of T. arjuna enhanced intracellular cardiac antioxidant activity [41, 42].

A recent comparative study revealed that the methanolic extract exhibited the highest antioxidant potential, with elevated levels of phenolic and flavonoid compounds, establishing a direct correlation between total phenolic content and antioxidative activity [43]. Another investigation demonstrated that both aqueous and alcoholic extracts of the bark reduced hydrogen



peroxide-induced reactive oxygen species in human monocytic cells by increasing the activities of catalase and glutathione peroxidase (GPO), thereby maintaining the cellular redox balance.

Further evidence from Mythili et al. confirmed that triterpenoids, particularly arjunolic acid, contribute significantly to the cardioprotective and antioxidant effects of *T. arjuna* by strengthening the body's endogenous antioxidant defense mechanisms [44].

3.3. Antihyperlipidemic and Antiatherogenic Activity:

In a double-blind, placebo-controlled clinical trial involving 100 patients with stable coronary artery disease (CAD), oral administration of 500 mg *T. arjuna* bark extract twice daily, along with standard therapy, resulted in a marked reduction in hyperlipidemia and inflammatory cytokines, including hsCRP, IL-18 ($P < 0.001$), IL-6, and TNF- α ($P < 0.05$) after three months of treatment [45].

Similarly, in another study, 30 patients with coronary artery disease receiving 500 mg of *T. arjuna* bark powder along with standard medication exhibited a 16% reduction in LDL cholesterol, 15% in total cholesterol, 11% in triglycerides, and a marginal decline in nitrite levels [46].

The hypolipidemic effect of *T. arjuna* is thought to result from its ability to enhance hepatic cholesterol clearance, suppress lipogenic enzyme activity, and inhibit HMG-CoA reductase, the key enzyme in cholesterol biosynthesis [47]. Parmar et al. further demonstrated that the bark extract improves cardiac and hepatic lipid peroxidation in albino rats and suggested a possible role of thyroid hormones, indicating a suppressive effect on thyroid activity [48].

Additionally, an in vivo study conducted on rabbits fed a high-fat diet showed that oral administration of 100–500 mg/kg of ethanolic bark extract effectively reduced hyperlipidemia, confirming the lipid-lowering potential of *T. arjuna* [49].

Before inducing sodium arsenite toxicity in experimental mice, treatment with arjunolic acid (20 mg/kg) was administered. The results indicated a significant reduction in total cholesterol, triglycerides, and LDL-C levels, along with an elevation in HDL-C levels [50].

In another study, 500 mg/kg of a 50% aqueous ethanol extract of *Terminalia arjuna* was given orally to rats with streptozotocin-induced diabetic cardiomyopathy. The treatment was initiated after eight weeks of diabetes induction and continued for 30 days. Findings revealed that *T. arjuna* supplementation led to a marked decrease in total cholesterol, triglycerides, and LDL-C, accompanied by an increase in HDL-C levels [51].

3.4. Effect on Thrombosis: In a recent investigation involving four medicinal plants native to Bangladesh, *Terminalia arjuna* was evaluated for its in vitro membrane-stabilizing and thrombolytic properties. The methanolic extract of *T. arjuna* demonstrated notable thrombolytic activity, achieving a clot lysis rate of 30.57%, and significantly reduced RBC hemolysis induced by both heat and hypotonic conditions. Although its thrombolytic potential was considered moderate, further research is necessary to isolate and identify the specific secondary metabolites responsible for this effect [56].

Additionally, limited data are available regarding the influence of *T. arjuna* on cytochrome P450 (CYP450) enzymes. Findings from a recent in vitro study suggest that certain components within

T. arjuna extracts can effectively inhibit CYP1A enzyme activity [57].

3.5. Effect on Aortic Prostaglandins: In an in vivo study, rabbits were administered T. arjuna bark powder in suspension form twice daily for 90 days. Results indicated a significant increase in aortic prostaglandin E₂ (PGE₂) levels, which enhanced blood circulation and improved overall cardiac performance in treated animals [58]

3.6. Effect on Endothelin-1 (ET-1) Levels: Rats with streptozotocin-induced diabetic cardiomyopathy were given 500 mg/kg of a 50% aqueous ethanol extract of T. arjuna orally. Treatment began after eight weeks of diabetes induction and continued for 30 days. The administration of T. arjuna helped restore vascular endothelial function by normalizing elevated ET-1 (endothelin-1) levels, thereby reducing pro-inflammatory mediators and enhancing cardioprotective effects in the treated rats [59].

3.8. Anti-inflammatory activity

Bark powder was shown to reduce inflammation in rats with carrageenan-induced paw edema [61].

A study demonstrated that powder from the bark of Terminalia arjuna lessened inflammation in rats that had carrageenan-induced paw edema [61].

Rats with inflamed paws caused by carrageenan experienced reduced swelling after being treated with bark powder [61].

The bark powder of Terminalia arjuna has anti-inflammatory effects, which were observed in rats with carrageenan-induced paw edema [61].

3.9. Anticancer activity

A substance called arjunic acid, extracted from the bark, was effective in treating human oral, ovarian, and liver cancer cell lines in a recent study.

In a recent study, arjunic acid, which is derived from the bark of Terminalia arjuna, was an effective anticancer treatment against specific human oral, ovarian, and liver cancer cells.

Research has found that arjunic acid, extracted from the bark, is a potent anti-cancer treatment for human oral, ovarian, and liver cancer cell lines [62].

Arjunic acid, found in the bark of Terminalia arjuna, effectively combated human oral, ovarian, and liver cancer cell lines in a recent laboratory study.

3.10. Antiviral activity

Casuarinin, a substance extracted from the bark, was used in laboratory conditions to treat the Herpes simplex Type 2 virus. It was found to both prevent viral entry and disrupt the later stages of the infection [62].

Lab tests showed that casuarinin, a compound from the tree's bark, can treat Herpes simplex Type 2 by blocking the virus from attaching and entering cells, as well as by interfering with the later stages of its lifecycle [62].

Casuarinin, extracted from the bark, has demonstrated antiviral capabilities against Herpes simplex Type 2 in vitro. It both prevents the virus from infecting cells and interferes with the progression of the infection [62].

The bark extract casuarinin has an antiviral effect on the Herpes simplex Type 2 virus, working in vitro to stop the virus from attaching to and entering cells while also interfering with the infection's later stages [62].



3.11. Recent advancement in antibacterial activity

Silver nanoparticles were synthesized using an 80% methanolic extract of *Terminalia arjuna* bark to test their antibacterial efficacy. The synthesized nanoparticles were analyzed using atomic force microscopy, UV-Visible spectroscopy, and particle size analysis. When tested against *Pseudomonas aeruginosa*, *Escherichia coli*, and *Staphylococcus aureus*, the nanoparticles showed antibacterial activity, leading to the conclusion that they could be used to treat bacterial skin infections [63].

A recent study explored the antibacterial properties of silver nanoparticles created with an 80% methanolic extract of *Terminalia arjuna* bark. These nanoparticles were effective against several bacteria, including *Pseudomonas aeruginosa*, *Escherichia coli*, and *Staphylococcus aureus*, suggesting potential use in treating bacterial skin infections [63].

By creating silver nanoparticles from an 80% methanolic extract of *Terminalia arjuna* bark, researchers evaluated their effectiveness against common bacteria. The nanoparticles displayed antibacterial action against *Pseudomonas aeruginosa*, *Escherichia coli*, and *Staphylococcus aureus*, indicating they could be used for treating skin infections [63].

Researchers assessed the antibacterial power of silver nanoparticles made from *Terminalia arjuna* bark extract. After being characterized by atomic force microscopy, UV-Visible spectroscopy, and particle size analysis, the nanoparticles demonstrated antibacterial effects against *P. aeruginosa*, *E. coli*, and *S. aureus*, suggesting their potential for treating bacterial skin infections [63].

4. DOSAGE AND FORMS OF TERMINALIA ARJUNA

1. Powder (Arjuna Churna)

- Dosage: 3–6 grams per day
- Administration: Usually taken with warm water or milk twice daily after meals.
- Purpose: Acts as a heart tonic, improves cardiac strength, and reduces cholesterol.

2. Decoction (Arjuna Kwath)

- Dosage: 50–100 ml per day
- Preparation: Boil 1 tablespoon (about 10 g) of bark powder in 200 ml of water until it reduces to half; strain and drink.
- Purpose: Useful in hypertension, chest pain, and heart weakness.

3. Arjunarishta (Fermented Herbal Tonic)

- Dosage: 10–20 ml twice daily, mixed with equal parts of water after meals.
- Purpose: Common Ayurvedic cardiac tonic — supports heart function, circulation, and blood pressure regulation.

4. Capsules / Tablets (Standardized Extracts)

- Dosage: 250–500 mg twice daily (depending on concentration).
- Form: Available as standardized extracts of *Terminalia arjuna* bark.
- Purpose: Convenient form for cardiovascular support and antioxidant benefits.

5. Arjuna Ksheera Paka (Milk Preparation)

- Dosage: 50–100 ml once or twice daily.

5. RELEVANT IMPACTS



The bark of *Terminalia arjuna* is generally considered safe for use; however, certain precautions should be observed before consumption:

1. **Pregnancy:** The use of *Terminalia arjuna* may be unsafe during pregnancy, and it is recommended to avoid other *Terminalia* species as well.
2. **Bleeding Disorders:** Since *T. arjuna* can slow blood coagulation, it may exacerbate bruising or bleeding in individuals with bleeding disorders.
3. **Breastfeeding:** There is insufficient evidence regarding the safety of *Terminalia* during lactation, so its use is not recommended while nursing.
4. **Diabetes:** *Terminalia* is known to lower blood glucose levels, which should be considered in diabetic patients.
5. **Surgery:** It is advised to discontinue *Terminalia* at least two weeks prior to surgery, as it may interfere with blood clotting and blood sugar regulation [49, 52].

CONCLUSION

Extensive experimental studies have confirmed that *Terminalia arjuna* possesses cardioprotective, anti-ischemic, anti-inflammatory, and antioxidant properties, including the ability to reduce LDL oxidation and lower atherogenic lipid levels. Its molecular actions in various cardiovascular cells have also been documented, and it contributes to enhanced cardiovascular function by improving autonomic regulation. Due to its multiple beneficial effects with minimal adverse outcomes, *T. arjuna* has the potential to complement or modify current therapeutic approaches. However, several gaps remain before it can be fully integrated into modern medicine, including the need for standardization of preparations, comprehensive toxicity studies, evaluation of drug

interactions, and large-scale, multicenter randomized clinical trials.

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