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Phytochemistry, pharmacological, medicinal significance of *Artocarpus heterophyllus* Lam. (Jackfruit): A review

Anil Kumar
Research Scholar, Dev Bhoomi Institute of Pharmacy and Research Dehradun, Uttarakhand India.

Amit Mishra
Research Scholar, Dev Bhoomi Institute of Pharmacy and Research Dehradun, Uttarakhand India.

Dr. Amandeep Singh
Professor, School of Pharmacy and Research Dehradun, Uttarakhand India.
Corresponding author email: dean.asso@dbuu.ac.in

Abstract*---Artocarpus heterophyllus*** Lam. is commonly known as Jackfruit belonging to the family moraceae, is a tropical climatic fruit native to Western ghat of India and common in Asia, Africa, and some region in South America. The various parts of this tree including bark, leaves, fruits, and seeds have a wide range of medicinal properties. It is used in the numerous traditional systems of medicine to treat a vast range of diseases. Various studies have shown that jackfruits possess antioxidant, anti- inflammatory, anti-bacterial, anti-cancer activity. The phytochemical studies have found that it contains flavonoids, sterols, and prenyl flavones which contributes in various pharmacological activity. Culinary uses include jam, wine, chips, pickle and leather. Even it has several benefits, unfortunately, the fruit is underutilized at commercial scale within those regions where it is grown. This review paper contributes towards phytochemical properties, pharmacological effects, and medicinal significance of the jackfruit.

***Keywords*---**Jackfruit, Anti-bacterial, Pharmacological, Artocarpus heterophyllus, Anti-cancer.

1. Introduction

The thought of planting plants for human health and general well-being, rather than only using as food is changing people's sensibility of plant biotechnology and

synthetic biology.[1] Plants and humans share an intricate relationship from the evolutionary history. The legacy has been continued till now as plant provide nutrition, fiber, pharmaceutical products to human being. [2] Several studies have shown that at the current scenario peoples are tend to bend towards plant-based medicines and they using it as "First-Stop" therapy for many mild to moderate illness.[3]

The Artocarpus heterophyllus is a species of tree belonging to the mulberry family i.e., *Moraceae,* also known by another name Jackfruit (Eng.), Kathal (Hindi), Kanthal (Beng.), Palaa (Tamil), Katahar (Nepali). It is native to Western ghats of India, Malaysia and also found in central and eastern Africa, South-Eastern Asia, the Caribbean, Florida, Brazil, Australia.[4] It is a large, evergreen tree, 10-15m in height, indigenous to the evergreen forests. Stems of this plant is straight rough whereas bark is green or black, leaves are broad and obovate. Seeds are separated by horny endocarpus enclosed by sub-gelatinous exocarpus oblong ellipsoid in nature.[5]

2. Taxonomical Classification

Kingdom: Plantae
Subkingdom: Tracheobionta
Division: Magnoliophyta – angiosperms
Class: Magnoliopsida – dicotyledons
Subclass: Hamamelidae
Order: Urticales
Family: Moraceae
Genus: Artocarpus
Species: *Artocarpus heterophyllus* Lam.

3. Parts Used

Apart from whole plant, seeds, fruits, bark, root, leaves, and latex are also used.

4. Synonyms

Artocarpus brasiliensis Gomez., *Artocarpus maxima* Blanco., *Artocarpus Philippinensis* Lam., *Artocarpus beterophylla* Lam., *Polyphema jaca* Lour., *Artocarpus integra* Thunb., *Artocarpus integrifolia* L.f., *Artocarpus integrifolius* Auct., *Artocarpus integer* Auct., *Soccus arboreus major* Rumph.

5. Morphology

5.1 Size

Jackfruit is a medium size plant having height of 10-15m and a stem of diameter of 30-80cm. The plants exude white colour latex when there is any physical injury was occurred.

5.2 Flowers:

This species bears male and female inflorescence on the same plant i.e., they are monoecious. Male spikes are found above the female spike on the newer branches. Flowers are tiny, pale green when young and they turned darker with

the age. The pollination was done by the help of air and insects, with cross pollination.

5.3 Leaves
Leaves are dark green in colour, entire, alternate, stiff and elliptic to oval in form. Leaves are often deeply lobed.

5.4 Fruit
The fruit type is compound fruit. They are sweet when ripe and show flavours like banana. Fruits are oblong cylindrical in shape.

5.5 Seeds
Seeds are light brown, rounded ovale, 2-3cm in length by 1-1.5cm in diameter, and enclosed in a thin, whitish membrane. They can be stored up to months in cool, humid and dry conditions.[6]

Fig. 1 Fig. 2

(Fig. 1) Jackfruit on the tree [7] (Fig. 2) Female (top) and Male (bottom) flower spikes.[8]

6. Use of Jackfruit in Traditional Medicine

Table (1) [9]

Plant Part	**Use**
Root	Skin disease, Asthma, Diarrhea.
Leaves	Ringworm infection prevention, gall stones treatment, Asthma, Ulcers.
Flowers	Inflorescence stops bleeding.

Fruits	Laxative
Pulp	Nutritious tonic
Seed	Vit. A deficiency, cures Diarrhea, Dysentery.
Bark	Ear problem treatment.

7. Phytochemical Activity

During the phytochemical screening the confirmation was found that the presence of phytosterols, anthraquinone, terpenoids, phenols, glycosides, flavonoids and diterpenes in the jackfruit trees. On behalf of these results, they confirm the potential antibacterial activity of *Artocarpus heterophyllus* stems, barks and the availability of medicinally important phytochemicals in other aerial parts of the plants. [10] *Artocarpus heterophyllus* contains a promising phytochemical known as Artocarpin which have potential to treat the colorectal cancer. The identification of Artocarpin which is a bioactive component of *A. heterophyllus* which might be merit investigation as a potential colorectal cancer chemo-preventive agent. [11] The composition of micronutrients shows that the jackfruit pulp was significantly higher in Potassium (K), Vitamin C, Zinc (Zn) while the leaves was significantly higher Calcium (Ca), Manganese (Mn) and Iron (Fe). The phytochemical compositions were stated that pulp was lowest in phytic acid, oxalate, alkaloids, tannin and flavonoid. The leaves were higher in alkaloid, tannins and flavonoids. Seeds were higher in phytic acid and oxalate. [12] The ethyl acetate fraction of the *Artocarpus heterophyllus* peel had the strongest antioxidant activity and ethyl acetate fraction is very potential to be as a natural antioxidant. [140] The *Artocarpus heterophyllus* extracts have a high content of polyphenols like flavonoids and these compounds were found to be have strong anti-oxidant capacity. [13]

Table (2)

Phytochemical constituents	**Therapeutic action/ Medicinal value**
Flavonoids	Antioxidants, Anti-Cancer, Potential cytotoxic. [14]
Tannins	Inhibit tumor growth, Antioxidants. [15]
Alkaloids	Anti-inflammatory, anti-cancer, anti-bacterial.
Oxalate	Anti-osteoporotic, Kidney stone prevention, Anti-bacterial. [16]
Phytic Acid	Interfere with Protein and Lipid utilization
Saponins	Antispasmodic effect, growth, reproduction of animals, haemolytic effect. [17]

8. Pharmacological Activity

8.1 Antibacterial Activity

The antibacterial and pesticidal activity of essential oil extracted from *Artocarpus heterophyllus* seeds. The bacterial strains gram -ve E. coli, pseudomonas

aeruginosa and gram +ve Staphylococus aureus tested were found to be sensitive to essential oils and it showed effective bactericidal activity.[5] The methanolic extract of dried powder of jackfruit leaves shows significant antibacterial activity against E. coli and S. enterica bacteria. They also stated that to provide further conclusion on consumption of plant derivatives to treat the disease required further study to be conducted in *in-vivo* models to confirm the interaction between plant products and antimicrobials.[18] The seed powder extract of *A. heterophyllus* during the green synthesis of silver nanoparticles (AgNPs) from aqueous solution of silver nitrate ($AgNO_3$) contains Jacalin, a lectin which is a single major protein which represents more than 50% of the proteins from the jackfruit crude seed extract having several biological activities. The AgNPs obtained showed highly potent antibacterial activity towards gram positive bacteria (eg., Bacillus cereus, Bacillus subtilis and Staphylococcus aureus) and Gram-Negative (eg. Pseudomonas aeruginosa). It also provides future opportunities in nanomedicine. [19] The unutilized part of jackfruit has best antibacterial activity against Xanthomonas axonopodis pv. Manihotis (Xam) was obtained from ethyl acetate extracts. The peels gave the highest inhibition followed by the fiber while the core gave the least. [20]

A. heterophyllus possess antimicrobial activity against some food borne pathogens. Due to the natural origin of this extract, it is more safety for people and environment and low risk for resistance development by pathogenic microorganisms. [21]

8.2 Anti-Osteoporotic Activity

The study shows that four new flavonoids, Aetoheteroids A, B, C, D were isolated from the roots of Artocarpus heterophyllus. Out of these four new compounds are characteristic in having a 2',4',5'-trioxygenation pattern for the B ring of the skeleton. Cathepsin K (Cat K) is a cysteine protease active at low pH that plays a critical role in osteoclastic bone resorption. [22] The calcium content of the jackfruit leaves was significantly higher than its pulp and seed. We already know that Calcium has role in rickets, osteoporosis and osteomalacia. So, the leaf extract of jackfruit may become the potential lead for the anti-osteoporotic drugs.[12]

8.3 Anti-inflammatory Activity

Three phenolic compounds were characterized as artocarpesin, norartocarpetin and oxyresveratrol. These three compounds exhibited potent anti-inflammatory activity. The results indicates that artocarpesin suppressed the production of Nitric oxide (NO) and prostaglandin E_2 (PGE_2) through the down-regulation of inducible nitric oxide (iNOS) and cyclooxygenase 2 (COX-2) protein expressions. [23] Two new prenylated chromones, artoheterophine A & B, as well as five known biogenetically related prenylated flavonoids were isolated from the stems and leaves of *A. Heterophyllus*. This research suggests that the prenylated chromones and flavonoids have significant anti-inflammatory activities and this may help in development of new natural anti-inflammatory drugs.[24] The study have found an undesired steroid isolation from the jackfruit i.e., artoheterophoid. They also isolated its seven other known analogues. These all compounds were separated

from the A. Heterophyllus first time. The anti-inflammatory activity of these compounds was done in-vitro by measuring inhibitory effect against nitric oxide (NO). All the eight compounds show remarkable inhibitory effects against NO production. [25]

8.4 Anti-Cancer Activity

In Artocarpus heterophyllus there was identified Artocarpin which exhibited selective cytotoxicity against human colon cancer cells. The Artocarpin impaired the anchorage-independent growth capability, suppressed colon cancer cell growth, and induced a G1 Phase cell cycle arrest which was followed by apoptotic as well as autophagic cell death. [11] Studies found that *Macrosolen cochinensis* is a parasite grows on the jackfruit leaves possess the anti-cancer activity. During their study they extracted the jackfruit mistletoe extract using maceration method. The results indicated that the IC_{50} value of ethanol extract, chloroform-fraction and ethyl acetate fraction of jackfruit mistletoe leaves showed a higher anticancer activity.

The cell death was caused due to the induction of cell apoptosis and cell cycle inhibition. The inhibition was done at G0-G1, S and G2-M Phase.[26] Tumorigenesis through which we characterized cancer, consists of a dysfunction of cellular proliferation, leading to uncontrolled cell growth. During the study they tested the effect of jackfruit flour on cell viability in a control colonic epithelial cell line and two colonic cancer cell lines. They reported that artocarpin, a phenolic compound found in the wood of jackfruit decreased cell viability. It induced apoptosis autophagy and they caused cell cycle arrest in G1 phase by targeting Akt1 and Akt2 kinase activity and reduced tumorigenesis in vivo, And thus show anticancer effects.[27] Antimutagenicity of herbal drugs and vegetal sources to consider them in everyday use for the possible application in dietary prevention of cancer. Their results showed that the anti-cancer activity was found in the jackfruit pulp. According to them a large number of dietaries antimutagens are present but epidemiological studies have found that consistent evidence of anti-carcinogenicity was found only for few dietary components. [28]

8.5 Anti-oxidant Activity

The jackfruit latex possesses bioactive properties, Antioxidant activity was estimated with the help of AE (Aqueous extract) and TFE (Trifluoroethanol extract). It also contains α-artostenone in jackfruit latex which also helps in antioxidant activity, which prevent oxidative stress and ultimately prevent cell damage. [29] The mature jackfruit seed flours have good anti-oxidant activity. The anti-oxidant activity of the jackfruit was found with the help of DPPH radical scavenging activity and Ferric reducing antioxidant power (FRAP). It also contains higher amount of fructose, sucrose and dextrose. [30] Extracted pectin from the slimy sheath of jackfruit by using oxalic have potential activity of anti-oxidant. Functional group analysis of jackfruit seeds slimy pectin (JSSP) using Fourier-transform infrared (FTIR) spectroscopy was established the JSSP is a novel source of antioxidant rich pectin. [31]

8.6 Anti-Diabetic Activity

The leaves of *A. Heterophyllus* show potential effect against induced diabetes in albino rats. The rats were treated for 21 days with the jackfruit leaves and the diabetes was induced with the help of streptozotocin. The study provides the important leads for anti-diabetic drugs. Although the mechanism of action was unclear in this study and to establish it further study is required. [32] During the extraction from the seed of jackfruit in the methanolic extract of its seeds an anti-diabetic drug was identified i.e., Vildagliptin. The study gives idea that its seeds contain this activity which may give us direction towards a potent anti-diabetic drug. [33] The aqueous extract of the *Artocarpus heterophyllus* leaves which becomes senescent is traditionally used in Sri Lanka as hypoglycemic agent. In current studies the same effect was tested on rats and the results obtained were of promising type of the desired activity. The glycemic level of rats was increased with the help of nicotinamide. [34] The ethyl acetate fraction of the water extract (EA/W) of the leaves of *Artocarpus heterophyllus* have shown anti-diabetic activity. The outcomes obtained during this study was found to be quite effective response against elevated glycemic level. [35] The Artocarpus Heterophyllus leaf was when extracted with ethanol, n-butanol shows the presence of flavonoids isoquertrin, and this flavonoid exerts hypoglycemic effects in streptozotocin diabetic rats. The anti-hyperglycemic effect was shown through the anti-oxidative pathway that might be referred through the flavonoid's contents. [36]

8.7 Anthelmintic Activity

The jackfruit leaves decoction content was found to be show anthelmintic activity. The study shows that increasing concentration of jackfruit leaves decoction showed high killing efficacy towards nematodes. The mean effective dose (ED_{50}) was found to be 40% concentration. The entire study was performed on goats. [37] Nematodes currently becomes resistant towards available anthelmintic drugs; therefore, it is a prominent problem in the treatment of helminths diseases. The findings of this study concludes that the Artocarpus heterophyllus leaves support the anthelmintic potential for therapeutic interests and justify its activity. [38]

9. Recent work and Current Advancement

9.1 Starch based bioplastic from jackfruit seed

The bioplastic made up of jackfruit seed showed that when the glycerol ratio was high then the bioplastic was softer and more flexible and increasing the percentage of citric acid increases the hardness and reduce the plasticity of the bioplastic. Thus, this study encourages to proceed further for the solution against plastic pollution which becomes a burning issue worldwide. [39] Jackfruit seeds contains high quantity of starch. 8-15% of the total weight of the jackfruit starch was present inside its seed. The enforcement of the microcrystalline cellulose during the production of bioplastic from jackfruit seed starch enhances the tensile strength of the bioplastic. The strength was due to the microcrystalline cellulose hydrogen bonds between it. [40]

9.2 Bio-Coagulant as Polluted Groundwater Treatment

Artocarpus heterophyllus peel and seeds were dried, powdered and finely sieved. Distilled water was added to the powder to get 1% suspension of it. This solution act as a natural bio-coagulant, used for the treatment of groundwater. These coagulants are effective in maintaining the pH of water and also helps in removing turbidity. It also reduces Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Salt content from the water. [41] For the treatment of the groundwater the most cost-effective method is bio-coagulant treatment. Jackfruit peel is a natural available source of starch which can be used as an alternative for chemical coagulants. The coagulation was done using the Jar Test Apparatus. Jackfruit peel was efficient coagulant as compared to other natural available coagulant i.e., Starch grass, Bitter guard seed, Banana flower leaf powder. [42]

9.3 Jackfruit Mucilage as Sustained Release Formulation of Drug

The jackfruit mucilage was isolated and used to develop Verapamil HCl tablets. The drug release kinetics was studied and found to be first order kinetics. The jackfruit mucilage delayed the drug release which could be the therapeutically better than conventional dosage form which leads to improved efficacy and better patient compliance. The study showed that natural mucilage could be the better alternative as compared to synthetic polymers in terms of utility and cost. [43] The jackfruit mucilage obtained from the fruits pulp of *Artocarpus heterophyllus* with the average yield of dried mucilage 23.14% w/w. The study shows that there are no considerable changes in the position of interaction either drug-polymer or polymer-polymer. The matrix tablets of diltiazem HCl when prepared with combination of 15% jackfruit mucilage were found to have good physical properties. With the help of this there could be development of desirable release modulation for a once daily administration. [44]

9.4 Jackfruit seed extract as Anti-Platelets

The aqueous seed extract of jackfruit enhanced the clotting time of human plasma. The anticoagulation was triggered by the extract could be due to its interference in an intrinsic pathway of the blood coagulation cascade. It may serve as a better alternative of thrombotic disorders. [45] The aqueous seed extract of jackfruit (AqSEJ) hydrolyzed casein suggesting the proteolytic activity. AqSEJ hydrolyzed human fibrinogen and fibrin clot. This activity of jackfruit did not show indirect hemolytic activity, hemorrhage and edema in the experimental animal. [46]

9.5 Jackfruit Market- Global Industry, Growth, Trends, and Forecasts 2021-2031

The study shows that the global market is expected to witness strong growth during the forecast period between 2021 and 2031. Due to the increased health benefits, the jackfruit demand will remain high in the post COVID-19 phase. Rising awareness about jackfruits immunity-boosting and nutritional characteristic is the key factor for the growth of jackfruit at global market. The global market for jackfruit is classified into five regions namely, North America, Asia Pacific, Europe, Middle East and Africa, and Latin America. Other regions

such as Middle East and Africa and Latin America witness lower to moderate growth in the jackfruit market. Some of the leading players in the global market includes Mother Dairy Fruits & Vegetables, Nutty Yogi, The Jackfruit Company, Anna Food Production and Artocarpus Food Pvt. Ltd. [47-49]

Conclusion

Considering the easily availability of jackfruit in our country and this plant have us of its all parts including wood and latex possess curative properties. And it seems there is still much more scope of scientific approaches to fully explore the medicinal activity of this plant. This review article is an effort to compile the major information which was gathered from the various researches and published till the current time. In this article we tried to sum of the phytochemical activity of the jackfruit as well as the various pharmacological activity of this plant. Jackfruit was a neglected fruit from the ancient time but at the current scenario the researchers accepting its importance in various types of medicinal uses too.

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