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Artocarpus heterophyllus Lam. (Moraceae): Phytochemistry, Pharmacology and Future Directions, a mini-review

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ABSTRACT:
The aim of this mini-review was to collect data obtained from various studies carried out by different authors concerning the phytochemistry and pharmacognosy of *Artocarpus heterophyllus* Lam. This review has been compiled using references from major databases such as PubMed, PubMed Central, Science Direct and Google scholar. An extensive survey of literature revealed that *Artocarpus heterophyllus* Lam. is a good source of health promoting secondary metabolites such as flavonoids, terpenoids, steroids, phenols, prenylflavones, glycosides, saponins, alkaloids and tannins. Due to the presence of these metabolites, this species may have wonderful applications (like anthelminthic properties).The bark, roots, leaves, and fruit are attributed with diverse medicinal properties and are used in various traditional and folk systems of medicine to treat a range of ailments. This plant possesses antioxidant, anti-inflammatory, antibacterial, anticariogenic, antifungal, antineoplastic, hypoglycemic properties and many others. The results of this review make *A. heterophyllus* an interesting candidate for advanced anthelminthic properties.
Keyword: *Artocarpus heterophyllus, jackfruit, anthelminthic activity,*

INTRODUCTION

Artocarpus heterophyllus Lam commonly called the jackfruit tree (or Jacquier in french); is one of the widely distributed plant in tropical and sub-tropical countries such as India, Brazil, Bangladesh, Thailand, Indonesia, Philippines, Malaysia … It is now cultivated in Democratic Republic of the Congo (DRC). *A. heterophyllus* belongs to the family Moraceae and bears large edible fruits which can reach 49 kg [1-12]. These fruits are known to have high nutritional potential and can be consumed as food, which can be cooked, baked or roasted on coals. Fruit pulp is eaten fresh and used in fruit salads. A fruit can contain from 100 to 500 seeds which can be consumed roasted, boiled, steamed, and are eaten as snack [12].

Artocarpus heterophyllus leaves and stem barks are used in traditional medicine to treat several diseases include hypertension, diabetes, cancers, anemia, asthma, dermatosis, diarrhea and like [13-25]. Biological activities of different extracts of *Artocarpus heterophyllus* are well documented and a considerable amount of phytochemicals was isolate from different parts of the plant [23, 25-49].

Recently few review articles was done on the nutritional properties of *Artocarpus heterophyllus* and on its benefit on human heath [3,16, 42,49]. In DRC, jackfruit tree leaves are used for their anthelminthic properties mainly on animals. So this mini review aims to document phytochemistry and Pharmacology of this plant for its probable use as anthelminthic on animals.

Botanical description and origin of *Artocarpus heterophyllus*

Artocarpus heterophyllus Lam, belongs to the family of Moraceae. It is an exotic tree originally from the Western Ghats of India. This plant is distributed over the tropical and subtropical regions. Jack fruit tree is monoecious, both male and female inflorescences are found on the same tree [1,2]. From the time of successful pollination, the complete process of fruit development takes about three to seven months. The fruit consists mainly of three regions, the fruit axis, the persistent perianth and the true fruit (Fig.1). The axis, the core of the fruit is inedible and is rich in latex due to the presence of laticiferous cells and holds the fruits together [3].The most important and bulk of the fruit is the perianth. It is made up of three regions of which the lower fleshy edible region, commonly called as the bulb; the middle fused region, that forms the rind of the syncarp and the upper free and horny non-edible region commonly known as the spikes. The ripe fruit (arils or flesh) contain well flavored yellow sweet bulbs and seeds. Each fruit is oblong cylindrical in shape and is 30–40 cm in length. When ripe they are acid to sweetish taste except for the thorny outer bark but the remaining parts of the fruit are edible [3].

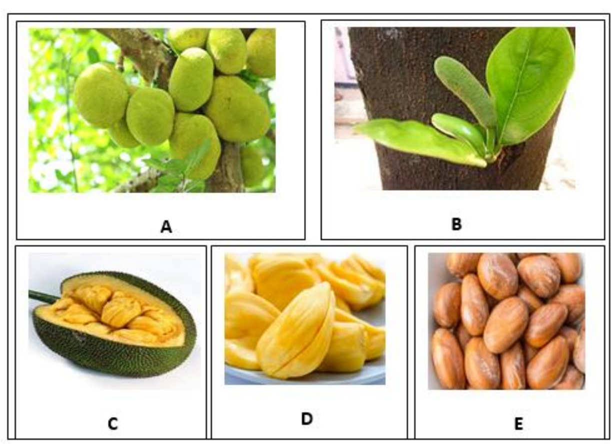

Fig.1. (A) Jackfruit tree with fruits of different sizes; (B) Jackfruit tree with fruits in different stages of fruiting; (C) inner aspect of a

ripe jackfruit with seeds; (D) edible ripe jackfruit pulp and (E) jackfruit seeds.
(Source: Google images collection)

Common names of Jackfruit

Jackfruit has different spellings in different countries, here is given some of these common spellings of this fruit. Jakfruit, bo luop mi (China), Jacquier (French), Nanka, (Indonesia), Jaca (Spain), Vaca (Portugal), Lanka, (Philippines), Kapiak (New Guinea), Uto ni India (Fiji), Ulu initia (Samoa), Chakka, Chakki, Kanthal, Kathar, Panos (India), Jaca, Jacca mole, Jaca dura (Brazil), Mit (Vietnam), Khanun, Makami, Banum (Thailand) [3,15,16, 42-61].

Environment and Propagation

Jackfruit thrives in tropical warm and humid frost-free climates. The trees have some salinity tolerance but poor drought and flooding tolerance. It grows in a variety of well-drained soils with a pH between 5 and 7.5. It needs irrigation in times of drought in order to produce fruit. Growth habits vary from tall and straight with a thin trunk to short with a thick trunk, varying with soil type, environment, and cultivar. Seeds from selected trees are the major means of propagation. After overnight soaking in water, they should be planted as soon as possible after harvest, as they lose viability within 1–3 months. Seeds germinate in 3–8 weeks. Seedlings are best grown under shade. To propagate a desirable tree, root cuttings can also be used, with stem cuttings and air layers also being successful. Grafting and budding are now widely used in India and Southeast Asia. Budding, grafting, and inarching are done onto 12-month-old rootstocks of *A. integer*, *A. heterophyllus*, other *Artocarpus* species, as well as the same species being propagated. However, the suitability of these rootstocks has not been evaluated in a range of environments. Modified veneer grafts and cleft grafts are among the most common. Sometimes seedlings, such as those of the Singapore variety, are true to type. In major producing areas, seeds are usually planted in the field and later top-worked with selected varieties. Seedlings need to be transplanted before they are 1 year old to avoid damage to the sensitive taproot [60].

Ethnobotany

Jackfruit appears in the Indian market in spring and is available till summer. The fruits are of dietary use and are an important source of carbohydrates, proteins, fats, minerals and vitamins. The heart wood is a very durable timber and is used in the preparation of furniture. The bark, roots, leaves, and fruits are attributed with diverse medicinal properties and are used in the various traditional and folk systems of medicine to treat a range of ailments. Preclinical studies have shown that the jackfruit possesses antioxidant [4], anti-inflammatory, antibacterial, anticariogenic, antifungal, antineoplastic, hypoglycemic properties, wound healing effects and causes a transient decrease in the sexual activity. Clinical studies have also shown that the decoction of the leaves possesses hypoglycemic effects in both healthy individuals and non-insulin-dependent diabetic patients. Phytochemical studies have shown that jackfruit contains several useful compounds like flavonoids, sterols and prenylflavones which may have been responsible for various pharmacological properties.

Jackfruit pulp is eaten afresh and used as fruit salads and possesses high nutritional values [5]. Jackfruit has also been reported to contain antioxidant prenylflavones [4] and the antioxidant property of fruit pulp has been evaluated recently [6]. However, jackfruit seeds are less popular as vegetables and are eaten when boiled or roasted and it is believed to be digested with difficulty [7]. The nutritional composition of jackfruit seeds has been reported [8, 9] and was found to contain similar elements as that of grains. In the same regard, the seeds are as well a rich source of fibers and vitamins. A major protein, Jacalin was isolated from jackfruit seeds and it was discovered that it possesses immunological properties [10,11]. Jackfruit seeds are not much explored in terms of nutrition and antioxidant properties although the chemical composition and mineral content of jackfruit seeds have been studied [12].

Chinese consider the jackfruit pulp and seeds tonic, cooling and nutritious, and "useful in overcoming the influence of alcohol in the system." The seed starch is given to relieve biliousness and the roasted seeds are regarded as aphrodisiac. The ash of jackfruit leaves, burned with corn and coconut shells, is used alone or mixed with coconut oil to heal ulcers. The dried latex yields artostenone, convertible to artosterone, a compound with marked androgenic action. Mixed with vinegar, the latex promotes healing of abscesses, snakebite and glandular swellings. The root is a remedy for skin diseases and asthma. An extract of the root is taken in case of fever and diarrhea, the bark is made into poultices and heated leaves are placed on wounds while the wood has a sedative property; its pith is abortive [13].

In Sri Lanka, *A. heterophyllus* (Jack) and *A. altilis* (Dhel) fruits are a popular food among the locals populations. *A. heterophyllus* bark and fruit are medicinally used to treat sprains, fractures, diabetes and are also used for laxative effect of abdomen and to increase the breast milk production in nursing mothers [14]. Almost all the parts of *A. heterophyllus* and *A. altilis* are utilized to treat several infections and other ailments in the Caribbean islands, Polynesian islands, Taiwan, Malaya, Java and Borneo [15, 16].

Morphological characterization of hard and soft jackfruit seed starch granules

The scanning electron microscopy analysis showed granules with round and bell shapes and some irregular shapes showing cuts in their surface, which appear to be characteristic of these starches (Fig. 2). The results shown here are for native starch from jackfruit seeds grown in Asia [41].

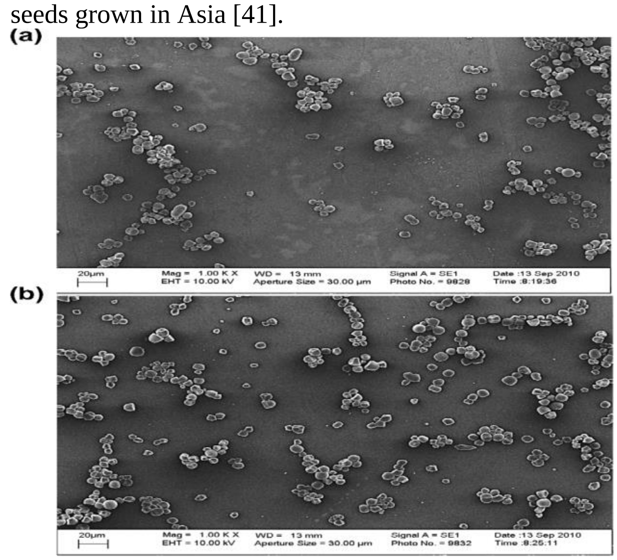

Fig. 2. Micrographs obtained through SEM at magnitude of 1000Xof jackfruit seed starch for soft (a) and hard (b) varieties (Source : Marta *et al.*, 2014 [41]).

Phytochemical Screening and pharmacology

The phytochemical screening of *A. heterophyllus* leaves showed the presence of flavonoids, terpenoids, steroids, phenols, glycosides and saponins while the stem bark showed all the above stated phytochemicals and in addition alkaloids and tannins[17].

A. heterophyllus contains various chemical constituents including several flavone colorings, morin, dihydromorin, cynomacurin, artocarpin, isoartocarpin, cyloartocarpin, artocarpesin, oxydihydroartocarpesin, artocarpetin, norartocarpetin, cycloartinone, and artocarpanone [62]. The nutritional analysis of jackfruit analysis yields moisture (6.7%), glucosides (38.0%), lipids (0.7%), protein (1.7%), and cellulose (59.0 %) [36]. The jackfruit also contains free sugar (sucrose), fatty acids, ellagic acid, and amino acids like arginine, cystine, histidine, leucine, lysine, methionine, threonine, tryptophan, and others [35]. Bark from the main trunk contains betullic acid and two new flavone pigments including cycloheterophyllin ($C_{30}H_{30}O_7$) and a phenolic compound having a novel skeleton named Heterophylol was also obtained from *A. heterophyllus* [31, 34].. The leaves and stem have shown the presence of sapogenins, cycloartenone, cycloartenol, β-sitosterol [38], and tannins, and they have shown estrogenic activity. The root contains β-sitosterol, ursolic acid, betulinic acid, and cycloartenone [33]. Jacalin, the major protein from *A. heterophyllus* seeds, is a tetrameric two-chain lectin combining a heavy chain of 133 amino acid residues with a light β chain of 20 to 21 amino acid residues. It is highly specific for the O-glycoside of Thomsen-Friedenreich antigen disaccharide (Galβ1-3GalNAc), even in its sialylated form. This property has made jacalin suitable for studying various O-linked glycoproteins, particularly human IgA1 [39]. Jacalin's uniqueness in being strongly mitogenic for human CD4 $^+$T lymphocytes has made it a useful tool for the evaluation of the immune status of patients infected with human immunodeficiency virus HIV-1 [37]. Two novel 2,4,6-trioxygenated flavanones, heteroflavanones A and B, were isolated from the root bark of *A. heterophyllus*. Their structures were elucidated as 5-hydroxy-7,2,4,6_-tetra methoxyflavanone and 8-(γ ,γ -dimethylallyl) 5-hydroxy7,2,4,6-tetra methoxyflavanone [31,32]. Three phenolic compounds were characterized as artocarpesin [(5,7,2,4_-tetrahydroxy-6-β-methylbut-3-enyl) flavone], norartocarpetin (5,7,2,4-tetrahydroxyflavone), and oxyresveratrol (trans-2,4,3,5-tetrahydroxystilbene) by spectroscopic methods. The carotenoids of *A. heterophyllus* were identified as β-carotene, α-carotene, β-zeacarotene, α-zeacarotene, and β carotene-5,6-epoxide, as well as a dicarboxylic carotenoid, crocetin [30].

Different structures of these compounds are displayed in figure 3 below.

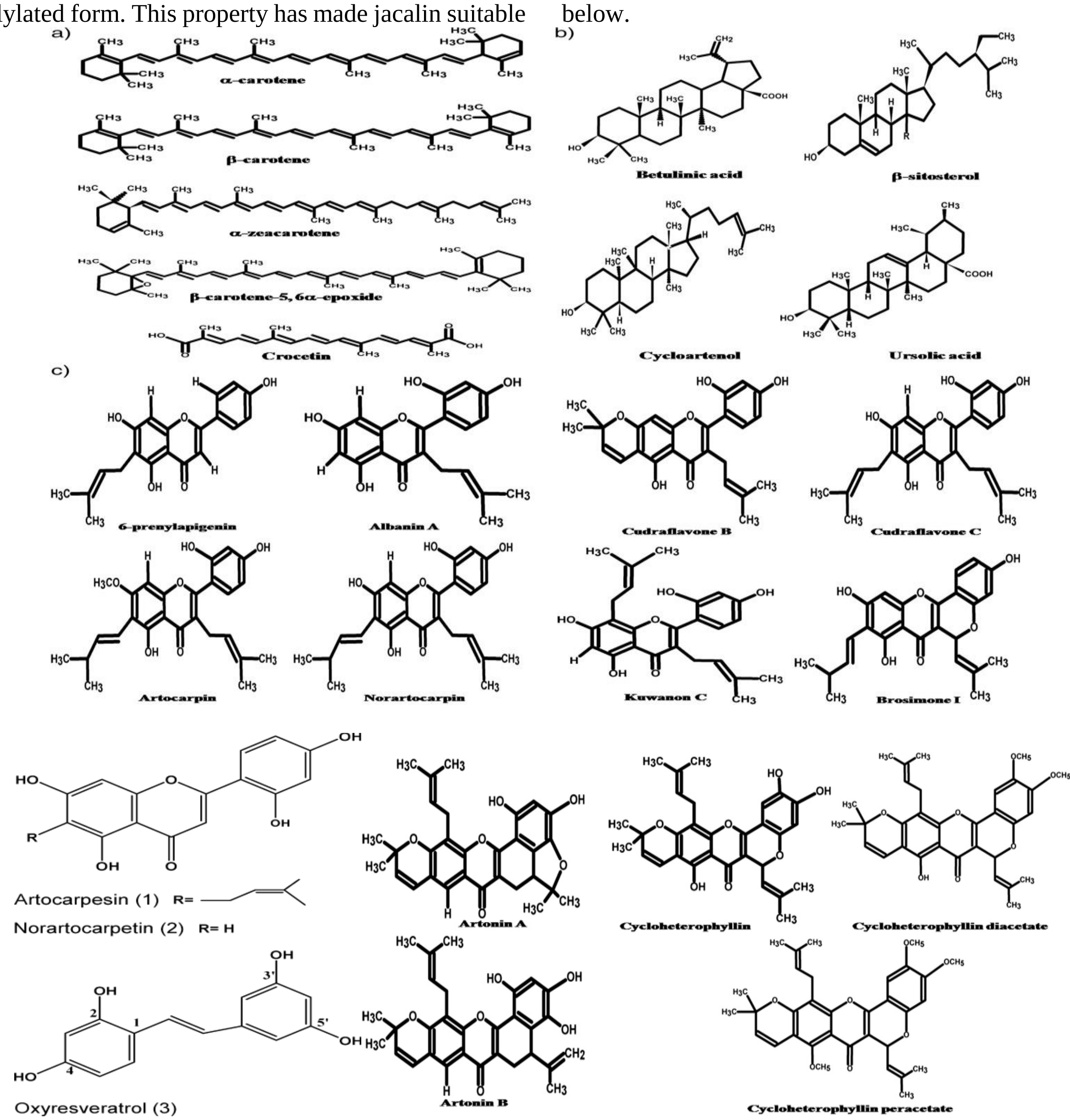

Figure 3. Structures of artocarpesin (1), norartocarpetin (2), and oxyresveratrol (3) isolated from the ethyl acetate extracts of *A. heterophyllus* fruits, (a). The carotenoids present in the jackfruit. (b). The sterols present in the jackfruit. (c) The prenylflavones present in the jackfruit (Source: Manjeshwar *et al.* [42]).

Antioxidant and antidiabetic activities

Lipid peroxidation is a marker of cellular oxidative damage initiated by reactive oxygen species [18]. It was reported that diabetics are highly sensitive to oxidative stress [19]. In STZ-diabetic animals, STZ generates nitric oxide, which is a powerful free radical oxidant [20] resulting in an increase in lipid peroxides as noticed in this study due to cellular oxidation [21]. The production of lipid peroxides was significantly declined in Jack

Fruit Ethanol Extract> Jack Fruit n-Butanol Extract> GLB-treated Streptozotocin-diabetic rats. The presence of quercitrin flavonoid (resembles isoquercitrin present in JackFruit Extract) that could attenuate the diabetic state by decreasing oxidative stress and preserving pancreatic ß-cell integrity [22]. Abnormalities in lipid profile are common complications found in 40% of diabetics [23]. The STZ-diabetic rats elicited a significant increase in the serum TC, TG, LDL-C, and VLDL-C levels. High levels of TC and, more importantly, LDL-C in blood are major coronary risk factors [24]. The *in vitro* antioxidant activity was evaluated by measuring the DPPH radical scavenging activity of different extracts of *A. heterophyllus*. The acetone extract showed higher radical scavenging activity (89.31±0.64%) than remaining extracts followed by methanol extract (87.56±0.47%), aqueous extract (86.54±0.77%), ethyl acetate + methanol extract (85.09± 0.69%), and ethyl acetate extract (17.71±0.97%). DPPH is a free radical generating compound and has been widely used to evaluate the free radical scavenging ability of various antioxidants [16]. In the results previously reported above, maximum antioxidant activity was found from acetone extract (89.31±0.78 %) even it showed higher scavenging activity as compared to the standard BHA and ascorbic acid (Fig. 4). High antioxidant activity of the acetone extract may be related to elevated vitamin C value [40].

The whole aqueous extract of the leaves as well as it aqueous and ethyl acetate fractions were subjected to *in vitro* phytochemical (phenolic content) and antioxidant assays (DPPH, ABTS, FRAP and Fe^{2+}chelating activity assay) [28]. The total extract was observed to possess the highest phenolic content (523.2 mg/g), followed by ethyl acetate (361.2 mg/g) and aqueous fractions (294.5 mg/g). The total water extract was highly effective in the DPPH assay and a low IC_{50} value of 73.5 µg/mL was observed when compared to that of aqueous and ethyl acetate fractions where it was 219.9 and 235.8 µg/ml, respectively. In the FRAP assay, the IC_{50} value was 565.8 342 and 72 µM Fe(II)/g for the total water extract, ethyl acetate and aqueous fraction respectively. In the ABTS scavenging assay, the ascorbic acid-equivalent antioxidant activity was observed to be 8.6, 28.6 and 34.8 µg/mL for ethyl acetate fraction, aqueous fraction and the whole extract, respectively. The total aqueous extract and its fraction, the aqueous and the ethyl acetate fractions are also observed to be potent chelators of ferrous ions and the IC_{50} values of 243.9, 222.6 and 251.8 µg/mL were observed for the three samples respectively, while it was 18 µg/mL for EDTA used as a positive control [28].

Anthelminthic activity

The ethyl acetate ethanol and aqueous extracts of *A. heterophyllus* seed exhibited significant anthelminthic activity in comparison with the control *in vitro*. Amongst all the extracts, Ethyl acetate extracts showed a good activity. It indicates that certain non-polar constituents are responsible for the activity. This anthelmintic activity is mainly due to the presence of secondary metabolites namely alkaloids, flavonoids and Triterpenoides [13]. The antihelminthic activity of different extracts of *A. heterophyllus* is displayed in table 1 below.

Table 1. Anthelmintic activity of various extracts of *A. heterophyllus*

Groups	Treatment	Concentration (mg/ml)	Time tajen for paralysis	Time taken for death
GP-1	Control	Normal saline (5%)	_	_
GP-2	Albendazole (standard)	25 mg 50 mg 100 mg	19.83±0.95 15.50±0.89 09.17±0.70	26.83±0.93 20.83±0.95 14.17±0.95
GP-3	Ethanol extract (test sample)	25 mg 50 mg 100 mg	95.33±0.88 64.50±0.92 46.67±0.67	117.50±0.99 86.67±0.84 66.17±0.87
GP-4	Aqueous (test sample)	25 mg 50 mg 100 mg	120.33±0.80 78.50±0.99 64.67±0.88	147.17±0.93 106.50±0.99 117.50±0.90
GP-5	Ethyl acetate (test sample)	25 mg 50 mg 100 mg	82.67±0.88 57.17±0.95 46.67±0.67	109.50±0.99 92.50±0.85 66.17±0.87

(Source: Yashaswini *et al*., 2016 [14])

Anti-inflammatory activity

Surfeit generation of free radicals especially under conditions of chronic inflammation is harmful to the cells. Preclinical studies with experimental animals have shown that the protease fraction and the phytochemical artocarpain-H extracted from the fruit stem latex possess anti-inflammatory effects. Artocarpain-H inhibited carrageenan induced rat paw edema and reduced the weight of the granulomain cotton pellet method and the effects were concentration dependent [29].

The anti-inflammatory properties of phenolic compounds isolated from the ethyl acetate extracts of *A. heterophyllus* fruits were shown *in vitro*. Three phenolic compounds were characterized asartocarpesin [5,7,2′,4′-tetrahydroxy-6-(3-methylbut-3-enyl) flavone] (1), norartocarpetin (5,7,2′,4′-tetrahydroxyflavone) (2), and oxyresveratrol [trans-2,4,3′,5′-tetrahydroxystilbene] (3) by spectroscopic methods and through comparison with data reported in the literature. The anti-inflammatory properties of the isolated compounds (1-3) were evaluated by determining their inhibitory effects on the production of proinflammatory mediators in lipopolysaccharide (LPS)-activated RAW 264.7 murine macrophage cells. These three compounds exhibited potent anti-inflammatory activity. The results indicated that artocarpesin (1) suppressed the LPS-induced production of nitric oxide (NO) and prostaglandin E2 (PGE2) through the down-regulation of inducible nitric oxide synthase (iNOS) and cyclooxygenase 2 (COX-2) protein expressions [25].

Maintaining a healthy thyroid gland and preventing anemia

Copper (10.45 mg/kg) plays an important role in thyroid gland metabolism, especially in hormone production and absorption and jackfruit is loaded with this important microminerals [47]. Jackfruit also contains iron (0.5 mg/100 g), which helps to prevent anemia and also helps in proper blood circulation [59].

Antifungal activity

The extract of the leaves is reported to be ineffective on

Aspergillus niger, A. rubrum, A. versicolor, A. vitis, Candida albicans, C. tropicalis, Cladosporium cladosporiods, Penicillium notatum, Trychophyton mentagrophytes and *T. tronsurum* [26]. However the chitinbindinglectin present in the seeds (denoted as jackin) is shown to inhibit the growth of *Fusarium moniliforme* and *Saccharomyces cerevisiae* [27]. It was proposed that future studies should be extended to animal models as these studies will clearly indicate the antifungal efficacy in the animal system study.

Inhibition of melanin biosynthesis

Jack fruit wood extract and the phytochemical artocarpanone was effective and inhibited both mushroom tyrosinase activity and melanin production in B16 melanoma cells [54]. Artoheterophyllin A, artoheterophyllin B, artoheterophyllin C, and artoheterophyllin D isolated from the twigs also possess a tyrosinase inhibitory activity [55].

Antibacterial activity

Khan *et al.* [26] studied the antibacterial effects of the crude methanolic extracts of bark, stem and root, heart wood of stem and roots, leaves, fruits and seeds as well as their petroleum, dichloromethane, ethyl acetate and butanol partitioned fractions on *Bacillus cereus, B. coagulans, B. megaterium, B. subtilis, Lactobacillus casei, Micrococcus luteus, M. roseus, Staphylococcus albus, S. aureus, S. epidermidis, Streptococcus faecalis, St. pneumoniae, Agrobacterium tumefaciens, Citrobacter freundii, Enterobacter aerogenes, Escherichia coli, Klebsiella pneumonia, Neisseria gonorrhoeae, Proteus mirabilis, P. vulgaris, Pseudomonas aeruginosa, Salmonella typhi, Salmonella typhymurium* and *Serratia marcescens* by the disc diffusion method at standard concentration of 4 mg/disc and chloramphenicol (10 μgdisc) as positive control. It was observed that of all the extracts and fractions investigated the butanol fractions of the root bark and fruits were found to be the most active [26]. Recently, Loizzo *et al.* [28] investigated the antibacterial activities of the whole aqueous extract as well as the aqueous extract and ethyl acetate fraction of jackfruit leaves against the foodborne pathogens namely *E. coli, Listeria monocytogenes, Salmonella typhimurium, Salmonella enterica, Bacillus cereus, Enterococcus faecalis* and *S. aureus* with Streptomycin sulphate (10 μg/disc) as positive control by the agar diffusion and broth dilution methods. In the disc diffusion assay the investigators observed that the three plant samples were effective against all bacteria except *B. cereus* and the zone of inhibition ranged from 7.5 to 15.0 mm. The whole aqueous extract possessed the highest inhibitory activity against *S. aureus* (15 mm), *E. faecalis* (14 mm), *S. typhimurium* (13 mm) and *E. coli* (11.3 mm), while the ethyl acetate fraction showed the highest inhibition against *S. enterica* (13 mm) and the aqueous fraction against *L. monocytogenes* (15 mm) [28]. The antibiotic streptomycin sulphate was observed to be more effective than any of the samples on *E. coli*, (24 mm) and *B. cereus* (13.5 mm), while was almost equal to any one of the plant samples in the remaining strains of bacteria [28]. In the minimum inhibitory concentration assay by broth dilution method, the whole aqueous extract possessed the highest inhibitory activity against *L. monocytogenes* (237.8 μg/mL); while the ethyl acetate fraction showed the highest effect on *E. coli* (225.6 μg/mL), *S. enteric* (444.7 μg/mL), *E. faecalis* (234.5 μg/mL), and *S. aureus* (221.9 μg/mL); and the aqueous fraction against *S. typhimurium* (342.4 μg/mL). None of the leaf samples were effective on *B. cereus* and the MIC was observed to be N1000 μg/mL, while the positive control streptomycin sulphate was effective on all the organisms and at lower concentrations in the range of 16 to 105 μg/mL, suggesting their limited potentiality as possible antibacterial agents [28]. The antibacterial activity of aqueous silver nanoparticles was assessed over this organism and the zone of inhibition was reported to be about 20 mm [63]. One of the most common species of the Aspergillus genus is *Aspergillus niger*. It is a filamentous fungi, that is a food contaminant and causes a disease called black mold on grapes, onions and peanuts. It is largely found in soil and indoors and forms black colonies. The antifungal activity of silver nanoparticles synthesized from *A. heterophyllus* leaf extract was done using the well diffusion method and the observed zone of inhibition was 15 mm [63].

Effect on sexual performance

Sub chronic treatment of high dose of jackfruit seed decreases sexual activity in rats without affecting vital functions. The observed effects were transient and reverted on withdrawal of the seeds from the diet [56].

Antiviral Properties

Jackfriut lectin (JFL) from *A. heterophyllus* has been found to have *in vitro* inhibitory activity with a cytopathic effect toward Herpes simplex virus type HSV-2, Varicella zoster virus (VZS) and Cytomegalovirus (CMV) [61]. Several plant lectins have been shown to inhibit infectivity of viruses. For instance, jackfruit has been found to inhibit *in vitro* infection of HIV-1 without preventing the virus from binding to the host cell [62]. The antiviral activity of JFL in response to HSV-2 and CMV, either before or after viral infection of cell monolayers, was observed at different doses. This result differed markedly from the lack of effect reported for collectin, mannan binding protein, and bovine conglutinin on HSV-2. This result suggest that JFL may act either on the surface of the host cell or directly on the viral envelope, thereby inhibiting viral infectivity [62].

Dietary aspect

Jackfruit is very nutritious including all its components, thus its significant use in various diets. The raw fruits are used in Vegetable curries and pickles [49]. While the ripe fruits are used to make ice cream, drinks, jam, halwa and jelly. Pulps can be desiccated and then be used as dried fruit during off season and the fruit can be used for the preparation of alcoholic liquor [46]. Moreover, ripe bulbs cooked with jaggery, coconut milk or cow's milk and seasoned with raisins, almonds and cashew nuts to make a sweet dish known as payasam on special occasions. The ripe bulbs used to make jack fruit nectar or reduced to concentrate or powder [2]. Jackfruit seeds are very nutritious and an important source of diet. They are boiled or roasted and eaten like chestnuts, or cooked in some local dishes [51]. The seeds are also marketed in canned forms, in boiled form like beans, in brine and in tomato sauce [2]. The seed flour is rich is protein and carbohydrates and contains a good water as well as oil absorption abilities, and it is also used as an alternative to wheat flour [44,49,53]..

In addition, tender jackfruit leaves and young male flower clusters may also be cooked and served as vegetables [2]. The leaves are used as a casing material for baking dishes and they are also secured together in the form of a round plate and used as a single use biodegradable.

The proximate composition of young fruits, ripe fruits and seed jackfruit is given in table 2.

Amino acid analysis of isolated protein of Jackfruit seed flour

Amino acids composition is represented in Table 3. Among the essential amino acids (EAAs), lysine (10.30%) was in the highest amount and then followed by isoleucine (8.61%). Lysine enables the production of energy, hormones and enzymes. Isoleucine is important for the regulation of blood sugar [57]. In case of non-essential amino acids, tyrosine acid (6.67%) was in the highest concentration followed by glycine (4.94%). Inadequate amount of tyrosine lead to a deficiency of norepinephrine in the brain, which causes depression. It suppresses the appetite and helps to reduce human body fat [57]. Glycine is necessary for the central nervous system and healthy prostate. Valine (1.73%) and arginine (2.44%) were found in the lowest concentration in the proteins isolated from JFS. The percentages of the other amino acids were trivial and did not give a remarkable trend [58]

Table 2. Proximate composition of young fruit, ripe fruit and seed of jackfruit based on fresh weight (per 100 g).

Composition	Young fruit	Ripe fruit	Seed
Water (g)	76.2–85.2	72.0–94.0	51.0–64.5
Protein (g)	2.0–2.6	1.2–1.9	6.6–7.04
Fat (g)	0.1–0.6	0.1–0.4	0.40–0.43
Carbohydrate (g)	9.4–11.5	16.0–25.4	25.8–38.4
Fiber (g)	2.6–3.6	1.0–1.5	1.0–1.5
Total sugars (g)	–	20.6	–
Minerals			
Total minerals (g)	0.9	0.87–0.9	0.9–1.2
Calcium (mg)	30.0–73.2	20.0–37.0	50
Magnesium (mg)	–	27	54
Phosphorus (mg)	20.0–57.2	38.0–41.0	38.0–97.0
Potassium (mg)	287–323	191–407	246
Sodium (mg)	3.0–35.0	2.0–41.0	63.2
Iron (mg)	0.4–1.9	0.5–1.1	1.5
Vitamins			
Vitamin A (IU)	30	175–540	01/10/17
Thiamine mg)	0.05–0.15	0.03–0.09	0.25
Riboflavin (mg)	0.05–0.2	0.05–0.4	0.11–0.3
Vitamin C (mg)	12.0–14.0	7.0–10.0	11
Energy (Kj)	50–210	88–410	133–139

(Source:[3,45,47-48,50,52**]**)

Table 3. Contents of amino acid present in total protein of Jackfruit seed flour

N°	Essential Amino Acids	Amount (%)	Non-Essential Amino Acids	Amount (%)
1	Lysine	10.30	Aspartic Acid	4.80
2	Isoleucine	8.61	Arginine	2.44
3	Leucine	6.73	Glutamic Acid	4.34
4	Methionine	4.82	Serine	4.46
5	Threonine	3.90	Glycine	4.94
6	Valine	1.73	Tyrosine	6.67
7	Histidine	1.92		

Source: Muhammed *et al.*, 2017 [58].

CONCLUSION

The literature survey revealed that *Artocarpus heterophyllus* Lam. is a pharmacologically and chemically studied plant species.The diversity of secondary metabolites present in the plant species especially flavonoids, terpenoids, steroids, phenols, glycosides, saponins, alkaloids and tannins show that *A. heterophyllus* Lam. is a good candidate for Tropical Plants Screening Research program for the development of lead compounds against genetic and parasitic diseases such as the evaluation of antihelminthic activity.

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