



Review Article

Multifunctional bioresources: The intersection of nutritional and pharmacological value in some tropical plants

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Abstract

An overview of the phytochemical and pharmacological characteristics of six different but valuable plant species is given here: drumstick (*Moringa oleifera*), ash gourd (*Benincasa hispida*), jamun (*Syzygium cumini*), kanuga (*Pongamia pinnata*), custard apple (*Annona squamosa*), and coco (*Theobroma cacao*). Their taxonomic diversity notwithstanding, they are all a collection of bioactive compounds with proven therapeutic and nutritional value. These plants include active ingredients including flavonoids, alkaloids, tannins, polyphenols, and vital vitamins and minerals, according to the study. Flavonoids and furanoflavones in *Pongamia pinnata* (Kanuga) seeds are most well-known for their antibacterial and anti-inflammatory properties. It is the unique acetogenin chemicals that give *Annona squamosa* its potent antioxidant and antidiabetic properties. *Syzygium cumini* (Jamun) is well known for its powerful antidiabetic and cardioprotective actions, majorly owing to anthocyanins, ellagic acid, and jamboline. *Benincasa hispida* (Ash Gourd) is prized for its cooling, diuretic, and nootropic action, being abundant in triterpenes and vitamins. *Moringa oleifera* (Drumstick) is touted as a nutritional powerhouse with leaves and pods holding high concentrations of vitamins, minerals, and antioxidants such as quercetin and chlorogenic acid. Last but not least, *Theobroma cacao* (Coco) seeds are a worldwide valued source of polyphenols, particularly flavanols, with cardiovascular and cognitive health-promoting effects. Together, this set of plants emphasizes the tremendous potential of natural products in functional food, nutraceuticals, and as leads towards new drugs, where additional investigation into how they work and how to use them sustainably is warranted.

Keywords: Phytochemicals, Bioactive compounds, Pharmacological activities, Antioxidant, Antidiabetic, Nutraceuticals, Medicinal plants, Functional food, Flavonoids, Polyphenols

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1. Introduction

1.1. *Theobroma cacao* L.: Food of the gods

These six species- namely, Cacao, Moringa, Kanuga, Custard Apple, Ash Gourd, and Jamun-have been the foundational pharmacy for humanity for millennia. Living repositories of chemical ingenuity, their traditional uses in medicine have now been rigorously validated by modern science.¹ Perfectly illustrating this journey from myth to molecule is the well-named "Food of the Gods," *Theobroma cacao* L. Ancient Mesoamerican civilizations recognized its therapeutic value and documented it in the 1590 Florentine Codex.² Modern research now confirms this wisdom by identifying a high density of polyphenols, including

epicatechin, along with a peculiar fatty acid profile responsible for its cardiovascular benefits and antioxidant properties.³ (Table 1, Table 2) Cacao, thus, has made a transition from being an ancient drug to a modern subject of clinical trials,⁴ reinforcing the continuing role of nature as a sophisticated chemist.(Figure 1)

1.2. *Moringa oleifera* Lam: The miracle tree

Moringa oleifera has been known as the "Miracle Tree" and is considered a holistic panacea in the traditional treatment of anemia, infection, and more. Its verified phytochemical profile includes phenolic acids and flavonoids responsible for potent anti-inflammatory and antioxidant properties that

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support its uses against chronic diseases and are a testament to traditional multi-system medicinal wisdom. (Figure 2)

1.3. *Pongamia pinnata*: The Multipurpose Legume

This discussion of non-edible oils brings into focus *Pongamia pinnata*, known as Kanuga, a tree firmly rooted in the Ayurvedic system with broad-spectrum applications related to skin diseases, parasites, and injuries.⁵ Modern science confirms its bioactive strength by demonstrating its cytotoxic, anthelmintic, anti-inflammatory, and antimicrobial properties.⁶ Today, *Pongamia's* traditional value finds convergence in modern applications with organic agriculture and as a source of biofuel and biopesticides.^{8,12} (Figure 3)

1.4. *Annona squamosa* L. and *Benincasa hispida*: Food as Medicine

Similarly, the Custard Apple (*Annona squamosa*) and examples of the transformation of food plants into medicine. While its fruit is nutritious, the leaves, bark, and seeds of Custard Apple contain powerful therapeutic chemicals.^{9,10} Its seeds were used as insecticides, while its leaf extracts were used to treat boils, and current research has isolated a number of alkaloids and flavonoids, which

are under studies for hepatoprotective, antiviral, and anticancer activities.¹¹ (Figure 4)

1.5. Ash Guard, or Winter Melon

Ash Gourd, a widely consumed vegetable, was concurrently recommended for diabetes, heart, and urinary disorders.¹³ Its systemic effect is now attributed to flavonoids, glycosides, and β -sitosterin, with established diuretic, nephroprotective, and anti-diabetic action, and thus fully embodies the concept of "food as medicine".¹⁴ (Figure 5)

1.6. *Syzygium cumini*

The Jamun tree, *Syzygium cumini*, serves as a model of traditional efficacy. For the treatment of diabetes, or Madhumeha in Ayurveda, this plant was used long before modern science provided evidence.¹⁵ Early studies confirmed that the seeds lowered blood glucose levels, which is now known to be from the action of its glycoside jamboline and ellagitannins on insulin and against oxidative stress.¹⁶ Validated antioxidant, antimicrobial, and gastroprotective properties of Jamun further confirm the comprehensive wisdom of its traditional applications.¹⁷ (Figure 6)



Figure 1: *Theobroma cacao* A) Fruit, B) Seed, C) Powder



Figure 2: *Moringa oleifera* A) Fruit, B) Seed, C) Powder



Figure 3: *Pongamia pinnata* A)Fruit, B)Seed, C) Powder



Figure 4: *Annona squamosa* : A) Fruit, B) Seed, C)Powder



Figure 5: *Benincasa hispida* : A) Fruit, B) Seed ,C) Powder



Figure 6: *Syzygium cumini*: A) Fruit, B) Seed, C) Powder

Table 1: Taxonomical classification

Common Name	Clade	Order	Family	Genus	Species	Botanical Name
Kanuga	<i>Eudicots</i> (Rosids)	<i>Fabales</i>	<i>Fabaceae</i>	<i>Millettia</i>	<i>Pinnata</i>	<i>Millettia pinnata</i> ¹⁸
Custard Apple	<i>Eudicots</i> (Magnoliids)	<i>Magnoliales</i>	<i>Annonaceae</i>	<i>Annona</i>	<i>Squamosa</i>	<i>Annona squamosa</i> ²⁰
Jamun	<i>Eudicots</i> (Rosids)	<i>Myrtales</i>	<i>Myrtaceae</i>	<i>Syzygium</i>	<i>Cumini</i>	<i>Syzygium cumini</i> ¹⁹
Moringa	<i>Eudicots</i> (Rosids)	<i>Brassicales</i>	<i>Moringaceae</i>	<i>Moringa</i>	<i>Oleifera</i>	<i>Moringa oleifera</i>
Ash gourd	<i>Eudicots</i> (Rosids)	<i>Cucurbitales</i>	<i>Cucurbitaceae</i>	<i>Benincasa</i>	<i>Hispida</i>	<i>Benincasa hispida</i>
Coco	<i>Monocots</i>	<i>Arecales</i>	<i>Arecaceae</i>	<i>Cocos</i>	<i>Nucifera</i>	<i>Cocos nucifera</i>

Table 2: Morphological classification

Common name	Habit	Leaf	Flower	Fruit	Seed
Kanuga (Indian Beech)	Medium-sized evergreen tree	Imparipinnate compound; 5-7 glossy, ovate leaflets	Raceme; Pea-like flowers, pinkish-white to purple, fragrant	Pod (legume); Flat, elliptical, indehiscent, single seeded	Seed is flat, brown, and bean-like within the pod
Custard apple	Small, semi-deciduous tree	Simple, alternate, lanceolate to oblong leaves	Solitary or in clusters; Greenish-yellow, bisexual flowers	Aggregate fruit from fused carpels; Tuberculate surface	Seeds numerous, hard, black, shiny, embedded in pulp
Jamun	Large, evergreen tree	Simple, opposite, elliptic-oblong, glossy leaves	Corymbose cyme; Flowers small, white, fragrant	Oblong berry; Purple-black when ripe, juicy	Seed is large, hard, oblong, usually single
Moringa	Fast-growing tree or shrub	Tri-pinnate compound leaves; Small, oval leaflets	Large, fragrant, white flowers in drooping panicles	Long, hanging, 3-sided capsule (drumstick)	Seeds are round with three papery wings
Ash gourd	Annual, trailing vine	Large, simple, cordate (heart-shaped), hairy leaves	Monoecious; Solitary, yellow, unisexual flowers	Very large, pepo; Oblong to round, waxy coating	Numerous, flat, white, embedded in pulp
Coco	Tall, single-stemmed tree	Large, pinnately compound, feather-like (4-6 m long)	Monoecious; Branched spadix; Flowers small, yellowish	Large, fibrous drupe; Single seed (the coconut)	Large, with solid endosperm (the "meat") and liquid endosperm (water)

Table 3: Phytochemical constituents of seeds

Botanical Name (Common Name)	Major Bioactive Compounds	Reported Pharmacological Activities	References
<i>Pongamia pinnata</i> : <i>Getonia floribunda</i> or <i>Ganuga</i> common names can be ambiguous)	If <i>Pongamia</i> (Karanja): Flavonoids (Karanjin, Pongapin) Furanoflavonoids Triterpenoids If <i>Getonia floribunda</i> : Triterpenes, Tannins, Flavonoids	For <i>Pongamia pinnata</i> : Antimicrobial, Anti-inflammatory, Antidiarrheal, Anticancer, Insecticidal For <i>Getonia floribunda</i> :	[21,22]

		Anti-inflammatory, Antiarthritic, Antioxidant	
<i>Annona squamosa</i> (Custard Apple, Sugar Apple)	Acetogenins (<i>Annonacin</i> , <i>Squamocin</i>) Alkaloids (Anonaine, Reticuline) Flavonoids (Quercetin, Catechin) Cyclic peptides	Anticancer, Antiparasitic, Antimicrobial, Antioxidant, Anti-inflammatory, Antidiabetic	[23,24]
<i>Syzygium cumini</i> (Jamun, Java Plum)	Anthocyanins (Cyanidin, Delphinidin glucosides) Ellagic acid & Ellagitannins (Jamboline) Flavonoids (Myricetin, Quercetin) Alkaloids (Jambosine)	Antidiabetic (Hypoglycemic), Antioxidant, Anti-inflammatory, Gastroprotective, Cardioprotective	[25,26,28]
<i>Moringa oleifera</i> (Moringa Drumstick Tree)	Glucosinolates & Isothiocyanates Flavonoids (Quercetin, Kaempferol) Phenolic acids (Chlorogenic acid) Alkaloids (Moringinine) Vitamins & Minerals (A, C, Calcium)	Antioxidant, Anti-inflammatory, Antihyperglycemic, Antihypertensive, Neuroprotective, Antimicrobial	[27,29]
<i>Benincasa hispida</i> (Ash Gourd, Winter Melon)	Flavonoids & Triterpenes (Ursolic acid) Sterols (β -Sitosterol) Glycosides Volatile oils & Carotenoids	Antioxidant, Antiulcer, Antidiabetic, Nootropic (cognitive enhancer), Diuretic, Immunomodulatory	[30,31,32]
<i>Theobroma cacao</i> (Cocoa)	Flavan-3-ols (Epicatechin, Catechin) Proanthocyanidins (Polymers of flavan-3-ols) Methylxanthines (Theobromine, Caffeine)	Cardioprotective, Antioxidant, Anti-inflammatory, Antidepressant, Neuroprotective, Improves endothelial function	[33]

2. Origin and Geographical and Distribution

The various native and invasive geographical ranges of these six plants underpin the levels of historical and current global importance. Kanuga is native to the Indian subcontinent and Southeast Asia, but its utility in biofuel and bioremediation has led to its recent introduction around the world. In contrast, the Custard Apple, *Annona squamosa*, is native to the tropical Americas, and Spanish and Portuguese explorers dispersed the fruits throughout the tropics, establishing it as one of the most common tropical orchard trees.^{34,35} The Jamun tree, *Syzygium cumini*, a native of both the Indian subcontinent and Southeast Asia, was widely disseminated by traders to supply fruit and timber; it often proves to be invasive in areas like Florida.^{36,37}

Moringa oleifera, native to the sub-Himalayan tracts of India, was introduced to Africa and beyond centuries ago and is now cultivated all over the world for its nutritional value.³⁹ The Ash Gourd, *Benincasa hispida*, which first appeared in

Southeast Asia, has also domesticated early through ancient trade routes, entrenching this plant in Asian cuisines and medicines.³⁸ And lastly, the Coconut Palm, *Cocos nucifera*, has a disputed origin in the Indo-Malaya region, whose ability to float allowed for natural pan tropical dispersal, which was later followed by active participation of ancient mariners, which has turned it into a coastal icon in more than 90 countries today.⁴¹ Taken all together, their journeys underpin a long story of natural adaptation and human cultivation.

3. Chemical Compounds and Active Compounds

This comprehensive phytochemical profile details the unique bioactive constituents of six valuable plant species. (**Table 3**) *Pongamia pinnata* (Kanuga) is an affluent repository of flavonoids like karanjin and pongapin, with seed oil rich in oleic acid, underpinning its antimicrobial and anti-inflammatory activities.⁵⁸ *Annona squamosa* (Custard Apple) is renowned for its potent acetogenins like

squamocin, which show cytotoxicity, supplemented by alkaloids and flavonoids providing antioxidant and anti-inflammatory potential.⁵⁹ *Syzygium cumini* (Jamun) contains a wide array of compounds like betulinic acid, myricetin, and essential oils like α -pinene that underpin its well-documented anti-diabetic and antioxidant effects. *Moringa oleifera* is a nutritional power-packed plant rich in vitamins, minerals, and unique bioactive compounds, including the glucosinolate-derived moringin, flavonoid quercetin, and full complement of amino acids, which provide mechanisms supporting its wide range of pharmacological actions.^{39,40} Ash Gourd, *Benincasa hispida*, is rich in triterpenes of value, including ursolic acid; immunomodulatory polysaccharides; and high water and mineral contents, accounting for its well-recognized diuretic, nootropic, and cooling action.⁴² Lastly, *Theobroma cacao*, or Coco, is best known for its high concentration of flavanols—particularly epicatechin—and methylxanthines, especially theobromine, responsible for its cardiovascular, cognition-enhancing, and mood-altering properties. Collectively, the chemical genius of these plants validates their traditional uses and underlines great potential as functional foods, nutraceutical sources, and novel lead drugs.

4. Traditionall and Medicinal Uses for Seeds

The plants profiled form an important part in traditional medicine worldwide, each providing a wide range of therapeutic uses: *Pongamia pinnata* (Kanuga) is used in traditional medicine; its seed oil is used for the treatment of skin diseases such as scabies, and ground seeds are used against bronchitis and rheumatic joints.^{43,60} Its extracts exert hypotensive and uterine-contracting effects. Similarly, different parts of Custard Apple have been used: leaf extracts for analgesic properties, roots as anticonvulsants, and seeds for their insecticidal and anticancer activities. Jamun is one of the mainstays of Ayurveda in managing diabetes; seeds, which contain jamboline, help in controlling blood sugar. The bark and fruits are utilized in the treatment of dysentery, digestive disorders, and as a blood cleanser.^{44,61}

Moringa oleifera (Drumstick) plays a nutritional and medicinal role. The leaves are used for skin ailments and as an antioxidant, bark juice is used to control fever, while its seeds help control diabetes and hyperlipidemia.⁴⁵ Ash Gourd is useful in Ayurveda and TCM because of its cooling action; the juice is used for peptic ulcers and acts as a diuretic, while the pulp is applied topically to boils and burns.⁴⁶ Finally, *Theobroma cacao* had great significance among indigenous Americans for its role as a stimulant against fatigue, helping in digestion, and maintaining healthy cardio-vascular health. Its butter was used topically for skin irritations and wounds. These plants in summary epitomize the immense and enduring impact that botanical resources have had on global healthcare traditions.^{47,48}

5. Pharmacological Activities

The pharmacological profiles of these six plants demonstrate a remarkable breadth of therapeutic activities, validated by modern scientific research. *Pongamia pinnata* has manifested a wide spectrum of actions: anti-ulcer through mucosal protection, anti-diarrheal activity by inhibition of bacterial invasion and toxin production, and significant anti-hyperglycemic and anti-lipid peroxidative effects in diabetes management.⁵⁵ Its potency extends to anti-inflammatory, antipyretic, antiviral (against HSV-1 and HSV-2), antibacterial, anti-plasmodial, and antioxidant/anti-hyperammonemic activities, showcasing its multifaceted nature.^{49,50,62} Similarly, *Annona squamosa*, or Custard Apple, is also reported as a source of potent bioactive compounds due to its acetogenins, which are widely recognized for their anticancer activities through disruption of mitochondrial ATP production in cancer cells.^{63,64} The plant also demonstrates strong antidiabetic, antioxidant, anti-inflammatory, analgesic, and antimicrobial properties, making it a highly valued resource in treating both chronic and infectious diseases.^{51,52}

Amongst others, *Syzygium cumini* (Jamun) is best known for its significant antidiabetic properties, mainly because of an alkaloid known as jamboline, which regulates insulin secretion and sensitivity.⁷⁰ Additional benefits are ensured through powerful antioxidant activity mediated by anthocyanins, along with gastroprotective, anti-inflammatory, antipyretic, and hepatoprotective activities against various disorders, from ulcers to liver damage.^{53,54,71} *Moringa oleifera*, the "Miracle Tree," lives up to its name with robust anti-inflammatory and antioxidant capacities, fighting chronic oxidative stress.^{65,66} It also shows significant antidiabetic and lipid-lowering potential, along with hepatoprotective, nephroprotective, and antimicrobial activities, underpinning its use in malnutrition and infection.^{56,57,73,74}

Benincasa hispida (Ash Gourd) is valued in Ayurveda as a "Medhya Rasayana" for its nootropic activity, which improves memory and learning.^{67,68} Its profile is complemented by adaptogenic, anxiolytic, diuretic, and nephroprotective effects, apart from the established antioxidant, anti-inflammatory, and antidiabetic activities, offering a holistic approach to cognitive, metabolic, and renal health.⁶⁹ Finally, *Theobroma cacao* (Cocoa) is a powerhouse for cardiovascular and cognitive health.^{72,75} Its high flavanol content is cardioprotective; it improves endothelial function and reduces blood pressure, while exerting neuroprotective and cognition-enhancing effects through improved cerebral blood flow.⁷⁶ Cocoa also possesses considerable antioxidant, anti-inflammatory, and insulin-sensitizing activities, making it a unique functional food.⁷⁷ Collectively, the broad-based and evidence-based pharmacological actions of these plants firmly establish their validity and point out immense potential as sources for novel

therapeutic agents, functional foods, and nutraceuticals against a wide array of modern health challenges.⁷⁸

6. Conclusion

In summation, the exploration of Kanuga (*Pongamia pinnata*), Custard Apple (*Annona squamosa*), Jamun (*Syzygium cumini*), Ash Gourd (*Benincasa hispida*), Drumstick (*Moringa oleifera*), and Coco (*Theobroma cacao*) demonstrates a striking intersection of nutritional strength and medicinal possibility in the realm of plants. Beyond their unique botanical classification and morphological features, these plants are bound together by their status as priceless assets of sustainable health and wellness. Every plant has a signature portfolio of value: from Kanuga's pesticidal and industrial use to Custard Apple's highly bioactive antitumor compounds; from Jamun's unmatched metabolic syndrome management efficacy to Ash Gourd's healing and cooling effects; from Drumstick's remarkable capacity to fight malnutrition to Coco's widely acclaimed cardiovascular and neurological effects. The variety is proof of the enormous, but as yet untapped, pharmacopeia of nature.

Finally, these crops are much more than simple agricultural products. They are the key link between ethnobotanical information and rigorous scientific affirmation. Their broad phytochemical profiles yield strong candidates for the design of new nutraceuticals, functional foods, and therapeutics from plants. Sustainable cultivation, standardized extraction protocols, and rigorous clinical trials are called for in the future to unlock their full promise. Embracing these natural assets is a key move toward a healthier, more sustainable future, showing that answers to some of our biggest health and nutrition dilemmas might already be within reach, growing in our fields and backyards.

7. Conflict of Interest

None.

8. Source of Funding

None.

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