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Botanical, Chemical and Pharmacological Properties of *Artocarpus lakoocha* (Monkey Fruit): A Review

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ABSTRACT

Artocarpus are members of the Moraceae family who are believed to be a large family comprises of nearly 60 genera and about 1400 species. The most important genus of the Moraceae family is *Ficus*, *Morus* and *Artocarpus*. The extract and bioactive compounds from bark, leaves, seeds and pericarp of monkey fruit have shown to possess exceptional phytochemical, nutritional and valuable pharmacological properties. This fruit is capable of offering numerous inhibitory factors such as antibacterial, antitubercular, antiviral, antifungal, antiplatelet, antiarthritic, tyrosinase inhibitory and cytotoxicity. This review devotes the complete overview of pharmacological and bioactive components exclusively found in the monkey fruit and its parts. However, fruit exhibits appreciable properties, but they are still unknown as well as underutilized. The remarkable properties of plants and the modern approaches are needed for the treatment of chronic diseases, the development of drugs and functional food products, or for the improvement of properties existed ones.

Key words: *Artocarpus lakoocha*, Antibacterial, Anti-candial, Monkey fruit, Oxyresveratrole.

Fruits impart a significant role in the human diet since the ancient period and few of them have received particular attention. Nutritional values, phytochemical constituents and bioactive compounds of the fruits and vegetables have found the direct way of wellness awareness and human wellbeing (Kumar *et al.* 2019; Mastinu *et al.* 2019; Yamika *et al.* 2019). Researchers and scientists have now recognized the potential of *Artocarpus,* including nutritional, nutraceuticals and pharmacological properties and have been utilized in the field of food, pharmacological and new product development (Khalid *et al.* 2017) and are of great value in Asian countries and Thailand. However, being a miracle fruit, its acceptance in other countries, especially Africa and Western countries is still a challenge because of different food habits and culture. Plant-based medicines had significant importance in medical science since the ancient period. According to a report of WHO, more than 2/3rd population of the world in developing countries depends directly or indirectly on primary products or secondary metabolites of plants for their health ailments (Canter *et al.* 2005; Padaliya *et al.* 2020). The appreciable properties of monkey fruit are gaining popularity in both traditional and modern medical science (Ashitha *et al.* 2020).

Artocarpus genus comprises over 50 species (Drewes *et al.* 1992) and the fruit of this genus is enlisted under compound fruit, which derives from swollen flower heads. Monkey fruit tree bears male and female flowers separately on the same tree, which is orange-yellow and reddish, respectively. The appearance of ripe monkey fruit is pinkish-brownish with a yellow tinge and the shape is irregular round (5-12 cm) (Fig 1 and Table 1). A velvety surface characterizes it with few brown-black soft spikes. The texture of monkey fruit is comparable to jackfruit, fibrous and rubbery with 10-30 seeds, which may vary in size and shape relies upon the maturity of the fruits. The seeds of the fruit are covered with a thin white coat and latex in it. A mature tree can yield up to 80 kg/tree having fruit weight ranging from 200-350 g. The tree has a height of 6 to 9 m and its deciduous leaves are large and leathery. The compounds present in this fruit have a significant role in the treatment of stomach and liver disease (Joshee *et al.* 2002).

The exceptional properties of the Artocarpus genus have long been appreciated and are used as traditional healing ailments in several parts of the world, including South-East Asia, India, the Western part of Java and Indonesia. This genus has immense potential to offer numerous benefits as nutritious fruits and also yields good quality timber. The fruits of this genus are more economical in comparison to the other genus and are considered as part of nutrients and nutraceuticals. Traditionally, diarrhea, diabetes, tapeworm infection, skin problems, malaria fever, hypertension and other health-related issues have been

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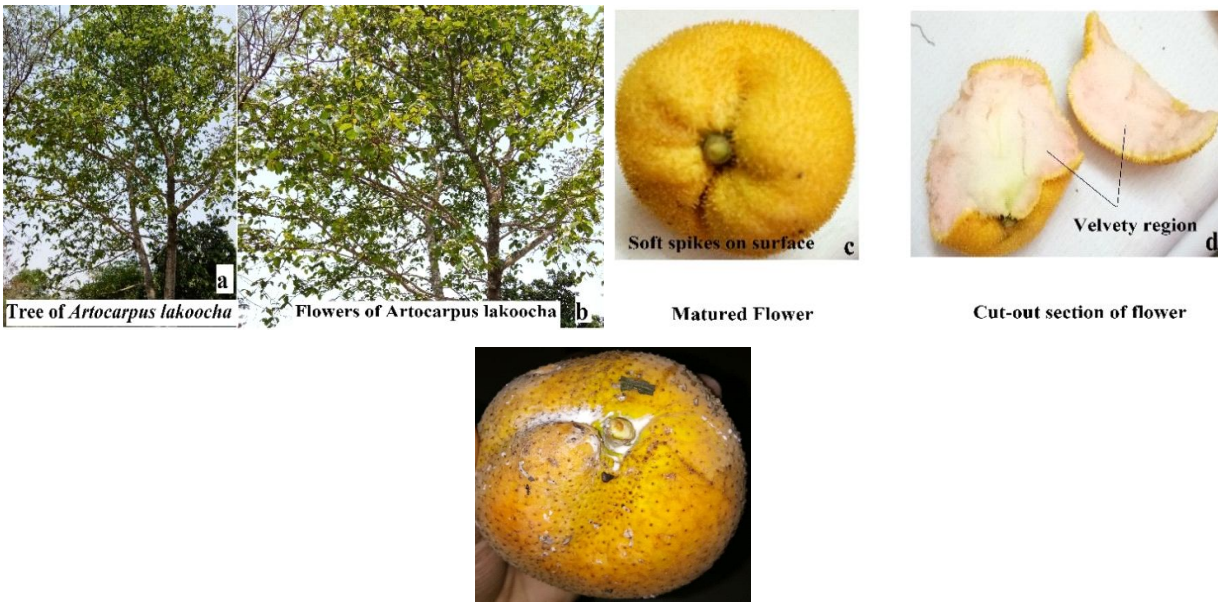


Fig 1a: *Artocarpus lakoocha* (Monkey fruit) Tree (a); Tree with flowers (b); Matured male flower (c); Cut-out section of male flower showing the pink-white velvet region (d); Ripen fruit. (Source: Images captured from the campus of Tezpur University, Assam, India).

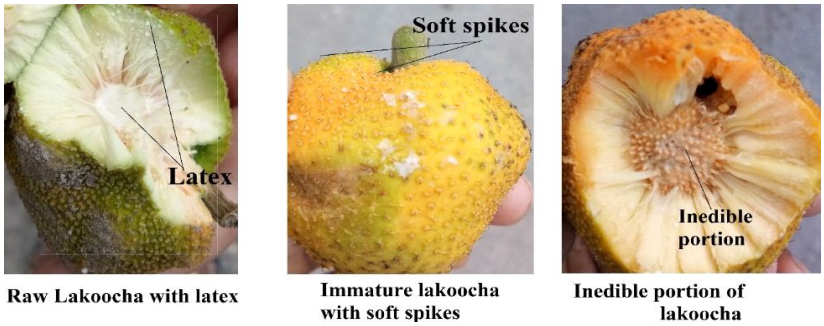


Fig 1b: Different characteristics features of Monkey fruit.
(Source: Images captured from the campus of Tezpur University, Assam, India).

cured successfully with the extract of the different parts of the plants. *Artocarpus lakoocha* is a member of the Moraceae family cultivated worldwide but believed to be originated in India. It is a tropical fruit that is mostly cultivated in Asian countries, including Sri Lanka, Singapore, Vietnam, Malaysia, Bhutan, Nepal, Thailand, Laos and Cambodia (Hossain *et al.* 2016). Though the Sub-Himalayan regions are best suited for its cultivation, it is also distributed in the subcontinent of India, including Uttar Pradesh, Jharkhand, Bihar, Assam, West Bengal, Tamil Nadu and Kerala. The unripe fruit, which has hot sensational character and sour taste, turn tangy-sweet upon ripening, which makes it unique than other fruits. In general, raw fruits have the potential to cause blood complaint, tridosa impotency and loss of appetite (Vanajakshi *et al.* 2016).

This review briefs the botanical, nutraceuticals and pharmacological properties of different parts of monkey fruit. Furthermore, seed, leaves, heartwood, fruit and pericarp of the fruit are focused on some *in-vivo* and *in-vitro* studies of pharmacology and the effect of metabolites are reviewed. Besides, pharmacological effects are detailed in the light of phytochemicals such as phenols, flavonoids, oxyresveratrol, stilbenoids and aryl benzofurans found in all parts of the plant.

Nutritional significance of monkey fruit

Monkey fruit possesses numerous health-promoting components like fibers, phytochemicals, Vitamin A and C, minerals, *etc*. (Table 2). This fruit can be taken as a staple diet and is a medicinal fruit. It was reported that fresh counterparts are a rich source of water (82%), fiber (2%) along with the appreciable amount of Vitamin A (423 IU) and Vitamin C (135 mg/100 g). Monkey fruit plays a vital role in the human diet due to the presence of the remarkable amount of vitamin C and β-carotene (Kekuda *et al.* 2012).

Minerals and vitamins

According to a report, monkey fruit has an appreciable amount of macro as well as microminerals including calcium (66.6 mg), magnesium (23.6 mg), potassium (350 mg), phosphorus (22.1 mg), iron (778 µg), zinc (3981 µg), copper

Table 1: Scientific classification of monkey fruit.

Classification	
Scientific Name	*Artocarpus lakoocha*
Common Name	Launch, Barhal, Dahu, Myauklok, Hat lom, Hat non
Synonym	*Artocarpus* cumingianavar, *Artocarpus* mollies Miq., *Artocarpus* ovatus Blanco
Family	Moraceae
Kingdom	Plantae
Division	Tracheophyta
Class	Magnoliophyta
Order	Rosales
Genus	Artocarpus
Species	Monkey fruit

(Source: Khare, 2007).

Table 2: Nutritional value of monkey fruit on the basis of fresh fruit.

Particular	
Water (%)	82.1
Carbohydrate (%)	13.3
Protein (%)	0.7
Lipid (%)	1.1
Fibre (%)	2.0
Vitamin A (IU)	423
Thiamin (µg %)	0.02
Riboflavin (µg %)	0.15
Niacin (µg %)	0.3
Ascorbic acid (mg/100g)	135
Potassium (mg/100g)	13.50
Magnesium (mg/100g)	23.60
Phosphorus (mg/100g)	22.10
Calcium (mg/100g)	66.60
Iron (mg/100g)	0.77
Zinc (mg/100g)	3.98
Manganese (mg/100g)	2.02
Copper (mg/100g)	7.97

(Source: Singh and Arora, 1978; Shajib *et al.* 2013).

(7974 µg), manganese (2025 µg) (Singh and Arora, 1978; Shajib *et al.* 2013).

Phytochemical profile

Monkey fruit exhibits a measurable amount of phytochemicals, including flavonoids, tannins, saponins, steroids, glycosides, triterpenoids, protein, phenolic compounds, resin and squalene. In a study, screening of secondary metabolites of monkey fruit was performed in different organic solvents such as petroleum ether, chloroform, ethanol and aqueous and revealed that the level of the alkaloid (high) and tannin (low) was significantly dependent on the altitude than the other metabolites (Krishnamurthy and Sarala, 2013). It is worthy of mentioning that monkey fruit represents medicinal properties, including antidiarrheal, anti-glycation, anti-aging, anti-inflammatory, analgesic, antibacterial, cytotoxic activity, insecticidal, pancreatic lipase inhibitory activity (Gautam and Patel, 2014). Moreover, it is also being stated that the incorporation of monkey fruit with goat milk and herbs can cure diseases like arthritic swelling, prevention of skin diseases, wound cleaning and dysentery (Vanajakshi *et al.* 2016). In another report, phytooxyresvertrol was obtained from monkey fruit studied for antioxidant and anti-glycation activities. The ethanolic extract of monkey fruit was first examined for anti-glycation activity. In particular, it was revealed that phytooxyresvertrol exhibited high anti-glycation activity (IC_{50}= 3.343 µg/mL), which was found bioequivalent to the OxyResvenox (reference standard). Also, the similarity of both compounds (isolated and standard) indicates that usefulness in an anti-aging product.

Furthermore, antioxidant activity was also found the high level in extract where total phenol content (12.671 mg gallic acid/g sample, 2,2 diphenyl-1- picrylhydrazyl (DPPH) (0.578 mg Vitamin C/g sample), ferric reducing antioxidant power (FRAP) (4.003 µmol Fe^{2+}/g samples) than oxyResvenox. Hence, it can be attributed that both free radicals and glycation products have an essential role in the onset of early cellular aging and also further clinical trials and other studies need to undertake for development or formulation of antiageing products based on the phytooxyresvertrol derived from monkey fruit (Povichit *et al*. 2010; Suwannalert *et al.* 2012). From the available literature, it is now clear that *Artocarpus* species are a plethoric source of the phenolic compound and offer numerous opportunities for the development of supplements, nutraceuticals, value-added products and other food-based application from edible fruit. In a report by Borah *et al.* (2017), they described the separation and antioxidant profile of resveratrol of monkey fruit. They observed the effect of solvent, time, temperature, the speed of agitation and solid to the solvent ratio on the extraction yield of resveratrol and antioxidant of extract. Furthermore, kinetics models were also applied to predict the extraction efficiency and obtained results showed that the process was dependent on the diffusional effect inside the sample. The extracted compound had shown potent radical scavenging activity with an IC_{50} value of 53.24 g/mL.

Pharmacological aspects of monkey fruit phytoextracts

Monkey fruit is reported to exhibit certain antibacterial properties, anthelmintic activity and cholesterol-lowering property (Table 3). It is believed to act as a tonic for the liver, blood and digestive tract (Joshee *et al.* 2002). In general, this fruit has a unique sweet-tangy taste and better-eating quality. Monkey fruit can be eaten fresh on ripening as nutritional food and raw parts of plants are often used in the preparation of curries, pickles, chutneys, sauce and drug development due to its medicinal value (Hossain *et al.* 2016; Jagtap and Bapat, 2010). In a study carried out by Gaikwad *et al.* (2012) reported that regular consumption of tropical fruits could decrease the threat of non-communicable diseases such as coronary heart disease, diabetes, cancer and neurodegenerative ailment. It is also rich in several phytochemicals and pharmacological components among

Table 3: Biological compounds present in different parts of monkey fruit.

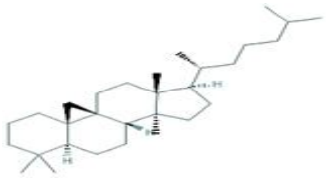
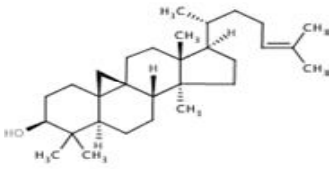
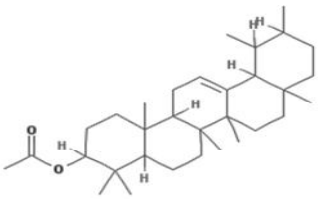
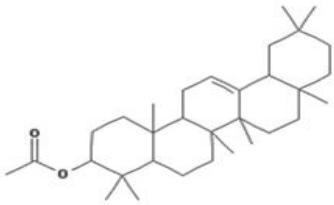
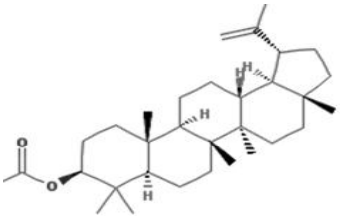
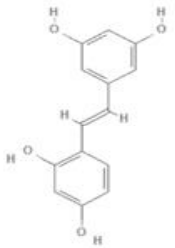
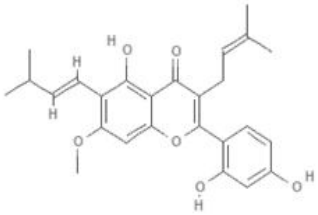
Parts of the tree	Biological compounds	Structure	Health benefits	References
	Cycloartenone		Antihyperglycemic, Hypolipidemic and Antiatherosclerotic	Kumar *et al.* (2010)
Fruit pericarp	Cycloartenol		Constituent of Titerpene alcohols of rice bran oil, act as first precursor for the synthesis of sterols and stanols.	Kumar *et al.* (2010)
	α- amyrin acetate		Anti-inflammatory activity, help in decreasing of mechanical sensitization and hypersensitivity and oedema, Radical scavenging, antihyperlipidemic	https://pubchem.ncbi.nlm.nih.gov/compound/293754; Okoye *et al.* (2014); Krishnan *et al.* (2014)
	β-amyrin acetate		Anti-inflammatory activity, help in decreasing of mechanical sensitization and hypersensitivity and oedema, Radical scavenging, antihyperlipidemic	https://pubchem.ncbi.nlm.nih.gov/compound/345510; Okoye *et al.* (2014); Krishnan *et al.* (2014)
Leaves	Lupeol acetate		Antioxidant activity, decreasing cholesterol, phospholipid and triglyceride levels and interruption cardiovascular disease	https://pubchem.ncbi.nlm.nih.gov/compound/92157; Han and Bakovic (2015)
	Oxyresveratrol		Significantly delayed the development of skin lesions, Antiviral, Cytotoxic, Anti-HSV, Anti-HIV	Chuanasa *et al.* (2008); Maneechai *et al.* (2009)
Seed	Artocarpion		Anticoagulant and antiplatelet aggregating properties; coagulant, mitogenic, antibacterial, antifungal and antitumor activities	Chowdhury *et al.* (1987); Wongkham *et al.* (1995)

Table 3: Continue....

Table 3: Continue....

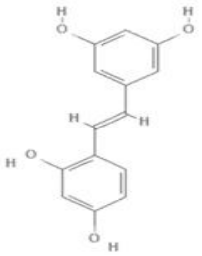
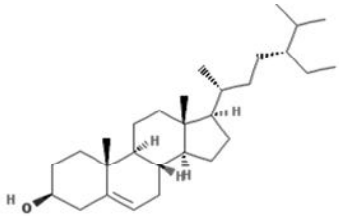
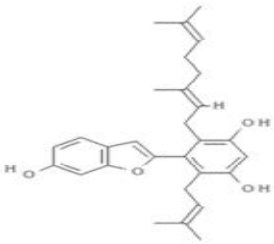
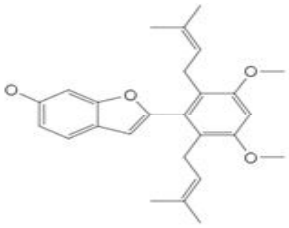
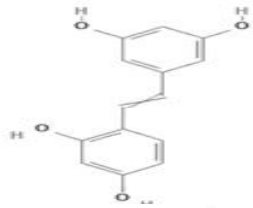
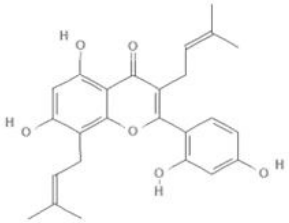
	Lectin	NA.	Carbohydrate (Mannose) binding and antigen detecting agent, inhibitor of Fusarium moniliforme and Saccharomyces cerevisiae	Mukesh *et al.* (2014)
Heartwood	Oxyresveratrol		Significantly delayed the development of skin lesions, Antiviral, Cytotoxic, Anti-HSV, Anti-HIV	Chuanasa *et al.* (2008); Maneechai *et al.* (2009)
	β –Sitosterol		Prevention and therapy for human cancer, induces apoptosis	National Center for Biotechnology Information.PubChem Compound Database; CID=222284, https://pubchem.ncbi.nlm.nih.gov/compound/222284
	Lakoochin B		Anti-mycobacterial activity, Cytotoxic against nasopharyngeal carcinoma and breast cancer	Puntumchai *et al.* (2004)
	Lakoochin A		Anti-mycobacterial activity, Cytotoxic against breast cancer	Puntumchai *et al.* (2004)
	Stilbene tetramethyl ether	NA.	NA.	Mongolsuk *et al.* (1957)
	2,4,3,5 tetrahydroxystilbene (THS)		Handling disease including lipid metabolism, memory disorder, inflammation of neuron, Alzheimer, Parkinson and other chronic diseases.	Mongolsuk *et al.* (1957)
	1.			

Table 3: Continue....

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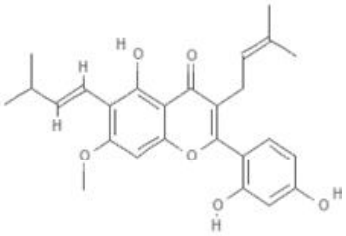
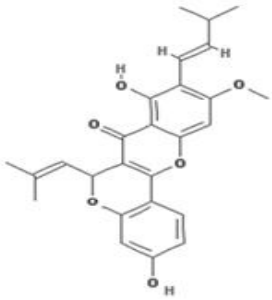
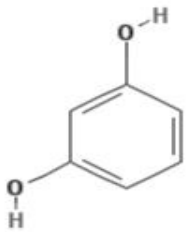
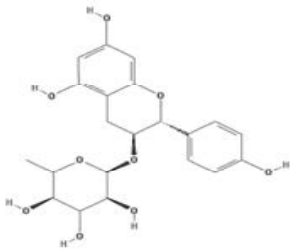
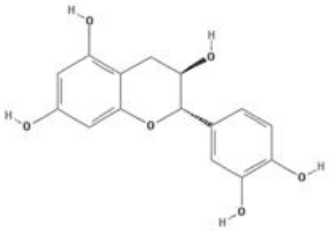
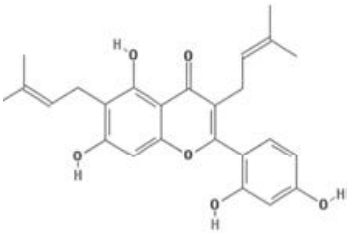
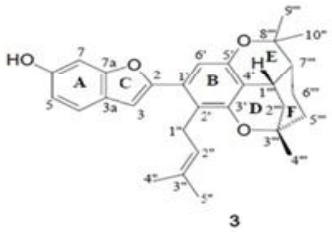
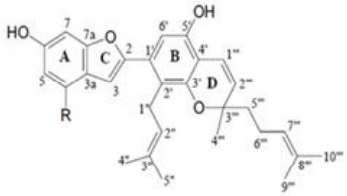
1. Norartocarpin 2. Artocarpin	 2.	1. Antioxidant and antityrosinase activity, Skin whitening agent 2. Cytotoxic for lung cancer cells	Ko *et al.* (2013); Tsai *et al.* (2017)
Cycloartocarpin		Significant antiplsmodial and antitubercular properties whereas relative cytotoxic activity for breast cancer and human oral epidermoid cancer	https://pubchem.ncbi.nlm.nih.gov/compound/5458462; Boonphong *et al.* (2007); Mukesh *et al.* (2014)
Resorcinol		Anticancer agents	https://pubchem.ncbi.nlm.nih.gov/compound/5054
Afzelechin 3-O-α-L -rhamnopyranoside		NA.	Afzelechin 3-O-alpha -L-rhamnopyranoside _ C21H24O9 - PubChem.htm
(+)-Catechin		Cancer prevention and strong antioxidant	https://pubchem.ncbi.nlm.nih.gov/compound/9064
Cudraflavone C		Significant antiplasmodial and antitubercular activities whereas relative cytotoxic activity for breast cancer and human oral epidermoid cancer	https://pubchem.ncbi.nlm.nih.gov/compound/5319924; Boonphong *et al.* (2007); Mukesh *et al.* (2014)

Table 3: Continue.....

Table 3: Continue.....

Root bark	Cycloartolakoochol	 3	Moderate activity against herpes simplex virus (HSV-1 and 2)	Sritularak, *et al.* (2010)
	1. Artolakoochol 2. 4-hydroxyartola koochol	 1 R = H 2 R = OH	Both compounds have inhibitory activity against acetylcholinesterase and butyrylcholinesterase	Sritularak, *et al.* (2010); Namdaung Sritularak, *et al.* (2017)

that oxyresveratrol is an important component which also exhibits nutraceuticals properties and is investigated for its therapeutic properties and mechanism of action on cutaneous herpes simplex virus (HSV) infection in mice. Oxyresveratrol exhibited more potential for inhibition (150 fold) in comparison to resveratrol (Shin *et al.* 1998). In another report, the fasciolicidal effect of crude extract of monkey fruit was investigated. For the determination of the potential effect of the extract, the *Fasciola gigantica* parasite was incubated in the medium of M-199 (1 g/mL of the extract and tricarbendazole) at the concentration of 80 µg/mL and 175 µg/mL using relative motility assay. The effect of the extract was found to be pronounced at the 12 h exposure, followed by 6 h and 3 h. The fasciolicidal effect was observed at the concentration of 175 µg/mL at 12 h, whereas marked decreased contraction and reduced parasite motility was seen at 6 h and 3 h. Furthermore, 250 µg/mL and 500 µg/mL have shown static pattern at 12 h and 24 h followed by the rapid reduction in RM values while 750 µg/mL and 1000 µg/mL concentrations showed remarked decrease in RM values and death of parasite occurred between 12-24 h incubation. So from the above discussion, it is cleared the varied concentration of extract exhibited inhibitory effect, reduced motility and death of parasite and all these parameters depend on the concentration of extract (Saowakon *et al.* 2009). Fruit extract was also investigated for anti-aging, antioxidant activity, toxicity levels. The quantitative assessment of toxic doses of the extract was determined using DNA nicking and bacterial reverse mutation. The obtained results have revealed that POV possesses the anti-aging property and 25 µg/mL concentration represented strong anti-DNA nicking activity (Povichit *et al.* 2010; Suwannalert *et al.* 2012). The extract of pericarp was used to assess the antibacterial activity through agar well diffusion method and antioxidant activity using DPPH free radical scavenging assay. The antibacterial activity was found to be more resistant in *Klebsiella pneumonia* and *Pseudomonas aeruginosa* than *Staphylococcus aureus*. The anthelmintic property was found to be dose-dependent property (Kumar *et al*. 2010). In another research, monkey fruit was used for anti-candial and anti-biofilm activity through methods of agar well diffusion method as well as 3-[4, 5- dimethyl-2-thiazolyl]-2, 5-diphenyl-2H-tetrazolium-bromide (MTT) assay. The result showed that minimum inhibitory concentration (MIC) and minimum fungicidal concentration (MFC) against *candida* strains were 0.05 to 3.12 mg/mL and 0.10 to 25 mg/mL respectively, whereas extract has strong anti-biofilm property. Moreover, killing activity assay was found to be dependent on time and extract concentration. It was also concluded that extract could be used against *candida* infection and secondary dermatitis (Senapong *et al.* 2014). In a report, Teanpaisan *et al.* (2014) evaluated the antibiofilm activity and the antimicrobial activity of the extract. It was prepared from the dried powder of fruit and investigated against oral pathogenic strains employing minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC) and time-kill assay. The result revealed that extract possessed inhibitory activity against both gram-negative strains and gram-positive strains. MIC and MBC of monkey fruit extract were ranging from 0.10-0.39 mg/mL and 0.10-3.12 mg/mL, respectively, whereas killing activity (MTT) was found to be dose and time-dependent. These findings suggested that fruit extract exhibits the appreciable antibiofilm and antimicrobial activities that may be used against oral pathogens. With such tremendous properties, it can be easily applied in the mouth freshener, mouthwash and toothpaste-like products. Gautam *et al.* (2016) had studied the estrogenic activity of the fruit extract by using female Sprague-Dawley rats. To study the estrogenic activity of fruit extract, both the ovaries were removed and a different dose of extract has been given through the oral route depending upon the body weight of the animal. It was found that the hydro-alcoholic extract of fruit had shown remarkable

estrogenic activity, which was confirmed by histopathological reports and biochemical parameters.

Another study was executed to evaluate the anthelmintic activity of the extract from monkey fruit (Traditional name: Puag-Haad (PH) against the parasite, the rumen fluke- *Paramphistomum cervi* that was incubated in the M199 medium consisting either extract albendazole (ABZ) or PH at concentrations 250, 500, 750, 1,000, 2,000 µg/mL, for durations of 3, 6, 12 and 24 h. The efficacy of the PH or ABZ was assessed using relative motility (RM) assay and was determined based on comparing the spontaneous movement loss and death of the trematodes of the treated and control groups. PH expressed potential in killing the trematodes and its maximum efficacy was observed at 2,000 µg/mL, which was higher than ABZ and had significantly different SI. and RM values than ABZ ($p<0.05$). SEM observations showed PH causing more damage to the tegument of *P. cervi* than ABZ does. The severity and rapidity of these damages were directly related to the time of incubation and concentration of the crude extract. These SEM-based study results established the anthelmintic activity of PH against *P. cervi* (Preyavichyapugdee *et al.* 2017).

The antihyperlipidaemic effect in the high-cholesterol diet (HCD)-fed rat model was looked into in an ethanol extract of *Ramulus mori* containing a high concentration of oxyresveratrol (ERMO). With the application of quantitative real-time reverse transcription-polymerase chain reaction and western blot analysis techniques, cholesterol metabolism-related genes and proteins such as low-density lipoprotein receptor (LDLR), lecithin cholesterol acyltransferase (LCAT), 3-hydroxy-3-methylglutaryl coenzyme A reductase (HMGCR), cholesterol 7-α-hydroxylase (CYP7A1) and acyl-coenzyme A cholesterol acyltransferase-2 (ACAT2) were examined. ERMO-treated HCD-fed rats showed a decrease in body and liver weights along with a reduction in serum lipid levels, atherogenic index (AI) and coronary artery risk index (CRI). The above studies of Hwang *et al.* (2015), therefore, depict ERMO as a potentially potent functional food for preventing hyperlipidemia. In a study carried out by He *et al.* (2017), an oxyresveratrol (Oxy) microemulsion (ME) with improved solubility and stability of Oxy was prepared to investigate its antibrowning effects on fresh-cut lotus root slices compared with 4-hexylresorcinol. Also, OxyME added with Ascorbic acid (VC) and VC and calcium chloride were checked for their antibrowning effects on fresh-cut lotus root slices. These results are, therefore, an indication for Oxy + VCME to be a suitable antibrowning agent for fresh-cut vegetables.

Botanical aspects of Monkey fruit

In a report of Kekuda *et al.* (2012), an extract of monkey fruit was probed for anti-cariogenic, pancreatic lipase inhibitory and cytotoxic activity against 12 isolates of mutans *Streptococci* whereas pancreatic lipase activity was tested against chicken pancreatic lipase. The outcome showed that the minimum concentration of the extract was inhibitory against cariogenic bacteria in comparison to the standard antibiotic. In the case of pancreatic lipase, inhibition was dose-dependent and the highest inhibition (82.49%) was observed at the concentration of 1000 mg/mL, whereas the pronounced effect was seen in cytotoxicity with LC_{50} of 452.49 µg/mL. Prashanthi *et al.* (2016) studied the larvicidal and pharmacognostic activity of leaves and fruits extracts against late 3rd or early 4th instar larvae of *Aedes aegypti, Anopheles stephensi and Culex quinquefasciatus*. The ethanolic extract of monkey fruit was subjected to the standardization of crude drugs. All three larvae were reared under the same condition and fed the powdered mixture of yeast and dog biscuit (1:3). After the pupae stage, all were placed into the surface of the water and transferred to a screen cage where further development of larvae can occur. All the feeding of females was carried out through a membrane feeding apparatus. The late 3rd stage and early 4th stage instar larvae colonies were examined for larvicidal activity. It was revealed that LC_{50} of ethanolic extract of fruit and leaves for larvicidal activity was 241.36, 624.88, 1162.86 and 1180.95, 1286.69, 1398.69 µg/mL respectively.

Monkey fruit leaves also exhibits appreciable pharmacological properties and medicinal properties. In a study, 24 compounds were extracted from leaves and investigated for anti-herpes simplex virus activity (HSV-1 and HSV-2). The result has revealed that flavonoids in the leaves, including ovalifolin, pongol methyl ether and millettocalyxin A and shown moderate anti-HSV activity. In a study, cytotoxicity activity, anti-inflammatory activity and analgesic property of the leaves were assessed employing the Brine Shrimp lethality bioassay method, Carrageenan-induced paw edema test in mice and Acetic acid-induced writhing test respectively. Also, CNS depressant and antidiarrheal activities were investigated of the methanolic extract of leaves. The result demonstrated that the LC_{50} value of leaves in brine shrimp lethality bioassay was 2.83 µg/mL, while remarkable anti-inflammatory effect and analgesic activities were found at 200 mg/kg concentration of methanolic extract of leaves. The CNS depressant activity was observed to be time-dependent at 60, 90 and 120 min in both tests (open field and hole cross) (Nesa *et al.* 2015).

The bark of monkey fruit has shown to possess exceptional phytochemical and pharmacological components, including β-sitosterol, artocarpin, norcycloartocarpin, norartocarpin, cycloartocarpin and resorcinol. β-sitosterol might have the prospective for prevention in human cancer and is the chief phytosterol found in plants. Phytosterols carry a double bond and hence are vulnerable to oxidation. Anti-atherogenic and anti-carcinogenic properties distinguish them. Compared to placebo, β-sitosterol improved urinary flow measures as well as the symptoms. It has been helpful for hyperandrogenic postmenopausal women as it alters the serum β-sitosterol concentration. These observations indicate that β-sitosterol can be used as a biomarker of exposure in observational studies and

also be a compliance indicator in dietary intervention studies for human cancer prevention. β-sitosterol initiates apoptosis and activates as key caspases in MDA-MB-231 human breast cancer cells (Gautam and Patel, 2014).

The active ingredient oxyresveratrol has shown inhibitory activity against mushroom tyrosinase, whereas melanin reducing efficacy was measured using Mexameter every week. The melanin reducing efficacy was calculated as a % reduction in melanin content relative to the initial melanin value (% whitening). It was found that monkey fruit bark giving effective and remarked whiteness in a short period in comparison to the other agents such as kojic acid and licorice extract. Thus, it is worth mentioning that oil in water emulsion-based formulation enhanced the whitening effects and monkey fruit bark has proven that it exhibits promising whitening property (Tengamnuay *et al.* 2006). Pandey and Bhatnagar (2009) reported the antibacterial activity of monkey fruit bark. The result showed that at minimum inhibitory extract concentration, no growth of Proteus mirabilis AM/98, *E. coli* MTCC 1568, *Shigella soneii* 2, *Bacillus pumilus* 8241, *Bacillus subtelis*, ATCC 6633 was observed. Recent studies have revealed the significant and appreciable properties of oxyresveratrol, found in the heartwood of monkey fruit and could be a possible medicine for the treatment of chronic disease, skin ailments and to treat a headache. It was assessed for antioxidant activity, anti-oxidative stress and phenol content using the ethanol extraction method. The antioxidant property was assessed by 2,2'-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid) (ABTS) decolorization, DPPH radical and H_2O_2 scavenging assay whereas anti-oxidative stress assessed utilizing AAPH-oxidized blood and glutathione (GSH) and malondialdehyde (MDA). It was found that antioxidant activities such as ABTS, DPPH and H_2O_2 scavenging were 128.30±0.13, 55.86±0.01 and 463.49±0.01 µmol Trolox/g, while a significant amount of total phenols, flavonoids and tannins were 325.63±2.99 mg GE, 521.98±0.01 mg QE and 124.03±0.46 g TE respectively, in one gram of ethanolic extract of monkey fruit. Also, MDA inhibition and improved GSH level were observed at a low concentration of extract and the toxicity effect was dependent on the high concentration of extract (Singhatong *et al.* 2010). Paug-Haad (Brown powder) is prepared from wood chips of monkey fruit and been used as a folk medicine for the tapeworm infection in Thailand. Paug-haad contains a significant amount of Oxyresveratrol in the range of 780.1-837.5 mg/g (Maneechai *et al.* 2009). In a study, Sritularak *et al.* (2010) investigated a new compound, 5, 7, 2',4'-tetrahydroxy-6-geranyl-3-prenylflavone in the methanolic extract of the monkey fruit bark. Besides, three known flavonoids, including (+)-afzelechin-3-O-α-L-rhamnopyranoside, (+)-catechin and cudraflavone C were also found. These extracted compounds were further studied for inhibitory activity against HSV-1 and HSV-2, employing the inactivation method. The activity of extracted compounds such as 5, 7, 2',4'-tetrahydroxy-6-geranyl-3-prenylflavone and cudraflavone C against HSV was found to be effective at some extent but (+)-afzelechin-3-O-α-L-rhamnopyranoside and (+)-catechin were ineffective against HSV types. In the other report, the TLC-densitometric method was established to quantify the oxyresveratrol in the aqueous and ethanolic extract of heartwood. Oxyresveratrol content in the heartwood extract was analyzed using the validated TLC-densitometric method. Result represented that ethanolic extract exhibited significant content (7.66% w/w dry weight) of oxyresveratrol than aqueous extract (6.80% w/w dry weight). It was observed that the TLC-densitometric method gives an accurate result, easy to use, simple and could be used to determine the level of oxyresveratrol (Rojsanga and Sithisarn, 2016).

In vitro screening for acetylcholinesterase (AChE) and butyrylcholinesterase (BChE) inhibitory activities of the monkey fruit root-bark extracts revealed interesting results. Bioassay-guided fractionation resulted in the isolation of two new and six known 2- aryl benzofurans, along with one stilbenoid and one flavonoid. Compound 2-aryl benzofurans exhibited more potent AChE inhibitory activity (IC_{50} =0.87–1.10 µM) than the reference drug, galantamine. Compounds 2-aryl benzofurans and, along with oxyresveratrol, displayed more significant BChE inhibition than the standard drug. The preferential inhibition of BChE over AChE indicated that it also showed a promising dual AChE and BChE inhibitor. The synthetic mono-methylated analogs 2-aryl benzofuran methylated derivatives were found to be suitable BChE inhibitors with IC_{50} values ranging between 0.31 and 1.11 µM (Namdaung *et al.* 2017).

Food and non-food applications

The ripened fruits are eaten fresh while raw fruits and the spike of male flower, preferred for the preparation of delicious sauce, pickle and curry or can be eaten boiled, steamed and roasted. The raw monkey fruit is mainly harvested to prepare pickles in the same procedure of mango and chili pickles. However, ripe fruits are also used in the preparation of sauces, beverages and chutney in the few parts of North India. Also, tribal parts of Eastern India use monkey fruit extract or whole with goat milk to prepare medicine to combat diarrhea and other stomach disorder (Vanajakshi *et al.* 2016). In a report by Krishnamurthy and Sarla (2013), value-added products were developed from monkey fruit such as powder, juice, sambhar, pappad, hulli and some local dishes, including fish curry and chicken curry. The protocols of local dishes were developed after interviews, personal intervention and involvement during the development of products in the few regions of Central Western Ghats.

Moreover, the produced powder from monkey fruit as an alternative of tamarind to prepare curry and other sour items. Monkey fruit pulp was used to prepare juice with cardamom and black pepper. Though products have been developed, they are not commercialized and the availability of fruit throughout the year is still a challenge. Being a miracle fruit with appreciable properties like health-boosting components, vital minerals and other pharmacological properties, still, no step is taken in the exploitation of this

underutilized fruit for product development as well as wellness of humankind. Very few skin toner, skin whitening, mouthwash and other herbal soaps are the name of commercialized products of monkey fruit. Despite the fruits, timber and woods are often used for the furniture, boats, cabinet. In Nepal and Himalaya region, monkey fruit leaves are used as fodder for animals due to its valuable properties and also used for food preparation for lactating animals. Moreover, tree and fruit exude sticky latex, which has multiple uses. It has a significant source of firewood in rural areas. In general, farmers prefer to cultivate because of the slow growth pattern of monkey fruit and most of the time, cultivated with a mixed cropping system.

CONCLUSION

The present review devotes the importance of *Artocarpus lakoocha* as fruit and its appreciable nutritional, nutraceuticals, pharmacological and medicinal properties for human care besides its edible characteristics. Its potent properties quench the scientist, manufacturer and consumer to utilize the specific components of fruit in the processing, preservation, handling, synthesis, development, or to improve the quality of food products, oral products, cosmetics and medicines. This fresh fruit is the dome of the functional food and beverage. The crude extract of the fruit, methanolic extract of leaves and heartwood of fruit, as reviewed here have been found to have potent antibacterial, anthelmintic, antimycotic, anti-skin aging and tyrosinase inhibitory activity, which are scientifically proven and essential in the treatment of chronic disease including breast cancer, coronary heart disease and other chronic infections (Gautam and Patel, 2014; Hossain *et al.* 2016). The different phytochemicals and secondary metabolites extracted from the heartwood have shown exceptional activities against HSV and HIV (Namdaung *et al.* 2017) HSV-1 and HSV-2. It has also shown to possess remarked that reducing properties, antioxidant properties and H_2O_2 scavenging activity (Chuanasa *et al.* 2008; Singhatong *et al.* 2010). Recent studies have revealed the significant and considerable properties of oxyresveratrol found in the heartwood and could be a possible medicine for the treatment of chronic disease, skin ailments and to treat a headache (Orwa *et al.* 2009). However, there is no significant evidence to support the *in vivo* interaction of the phytochemical and pharmacological compounds. Therefore, there is a need to study the *in vivo* interaction, toxicity at a different level of the pharmacological compounds. At the same time, development of novel, useful products and utilization of properties in the supplements so that can fight against the dreaded disease.

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