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Manish Kumar Vijay
Scientist-B, ICFRE- Tropical Forest Research Institute, Jabalpur, Madhya Pradesh, India

Neelu Singh
Scientist-G, ICFRE- Tropical Forest Research Institute, Jabalpur, Madhya Pradesh, India

Corresponding Author:
Manish Kumar Vijay
Scientist-B, ICFRE- Tropical Forest Research Institute, Jabalpur, Madhya Pradesh, India

Nutritional composition, photochemistry, and Pharmacognostic activities of *Flacourtia indica* (Burm.f.) Merr.: An important wild edible fruit species of central India

Manish Kumar Vijay and Neelu Singh

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Abstract
Flacourtia indica (Burm.f.) Merr., commonly known as Governor's Plum, is a prominent wild edible fruit species indigenous to central India, exhibits diverse nutritional, photochemical, and pharmacognostic properties. Nutritional analysis reveals that *Flacourtia indica* fruits are rich in essential nutrients, including vitamins, minerals, and dietary fiber, making them valuable in local diets, particularly for their high vitamin C content, which contributes to significant antioxidant capacity. Phytochemical investigations have identified various bioactive compounds such as flavonoids, phenolics, tannins, and saponins, which are known for their potent antioxidant activities, crucial in combating oxidative stress and preventing chronic diseases. The high concentration of phenolic compounds suggests strong free radical scavenging activity, beneficial in mitigating inflammation and enhancing overall health. Pharmacognostic studies further demonstrate the medicinal potential of *Flacourtia indica*, with traditional uses documented for treating ailments such as diarrhea, fever, and respiratory infections. Modern pharmacological evaluations support these traditional applications, revealing significant antimicrobial, anti-inflammatory, and analgesic properties in *Flacourtia indica* extracts. These findings *indica*te that *Flacourtia indica* could be a natural source for developing novel therapeutic agents. Overall, *Flacourtia indica* emerges as a nutritionally rich fruit with substantial photochemical and pharmacognostic benefits, offering potential for integration into diets and development into pharmaceutical products to enhance health outcomes and support sustainable practices in central India. Further research is warranted to explore the full spectrum of its bioactive compounds and their mechanisms of action.

Keywords: Traditional medicine, nutritional composition, phytochemicals, pharmacognostic activities, wild edible fruit, central India

Introduction
Flacourtia indica (Burm. f.) Merr. is a branched, deciduous, and dioecious shrub or small tree belonging to the Salicaceae family, formerly classified under Flacourtiaceae. The botanical name carries historical and geographical significance: 'Flacourtia' honors E. de Flacourt (1607-60), a governor of Madagascar who visited the Cape before van Riebeeck, while '*indica*' *indica*tes its presence in the eastern regions, including the small Transvaal bushveld. This species is endemic to various countries in Africa and Asia and is commonly known as "Indian plum," "Governor’s plum," and "Madagascar plum."

Taxonomic tree
Kingdom: Plantae
Phylum: Spermatophyta
Class: Dicotyledonae
Order: Violales
Family: *Flacourtia*ceae
Genus: *Flacourtia*

It is a versatile plant with significant medicinal and practical uses. Native to tropical regions, this resilient species offers both edible and therapeutic benefits.

The fruit is renowned for its medicinal applications, traditionally used to treat nausea, vomiting, bilious disorders, jaundice, and an enlarged spleen. Beyond its medicinal value, the fruit is a culinary delight, versatile in preparations ranging from raw consumption to processed products like jams, jellies, pickles, and even wine. The young shoots are also edible. *Flacourtia indica* 's defensive spines make it an excellent choice for natural fencing, forming impenetrable barriers suitable for agroforestry. Medicinally, the plant is integral to Ayurveda, with infusions of its bark, leaves, and roots used to treat fever, diarrhea, inflammation, and various other ailments. Its leaves have carminative, astringent, and tonic properties, addressing issues like asthma, pain, gynecological complaints, and snake bites. The root decoctions are used for pain relief, and the bark serves as an anti-rheumatic liniment. The plant also contributes to agroforestry, with its spiny nature creating effective hedges and windbreaks. The wood, though limited in size, is hard, heavy, and durable, used for making agricultural implements, building materials, and charcoal. *Flacourtia indica* is not only a valuable food source but also serves multiple roles in traditional medicine, agroforestry, and practical applications, showcasing its comprehensive utility and importance in both historical and modern contexts. Known for its edible fruits, the plant is widely recognized in traditional medicine systems for its diverse therapeutic properties. This review consolidates existing knowledge on the nutritional composition, phytochemistry, and pharmacognostic activities of *Flacourtia indica*, underscoring its relevance in both traditional and modern healthcare contexts.

Materials and Methods

An exhaustive literature review was conducted, encompassing a comprehensive exploration of diverse resources, including prominent databases such as PubMed, Google Scholar, Web of Science, and Springer Nature. This thorough investigation involved employing various combinations of keywords to ensure inclusivity. Additionally, valuable insights were extracted from sources beyond traditional databases, such as pertinent websites and relevant thesis works. The overarching objective of this methodological approach was to comprehensively gather information pertaining to nutritional composition, phytochemistry, and pharmacognostic activities of *Flacourtia indica.*

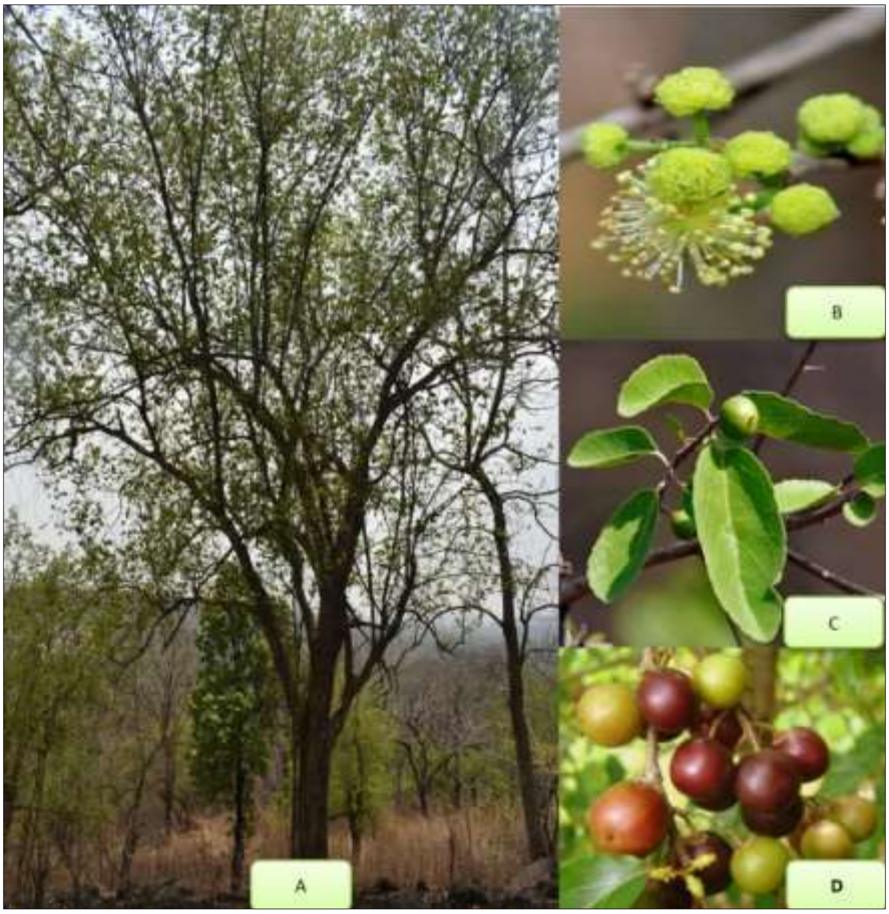

Fig 1: *Flacourtia indica* plant morphology A. Plant B. Flower C. Leaf and immature fruit (Green) D. Mature Fruits (Purple)

Results and Discussion

The results of the extensive literature review revealed a rich compilation of information on the nutritional composition, phytochemistry, and pharmacognostic activities of *Flacourtia indica*

Nutritional Composition

The nutritional analysis of *Flacourtia indica* fruits revealed a rich profile of essential nutrients. The fruits are particularly high in vitamin C, contributing to their potent antioxidant properties. Additionally, they contain significant amounts of dietary fiber, essential vitamins such as A and E, and minerals like calcium, potassium, and iron. This nutrient density makes *Flacourtia indica* a valuable dietary component, potentially addressing nutritional deficiencies in local populations.

Table 1: A review of studies carried out on Nutritional composition of *Flacourtia indica*

Component	Content value	References
Water (per 100 g)	74.2g	Janick and Paull, 2008 [18]
Calories (per 100 g)	94 kcal	
Protein (per 100 g)	0.5g	
Lipid (per 100 g)	0.6g	
Carbohydrates (per 100 g)	24.2g	
Fiber (per 100 g)	1.2g	
Ash (per 100 g)	0.5g	
Total Dietary Fiber	12.25±0.29%	Perera *et al.*, 2022 [51]
Total Phenolic Content	8.137±0.89 mg GAE/g	
FRAP	0.015±0.003 mM Fe^{2+}/g	
DPPH IC50	0.089±0.001 mg/mL	
Minerals (mg/kg)	Potassium: 434.60±0.36; Magnesium: 9.83±0.74; Sodium: 3.56±0.14; Phosphorus: 16.69±0.46; Calcium: 23.43±0.45; Iron: 0.28±0.08; Manganese: 0.47±0.11; Aluminum: 0.33±0.04; Copper: 0.11±0.04	
Moisture	78.61%	
Ash	1.17%	
Protein	3.17%	
Fat	0.53%	
Moisture (Peel)	15.203±0.267%	Jayasinghe and Weerasooriya, 2021 [19]
Lipid (Peel)	9.277±0.165%	
Ash (Peel)	13.927±0.488%	
Protein (Peel)	22.411±0.535%	
Carbohydrates (Peel)	29.662±0.665%	
Calories (Peel)	291.785 kcal/100 g	
Fiber (Peel)	Lower than seeds	
Moisture (Seeds)	8.890±0.200%	
Lipid (Seeds)	0.6517±0.0217%	
Ash (Seeds)	2.567±0.0246%	
Fiber (Seeds)	50.960±0.484%	
Protein (Seeds)	17.54±0.309%	
Carbohydrates (Seeds)	19.39±0.520%	
Calories (Seeds)	153.6 kcal/100 g	
Antinutritional Factors	Oxalate: 0.7934±0.132; Phytate: 0.3534±0.04163; Tannin: 1.956±0.030; Saponin: Present	Valvi and Rathod, 2011 [52]
Macroelements (mg)	Nitrogen: 0.64±0.025 mg; Phosphorus: 0.13±0.017 mg; Potassium: 1184.3±4.5mg; Calcium: 434.8±0.1mg; Magnesium: 130±1.3mg; Sodium: 146.3±1.5mg	
Microelements (mg)	Iron: 15.23±0.19mg; Zinc: 2.13±0.32mg; Copper: 7.6±0.06mg; Manganese: 10.37±0.49mg	
Crude Protein	17.33 mg/g	Misra and Misra, 2016 [29]
Total Sugar	226.83 mg/g	
Total Lipids.	0.075 mg/g	
	Seeds per fruit 9.0	Tripathi, Shetti, and Rupa, 2019 [53]
	Taste Sour	
	Total Soluble Solids (TSS) 15.0 o Brix	
	Moisture Content 89.0%	
	Dry Weight 11.0%	
	Ascorbic Acid 5.6 mg/100 g	
	Iron (Fe) 51 ppm	
	Manganese (Mn) 10.9 ppm	
	Zinc (Zn) 11.1 ppm	
	Copper (Cu) 8.2 ppm	
	Nitrogen (N) 0.81%	
	Phosphorus (P) 0.099%	
	Potassium (K) 0.9%	
	Calcium (Ca) 1.07%	
	Magnesium (Mg) 0.207%	
	Sulfur (S) 0.088%	
	Fruit Weight 2.84 g	
	Length 1.019 cm	
	Width 1.048 cm	
	Shape Round	
	Color Bright Red	
	Flesh Color Yellow	
Edible Portion	66.86% to 84.13%	Ara *et al.*, 2014 [5]
pH	3.64±0.01	
Moisture	66.86±1.81%	
TSS	6.52±0.17% - 3.24±0.17% to 4.16±0.28%	
Titratable Acidity	0.51±0.09%	
Total Carbohydrates	31.31±3.64 gm	
Minerals (mg)	Manganese: 2.85±0.26, Sodium: 139.32±9.53, Potassium: 56.19±7.42, Calcium: 79.41±4.96 mg, Magnesium: 28.62±5.46 mg, Copper (ND), Iron (ND)	

Phytochemical Composition

Phytochemical screening of *Flacourtia indica* fruits identified a variety of bioactive compounds, including flavonoids, phenolics, tannins, and saponins. These compounds are known for their health-promoting properties, particularly their antioxidant activities. The high levels of phenolic compounds suggest that *Flacourtia indica* has strong free radical scavenging capabilities, which can mitigate oxidative stress and reduce the risk of chronic diseases such as cardiovascular disorders and cancers. Flavonoids and tannins contribute to the anti-inflammatory and antimicrobial properties of the fruit, further enhancing its medicinal value.

Table 2: A review of studies carried out on Phytochemical Constituents of *Flacourtia indica*

Phytochemical Constituents	References
19 Phytoconstituents (Leaf Extract), 7 Phytoconstituents (Fruit Extract)	Tiwari, V.J., 2017 [54]
2-(2-benzoyl-b-D-glucopyranosyloxy)-7-(1a,2a,6a-trihydroxy-3-oxocyclohex-4-enoyl)-5-hydroxybenzyl alcohol, poliothrysoside, catechin-[5,6-e]-4b-(3,4-dihydroxyphenyl)dihydro-2(3H)-pyranone, 2-(6-benzoyl-b-D-glucopyranosyloxy)-7-(1a,2a,6a-trihydroxy-3-oxocyclohex-4-enoyl)-5-hydroxybenzyl alcohol, chrysoeriol-7-O-b-D-glucopyranoside, mururin A	Sashidhara *et al.*, 2013 [55]
B-sitosterol, Ramontoside, butyrolactone lignin disaccharide, scoparone, aesculetin	Satyanarayana *et al.*, 1991 [56]; Bhaumik *et al.*, 1987 [6]; Nazneen *et al.*, 2009 [31]
Coumarins and phenolic glycosides	Kaou *et al.*, 2010 [21]
Lignan glycosides, monoterpene glycoside	Chai *et al.*, 2009 [10]
Phenolic glucoside esters, Flacourtosides A-F	Bourjot *et al.*, 2012 [8]; Boeckler *et al.*, 2011 [57]
Phenolic Glycosides	Madan *et al.*, 2009 [27]
Poliothrysoside	Sashidhara *et al.*, 2013 [55]
Pyrocatechol, Homaloside D	Kaou *et al.*, 2010 [21]
Terpenoids, flavonoids	Pachute *et al.*, 2011 [33]
Various phytocompounds with non-mutagenic and non-carcinogenic properties	Hussain *et al.*, 2016 [16]
Phenolic composition, total phenolics, flavonoids, condensed tannins	Ndhlala *et al.*, 2007 [32]

Table 3: A review of studies carried out on Pharmacological Activity of *Flacourtia indica*

Pharmacological Activity	References
Activities Against Oxidative Stress and Cardiovascular Diseases	Akter, S., *et al.*, 2020[1]; Pachute, S. M., *et al.*, 2011 [33]; Sreejith, M., *et al.*, 2013 [58]; Kaou, C., *et al.*, 2010 [21]
Analgesic, Anti-inflammatory, Diuretic Activities	Juthika *et al.*, 2013 [20]
Anti-anemic, Hypoglycemic Abilities, Anti-diabetic Ability	Idoko *et al.*, 2019 [17], Singh *et al.*, 2011 [59]
Antiasthmatic activity	Tyagi *et al.*, 2011 [60]
Antibacterial activity and Anti-pathogenic Abilities	Eramma and Devaraja, 2013 [13]; Koperuncholan and Kulandaivel, 2022 [25]; Hajra *et al.*, 2011 [15]
Antibacterial, antimalarial, hepatoprotective, anti-inflammatory	Eramma and Devaraja, 2013 [13]; Kaou *et al.*, 2010 [21]; Nazneen *et al.*, 2009 [31]; Kundu *et al.*, 2013 [61], Clarkson *et al.*, 2004 [12]
Anticancer and Antioxidant Properties	KI-Woong, K., *et al.*, 2014 [24]; Singh *et al.*, 2016 [62]; Pachute, S. M., *et al.*, 2011 [33]
Anticancer effects, induction of apoptosis, ROS generation	Park *et al.*, 2014 [63]
Antidiabetic Ability	Singh *et al.*, 2011 [59]; Makuttan, N. S., *et al.*, 2022 [28]; Idoko *et al.*, 2019 [17],
Anti-inflammatory activity	Lalsarea *et al.*, 2011 [64]; Kundu *et al.*, 2013 [61]
Anti-Inflammatory and Antimicrobial Activity	Lalsarea, *et al.* 2011 [64]; Chingwaru, W., *et al.* (2020) [11]
Antioxidant Activities	Singh *et al.*, 2016 [62]; Akter *et al.*, 2020 [1], KI-Woong *et al.*, 2014 [24]; Amarasinghe *et al.*, 2011 [3]; Misra and Misra, 2016 [29]; Biswas and Battu, 2016 [7]
Antioxidant, anti-inflammatory, broad-spectrum antimicrobial	Lalsarea *et al.*, 2011 [64]
Antiplasmodial activity of β-hematin	Sashidhara *et al.*, 2013 [55]
Antiradical, cytotoxic, antibacterial, antifungal	Kekuda *et al.*, 2017 [22]
Antivenom Agent	Mosaddik, M. A., *et al.* (2004) [30]
Antivenom and Hypolipidemic Activities	Mosaddik, M. A., *et al.* (2004) [30]; Khan, M. T. H., *et al.* (2002) [23]; Cavalcante, G. S., *et al.* (2007) [9]; Chai *et al.*, 2006 [65]
Antiviral and Antitumor Agent	Mosaddik, M. A., *et al.* (2004) [30]; Khan, M. T. H., *et al.* (2002) [23]; Cavalcante, G. S., *et al.* (2007) [9]
Apoptosis of human colon cancer cells	Park *et al.*, 2014 [63]
Diuretic activity	Ancy *et al.*, 2013 [4]
Hepatoprotective activity	Tyagi *et al.*, 2010 [66]; Varkey *et al.*, 2011 [67]; Gnanaprakash *et al.*, 2010 [14]; Nazneen *et al.*, 2009 [31]
Hepatoprotective and Hypoglycemic Abilities, Gluco-stabilizing Abilities	Idoko, A. O., *et al.* (2019) [17]; Varkey, J., *et al.*, 2011[67]
Hepatoprotective properties	Nazneen *et al.*, 2009 [31]
Hepatoprotective, Antidyslipidemic, Anticancer, Anthelmintic, Antimalarial Activities	Granaprakash *et al.*, 2010 [68]; Singh *et al.*, 2016 [62]; Pachute *et al.*, 2011 [33]; KI-Woong *et al.*, 2014 [24]
Hepatoprotective, antioxidant activity	Tyagi *et al.*, 2010 [66]; Varkey *et al.*, 2011[67]
Hypolipidemic, hypoglycemic activities; antioxidant and enzyme inhibiting properties	Mosaddik *et al.*, 2004 [30]; Khan *et al.*, 2002 [23]; Cavalcante *et al.*, 2007 [9]; Chai *et al.*, 2006 [65]; Alakolanga *et al.*, 2015 [2]
Inhibitory effects on alpha-amylase and alpha-glucosidase	Makuttan *et al.*, 2022 [28]
Lipophilic activity	Singh *et al.*, 2016 [62]

Pharmacognostic Activities
The pharmacognostic evaluation of *Flacourtia indica* highlighted its traditional uses in treating ailments like diarrhea, fever, and respiratory infections. Laboratory studies confirmed that extracts from the fruit exhibit significant antimicrobial activity against common pathogens, supporting its use in traditional medicine. The anti-inflammatory and analgesic properties of *Flacourtia indica* extracts were also validated, suggesting potential therapeutic applications in managing pain and inflammation.

Discussion
The comprehensive analysis of *Flacourtia indica* underscores its importance as a wild edible fruit with substantial health benefits. The high nutritional value, combined with its rich phytochemical composition, positions *Flacourtia indica* as a potential functional food. Its traditional medicinal uses are supported by scientific evidence, *indica*ting that *Flacourtia indica* could be developed into natural therapeutic agents. The integration of *Flacourtia indica* into local diets can help improve nutritional status and health outcomes in central India. Moreover, its pharmacognostic properties suggest that it could serve as a sustainable source of bioactive compounds for pharmaceutical applications. Future research should focus on isolating specific bioactive compounds and elucidating their mechanisms of action to fully harness the therapeutic potential of *Flacourtia indica*. In conclusion, *Flacourtia indica* represents a nutritionally rich and pharmacologically valuable species. Its promotion as a functional food and medicinal resource could enhance health and well-being while supporting biodiversity and sustainable agricultural practices in central India.

Conclusion
Flacourtia indica (Burm.f.) Merr. emerges as a nutritionally rich and pharmacologically valuable wild edible fruit species with significant potential for health and therapeutic applications. The comprehensive analysis of its nutritional composition reveals a high content of essential vitamins, minerals, and dietary fiber, making it a valuable addition to local diets, particularly in addressing nutritional deficiencies in central India. The phytochemical profile of *Flacourtia indica*, rich in flavonoids, phenolics, tannins, and saponins, highlights its potent antioxidant, anti-inflammatory, and antimicrobial properties. These bioactive compounds contribute to the fruit's ability to combat oxidative stress and chronic diseases. Pharmacognostic studies support the traditional medicinal uses of *Flacourtia indica* for treating various ailments, confirming its significant antimicrobial, anti-inflammatory, and analgesic properties. This validation of traditional knowledge through modern scientific methods opens avenues for developing *Flacourtia indica* into natural therapeutic agents. Incorporating *Flacourtia indica* into local diets and exploring its pharmacognostic applications can improve health outcomes and support sustainable practices in central India. Further research is warranted to isolate specific bioactive compounds and elucidate their mechanisms of action, fully harnessing the therapeutic potential of *Flacourtia indica*. Promoting *Flacourtia indica* as a functional food and medicinal resource can enhance health and well-being while preserving biodiversity and supporting sustainable agriculture.

Conflict of Interest
The authors declare no conflicts of interest.

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