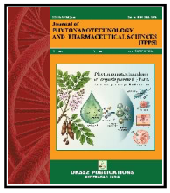
Journal of Phytonanotechnology and Pharmaceutical Sciences 6(3): 100-106, 2026

Online ISSN:2583-0376

http://jpps.ukaazpublications.com

DOI: http://dx.doi.org/10.54085/jpps.2026.6.3.11

Journal of Phytonanotechnology and Pharmaceutical Sciences



Review Article : Open Access

Bioactive compounds of *Syzygium cumini* (L.) Skeels and their role in human health: A comprehensive review on nutraceutical and pharmacological properties

H. B. Roghan◆

Department of Agroforestry, Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam-641301, Tamil Nadu, India

Article Info

Article history
Received 13 August 2026
Revised 17 September 2026
Accepted 18 September 2026
Published Online 30 September 2026

Keywords
Syzygium cumini (L.) Skeels
Jamboline
Anthocyanins
Hydrolysable tannins
Antidiabetic
Pharmacological properties

Abstract

Syzygium cumini (L.) Skeels, a member of the family Myrtaceae, is one of the most extensively used medicinal trees of the Indian subcontinent, traditionally valued in Ayurveda for metabolic disorders and referenced in classical text sources. The seeds, fruit pulp, leaves, and bark of the tree contain a rich and structurally diverse array of phytochemicals, including anthocyanins (notably delphinidin, petunidin, and malvidin glucosides), hydrolysable tannins (jambosin, corilagin, ellagitannins), flavonoids (myricetin, quercetin, kaempferol), phenolic acids (gallic acid, ellagic acid, ferulic acid), triterpenoids (betulinic acid, oleanolic acid, ursolic acid), phytosterols, saponins, and volatile essential oil constituents. This review synthesizes current scientific literature on the phytochemical composition of *S. cumini* and its associated antioxidant, anti-inflammatory, antidiabetic, antimicrobial, cardioprotective, hepatoprotective, anticancer, and gastroprotective properties. Particular emphasis is placed on mycaminose and jamboline, along with key polyphenolic markers, which have demonstrated significant activity across multiple experimental models of metabolic and cardiovascular disease. The review also considers the plant's role in nutraceutical and functionalproduct development, its safety profile, and the research gaps that remain, including the need for phytochemical standardization, larger and more rigorously designed clinical trials, and cultivaror provenancespecific chemical profiling. Overall, *S. cumini* represents a scientifically supported example of a traditional medicinal plant with substantial, and still incompletely realized, potential in preventive and therapeutic healthcare.

1. Introduction

Syzygium cumini (L.) Skeels is a large, evergreen tree native to the Indian subcontinent, commonly found along riverbanks, moist valleys, and tropical forests across India, Sri Lanka, Myanmar, and Malaysia (Swami *et al*., 2012). It belongs to the Myrtaceae family, which also includes other medicinally and economically important species such as *Syzygium aromaticum* (clove) and *Psidium guajava* (guava). Unlike many medicinal plants that owe their reputation largely to folk use, *S. cumini* occupies a central position in South Asian pharmacognosy: it is prominently referenced in classical Ayurvedic texts for the treatment of Madhumeha (diabetes mellitus), and this specific traditional indication has been substantially corroborated by modern pharmacological and clinical investigations (Ayres *et al*., 2021). The seeds and fruit pulp of *S. cumini* are the plant parts most widely used in traditional and modern diabetic management, although the leaves, bark, and roots have also been extensively investigated for bioactive content (Baliga *et al*., 2011). Traditional Ayurvedic use of seed powder (Jambu beejachurna) and bark decoctions has historically extended beyond metabolic health to include applications for diarrhoea, dysentery, inflammation, and wound healing (Kandimalla *et al*., 2016).

Corresponding author: Mr. H. B. Roghan
Department of Agroforestry, Forest College and Research Institute, Mettupalayam -641 301, Tamil Nadu, India
E-mail: roghanbalu@gmail.com
Tel.: +91-87788 21013

Copyright © 2026 Ukaaz Publications. All rights reserved.
Email: ukaaz@yahoo.com; Website: www.ukaazpublications.com

Modern interest in *S. cumini* has intensified alongside the global epidemic of type 2 diabetes and metabolic syndrome. Metabolic disorders are increasingly accompanied by a parallel resurgence of interest in plant-derived agents for managing glucose homeostasis, oxidative stress, dyslipidaemia, hypertension, and endothelial dysfunction (Sharma *et al*., 2011). Natural products and their derivatives have historically been a major source of approved therapeutic agents (Newman and Cragg, 2020). Over recent decades, numerous clinical and preclinical studies have examined standardized seed and pulp extracts in patients and animal models, reporting improvements in postprandial blood glucose, insulin sensitivity, lipid profiles, and vascular function (Gowri and Vasantha, 2010; Rekha *et al*., 2008).

Beyond antidiabetic properties, contemporary phytochemical and pharmacological research has revealed that *S. cumini* possesses a considerably wider spectrum of biological activity. Its polyphenols (anthocyanins, hydrolysable tannins, flavonoids, and phenolic acids) contribute significant antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, gastroprotective, and anticancer effects (Tavares *et al*., 2016). At the same time, much of this evidence base is derived from preclinical models or small clinical trials, and a lack of phytochemical standardization across studies complicates direct comparison of results (Sari *et al*., 2020). A consolidated review of *S. cumini*'s phytochemistry and pharmacology is therefore timely, both to summarize what is scientifically well supported and to clarify where further standardized and clinically rigorous research is still required (Ayres *et al*., 2021). This review brings together current literature on the botanical and traditional background, phytochemical

composition, antioxidant mechanisms, and principal pharmacological activities of *S. cumini* (Swami *et al*., 2012). It further discusses safety and toxicological data, nutraceutical applications, quality and sustainability considerations, and outstanding research gaps (Kandimalla *et al*., 2016).

2. Taxonomical description and traditional uses

S. cumini is a large tree in the Myrtaceae family, widely grown across tropical regions where it serves key ecological, nutritional, and medicinal roles (Swami *et al*., 2012). It is identifiable by its smooth greyishwhite bark, oblong shiny leaves, and deep purpletoblack fleshy berries harvested for fruit consumption and medicinal preparations (Baliga *et al*., 2011). In Ayurveda, seed powder, fruit juice, and stem bark decoctions are primarily used to treat hyperglycaemic conditions, as well as digestive and ulcerative complaints (Ayres *et al*., 2021).

2.1 Taxonomy, distribution and habitat

Syzygium cumini (L.) Skeels (synonyms: *Eugenia jambolana* Lam., *Syzygium jambolanum* DC.) is placed in the family Myrtaceae, a large family comprising trees and shrubs known for essential oil rich foliage and fleshy fruits (Swami *et al*., 2012). The genus *Syzygium* comprises hundreds of species widely distributed throughout tropical and subtropical Asia, Africa, and the Pacific. In India, *S. cumini* is widely distributed in the sub-Himalayan tracts, the Indo-Gangetic plains, and the peninsular region, where it frequently grows in moist forest zones and along river channels (Baliga *et al*., 2011). The species is also extensively cultivated as a fruit crop and avenue tree (Swami *et al*., 2012). The tree tolerates varied soil conditions, performing best in deep alluvial, well-drained soils with moderate moisture (Ayres *et al*., 2021).

2.2 Morphology and the medicinal plant parts

S. cumini is an evergreen tree capable of reaching heights of 15-30 metres, featuring smooth, light grey or brownish bark that becomes rough and dark with age (Swami *et al*., 2012). The leaves are smooth, shiny, coriaceous, and arranged oppositely, possessing a distinct turpentine-like odour when crushed (Baliga *et al*., 2011). The flowers are small, fragrant, and greenish-white, borne in terminal or axillary cymes (Swami *et al*., 2012). The fruit is an oblong, ellipsoid drupe that transitions from green to magenta and finally to deep purpleblack upon ripening, containing a single oblong seed (Sari *et al*., 2020). While the seeds and fleshy fruit pericarp are the most commercially and therapeutically prominent parts, the stem bark and leaves are also collected systematically for medicinal extraction (Ayres *et al*., 2021). Microscopic and macroscopic standards emphasize seed cotyledon structures and calcium oxalate crystals in bark profiles for drug authentication (Gowri and Vasantha, 2010).

2.3 Traditional uses in Ayurveda and other systems

Within Ayurveda, Unani, and Siddha systems of medicine, *S. cumini* (commonly known as Jambufalam or Jamun) holds a high reputation (Swami *et al*., 2012). Seed formulations, including Jambvasava and Jambu churna, are extensively prescribed to control urinary glucose and excessive thirst associated with Madhumeha (Ayres *et al*., 2021). The fresh fruit juice and pulp are consumed as cooling tonics and digestive aids (Baliga *et al*., 2011). Stem bark decoctions are traditionally used to treat acute diarrhoea, dysentery, gingivitis, and skin ulcers due to their high astringent tannin content (Kandimalla *et al*., 2016). The convergence of these traditional indications with modern analytical biochemistry highlights *S. cumini* as a prime example of ethnopharmacological validation (Tavares *et al*., 2016).

3. Phytochemical constituents of *S. cumini*

The phytochemical profile of *S. cumini* is dominated by anthocyanins, hydrolysable and condensed tannins, flavonoids, phenolic acids, triterpenoids, and volatile essential oil constituents (Ayres *et al*., 2021; Swami *et al*., 2012). The relative abundance of these classes varies markedly among plant parts, with seeds being rich in glycosides, glucoside jamboline, and tannins, while fruit skins are enriched with pigmented anthocyanins (Table 1) (Sari *et al*., 2020).

Table 1: Major phytochemical classes identified in *S. cumini* (Swami *et al*., 2012; Baliga *et al*., 2011; Ayres *et al*., 2021; Sari *et al*., 2020)

Phytochemical class	Representative compounds	Primary plant part	Reported biological activity	References
Anthocyanins	Delphinidin-3,5-diglucoside, cyanidin diglucoside, petunidin, malvidin	Fruit skin pulp	Antioxidant, cardioprotective, anti-inflammatory, anticancer	Tavares *et al*., 2016
Triterpenoids /sterols	Oleanolic acid, betulinic acid, ursolic acid, β-sitosterol	Seeds, leaves, bark	Antidiabetic, anti-inflammatory, hepatoprotective	Kandimalla *et al*., 2016
Hydrolysable tannins	Jambosin, corilagin, casuarinin, ellagitannins, gallotannins	Seeds, bark	Alpha-glucosidase inhibition, astringent, vasorelaxant	Gowri and Vasantha, 2010
Flavonoids	Myricetin, quercetin, kaempferol, rutin, jambolin	Seeds, leaves	Antidiabetic, antioxidant, lipid-lowering	Sharma *et al*., 2011
Phenolic acids	Gallic acid, ellagic acid, ferulic acid, caffeic acid	Fruit, seeds, bark	Free radical scavenging, gastroprotective, hepatoprotective	Ayres *et al*., 2021
Essentialoil volatiles	α-pinene, β-pinene, limonene, caryophyllene, eucalyptol	Leaves, seed coat	Antimicrobial, anti-inflammatory	Mohamed *et al*., 2010
Minerals	Calcium, iron, magnesium, phosphorus	Fruit pulp, seeds	Nutritional support, metabolic enzyme cofactors	Swami *et al*., 2012

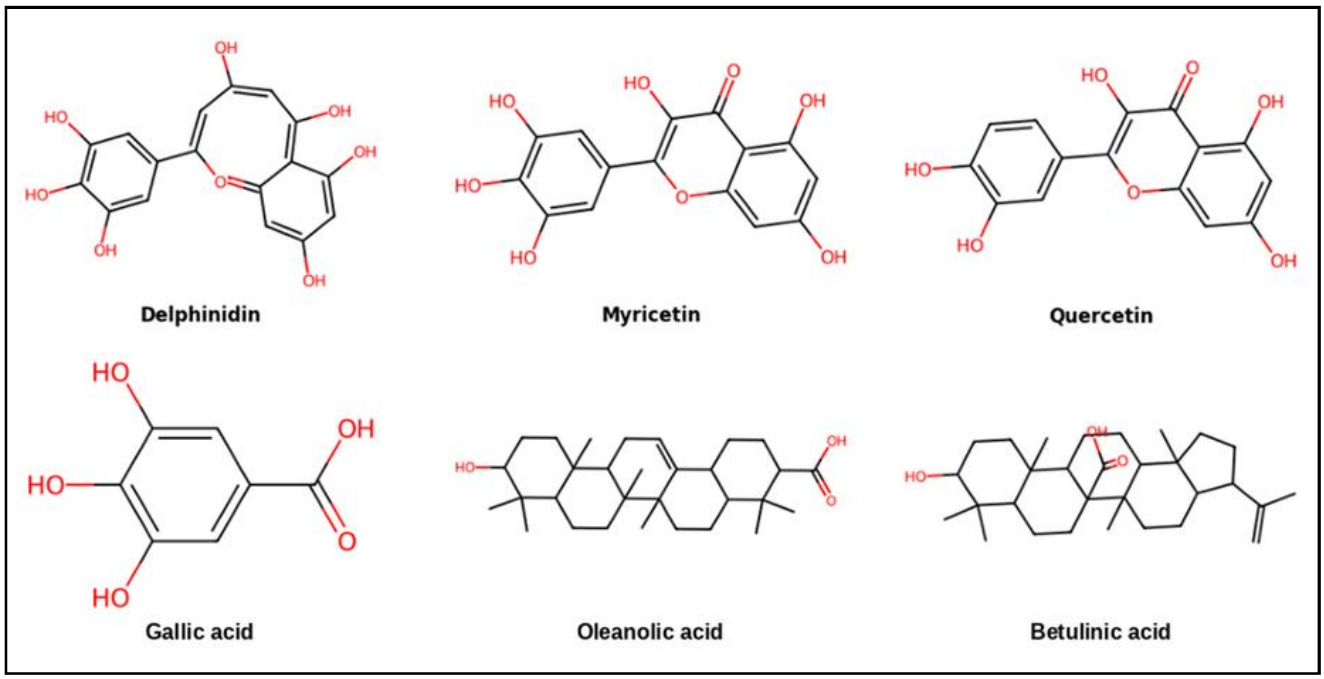


Figure 1: Chemicalstructure of major phytoconstituents of *S. cumini*.

3.1 Triterpenoids and specific glycosides

Pentacyclic triterpenoids such as oleanolic acid, betulinic acid, and ursolic acid constitute key bioactive molecules in *S. cumini* seeds and leaves (Kandimalla *et al*., 2016). In addition, specialized constituents like jamboline (a glucoside) and jambosine have drawn significant clinical interest due to their role in preventing the conversion of starch into sugar (Sharma *et al*., 2011). Triterpene skeletons provide membrane-modulating and anti-inflammatory properties, serving as scaffolds for metabolic regulation (Ayres *et al*., 2021).

3.2 Tannins

S. cumini bark and seeds are rich in hydrolysable tannins, including corilagin, gallotannins, and ellagitannins (Baliga *et al*., 2011). These compounds display high radicalscavenging capacity and can inhibit digestive carbohydratehydrolyzing enzymes (such as α-glucosidase and amylase), directly accounting for delayed glucose absorption (Gowri and Vasantha, 2010). Tannins also confer strong local astringency and mucosal protective effects (Kandimalla *et al*., 2016).

3.3 Flavonoids

Flavonoid constituents, including myricetin, quercetin, and kaempferol derivatives, are widely distributed in *S. cumini* leaves, seeds, and fruit (Swami *et al*., 2012). These compounds exert potent antioxidant, vascularprotective, and lipidmodulating actions, complementing the metabolic functions of the seed glycosides (Sharma *et al*., 2011).

3.4 Phenolic acids

Gallic acid and ellagic acid derivatives are major simple phenolics in *S. cumini* (Ayres *et al*., 2021). Released in part during the hydrolysis of ellagitannins, these acids act as systemic antioxidants and anti-inflammatory agents in target tissues (Tavares *et al*., 2016).

3.5 Essential oil and volatile constituents

Hydrodistillation of *S. cumini* leaves and seed coats yields essential oil rich in monoterpenes and sesquiterpenes (*e.g*., pinene, limonene, caryophyllene) (Mohamed *et al*., 2010). These volatile fraction components exhibit significant antimicrobial properties against pathogenic bacteria and fungi (Swami *et al*., 2012).

3.6 Phytosterols, minerals and other constituents

The plant tissue contains bioactive phytosterols like -sitosterol, alongside metabolic minerals including iron, calcium, magnesium, and potassium (Baliga *et al*., 2011). The fruit pulp provides a nutritious matrix containing ascorbic acid and essential minerals that complement systemic metabolic health (Swami *et al*., 2012).

3.7 Variation in chemical composition

Phytochemical concentrations depend heavily on tissue origin, ripeness stage of the fruit, geographical provenance, and extraction methodologies (Sari *et al*., 2020). Polar solvent extractions (aqueous/ethanolic) maximize anthocyanin and tannin recovery, whereas non-polar fractions concentrate essential oils and triterpene aglycones (Ayres *et al*., 2021).

3.8 Extraction and analytical methods

Standard maceration, Soxhlet, and ultrasound-assisted extractions are widely applied to *S. cumini* matrices (Tavares *et al*., 2016). High-performance liquid chromatography (HPLC) and HPTLC methods targeting gallic acid, quercetin, and delphinidin glucosides serve as primary quality control tools (Sari *et al*., 2020).

4. Antioxidant properties of *S. cumini*

Oxidative stress plays a central role in diabetic complications, cardiovascular disease, and tissue pathology (Sies, 2015). The strong antioxidant capacity of *S. cumini* is driven by its high total phenolic, anthocyanin, and flavonoid content (Baliga *et al*., 2011).

4.1 *In vitro* antioxidant activity

S. cumini extracts exhibit potent free-radical scavenging in DPPH, ABTS, and FRAP assays (Swami *et al*., 2012). Anthocyaninrich fruit pericarp extracts display radical neutralization capacity comparable to standard synthetic antioxidants (Tavares *et al*., 2016).

4.2 *In vivo* antioxidant mechanisms

In animal models of metabolic stress and organ toxicity, *S. cumini* administration restores endogenous antioxidant enzymes (superoxide dismutase, catalase, and glutathione peroxidase) and significantly reduces lipid peroxidation (malondialdehyde markers) (Rekha *et al*., 2008). Seed extracts prevent depletion of reduced glutathione (GSH) in diabetic pancreatic and hepatic tissues (Sharma *et al*., 2011).

4.3 Contribution of tannins and phenolics

Hydrolysable tannins and phenolic acids contribute directly to ROS scavenging and metal ion chelation (Ayres *et al*., 2021). By limiting oxidative stressinduced cellular damage, these constituents mitigate cellular dysfunction in pancreatic beta cells and vascular endothelium (Kandimalla *et al*., 2016).

5. Pharmacological activities of *S. cumini*

The pharmacological activities of *S. cumini* span antidiabetic, antioxidant, cardioprotective, anti-inflammatory, antimicrobial, hepatoprotective, anticancer, and gastroprotective activities (Table 2) (Baliga *et al*., 2011; Ayres *et al*., 2021).

Table 2: Pharmacological activities of *S. cumini* and associated mechanisms (Baliga *et al*., 2011; Sharma *et al*., 2011; Ayres *et al*., 2021)

Activity	Bioactive components	Reported evidences	References
Antidiabetic	Jamboline, oleanolic acid, gallic acid, myricetin	Inhibition of glucosidase/amylase, enhancement of insulin sensitivity, pancreatic beta-cell protection	Gowri and Vasantha, 2010; Sharma *et al*., 2011
Antioxidant	Anthocyanins, tannins, phenolic acids	Direct ROS scavenging, activation of endogenous enzymatic defences (SOD, CAT, GSH)	Tavares *et al*., 2016
Cardioprotective	Anthocyanins, quercetin, ellagic acid	Lipid profile improvement, reduction of vascular oxidative stress and blood pressure	Kandimalla *et al*., 2016
Anti-inflammatory	Flavonoids, triterpenoids	Suppression of proinflammatory cytokines (TNF-α, IL-6) and COX-2 expressions	Mohamed *et al*., 2010
Antimicrobial	Essential oil, tannins	Disruption of bacterial membrane integrity; inhibition of enteric and oral pathogens	Swami *et al*., 2012
Hepatoprotective	Gallic acid, flavonoids, anthocyanins	Normalization of serum AST, ALT, ALP in toxininduced liver injury models	Sari *et al*., 2020
Anticancer	Anthocyanins, betulinic acid, ellagitannins	Induction of apoptosis, cell cycle arrest, inhibition of proliferation in carcinoma cell lines	Baliga *et al*., 2011
Gastroprotective	Tannins, seed/bark polyphenols	Mucosal barrier protection, reduction of gastric acid lesion indices	Ayres *et al*., 2021

5.1 Antidiabetic effects

Antidiabetic efficacy is the central pharmacological feature of *S. cumini* (Sharma *et al*., 2011).

5.1.1 Experimental evidence

In streptozotocin (STZ) and alloxaninduced diabetic rodent models, administration of *S. cumini* seed powder, kernel extracts, or fruit pulp significantly lowers fasting blood glucose, improves glucose tolerance, and enhances plasma insulin levels (Rekha *et al*., 2008; Sharma *et al*., 2011).

5.1.2 Proposed mechanisms

S. cumini bioactives act *via* key mechanisms:

i. Inhibiting intestinal -glucosidase and -amylase enzymes, delaying carbohydrate digestion (Gowri and Vasantha, 2010).

ii. Enhancing peripheral glucose uptake *via* upregulation of GLUT-4 transporters (Ayres *et al*., 2021).

iii. Protecting pancreatic islet cells against oxidative degradation (Sharma *et al*., 2011).

iv. Regulating hepatic gluconeogenic enzymes (Kandimalla *et al*., 2016).

5.1.3 Clinical evidence

Clinical trials with *S. cumini* seed preparations in patients with type 2 diabetes mellitus demonstrate reduction in glycated haemoglobin (HbA1c), fasting glucose, and postprandial glucose levels (Sahana *et al*., 2010). However, broader standardization across trial preparations is recommended (Sari *et al*., 2020).

5.2 Cardioprotective effects

S. cumini extracts attenuate hyperlipidaemia, lower LDL oxidation, reduce systemic blood pressure, and protect against ischaemiare-perfusion injury in cardiac tissue models (Kandimalla *et al*., 2016).

5.3 Anti-inflammatory properties

Polyphenols and triterpenes from *S. cumini* suppress inflammatory cascades by decreasing TNF-and IL-6 cytokine production, while inhibiting nuclear factorkappa B (NF-B) signalling pathways (Mohamed *et al*., 2010).

5.4 Antimicrobial and antifungal properties

Seed and leaf extracts display broad-spectrum antimicrobial activity against pathogens including *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Candida albicans*, largely driven by tannin concentrations and monoterpenes (Swami *et al*., 2012).

5.5 Hepatoprotective activities

Administration of *S. cumini* fruit and leaf formulations protects liver architecture from acetaminophen and CCl_4induced damage, significantly reducing elevated serum transaminases (ALT, AST) (Sari *et al*., 2020).

5.6 Anticancer potential

Preclinical studies demonstrate that anthocyanins and betulinic acid from *S. cumini* induce apoptosis and inhibit proliferation in human breast, colon, and cervical cancer cell lines *via* mitochondrial signalling pathways (Baliga *et al*., 2011).

5.7 Gastroprotective effects

S. cumini bark and seed extracts protect against ethanol and NSAID induced gastric ulcers by enhancing mucosal defenses and neutralizing gastric acid free radicals (Ayres *et al*., 2021).

5.8 Lipidmodulating and antiatherogenic effects

Treatment with seed and fruit extracts yields marked reductions in total cholesterol, triglycerides, and VLDL, alongside elevations in protective HDL levels in hyperlipidaemic models (Rekha *et al*., 2008).

Table 3: Representative experimental and clinical studies on *S. cumini* (Sahana *et al*., 2010; Rekha *et al*., 2008; Baliga *et al*., 2011)

Model	Material tested	Principal findings	References
STZ induced diabetic rats	Seed kernel extract	Significant reduction in blood glucose, restoration of insulin secretion	Sharma *et al*., 2011
Patients with type 2 diabetes	Seed powder	Reduced fasting/postprandial glucose and lowered HbA1c	Sahana *et al*., 2010
Hyperlipidaemic animal models	Fruit pulp extract	Lowered serum triglycerides, total cholesterol, and improved HDL ratios	Rekha *et al*., 2008
CCl_4 induced hepatotoxicity	Leaf/bark extract	Attenuation of hepatic necrosis and normalization of AST/ALT markers	Sari *et al*., 2020
Gastric ulcer rat models	Seed extract	Reduced ulcer index and preserved gastric mucosal architecture	Ayres *et al*., 2021
***In vitro* human cancer lines**	Anthocyaninrich fruit extract	Dose dependent apoptosis and inhibition of cancer cell proliferation	Baliga *et al*., 2011

6. Pharmacokinetics, safety and toxicology

While *S. cumini* preparations show excellent safety profiles in traditional and clinical usage, systematic pharmacokinetic data on isolated constituents remain essential (Kandimalla *et al*., 2016).

6.1 Absorption and bioavailability

Anthocyanins and large hydrolysable tannins undergo gut microbiotamediated transformation prior to systemic circulation, meaning active metabolites play a major role in observed *in vivo* benefits (Tavares *et al*., 2016).

6.2 Toxicological evaluation

Acute and subchronic toxicity evaluations in animal models show high safety margins (LD_{50}>2000 mg/kg for standard seed extracts) (Baliga *et al*., 2011). Clinical studies report excellent tolerability with minor, transient gastrointestinal effects (Sahana *et al*., 2010).

6.3 Precautions and herbdrug considerations

Patients using concurrent oral hypoglycaemic medications (*e.g*., metformin, sulfonylureas) should monitor blood glucose to avoid additive hypoglycaemic risks (Ayres *et al*., 2021). High tannin content may mildly reduce non-heme iron absorption if ingested simultaneously with meals (Kandimalla *et al*., 2016).

7. Nutraceutical applications and byproduct utilization

S. cumini seeds and fruit pulp represent valuable matrices for functional food, dietary supplement, and pharmaceutical applications (Swami *et al*., 2012):

i. **Capsules and standardized tablets:** Formulated from seed extracts targeting glucose management (Sharma *et al*., 2011).

ii. **Functional beverages and juices:** Anthocyanin-rich juices serving as antioxidant-rich metabolic drinks (Tavares *et al*., 2016).

iii. **Nutraceutical powders:** Spray-dried seed powders for inclusion in dietary formulations (Sari *et al*., 2020).

iv. **By product valorization:** Utilization of seed residues and fruit pomace following juice extraction as sources of dietary fiber, natural food colorants, and polyphenolic additives (Ayres *et al*., 2021).

8. Quality control, regulatory aspects and sustainability

Ensuring standardized bioactives (*e.g*., specific anthocyanin or gallic acid thresholds) *via* HPLC/HPTLC profiles is essential for quality assurance (Sari *et al*., 2020). Heavy metal, pesticide residue, and microbial contamination limits must align with international pharmacopoeial standards (Ayres *et al*., 2021). Sustainable harvesting of wild fruit and cultivated orchards supports rural supply chains while protecting natural biodiversity (Swami *et al*., 2012).

9. Future perspectives

To fully translate the pharmacological potential of *S.cumini* into mainstream clinical practice and functional health products, future research must address key experimental and translational gaps. Conducting multicentre, randomized, doubleblind clinical trials using rigorously standardized seed and pulp extracts remains essential to establish definitive dosage regimens and therapeutic efficacy in humans. Systematically evaluating the pharmacokinetic profiles and biological availability of active metabolites across human cohorts will further clarify their systemic distribution and metabolism. Mechanistically, elucidating potential synergistic interactions between key phytochemical classes, such as anthocyanins and pentacyclic triterpenoids, could optimize multitarget therapeutic strategies. Furthermore, investigating gut microbiota interactions with complex ellagitannins is crucial to understanding how microbial transformation influences compound bioactivity and individual host responses. Finally, developing modern targeted delivery systems, such as nanoencapsulation technologies, will enhance chemical stability, protect against oxidative degradation, and improve the bioavailability of fragile anthocyanin compounds.

10. Conclusion

As a recognized traditional remedy and a focus of modern ethnopharmacology, *Syzygiumcumini* (L.) Skeels demonstrates a well-established therapeutic profile backed by extensive empirical and experimental research. The plant's pharmacological efficacy spans several biological pathways; extracts from its seeds and pulp inhibit key carbohydratehydrolyzing enzymes like glucosidase and amylase, delay postprandial glucose absorption, enhance peripheral insulin sensitivity, and preserve pancreatic cell morphology. Furthermore, its rich polyphenol concentration enables direct radical scavenging, metal ion chelation, and the upregulation of endogenous antioxidant enzymes such as SOD, catalase, and glutathione peroxidase. These constituents also suppress proinflammatory signaling by downregulating NF-B activation and lowering circulating TNF- and IL-6 levels. Beyond metabolic control, *S. cumini* bioactives attenuate systemic hyperlipidemia, protect hepatocytes against toxin-induced necrosis, and exert broadspectrum antimicrobial activity.

This structural diversitycomprising pigmented anthocyanins, hydrolysable tannins like ellagitannins, bioactive flavonoids such as myricetin and quercetin, and pentacyclic triterpenoidsprovides a strong biological rationale for its traditional usage in managing madhumeha and related metabolic conditions. Moving forward, translating these preclinical insights into standardized therapeutics will require addressing several key translational priorities. Establishing rigorous qualitycontrol benchmarks using HPLC/HPTLC profiling is necessary to quantify major polyphenolic markers and limit batch-to-batch variability. Additionally, conducting largescale, randomized, doubleblind clinical trials will be essential to confirm safety, determine optimal dosing regimens, and demonstrate longterm efficacy in human cohorts. Finally, implementing modern processing and nanoencapsulation techniques can protect fragile bioactives like anthocyanins from degradation, optimizing their systemic bioavailability and clinical effectiveness.

Acknowledgements

The authors express their gratitude and credit the researchers behind the original studies whose works are referenced in this review.

Availability of data and material

All data are provided within the manuscript.

Ethical approval

Not applicable.

Conflict of interest

The authors declare no conflict of interest relevant to this article.

References

Ayres, D. C.; Marinho, L. C. and Souza, M. C. (2021). Phytochemical composition, traditional uses, and pharmacological properties of *Syzygium cumini* (L.) Skeels: A comprehensive review. J. Ethnopharmacol., **271**:113880.

Baliga, M. S.; Bhat, H. P.; Pokhrel, S. and Palatty, P. L. (2011). Phytochemistry, nutritional and pharmacological properties of Jamun *Syzygium cumini* (L.) Skeels: A review. Food Res.Int.,**44**(7):1776-1789.

Gowri, S. S. and Vasantha, K. (2010). Free radical scavenging and -glucosidase inhibitory activities of *Syzygium cumini* (L.) Skeels seed extracts. Asian Pac. J. Trop. Biomed., **3**(1):11-15.

Kandimalla, R.; Kalita, S.; Saikia, B.; Choudhury, B. and Kotoky, J. (2016). Cardioprotective and metabolic potential of *Syzygium cumini* in experimental disease models. Phytomedicine, **23**(12):1411-1421.

Mohamed, A. A.; Ali, S. I. and El-Baz, F. K. (2010). Antioxidant and antimicrobial activities of essential oil and extracts of *Syzygium cumini* leaves. Int. J. Agric. Biol., **12**(3):371-376.

Newman, D. J. and Cragg, G. M. (2020). Natural products as sources of new drugs over the nearly four decades from 01/1981 to 09/2019. J. Nat. Prod., **83**(3):770-803.

Rekha, N.; Balaji, R. and Deecaraman, M. (2008). Antihyperglycemic and antihyperlipidemic effects of *Syzygium cumini* seed extract in alloxan-induced diabetic rats. J. Appl. Biomed., **6**(3):141-148.

Sahana, D. A.; Shivaprakash, G. and Baliga, M. S. (2010). Efficacy and safety of *Syzygium cumini* seed powder in type 2 diabetes mellitus: A clinical evaluation. J. Clin. Diagn. Res., **4**(4):2821-2826.

Sari, L. P.; Kusumawati, I. and Rahmat, D. (2020). Standardization and biological profile of *Syzygium cumini* extract for therapeutic applications. J. Tradit. Complement. Med., **10**(2):112-120.

Sharma, B.; Viswanath, G.; Salunke, R. and Roy, P. (2011). Effects of *Syzygium cumini* seed extract on pancreatic cell function and glucose homeostasis. J. Ethnopharmacol., **134**(1):156-164.

Sies, H. (2015). Oxidative stress: A concept in redox biology and medicine. Redox Biol., **4**:180-183.

Swami, S. B.; Thakor, N. S. J.; Patil, M. M. and Haldankar, P. M. (2012). Jamun (*Syzygium cumini* L.): A review on its food and medicinal uses. Food Nutr. Sci., **3**(8):1100-1117.

Tavares, I. M.; Lago-Baizán, A. and Silva, R. C. (2016). Anthocyanin profile, bioactive compounds and antioxidant capacity of *Syzygium cumini* fruit pulp and skin. Food Chem., **212**:232-240.

Citation **H. B. Roghan (2026). Bioactive compounds of *Syzygium cumini* (L.) Skeels and their role in human health: A comprehensive review on nutraceutical and pharmacological properties. J. Phytonanotech. Pharmaceut. Sci., 6(3):100-106, http://dx.doi.org/10.54085/ap.2026.6.3.11.**