



Pharmacology and Phytochemistry of Artocarpus Family: A Review

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ABSTRACT: The genus *Artocarpus*, belongs to family Moraceae and consists of more than 50 species. The species are either evergreen or deciduous trees are found in India, Southern China, Malaysia and the Solomon Islands. Fruits of *Artocarpus* species are edible and used as traditional medicines. All the parts of the tree such as leaves, fruits, seeds, roots and barks are of great Ayurvedic and Unani medicinal importance. The extracts have been used traditionally in the treatment of diabetes, diarrhea, dermatitis, malarial fever, asthma, tapeworm infection, anaemia, wound healing, anti - syphilitic, vermifuge activity, to induce lactation in women and domesticated animals and aphrodisiac properties. Latex obtained from the family promotes healing of abscesses, snakebite and glandular swellings. Our study aims at comprising the available information on the phytochemicals and pharmacological studies with reference to *Artocarpus*. The species of *Artocarpus* are highly rich in secondary metabolites like flavanoids, stilbenoids, arylbenzofurans and a lectin (Jacalin) which makes them a promising source of phytomedicine. This review focuses on therapeutic substances from the *Artocarpus* species, their extraction, characterization, nano-synthesis, assessment of their roles in traditional and modern medicine. © 2020 iGlobal Research and Publishing Foundation. All rights reserved.

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INTRODUCTION

Moraceae is a widespread family often called the mulberry or fig family comprised in the Angiosperms or flowering plants. Moraceae members are monoecious or dioecious with 37 to 43 genera and 1100 to 1400 species including important group such as *Artocarpus*, *Morus*, *Ficus* which are widespread in tropical and subtropical areas. Moraceae constitutes trees, shrubs, vines, or rarely herbs, with milky or watery latex and spiny fruit cover. Stipules are present and are caducous. The leaves appear alternate and possess well-defined petioles. The leaf blades are simple with cystoliths, with entire or palmately lobed margins, venation is pinnate and palmate. Axillary inflorescences are observed while the flowers are unisexual and small. Calyx lobes may vary 1 or 2 - 4 or 8, are free or connate, imbricate or valvate. Corolla is absent. The male flowers except in *Artocarpus*, are straight or inflexed in bud with 1-or 2-loculed, crescent-shaped to top-shaped anthers and rudimentary sterile pistil. Female flowers possess four calyx lobes with superior, semi-inferior, or inferior, 1(or 2)-loculed

ovary, anatropous or campylotropous ovules and stigmas are usually filiform. Fruits are drupe enveloped by an enlarged calyx and/or immersed in a fleshy receptacle, often joined into a syncarp. Seeds are solitary with or without endosperm [1]. The flowers are unisexual and minute, and are densely aggregated [2]. Economically, the most important species of *Morus* and *Maclura* are associated with the production of silk. Some species among *Broussonetia*, *Maclura* and *Morus* are important for paper making, some species of *Artocarpus*, *Ficus*, and *Morus* have edible fruit and some species of *Artocarpus* and *Broussonetia* are used for furniture or timber. This review is an effort to compile all major information on the commonly available *Artocarpus* species, its phytochemical as well as pharmacological profile.

Artocarpus is one of the genera belonging to the family Moraceae. It consists of more than 50 species distributed in the tropical and subtropical regions of Asia. It is native to Western Ghats of India, Malaysia and also found in Central and Eastern Africa, South-Eastern Asia. They are monoecious, evergreen or deciduous trees with edible fruits and white latex.

Leaves of this genus are spirally arranged or distichous and are simple, pinnatifid or pinnate, coriaceous, glabrous to pubescent, leathery and margin entire. Inflorescences are seen on the main branches which are unisexual, capitates and many flowered. Male flowers are surrounded by peltate to calvate interfloral bracts with globose to oblong biloculed anthers. Female flowers are with tubular perianth, basally thin walled enclosing ovary which is unilocular and apically thick walled and the perianths are partially or completely fixed one to another to form syncarp. Flowers and bracts fuse at the tip to form syncarp which gives an aggregate fruit which is fleshy throughout. Seeds are with fleshy cotyledons. It grows in a soil which is well drained but moist, with a pH of 4.3 to 8.0 and with medium soil fertility. The optimum temperature is 19°C to 29°C, altitude at approximately 1600 meters above sea level and the annual rain fall between 1000 and 2400 mm [3]. Some of the important species belonging to this genus are *A. communis*, *A. altilis*, *A. heterophyllus*, *A. hirsutus* and *A. lakoocha*.



Figure 1. Fruit of *A. heterophyllus*
(<https://www.newssoftown.com/>)

Indices	Values
Water Absorption Capacity (%)	25.00±1.67
Fat Absorption Capacity (%)	17.00±1.37
Bulk density (%)	0.80±0.02
Foaming Capacity (%)	25.34±0.02
Foam stability (%)	33.00±0.01
Swelling Power (g/g)	4.77±0.01

Table 1. Physio chemical properties of *A. heterophyllus* seed [Ocloo *et.al.*, 2010].

The total fruit weight comprises of seeds (8- 15 %) which are the storage source of polysaccharides like guar galactomannans, glucomannans, xyloglucans and galactomannans, phenols, proteins, carbohydrates. The oil content of this plant is 11.39% [7]. The brown spermoderm around the endosperm is a rich source of starch and proteins [8, 9]. The qualitative analysis of phytochemicals in the seeds of *A. heterophyllus* showed the presence of phenolics. Quantitative analysis of total phenols and total flavonoids of *A. heterophyllus* seed extracts was conducted using Gallic Acid Equivalents (GAE) and Quercetin Equivalents (QE). *A. heterophyllus* seeds and the seed oils are good antibacterial agents towards *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*. The parts of jackfruit have shown the antioxidant activity and phenolic content. The seed extract showed higher antioxidant (DPPH scavenging) activity with an IC₅₀ of 410 µg/ml. Scavenging of H₂O₂ and its percentage inhibition by methanolic extracts of seeds of *A. heterophyllus* were studied. The extracts exhibited an IC₅₀ value of 32.51 µg/ml [10]. The seed oils of jackfruit show remarkable antioxidant activity. Such properties can be explored for the economic, nutritional and health applications. Gas chromatographic analysis of the seed oils revealed high amount of unsaturated fatty acids like methyl dodecanoate, methyl decanoate and tetradecane. Green synthesis of nanoparticles from aqueous solution of silver nitrate using *A. heterophyllus* seed powder as a reducing agent explored good antimicrobial activity against Gram positive and Gram negative bacteria. Jacalin present in the seeds of jackfruit is of potential use in nano-medicine. Jackfruit seeds are a very good source of lectins called Jacalin [11]. Jacalin is a tetrameric two chain lectin with a molecular mass of 65kD comprising a heavy α-chain of 133 amino acid residues and a light β-chain

PHYTOCHEMISTRY AND PHARMACOLOGICAL PROPERTIES

Artocarpus heterophyllus Lam

Artocarpus heterophyllus Lam, also called as Jackfruit or Ceylon Jack tree is an integral part of Indian diet. It is very popular in Bangladesh and considered as their national fruit. The term jackfruit is derived from the Portuguese term Jaca and Malayalam an Indian regional language chakka [4]. This fruit is considered as “poor man’s food” as it is inexpensive and easily available in large quantity during summer when food is scarce. The presence of flavonoids, alkaloids, saponins, tannins, terpenoids, glycosides, xanthoproteins and phenols contribute to its medicinal properties. They possess antibacterial, antioxidant, anti-diabetic, anti-inflammatory, anti-diuretic, immunomodulatory properties useful in the treatment of fever, skin diseases, convulsions, constipation, ophthalmic disorders, and snake bite. The leaves and stem barks are used to treat anemia, asthma, dermatitis, diarrhea, and cough. Leaves are used to increase lactation in women and animals. Many value added products like; instant soups, bakery products, baby foods, candy and ice cream are manufactured using wheat flour added with jackfruit seed powder [5]. Fruit contains sugars like glucose, fructose, sucrose contributing for total carbohydrate of 18.9g protein (1.9g), fat (0.1g), moisture (77%) and fiber (1.1g), minerals of (0.8g), where calcium (20mg), phosphorous (30 mg), iron (500mg), vitamin A (540IU), thiamin (30mg) and calorific value of 84 are available [6].

of 20-21 amino acid residues. Jacalin contributes to more than 50% of the total protein present in the seed.

Phytoconstituents	Plant part
Carbohydrates- starch, sugar, dietary fiber	Fruit, Seed
Minerals- Calcium, Magnesium, Phosphorous, Sodium, Iron	Fruit, Seed
Fatty Acids- Capric, Myristic, Lauric, Palmitic, Oleic, Stearic	Fruit
Organic acids- Malic acid, citric acid	Fruit
Carotenoids- 2- carotene, 1- carotene, 1- zeaxanthin, 2- zeaxanthin, dihydroxy carotenoids	Fruit, Seed
Flavonoids- Artocarpin, Artocarpetin, Artocarpin A, Morin, Dihydroartocarpin, Artocarpone, Artocarpesin	Fruit
Lectin- Jacalin	Seed
Volatiles- Isopentylisovalerate, Butyl isovalerate, Butyl acetate	Seed, Fruit
Tannins	Stem, Leaf
Vitamins- Vitamin A, Thiamine, Riboflavin, Vitamin E	Fruit

Table 2. Phytoconstituents of *A. heterophyllum* [Tejpal et.al., 2016]

The anti-inflammatory activity stabilizes lysosomal membrane and inhibits the inflammatory process by restricting the release of lysosomal enzymes preventing the damage to surrounding tissues. The red cell membrane stabilizing activity on seeds and the highest inhibition of heat induced hemolysis in the methanolic extracts were studied.

Pharmacological activities	Plant Parts	Extracts	Phytoconstituent
Anti-infective			
Anti-fungal	Leaf, Seed	Alcoholic extract	Chalcone
Anti-viral	Seed	Alcoholic extract	Oxyresveratrol
Anti-fungal	Bark of stem and root, leaves and fruit	Alcoholic extract	Isoprenyl flavones
Anti-cancer	Wood	Alcoholic extract	Isoprenoid flavonoids
Anti-inflammatory diseases			
Anti-inflammatory	Fruit	Ethyl acetate extract	Flavonoids
Wound healing	Leaf	Alcoholic extract	Lectin
Anti-diabetic	Leaf	Aqueous extract	Prenyl Flavonoids

Miscellaneous			
Antioxidant	Fruit and seed	Alcoholic extract and aqueous	Prenyl Flavonoids
Anti-malarial	Bark if root and stem	Aerial part extract	Prenylated Flavones
Anti-diarrhoeal	Bark if root and stem	<i>A. integrifolia</i> extract	Prenylated Flavones
Anti-carcinogenic	Leaf	Alcoholic extract	Flavonoids
Anti-platelets	Root, Seed	Alcoholic extract	Flavonoids
Anti-tubercular	Root, Stem	Dichloromethane extract	Prenylated Flavones
Anti-atherosclerosis	Fruit, root	Ethyl acetate extract	Flavonoids
Anti-arthritis	Leaf, fruit	Ethyl acetate extract	Flavonoids

Table 3. Pharmacological activities of *A. heterophyllum* [Tejpal et.al., 2016]

The jackfruit seed flour starch is high in amylose, and hence can be used as thickening and binding agent in food industry. Galactomannan is one of the important polysaccharide found in seeds is extracted with greater efficiency using 50% ethanol [12]. The seeds are known to function as good diuretics and extensively used in the ayurvedic medicine. They help in controlling hypertension by increasing the excretion of sodium along with water and decreasing the reabsorption of anions usually chloride. The seed extract shows remarkable anti-inflammatory activity against carageenan induced inflammation.

A. heterophyllum latex has high content of phenols and tannins in methanolic, ethanolic and chloroform extract [11]. Latex finds application in clotting, wound healing and possess antimicrobial activity [13]. Latex is a good source of glycosides, tannins and proteins [14]. The leaf ethanolic extract is a good source of antimicrobial agents [15].

Artocarpus hirsutus

Artocarpus hirsutus commonly known as Wild jack. It is a folk medicinal plant used for treating ulcers, wounds, joint pains, etc. It is a large evergreen tree, growing up to 70m height, grey coloured bark, branches are strigose with tawny hairs, leaves are upto 25x14cm broadly ovate, obovate or

elliptic. *A. hirsutus* fruits are used in traditional medicine for curing skin diseases like abscesses, hydrocele, pimples, heal sores and skin cracks [16]. The decoction of *A. hirsutus* bark and roots is known to cure diarrhea and powdered bark heals sores. Leaves are used in treating buboes and hydrocele [17].



Figure 2. Fruit of *A. hirsutus* (commons wikimedia.org)

The seed kernel of *A. hirsutus* appears as dark brown to sandy color in seed powder and the seed oil is dark yellow with characteristic sweet in odor while seed kernel and powder is bitter in taste. *A. hirsutus* seed oil contains a specific activity of 0.9471, an acid value of 1.09, saponification value 171.1 iodine value 103.26, peroxide value of 6.76 and an unsaponifiable matter of 5.83%.

The oil extracted from wild jack seeds heals wound in humans and animals. The seeds are roasted and consumed as snacks by tribal people. Diverse endophytes were isolated from the barks releasing bioactive molecules which are potent antioxidant, anticancer, antimicrobial agents [18]. The silver nano-particles synthesized with leaf extract of wild jack showed good anti-microbial activity [19]. The protein content in the different *Artocarpus sp* was studied. A higher level of protein was noted in *A. hirsutus*, followed by *A. heterophyllus*, *A. integer* and *A. incisus* [20]. The protein profiling by SDS-PAGE revealed 12 similar protein bands in seeds of these species with a molecular weight ranging from 61kD to 11kD. These proteins were attributed with functions in storage, structure, cell recognition, enzyme inhibition and biological activity [21]. The roots of *A. hirsutus* contains secondary metabolites like stigmaterol, lupeol, cyclomorulin, cycloartomunin and betulinic acid [22]. The root extract showed potent anti-bacterial and anti-fungal activity [23]. Unripe fruit acts as astringent and ripe fruit functions as appetizer, coolant, aphrodisiac, and in ayurvedic treatment.

Artocarpus lakoocha

Artocarpus lakoocha is commonly called as Monkey jackfruit in some of the Asian countries such as Bangladesh, Bhutan, Nepal, Myanmar, Malaysia and Singapore [24]. They are rich sources of strong antioxidants like phenolics and flavonoids. The leaves of the plant constitute 16% of crude protein, used

as food and timber [25]. Leaves are used as neonatal animal feed. The Monkey jackfruit is known to function as a liver refresher and possess various pharmacological activities like anti-inflammatory, anti-viral, anti-cancer and anti-HIV properties. The bark is used in wound healing and to cure abscess. Different metabolites from fruit such as cycloartenone, cycloartenol α -amyrin and lupeol acetate were isolated [26]. Agglutinin lectin has been isolated from the seeds of lakoocha and function as a purgative and hemagglutinating agent. The heartwood contains phytochemical constituents such as cartocarpin, norartocarpin, norcycloartocarpin, cycloartocarpin, resorcinol, oxyresveratrol and β -sitosterol [27]. Oxyresveratrol is a neuroprotective compound found in the plant also has antioxidant and anti-inflammatory, anti-helminthic, anti-herpetic properties anti-HIV and HSV and anti-glycation activity [28]. The preliminary phytochemical analysis of methanol extract of *A. lakoocha* fruit pericarp revealed the presence of tannins [29, 30] and alkaloids responsible for the anti-helminthic effect. Tannins are found to be useful in treating skin lesions. Tannins bind to free proteins in the gastrointestinal tract of host animal or glycoprotein on the cuticle of the parasite and may cause death thus showing anti-helminthic activity [31]. Monkey jackfruit extracts are used in cosmetics for skin whitening [32]. In addition to oxyresveratrol, resveratrol and traces of some flavonoids were reported in the heartwood of this plant [33]. *A. lakoocha* fresh young leaf and fruit pulp extract is used to synthesize gold nanoparticles [34].



Figure 3. Fruit of *A. lakoocha* (projectnoah.com)

Artocarpus camansi

Artocarpus camansi is commonly known as breadnut and is considered to be a form of seeded breadfruit that is *A. altilis* (bread fruit). *A. camansi* is found in Indonesia, New Guinea and Philippines. The mature trees yield 600 to 800 fruits. The seeds are high in protein with low fat content. The seeds are good source of vitamins, minerals, unsaturated fatty acids like oleic acid, linoleic acid and arachidonic acid. Some of the minerals found in the seeds are sodium, potassium, calcium, magnesium, manganese and copper. They are also rich in amino acids leucine and phenylalanine [35, 36]. *A. camansi* seeds contain fatty acid composition of oleic acid 12.4%, stearic acid 2%, lauric acid 1.7%, palmitic acid 21.4%,

linolenic acid 14.8% and 1.9 % arachidonic acid [36]. Organic acid such as butyric acid (0.012±0.12), citric acid (0.185±0.32), acetic acid (0.050±0.48), malic acid (0.012±0.17), lactic acid (0.317±0.51) (in mg/kg) are found in the seeds [36].



Figure 4. *A. camansi* (topropicals.com)

Amino acid composition (mg/g N)	Breadnut seeds
Arginine	293
Histidine	167
Isoleucine	245
Leucine	392
Lysine	275
Phenylalanine	312
Tyrosine	185
Cystine	112
Tryptophan	24
Methionine	95

Table 4. Amino acid composition of *A. camansi* seeds [Adeleke et. al., 2010]

Artocarpus altilis

Artocarpus altilis also known as *A. communis*, *A. incis*es and commonly called as bread fruit. It is native to Indonesia, Guinea and Philippines. The fruit is a rich source of carbohydrate with low fat and it is considered as starch rich crop. Fruits can be with seeds and without seeds. Leaves are found to be a rich source of steroids, phytosterols, gums and resins. Secondary metabolites such as arylbenzofurans, flavonoids and stilbenoids do occur. Fruits are a good source of many chemical constituents such as morin, moracin, dihydromorin, cynomacurin, oxydihydroartocarpesin, artocarpetin, norartocarpetin, cycloartinone, cyclogeracommunin, cyclocommunol, cycloartenyl acetate, β sitosterol, ursolic acid, betullic acid acetate, artoflavon, cudraflavone, artocarpanone, oxyresveratrol and orartocarpanone [37].

The plant has many pharmacological uses, such as anti-inflammatory, anti-fungal, anti-diabetic, anti-bacterial, anti-cholinergic and antioxidant activity. The leaf extracts show toxicity towards cancer cells, and anti-helminthic activity. The extracts also act as cosmetic whitening agents. Root extract

possess anti-coagulant activity. The latex of the plant is used in treating diarrhea [38], dysentery, indigestions [39] and menorrhagia [40]. The leaves are crushed and used for treating skin ailments, ear infections[39], to treat fever, hypertension [41], liver disease [39], oral inflammation and pain [42], fresh leaf buds [40] and leaf buds along with coconut oil are used in ciguatera poisoning [43].The male inflorescence is used as a mosquito repellent [38]. The plant contains phytochemicals such as 2-geranyl-2'-3,4,4 hydroxy dihydro chalcone which inhibits 5-α reductase [44], Artochamins-B, Artochamins-D, dihydroartomunaxanthone [45], Artonon-E and KB-2 [46]. Frutackin is a compound extracted from seeds of breadfruit is known to possess anti-fungal property [47]. Morusin possess anti-tumor property and they are found in the stem bark. Moracin M from fruit is antioxidant, anti-fungal, cytotoxic and phytotoxic. Oxyresveratrol from fruit extract is an antioxidant and anti-fungal agent [48]. *A. altilis* leaf extracts are used to synthesize anti-bacterial and antioxidant silver nano-particles [49].



Figure 5. *A. altilis* (en.wikipedia.org)

	<i>A. heterophyllus</i>	<i>A. camansi</i>	<i>A. altilis</i>	
			Fresh Fruit	Fresh Seeds
Macronutrients(g)		Value per 100 g		
Water	76.2-85.2	56.0-66.2	ND	ND
Energy(c)	95	ND	105-138	-
Carbohydrate	23.5	76.2	21.5-33	26.6-44.03
Dietary Fiber	1.5	ND	ND	ND
Fat	0.64	6.2-29.0	0.1-2.36	2.5-5.59
Protein	1.72	13.3-19.9	0.6-2.24	5.25-13.3
Moisture content (%)	ND	ND	62.7-89.16	35.08-61.9
Starch (%)	ND	ND	20.1	-
Total fiber (%)	ND	ND	0.9-7.37	1.34-2.14
Soluble fiber (%)	ND	ND	2.81	-

Ash (%)	ND	ND	0.56-1.2	1.5 - 5.58
Copper (mg/100g)	ND	ND	0.08	-
Boron (mg/100g)	ND	ND	0.52	-
Retinol equivalents	ND	ND	15.2	-
Sugar	19.08	ND	2.9	-
Micronutrients(mg)	In mg			
Calcium	34	66-70	0.05-30	0.11-49.3
Iron	0.6	8.7	0.29-2.4	2.3-3.87
Magnesium	37	10	20-34	ND
Manganese	0.197	ND	ND	ND
Phosphorous	36	320-360	0.04-79	0.35-189
Potassium	303	380-1620	283-480	-
Sodium	3.3	1.6	1.0-70	ND
Zinc	0.42	ND	0.07-0.12	-
Vitamins (mg)		ND	ND	ND
Folate (µg)	24	ND	ND	ND
Niacin	0.92	8.3	0.75-1.4	-
Pyridoxine	0.329	ND	ND	ND
Riboflavin	0.055	ND	0.02-0.05	-
Thiamine	0.105	ND	0.09-0.15	-
Vitamin A (IU)	110	ND	ND	ND
Vitamin C	13.7	ND	1.6-34.4	1.9-22.6
Vitamin E	0.34	ND	ND	ND
Phytonutrients (µg)				
Carotene-β	61	ND	19.6	-
Crypto-xanthin-β	5	ND	ND	ND
Lutein-zeaxanthin	157	ND	38.6-119.7	-

Table 5. Phytochemistry of *A. heterophyllum* [Tejpal et. al., 2016], *A. camansi* per 100 grams. [Ragone, 2006], *A. altilis* [Jones et.al., 2011] [51]

APPLICATIONS

The present review discusses about the importance and significance of Artocarpus species. The seeds and fruits of Artocarpus are rich in vitamins, minerals, phenols, flavanoids and antioxidants. Various value-added products are available from the seeds of these plants, which are good source of instant energy. The extracts of these plants exhibits remarkable benefits such as anti-bacterial, anti-fungal, anti-diarrhoeal, anti-tyrosinase, anti-inflammatory and anti-diabetic activities. Some species are used in the treatment of tapeworm

infection. They have wide applications in cosmetics as skin whitening agents. The flavones and flavanoids present in Artocarpus contribute for the anti- cancer activity and can be developed as good chemotherapeutic agents.

Lectin, a protein isolated from the seeds of Artocarpus is good hemagglutinating agents, and can be used as a therapeutic ailment for the treatment of HIV infection. Thus they have got a wide application in the field of biochemistry.

CONCLUSION

The review presents the biological activities and the phytoconstituents in the commonly found Artocarpus members of India. They are rich resources of substances with antioxidant, anti - inflammatory, anti - helminthic, anti - diabetic, anti - analgesic, anti - herpetic, anti - HSV, anti - HIV and anti - cancerous activities. In case of *A. lakoocha* agglutinin lectin functions as a purgative and heamagglutinating agent. *A. heterophyllum* lectins like Jacalin is a promising material in nanomedicine. Artocarpus species, especially *altilis* is potent resource of various chemotherapeutic agent involved in control of growth of cancerous cells. *A. altilis* finds cosmetic applications since they possess tyrosinase inhibitory activity. *A. communis* extracts inhibits 5- lipoxygenase activity and a compound extracted from *A. incisus* inhibits α - reductase activity. Thus, Artocarpus members will be a resource of substances with various therapeutic properties. In the future they could be contributing safe phytochemicals and enhance the quality of health in generations to come.

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SUPPLEMENTARY DATA

Supplementary data is available at below link: [Supplementary file.](#)

DATA AVAILABILITY

Not declared.

CONFLICTS OF INTEREST

Nil

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