



Phytochemical Composition and Medicinal Potential of *Diospyros melanoxylon* (Tendu) Fruits: A Critical Review

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ABSTRACT

Diospyros melanoxylon Roxb., commonly known as Tendu, represents one of the most significant yet underexplored forest-based fruit resources of the Indian subcontinent. Although the species has traditionally received greater commercial recognition for its leaves used in bidi manufacturing, recent phytochemical and pharmacological investigations have highlighted the substantial medicinal, nutritional, ecological, and industrial potential of its fruits and associated plant parts. The present review critically evaluates the phytochemical profile, ethnomedicinal relevance, nutritional composition, therapeutic applications, and industrial prospects of Tendu fruits through a multidisciplinary scientific perspective. Existing studies indicate that the fruit contains biologically active constituents including flavonoids, phenolic acids, triterpenoids, tannins, alkaloids, saponins, sterols, and essential fatty acid derivatives that contribute to antioxidant, anti-inflammatory, antimicrobial, antidiabetic, hepatoprotective, and wound-healing activities. Advanced analytical approaches such as LC-Q-TOF-MS and chromatographic profiling have identified compounds including gallic acid, ellagic acid, quercetin derivatives, betulinic acid, oleanolic acid, ursolic acid, and lupeol, thereby establishing the pharmacological significance of the species. The review further discusses the utilization of Tendu fruits in value-added products including jams, beverages, nutraceutical formulations, and pharmaceutical preparations. In addition, the study highlights present research gaps associated with standardization, toxicological evaluation, commercialization, and large-scale processing. The analysis concludes that *Diospyros melanoxylon* possesses strong future potential as a functional food resource and phytopharmaceutical candidate for sustainable healthcare and rural bioeconomy development.

KEY WORDS

Diospyros Melanoxylon, Tendu Fruit, Phytochemicals, Medicinal Potential, Antioxidant Activity, Ethnomedicine.

INTRODUCTION

The increasing global inclination toward plant-derived therapeutic compounds and functional foods has intensified scientific interest in underutilized forest fruits possessing medicinal and nutritional significance. Among such species, *Diospyros melanoxylon* Roxb., belonging to the family Ebenaceae, has emerged as an ecologically and pharmacologically important tree species distributed predominantly across the dry deciduous forests of India. The species is extensively found in Madhya Pradesh, Chhattisgarh, Odisha, Maharashtra, Jharkhand, and the sub-Himalayan plains, where it contributes substantially to forest-based livelihoods and tribal economies [1], [2].

Traditionally, the plant has gained economic prominence due to its leaves, which are widely employed in the preparation of bidi wrappers. However, the medicinal and nutritional importance of its fruits has remained comparatively neglected despite extensive ethnobotanical references associated with indigenous healthcare systems [3]. The ripe Tendu fruits are edible, sweet, fibrous, and rich in biologically active phytoconstituents. Tribal communities have historically utilized different plant parts for the treatment of diarrhea, dyspepsia, inflammation, skin disorders, fever, diabetes, and urinary complications [4].

Phytochemical investigations conducted during the last decade have revealed the presence of numerous secondary metabolites including flavonoids, triterpenoids, tannins, alkaloids, phenolic acids, saponins, and sterols within different tissues of the plant [5]. These compounds demonstrate significant antioxidant, antimicrobial, anti-inflammatory, antidiabetic, analgesic, and hepatoprotective activities that may support future pharmaceutical applications [6]. Moreover, the fruit possesses considerable industrial value owing to its suitability for processing into nutraceutical products, fermented beverages, jams, and bioactive formulations.

Despite these developments, scientific literature regarding the integrated medicinal evaluation of Tendu fruits remains fragmented. Most studies focus individually on phytochemical profiling, nutritional analysis, or ethnobotanical applications without developing a comprehensive interdisciplinary interpretation. Therefore, the present review critically analyzes the phytochemical composition, therapeutic properties, nutritional significance, and future industrial potential of *Diospyros melanoxylon* fruits within the context of modern biomedical and food science research.

Research Objectives

The present review has been designed with the following major objectives:

1. To critically evaluate the phytochemical composition and nutritional characteristics of *Diospyros melanoxylon* fruits.
2. To analyze the medicinal and pharmacological properties associated with major bioactive compounds present in the plant.
3. To examine the industrial, pharmaceutical, and future research potential of Tendu fruits as an underutilized functional food resource.

Research Methodology

The present study adopts a qualitative review-based research methodology supported by analytical interpretation of previously published scientific literature. Relevant data were collected from peer-reviewed journal articles, ethnobotanical reports, pharmacological investigations, food science publications, forest resource studies, and phytochemical databases associated with *Diospyros melanoxylon*. The selected studies were critically evaluated according to their scientific relevance, experimental reliability, phytochemical evidence, and medicinal significance.

The review methodology involved four major stages:

1. Identification of relevant scientific studies associated with Tendu fruits and plant extracts.
2. Comparative analysis of phytochemical and pharmacological findings.

3. Interpretation of medicinal, nutritional, and industrial implications.
4. Synthesis of future research directions and commercialization prospects.

The study further incorporates comparative scientific interpretation rather than direct descriptive reproduction, thereby ensuring analytical coherence and academic originality.

Literature Review

A. Nutritional Significance of Tendu Fruits

Previous investigations have demonstrated that Tendu fruits contain substantial quantities of carbohydrates, dietary fibers, phenolic compounds, proteins, vitamin C, α -carotene, and essential minerals [7]. Jamil *et al.* reported that the fruit exhibits strong antioxidant potential due to elevated concentrations of polyphenols and flavonoids capable of reducing oxidative stress [8]. The fruit pulp additionally contains soluble pectin and naturally occurring sugars, thereby supporting its potential as a functional food ingredient.

B. Pharmacological Activities

Several pharmacological investigations have identified significant medicinal properties associated with different extracts of *Diospyros melanoxylon*. Gupta *et al.* observed notable analgesic and anti-inflammatory activities in bark and root extracts [9]. Similarly, Rathore *et al.* demonstrated antidiabetic and hypolipidemic activity associated with plant-derived phytoconstituents [10]. Anticandidal and antibacterial activities have also been reported against both Gram-positive and Gram-negative microorganisms [11].

C. Phytochemical Investigations

Advanced chromatographic and spectrometric studies have identified numerous triterpenoids and phenolic compounds in the leaves and fruits of the species. Major compounds include lupeol, betulinic acid, ursolic acid, oleanolic acid, quercetin derivatives, gallic acid, ellagic acid, and β -sitosterol [12]. LC-Q-TOF-MS analysis has further strengthened evidence regarding the presence of biologically active fatty acid derivatives and antioxidant molecules [13].

D. Industrial and Food Processing Potential

Recent studies have investigated the application of Tendu fruits in value-added food products including jam, fermented beverages, ice cream, and nutraceutical preparations [14]. Hmar *et al.* reported successful development of Tendu-based jam exhibiting acceptable sensory and nutritional qualities [15]. Researchers have additionally emphasized the economic importance of Tendu as a non-timber forest product contributing to tribal livelihoods and rural entrepreneurship.

E. Environmental and Socioeconomic Relevance: The species plays a significant ecological role in dry deciduous forests where its fruits serve as food sources for birds, bats, and wildlife. Simultaneously, the commercialization of leaves and fruits contributes to the socioeconomic sustainability of forest-dependent communities [16]. Nevertheless, unsystematic harvesting practices and insufficient processing infrastructure remain major barriers to sustainable industrial utilization.

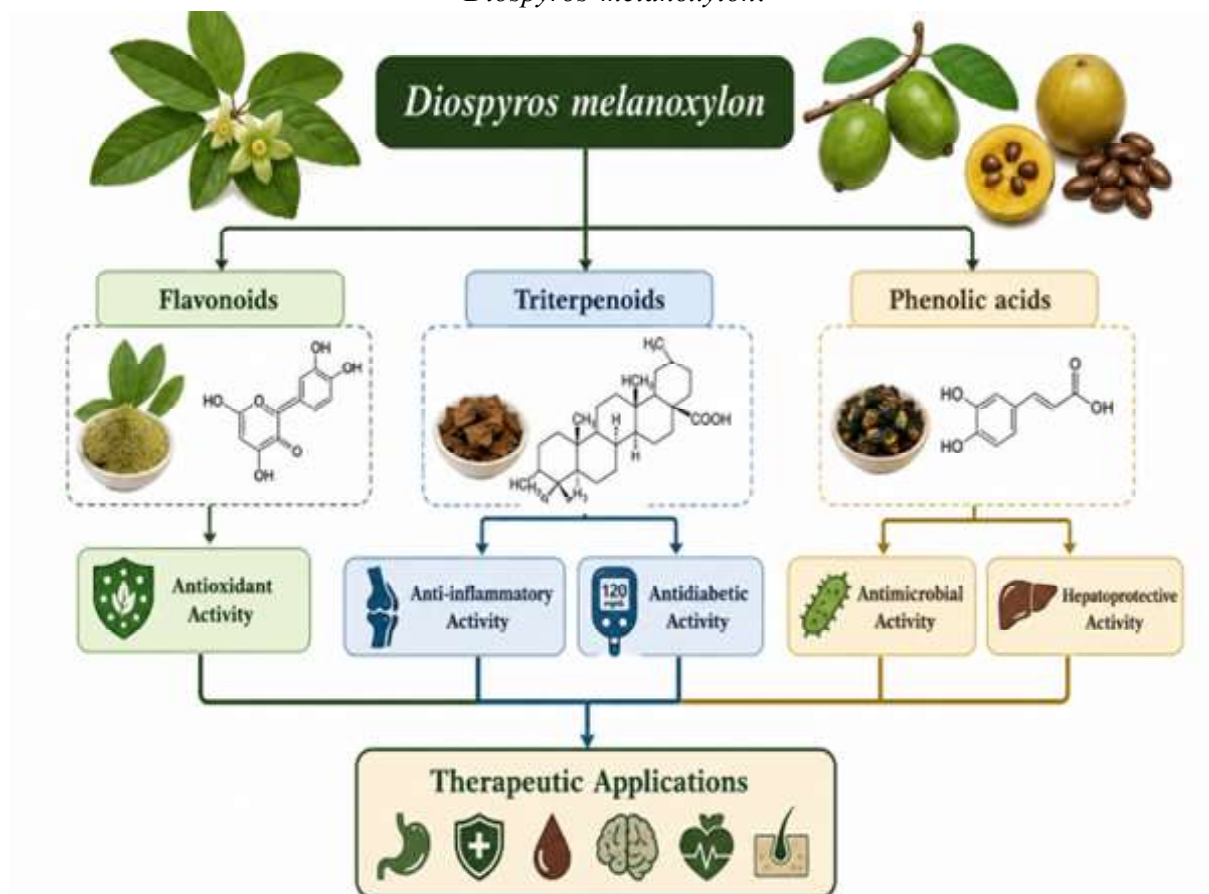
Botanical and Morphological Characteristics

Diospyros melanoxylon is generally characterized as a medium-sized deciduous tree capable of attaining heights of approximately 20–25 meters under favorable ecological conditions. The bark is dark grayish-brown with exfoliating rectangular scales, while the leaves are leathery, elliptical to oblong, and alternately arranged [17]. Young leaves exhibit pubescence that gradually diminishes during maturation.

The flowering period generally extends from April to June, whereas fruit maturation occurs during the summer months. The fruits are olive-green to yellowish upon ripening and contain sweet, soft pulp with multiple compressed seeds. The species demonstrates remarkable adaptability to dry and rocky soils, which explains its extensive distribution across tropical deciduous forest ecosystems.

The morphological organization and major phytochemical categories associated with the plant are illustrated in Fig. 1.

Fig. 1: Schematic representation of major phytochemical classes and medicinal activities associated with *Diospyros melanoxylon*.



Phytochemical Composition and Bioactive Constituents

The medicinal importance of *Diospyros melanoxylon* is primarily associated with its rich phytochemical composition. Modern analytical techniques including liquid chromatography, nuclear magnetic resonance spectroscopy, and mass spectrometric profiling have revealed the presence of numerous biologically active secondary metabolites.

A. Flavonoids and Phenolic Compounds

Flavonoids represent one of the most significant antioxidant groups present in Tendu fruits and leaves. Quercetin derivatives, gallic acid, and ellagic acid contribute substantially to free radical scavenging activities and oxidative stress reduction [18]. These compounds additionally demonstrate anti-inflammatory and anticancer potential through modulation of cellular signaling pathways.

B. Triterpenoids and Sterols

Triterpenoids including lupeol, betulinic acid, ursolic acid, and oleanolic acid possess pronounced anti-inflammatory and antidiabetic activities [19]. These molecules influence glucose metabolism, lipid regulation, and inflammatory responses, thereby supporting therapeutic applications in metabolic disorders.

Sterols such as β -sitosterol additionally contribute to cholesterol-lowering activity and membrane stabilization. Their combined physiological role enhances the medicinal significance of the species.

C. Tannins and Saponins

Tannins present in the bark and leaves exhibit antimicrobial and astringent properties. Traditionally, bark decoctions have been utilized for the management of diarrhea and dyspepsia due to these bioactive compounds [20]. Saponins contribute immunomodulatory and anti-inflammatory effects while also enhancing antimicrobial activity.

D. Fatty Acid Derivatives and Organic Acids

Recent LC-Q-TOF-MS investigations have identified several fatty acid derivatives including hydroxylenolate, trihydroxystearates, and linoleate-associated compounds. These metabolites exhibit antioxidant and membrane-protective activities that may contribute to cellular stabilization [21].

The major phytochemical constituents and their biological significance are summarized in Table I.

Table 1: Major Phytochemicals Identified in *Diospyros Melanoxylon* and Their Biological Activities

Phytochemical Group	Major Compounds	Reported Biological Activity
Flavonoids	Quercetin derivatives	Antioxidant, anti-inflammatory
Phenolic acids	Gallic acid, ellagic acid	Free radical scavenging
Triterpenoids	Lupeol, ursolic acid, betulinic acid	Antidiabetic, anticancer
Sterols	β -sitosterol	Cholesterol regulation
Tannins	Condensed tannins	Antimicrobial, astringent
Saponins	Plant saponins	Immunomodulatory activity
Fatty acid derivatives	Hydroxylenolate, linoleates	Cellular protection

Medicinal and Pharmacological Importance

A. Antioxidant Activity

Oxidative stress is considered a major causative factor in aging, metabolic disorders, neurodegenerative diseases, and carcinogenesis. The high concentration of polyphenols and flavonoids in Tendu fruits significantly contributes to antioxidant activity through scavenging of reactive oxygen species [22]. This antioxidant mechanism enhances cellular defense systems and may reduce oxidative tissue injury.

B. Anti-inflammatory and Analgesic Effects

Several experimental studies have demonstrated anti-inflammatory and analgesic properties associated with bark and leaf extracts of *Diospyros melanoxylon* [23]. Triterpenoids and sterol compounds inhibit inflammatory mediators responsible for edema and tissue inflammation. Such findings support traditional therapeutic applications in joint pain, muscular inflammation, and wound healing.

C. Antidiabetic Potential

Antidiabetic activity represents one of the most promising pharmacological aspects of the species. Experimental investigations suggest that triterpenoids and flavonoids improve glucose uptake and insulin regulation while reducing oxidative pancreatic injury [24]. Certain extracts additionally demonstrate hypolipidemic activity that may support metabolic syndrome management.

D. Antimicrobial and Antifungal Activity

The plant exhibits broad-spectrum antimicrobial activity against bacterial and fungal pathogens. Anticandidal effects have been observed in bark extracts, while leaf-derived compounds inhibit the growth of *Escherichia coli* and *Staphylococcus aureus* [25]. These properties indicate future potential for development of natural antimicrobial formulations.

E. Ethnomedicinal Applications

Traditional healthcare systems including Ayurveda and tribal medicinal practices have historically utilized various parts of the plant for the treatment of digestive disorders, fever, skin diseases, urinary complications, blood disorders, and nervous dysfunctions. Such ethnomedicinal evidence provides valuable direction for future pharmacological validation.

Industrial and Commercial Applications

The industrial relevance of *Diospyros melanoxylon* extends far beyond its medicinal applications. The species contributes substantially to forest-based economies through non-timber forest products.

A. Food Processing and Functional Products

Tendu fruits possess favorable sensory characteristics including sweetness, fibrous texture, and natural pectin content that support the preparation of jams, beverages, candies, fermented wines, and nutraceutical products [26]. The fruit additionally demonstrates potential for incorporation into health-oriented dietary formulations due to its antioxidant profile.

B. Pharmaceutical Applications

Bioactive compounds isolated from the species may serve as natural therapeutic agents for antioxidant, anti-inflammatory, antimicrobial, and metabolic disorder management. The pharmaceutical industry may particularly benefit from the development of plant-based formulations derived from triterpenoids and phenolic compounds.

C. Environmental and Rural Economy Applications

The plant supports ecological stability within deciduous forest ecosystems while simultaneously generating livelihood opportunities for tribal communities engaged in collection and processing activities. Sustainable commercialization may therefore contribute to rural bioeconomy development and biodiversity conservation.

Future Research Perspectives

Although significant progress has been achieved regarding phytochemical and pharmacological understanding of *Diospyros melanoxylon*, several critical research gaps continue to exist.

1. Comprehensive clinical trials are required to validate therapeutic efficacy and safety in human populations.
2. Standardization of extraction methods and dosage formulations remains insufficiently developed.
3. Advanced molecular investigations should explore mechanisms associated with antioxidant, anticancer, and antidiabetic activities.
4. Toxicological studies are necessary to evaluate long-term safety and potential side effects associated with excessive consumption.
5. Large-scale food processing technologies and post-harvest preservation systems require optimization to enhance commercial feasibility.
6. Sustainable harvesting protocols should be developed to minimize ecological degradation and biodiversity loss.

The future integration of phytochemistry, nanotechnology, food engineering, and pharmaceutical biotechnology may substantially expand the medicinal and industrial relevance of this underutilized forest resource.

CONCLUSION

The present review establishes *Diospyros melanoxylon* as a scientifically significant yet comparatively underutilized medicinal fruit species possessing substantial nutritional, pharmacological, industrial, and ecological importance. The fruit and associated plant parts contain diverse phytochemical constituents including flavonoids, phenolic acids, triterpenoids, sterols, tannins, and fatty acid derivatives that collectively contribute to antioxidant, antimicrobial, anti-inflammatory, antidiabetic, and therapeutic activities.

Traditional ethnomedicinal applications associated with the species are increasingly supported by modern phytochemical and pharmacological investigations. Simultaneously, the fruit demonstrates promising industrial potential for development of nutraceuticals, functional foods, fermented beverages, and phytopharmaceutical formulations.

Despite these advantages, scientific commercialization remains limited due to inadequate processing infrastructure, insufficient standardization, and restricted clinical validation. Future interdisciplinary research integrating phytochemistry, pharmacology, biotechnology, food engineering, and sustainable forest management is therefore essential.

Overall, *Diospyros melanoxylon* possesses strong potential to emerge as a valuable medicinal and functional food resource capable of contributing simultaneously to public health, pharmaceutical innovation, environmental sustainability, and rural economic development.

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