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Phytochemistry, nutritional and pharmacological properties of *Artocarpus heterophyllus* Lam (jackfruit): A review

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ABSTRACT

Artocarpus heterophyllus Lam, commonly known as the jackfruit tree and belonging to the family Moraceae, is an exotic tree originally native to the Western Ghats of India. The fruits are of dietary use and are an important source of carbohydrate, protein, fat, minerals and vitamins. The heart wood is a very durable timber and is used in the preparation of furniture. The bark, roots, leaves, and fruit 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 jackfruit possesses antioxidant, anti-inflammatory, antibacterial, anticariogenic, antifungal, antineoplastic, hypoglycemic, 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 useful compounds like the flavonoids, sterols and prenylflavones which may have been responsible for the various pharmacological properties. The present paper reviews the nutritional value, culinary uses, the phytochemical compounds, traditional usage and validated pharmacological properties of jackfruit.

1. Introduction

Artocarpus heterophyllus Lam, (Fig. 1) belonging to the family Moraceae (mulberry family) and popularly known as jackfruit or Ceylon Jack tree, is one of the important and commonly found trees in the home gardens of India and Bangladesh (Anonymous, 2006; Bose, 1985; Elevitch & Manner, 2006; Haq, 2006; Narasimham, 1990; Prakash, Kumar, Mishra, & Gupta, 2009; Reddy, Patil, Shashikumar, & Govindaraju, 2004; Samaddar, 1985). The term jackfruit is derived from the Portuguese word Jaca, which in turn is adopted from the word "Chakka" of Malayalam (a regional Indian language) (Anonymous, 2006; Pradeepkumar & Kumar, 2008). Jackfruit tree produces the largest tree-borne fruits in the world and a mature tree can yield anywhere between ten to two hundred fruits (Alagiapillai, Kuttalam, Subramanian, & Jayasekhar, 1996; Haq, 2006; Narasimham, 1990; Reddy et al., 2004; Samaddar, 1985). At times these fruits which contain numerous hard cone-like points may be as heavy as 45 kg in weight, and up to 36 in. in length and 20 in. in diameter (Prakash et al., 2009). Due to these characteristics in the ancient Indian language of Sanskrit jackfruit is referred to as Atibruhatphala (Ati = very, bruhat = big, phala = fruit) and Kantaphala (Kanta = thorny, phala = fruit) (Anonymous, 2006; Haq, 2006; Prakash et al., 2009; Samaddar, 1985). The other colloquial names used in various Indian languages and in other countries are enlisted in Table 1.

In India, the trees are found distributed continuously in places where rainfall is high and, sporadically in areas where it is low (Muralidharan, Ganapathy, Velayudhan, & Amalraj, 1997; Narasimham, 1990; Singh, Krishnamurthy, & Katyal, 1963). Jackfruit is a popular food and ranks third in total annual production after mango and banana in South India (Morton, 1987). It is the national fruit of Bangladesh and is considered to be an extremely important tree by the natives (Bose, 1985). The plant is frequently referred to as 'poor man's food' as it is cheap and

Abbreviations: ABTS, 2, 2′-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid); ALT, Alanine aminotransferase; AST, Aspartate aminotransferase; COX-2, Cyclooxygenase-2; DPPH, 1,1-diphenyl-2-picrylhydrazyl; EDTA, Ethylenediaminetetraacetic acid; FRAP, Ferric Reducing Antioxidant Power; iNOS, Inducible nitric oxide synthase; LPS, Lipopolysaccharides; MIC, Minimum inhibitory concentration; DMPD, N-dimethyl-p-phenylendiamine; NO, Nitric oxide; PGE2, Prostaglandin E2.

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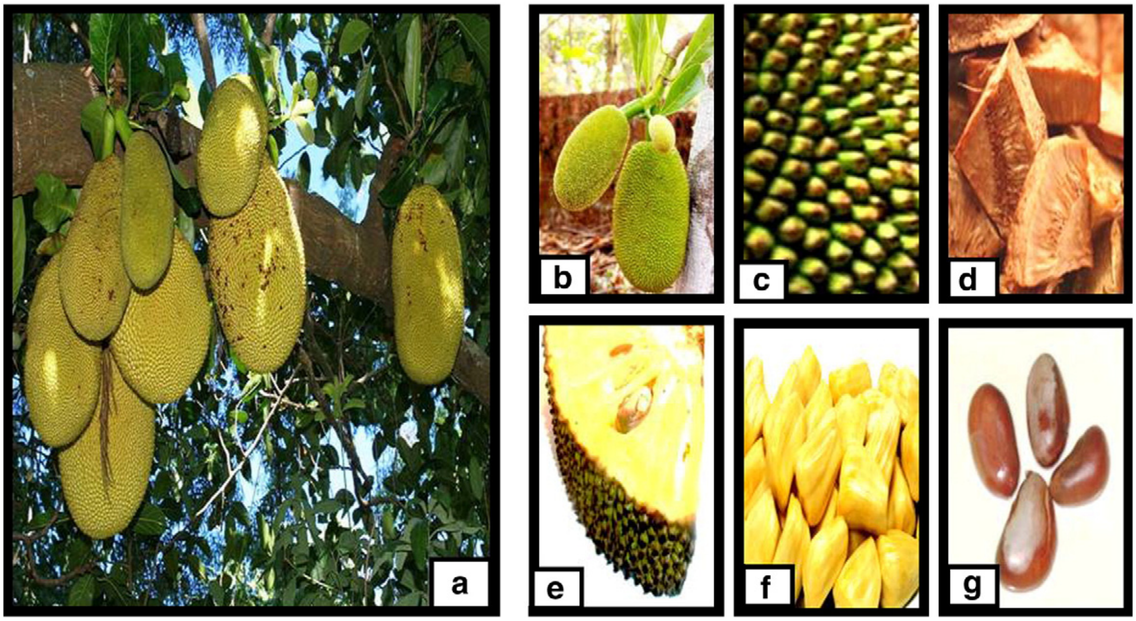

Fig. 1. Jackfruit tree with the fruits of different sizes (a); jackfruit tree with the fruits in different stages of fruiting (b); the jackfruit with conical carpel apices (c); raw jackfruit pieces used for curries (d); the interior of a ripe jackfruit with the seed (e); the ripe eatable pulp of jackfruit (f); and the jackfruit seed (g).
Pictures a, b, e, and f courtesy from the Wikipedia collection.

plentiful during the summer season when food is scarce (Jagtap, Panaskar, & Bapat, 2010; Rahman, Huq, Mian, & Chesson, 1995; Samaddar, 1985). Jackfruit is a prized food in regions where it does not grow, but is unfortunately considered to be trivial in areas where it is found in abundance (Jagtap et al., 2010; Morton, 1987). The jackfruit tree has dietary, medicinal and economic use and the details are listed in Table 2.

2. History and distribution

Historical reports suggest that jackfruit tree is supposed to have originated in the rain forests of the Western Ghats in the Southwestern part of India. However with time, the trees have been introduced to other parts of India and tropical regions of the world. Today, the trees are found widely growing in Bangladesh, Malaysia, Burma, Sri Lanka, Indonesia, Philippines, in the Caribbean islands, in the evergreen forest zone of West Africa, in northern Australia, in parts of USA (Florida and California), Brazil, Puerto Rico, Pacific Islands Palau, Yap, Pohnpei, Nauru, Tabiteuea in Kiribati, Samoa, and other islands (Azad, Jones, & Haq, 2007; Bose, 1985; Burkill, 1997; Elevitch & Manner, 2006; Haq, 2006; Narasimham, 1990; Rahman et al., 1995; Samaddar, 1985).

3. Botanical aspects

Jack fruit tree is monoecious and both male and female inflorescences are found on the same tree (Bose, 1985; Morton, 1987). From the time of successful pollination, the complete process of fruit development takes about three to seven months. The time of fruiting varies in different countries and is enlisted in Table 3. The fruit consists mainly of three regions, the fruit axis, the persistent perianth and the true fruit. 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 (Prakash et al., 2009).

The most important and bulk of the fruit is the perianth (Prakash et al., 2009). It is made up of three regions 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 (Prakash et al., 2009). The ripe fruit (arils or flesh) contain well flavored yellow sweet bulbs and seeds (Prakash et al., 2009). Each fruit is oblong cylindrical in shape and is 30–40 cm in length. When ripe they are acid to sweetish to taste. Except for the thorny outer bark all parts of the fruit are edible (Anonymous, 1985; Prakash et al., 2009).

4. Varieties of jackfruit

As fertilization is by cross-pollination and propagation, mostly through seeds, numerous types of jackfruit are observed. This when categorized according to the phenotypic and organoleptic characteristics (like the size of the tree, structure of the leaf, fruit form, age of fruit bearing, quality of the fruit pulp, their size, shape, density of spines, color, texture, odor, quality and period of maturity) has accounted to a great variety of fruits (Elevitch & Manner, 2006; Haq, 2006). Depending on the variety, the bulb can be cream, white, light yellow, yellow, deep yellow, lemon yellow light saffron, saffron, deep saffron or orange in color (Jagadeesh et al., 2007). When fully ripe, the intact jackfruit emits a strong disagreeable odor, resembling that of decayed onions, while the pulp of the opened fruit smells of pineapple and banana (Anonymous, 1985; Elevitch & Manner, 2006; Haq, 2006; Prakash et al., 2009).

Depending on the consistency of the fruit and its pulp two types of morphotypes are recognized, one that has fruits with small, fibrous, soft and spongy flakes with very sweet carpels and good aroma, while the other variety is crunchy, though not as sweet, with crisp carpels (Elevitch & Manner, 2006; Odoemelam, 2005; Shyamalamma, Chandra, Hegde, & Naryanswamy, 2008). These types are apparently known in different areas by various local names. In Thailand they are known as *Kha-nun nang* (firm) and *Kha-nun lamoud* (soft); in Srilanka as *Vela* (soft) and *Varaka* or *Waraka* (firm); in Malayalam as *Koozha chakka* (soft) and *Koozha pazham* (firm); and in Konkani as tulvo (soft) and barko (firm) (Morton, 1987). Some of the famous varieties of jackfruit growing in different parts of the world are enlisted in Table 4.

5. Proximate composition

Multiple studies carried out in the past have shown that the proximate and phytochemical composition varies with the variety of

Table 1
The different vernacular names of *Artocarpus heterophyllus* in India and other countries. Alagiapillai et al., 1996; Elevitch & Manner, 2006; Haq, 2006; Narasimham, 1990; Prakash et al., 2009; Reddy et al., 2004.

Language	Names
Scientific names	*Artocarpus heterophyllus* Lam, *Artocarpus brasiliensis* Gomez., *Artocarpus heterophylla* Lam., *Artocarpus maxima* Blanco, *Artocarpus philippensis* Lam., *Polyphema jaca* Lour., *Soccus arboreus* major Rumph., *Artocaipus tegra* (Thunb.), *Artocarpus tegrifolia* L.f., *Artocarpus tegrifolius* auct., *Artocarpus teger* auct
Names in various Indian languages	
Sanskrit	Panasa, Atibruhatphala or Kantaphal
Hindi	Kathal or Panas
Bengali	Kanthal
Bhojpuri	Katahar
Guajarati	Phanas
Kannada	Halasu
Konkani	Phanas
Malayalam	Chakka
Marathi	Phanas
Oriya	Panasa or Kantaphal
Tamil	Palaa
Telugu	Panasa
Tulu	Pelakai, Gujje or Kujje
Names in other countries and languages	
Brazil	Jaca
Cambodia	Khnor or Khnaôr
Caribbean countries	Katahar
Cebuano	Nangka
Chese	Boluomi
China	Po-lo-mi
Chinese	Bōluómì
Columbia	Jaqueira
Cuba	Rima
English	Jackfruit
Filipo	langka, nancas
German	Jackfrutchbaum
Guyana	Cartahar
Indonesia	Nangka, Nongka, Lamasa, Malasa
Indonesian	Nangka
Iranian	Derakhte Nan
Javanese	nangka, nongko
Kapampangan	Yangka
Korean	Baramil
Laos	mak mi or may mi
Malagasy	Finésy
Malay	Nangka
Malaysia	Nangka, Tsjaka, Jaka
Myanmar	Peignai
Nepali	Katahar, Rookh-Katahar
Nicaragua	Casta
Papua New Guinea	Kapiak
Philippes	Langka or Nangka
Portuguese	Jaca
Spanish	Fruta de Jack, Jaka, buen pan, jaca, pan de fruta, rima
Singhalese	Jak, Palaamaram
Swahili	Fenesi
Tagalog	Langka
Thailand	Khanun, Makmi, Banun, banun, makmi Khanoon, Kanoon
USA: Puerto Rico	Jaca
Vietnamese	Mit

jackfruit. Studies have also shown that depending on the variety of the jackfruit, the concentration of carbohydrates and proteins in the seeds vary although they are from the same region. Recently, Chrips, Balasingh, and Kingston (2008) evaluated the protein and carbohydrate concentration of different varieties of jackfruit seed isolated from the fruits growing in Kanyakumari district of India. The authors observed that the protein concentration was as follows for the following varieties of jackfruit seed: Nettadivarika (6.8%) > Mondan (6.5%) > Venkanni (6.0%) > Valayan (5.9%) > Chemparethy (5.3%); while that for the carbohydrate was Mondan (42.8%) > Valayan (42.5%) > Nettadivarika (40.3%) > Venkanni (40.2%) > Chemparethy (37.4%) (Chrips et al., 2008). Variation in the levels of fats, minerals and vitamins has also been reported and is represented in Table 5. Additionally, when compared to other tropical fruits like orange, banana, mango, pineapple papaya and ber, jackfruit pulp and seeds quantitatively contains more protein, calcium, iron and Thiamine and are a good source for these essential nutrients (Bhatia, Siddapa, & Lal, 1955; Haq, 2006; Kumar, Singh, Abidi, Upadhyay, & Singh, 1988).

6. Phytochemical composition of jackfruit

Studies have shown that jackfruit contains many classes of compounds such as carotenoids, flavanoids, volatile acids sterols and tannins, and that their concentration changes with the variety (Arung, Shimizu, & Kondo, 2007; Chandrika, Jansz, & Warnasuriya, 2004; Lu & Lin, 1993; Ong et al., 2006; Venkataraman, 2001; Wong, Lim, & Wong, 1992). Carotenoids are known to impart yellowish-red color to many foods and their ratio is supposed to render the jackfruit the various yellow to orange shades of color (Jagdeesh, Reddy, Basavraj, Swamy, & Hegde, 2010). The kernel is reported to contain β-carotene, α-carotene, β-zeacarotene, α-zeacarotene and β-carotene-5,6α-epoxide and a dicarboxylic carotenoid and crocetin (Chandrika et al., 2004). Recent studies have also shown that the key carotenoids present in jackfruit are all-*trans*-lutein (24–44%), all-*trans*-β-carotene (24–30%), all-*trans*-neoxanthin (4–19%), 9-*cis*-neoxanthin (4–9%) and 9-*cis*-violaxanthin (4–10%). However, both qualitative and quantitative differences were seen in the fruits harvested from different varieties of trees (Faria, Rosso, & Mercadante, 2009). Wong et al. (1992) investigated the steam-distilled volatile constituents from jackfruit grown in Malaysia and observed that the jackfruit contained forty five volatile components of which thirty two were novel. The esters, which impart the desired flavor to the fruit were found in high concentrations (31.9%) (Wong et al., 1992).

Jackfruit plant is also reported to contain artocarpine, artocarpetin, artocarpetin A, cycloheterophyllin, artonins A, artonins B, morin, dihydromorin, oxydihydroartocarpesin, cynomacurin, artocarpin, isoartocarpin, cyloartocarpin, artocarpesin, artocarpetin, norartocarpetin, cycloartinone and artocarpanone (Ko, Cheng, Lin, & Teng, 1998; Pavanasasivam, Uvais, & Sultanbawa, 1973; Prakash et al., 2009; Rao, Varadan, & Venkataraman, 1973). The heartwood is reported to contain brosimone, cudraflavone B, prenylapigenin, norartocarpin, kuwanon C, artocarpin, cudraflavone C, apigenin, albanin A, morin, 2′,4′-Dihydroxyflavone, 3-Methylbut-2-en-1-ol, 2-Methylpent-2-ene, artocarpesin, norartocarpetin and oxyresveratrol (Arung et al., 2007; Venkataraman, 2001).

The bark from the stem also contains betullic acid and two new flavone pigments, cycloheterophyllin, triterpenic compounds like cycloartenyl acetate, cycloartenone, heterophylol and tannin (Barik, Bhaumik, & Kundu, 1997; Lin & Lu, 1993; Prakash et al., 2009). The leaves and stem are also reported to contain sapogenins, cycloartenone, cycloartenol, β-sitosterol and tannins (Prakash et al., 2009). The roots are reported to contain β-sitosterol, ursolic acid, betulinic acid, cycloartenone, 2′,4′, 6′-trioxygenated flavanones, heteroflavanones A, heteroflavanones B, 5-hydroxy-7, 2′,4′,6′-tetramethoxyflavanone and 8-(γ,γ,α-dimethylallyl)5-hydroxy-7,2′,4′,6′-tetramethoxyflavanone (Dayal & Seshadri, 1974; Lin, Lu, & Huang, 1995; Lu & Lin, 1993; Prakash et al., 2009). Some of the phytochemicals present in jackfruit are depicted in Fig. 2.

Table 2
Dietary and medicinal and miscellaneous uses of Jack fruit tree.

Uses	Observation
Dietary	1. The raw fruits are used in vegetable curries and pickles (Prakash et al., 2009).
	2. The ripe fruits are used to make ice cream, drinks, jam, halwa and jelly. Pulps desiccated and used as dried fruit during off season. Fruit can also be used to prepare alcoholic liquor (Elevitch & Manner, 2006).
	3. 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.
	4. The ripe bulbs used to make jack fruit nectar or reduced to concentrate or powder (Morton, 1987).
	5. The seeds are nutritious and important source of diet. They are boiled or roasted and eaten like chestnuts, or cooked in some local dishes (Samaddar, 1985). The seeds are also marketed in canned forms in boiled form like the beans, in brine and in tomato sauce (Morton, 1987).
	6. Seed flour, which is high in protein and carbohydrate and has good water and oil absorption abilities, is used as an alternative for wheat flour and to prepared reduced calorie cake (Anonymous, 1985; Mukprasirt & Sajjaanantakul, 2004a,b; Prakash et al., 2009; Tulyathan et al., 2002).
	7. Tender jackfruit leaves and young male flower clusters may also be cooked and served as vegetables (Morton, 1987).
	8. The leaves are used as a casing material for baking dishes. The leaves are also secured together in the form of a round plate and used as a single use biodegradable plate (Morton, 1987).
Medicinal	1. Jackfruit tree is of great importance in the various folk and traditional system of medicine in Asia. Reports suggest that almost all parts of the jackfruit tree are of use in the preparations of various Ayurvedic and Yunani medicines (Gupta & Tandon, 1996; Saxena, Bawa, & Raju (2009), 2009).
	2. Ripe jackfruit is considered to be nutritious, cool, delicious, satisfying and to prevent excessive formation of bile, to develop flesh, phlegm, to strength the body and increases virility (Anonymous, 2006).
	3. Extract from the seeds or bark are supposed to be helpful in digestion.
	4. Fresh extract from seeds are also useful in the treatment of diarrhea and dysentery (Anonymous, 2006).
	5. Roots useful in treating various skin diseases, asthma and diarrhea.
	6. An ash produced by burning bark is supposed to heal abscesses and ear problems (Gupta and Tandon, 2004).
	7. The decoction of seeds or bark is supposed to help in digestion while ripe fruits may be used as a natural laxative (Hossain & Nath, 2002).
	8. Bark of a mature tree is also supposed to be useful in the treatment of dysentery and releasing the placenta after calving in cows (Morton, 1987).
	9. Wood possesses sedative properties, while the pith is believed to induce abortion (Morton, 1987).
	10. The leaf decoction and latex are supposed to be effective in the treatment of asthma, to prevent ringworm infestation, and heal cracking of the feet (Gupta and Tandon, 2004).
	11. The infusion of mature leaves and bark is supposed to be effective in the treatment of diabetes, gall stones and to relieve asthma.
	12. Leaves are also effective in healing cuts, wounds and abscesses (Gupta and Tandon, 2004).
	13. Leaves are believed to possess antisyphilitic and vermifuge activity and to induce lactation in women and domesticated animals (Khan et al., 2003).
	14. Leaves are thought to possess wound healing effects, reduce pain, decrease abscesses and relieve ear problems (Morton, 1987).
	15. In the Chinese system of medicine, jackfruit is found to be of use in overcoming the influence of alcohol.
	16. Starch extract from the seed is supposed to relieve biliousness, while the roasted seeds are considered to be aphrodisiac (Morton, 1987).
	17. Latex mixed with vinegar is believed to promote healing of abscesses, snakebite and glandular swellings.
	18. Placing of heated leaves on wounds and the ash obtained by burning with corn and coconut shells is used alone or with coconut oil to heal ulcers (Elevitch & Manner, 2006).
Other	1. The Jackwood with good grains is a useful and a durable timber. It is termite proof and resistant to fungal and bacterial decay (Prakash et al., 2009).
	2. Mature wood is used to make furniture, turnery, masts, oars, implements, brush backs and Indian traditional musical instruments like veena, mridangam and kanjira (Prakash et al., 2009).
	3. Sawdust or chips of heartwood is useful as a dying agent and is useful in coloring silk and the cotton robes used by the Buddhist priests (Morton, 1987).
	4. The splinters of the wood are inserted in bamboos used to collect coconut toddy, as this jack wood imparts yellow color to palm sugar (Morton, 1987).
	5. The latex collected from the trees is used to mend cracks on earthen pots and china ware (Prakash et al., 2009).
	6. The canopy of the full grown trees provide good shade and is used to grow important cash crops like coffee, pepper, betel nut, vanilla, cocoa and cardamom. They may also be used as an intercrop with coconuts, durian and mango (Elevitch & Manner, 2006).
	7. The leaves as well as the non pulp parts of the jackfruit are of use as feed for livestock (Elevitch & Manner, 2006).
	8. The leaves are also excellent adsorbents and are reported to remove methyleneblue, an industrial dye from the aqueous solutions (Uddin et al., 2009).
	9. The trees are also of use in landscaping in gardens and are effective at withstand hurricane-force winds (Elevitch & Manner, 2006).

7. Validated pharmacological studies (Table 6)

7.1. Antioxidant effect

The generation of excess free radicals damages the biomolecules and their prevention is vital for cytoprotective effects. Multiple

Table 3
Main season(s) of availability of jack fruit in different countries.
Haq, 2006.

Country	Month of the year
Australia	June–April
Bangladesh	June–August
Brazil	January–March, August–October
Colombia	January–December
India	April–July
Indonesia	August–January
Jamaica	January–July
Kenya	June–October
Malaysia	April–August, September–December
Philippines	March–August
Sri Lanka	February–November
Thailand	January–May, October–December
Uganda	January–December
USA (Florida)	May–August, September–October

Table 4
List of different cultivators of jack fruit available in the various countries.
Haq, 2006; Morton, 1987.

Country	Cultivar names
Australia	Golden nugget, Black gold, Honey gold, Lemon gold, Cheena, Chompa Gob, Coching, Galaxy, Fitzroy, Nahen, Kapa, Mutton, Varikkha, galaxy, fitzroy, nahen, cheenax, kapa, mutton, and varikkha
Bangladesh	Topa, Hazari, Chala, Goal, Koa, Khaja
India	Khujja or Karcha, Ghila, or Ghula, Hazari, rudrakshi, gulabi, hazar, jackfruit NJT 1, jackfruit NJT 2, jackfruit NJT 3 jackfruit NJT 4, koozha navarikka or pazam varikka, safeda, khaja, bhusila, bhadaiyan, handia, mammoth, everbearer, rose-scented, Kooli, Varika, Gerissal, Barica, Ghila, Karcha, Rudrakshi, Champa, Hazari, Gulabi, Safeda, Khaja, Bhusila, Bhadaiyan, Handia, T-Nagar jak, Velipala, Gulabi, Champa, Hazari, Singapore or the Ceylon Jack
Indonesia	Kandel, Mini, Tabouey
Malaysia	J-30, J-31, NS-1, Na2, Na29, Na31
Myanmar	Talaing, Kala
Philippines	J-01, J-02, TVC, Torres
Singapore	Jak/Ceylon jak
Sri Lanka	Vela, Varaka (Waraka), Peniwaraka, Kuruwaraka, Singapore or the Ceylon Jack
Jamaica	Peniwaraka or honey jack, Kuruwaraka
Thailand	Dang rasimi, Kun Wi Chan, Kha-num nang, Kha-num lamoud
USA (Florida)	Black gold, Cheena, Dang Rasimi, Galaxy, Golden Nugget, Honey Gold, Lemon Gold, J-30, J-31, NS-1, Tabouey, Delightful

Table 5
Proximate composition of young fruit, ripe fruit and seed jackfruit on the basis of fresh weight (per 100 g).
Arkroyd et al., 1966; Azad, 2000; Gunasena et al., 1996; Haq, 2006; Narasimham, 1990; Soepadmo, 1992.

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

studies have proved that polyphenols, carotenoids, anthocyanins and flavonoids present in fruits and medicinal plants are reported to be excellent scavengers of the free radicals and to prevent the cellular damage (Alia et al., 2008; Leopoldini, Rondinelli, Russo, & Toscano, 2010; Rufino et al. in press; Sánchez-Moreno, Larrauri, & Saura-Calixto, 1999). With respect to jackfruit, Soong and Barlow (2004) studied the antioxidant effects of the ethanolic extract of the defatted jackfruit seed and the edible part by ABTS cation radical-scavenging assay and ferric-reducing antioxidant power assays. The results of the ABTS cation radical-scavenging assay showed that the fresh seed and flesh possess 7.4 and 3 μmol/g ascorbic acid-equivalent antioxidant effects, while the freeze dried sample exhibited 25.4 and 11 μmol/g ascorbic acid-equivalent antioxidant activity. In the ferric-reducing antioxidant power assays it was observed that the seed and the flesh contained 2.8 and 6.8 μmol/g FRAP, respectively. The seed and flesh contained 27.7 and 0.9 gallic acid equivalent phenolic contents and this is believed to have contributed to about 70% of the total antioxidant activity (Soong & Barlow, 2004). Studies have also shown that the ethanolic extract of the dried mature fruits scavenged DPPH radicals *in vitro* and that the IC50 was 410 μg/ml (Soubir, 2007).

Recently, Jagtap et al. (2010) studied the antioxidant activities of the acetone, methanol, ethanol, and aqueous extracts of the fully ripe fruit pulps in various *in vitro assays*. In the DPPH scavenging assay, the authors observed that the methanolic and aqueous extracts were more effective than the acetone and ethanolic extract at all the concentrations studied (1 to 5 mg/ml). Further it was also observed that at low concentrations (1–3 mg/ml) the effect was better than that of vitamin C used as positive control. In the FRAP assay, all extracts were observed to be better than vitamin C. The ethanolic extract was observed to be more effective at lower concentrations (1 and 2 mg/ml), while the methanolic was better at higher (3 to 5 mg/ml) concentrations. In the DMPD radical cation decolorization assay all extracts exhibited a concentration dependent antioxidant activity. However none of the extracts were as effective as vitamin C. Of the four extracts, the methanolic extract was better than the ethanol, aqueous and acetone extracts and the concentration causing 50% inhibition (IC_{50}) were observed to be 3.43, 3.6 and 3.9 mg/ml, respectively (Jagtap et al., 2010). The phytochemical analysis showed that the ethanolic extract contained more phenolics (0.46 mg of gallic acid equivalents/g), while the aqueous extract was rich in flavonoids (1.20 mg of rutin equivalents/g).

The whole aqueous extract of the leaves as well as it aqueous and ethyl acetate fraction were subjected to phytochemical (phenolic content) and antioxidant assays (DPPH, ABTS, FRAP, and Fe^{2+}chelating activity assay) *in vitro* (Loizzo et al., 2010). The total extract was observed to possess the highest phenolic content (523.2 mg/g), followed by the ethyl acetate (361.2 mg/g) and aqueous fraction (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 fraction 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 (Loizzo et al., 2010).

With regard to phytochemicals, the prenylflavones (artocarpine, artocarpetin, artocarpetin A, cycloheterophyllin, and artonins A and B) present in the leaves were investigated for their antioxidant effects in various *in vitro* assays (Ko et al., 1998). It was observed that the phytochemical artocarpine, artocarpetin, artocarpetin A, and cycloheterophyllin diacetate and peracetate had no effect on iron-induced lipid peroxidation in rat brain homogenate and did not scavenge the DPPH radicals. Cycloheterophyllin and artonins A and artonins B also inhibited the copper-catalyzed oxidation of human low-density lipoprotein (Ko et al., 1998). The compounds cycloheterophyllin, artonins A and artonins B are also observed to be efficient in inhibiting the iron-induced lipid peroxidation in rat brain homogenate, scavenged the DPPH, peroxyl and hydroxyl radicals. However, these phytochemicals were ineffective in inhibiting xanthine oxidase activity or scavenging superoxide anion, hydrogen peroxide, carbon radical or peroxyl radicals. Together these results clearly indicate that cycloheterophyllin, artonins A and artonins B are powerful antioxidants against lipid peroxidation (Ko et al., 1998). Cumulatively the presence of all these components in the jackfruit may have been responsible for the observed free radical scavenging and antioxidant effects in the cell free and *in vitro assays*. Future studies should be on observing for these properties in the relevant animal systems of study with suitable control drugs as only then will its effectiveness be realized.

7.2. Anti-inflammatory effect

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 granuloma in cotton pellet method and the effects were concentration dependent (Chanda et al., 2009).

Cell culture studies have also shown that the jackfruit flavanoids are effective in inhibiting the release of inflammatory mediators from the mast cells, neutrophils and macrophages (Wei et al., 2005). The phytochemicals cycloheterohyllin, artonins B, and artocarpanone inhibited the superoxide anion formation in fMLP-stimulated rat neutrophils (Wei et al., 2005). Dihydroisocycloartomunin inhibited the release of β-glucuronidase and histamine from rat peritoneal mast cells stimulated with P-methoxy-N-methylphenethylamine, while artocarpanone inhibited formyl-Met-Leu-Phe stimulated release of lysozyme from the rat neutrophils. Artocarpanone also exhibited significant inhibitory effect on lipopolysaccharide-induced production of NO and iNOS protein expression in RAW 264.7 cells (Wei et al., 2005). Additionally, artocarpesin, norartocarpetin and oxyresveratrol also decreased the LPS (1 μg/ml)-induced generation of nitric oxide in the RAW 264.7 cells and the effect was dose dependent (0–50 μM). The optimal effect was observed for artocarpesin followed by norartocarpetin and oxyresveratrol and at non toxic concentrations (Fang et al., 2008).

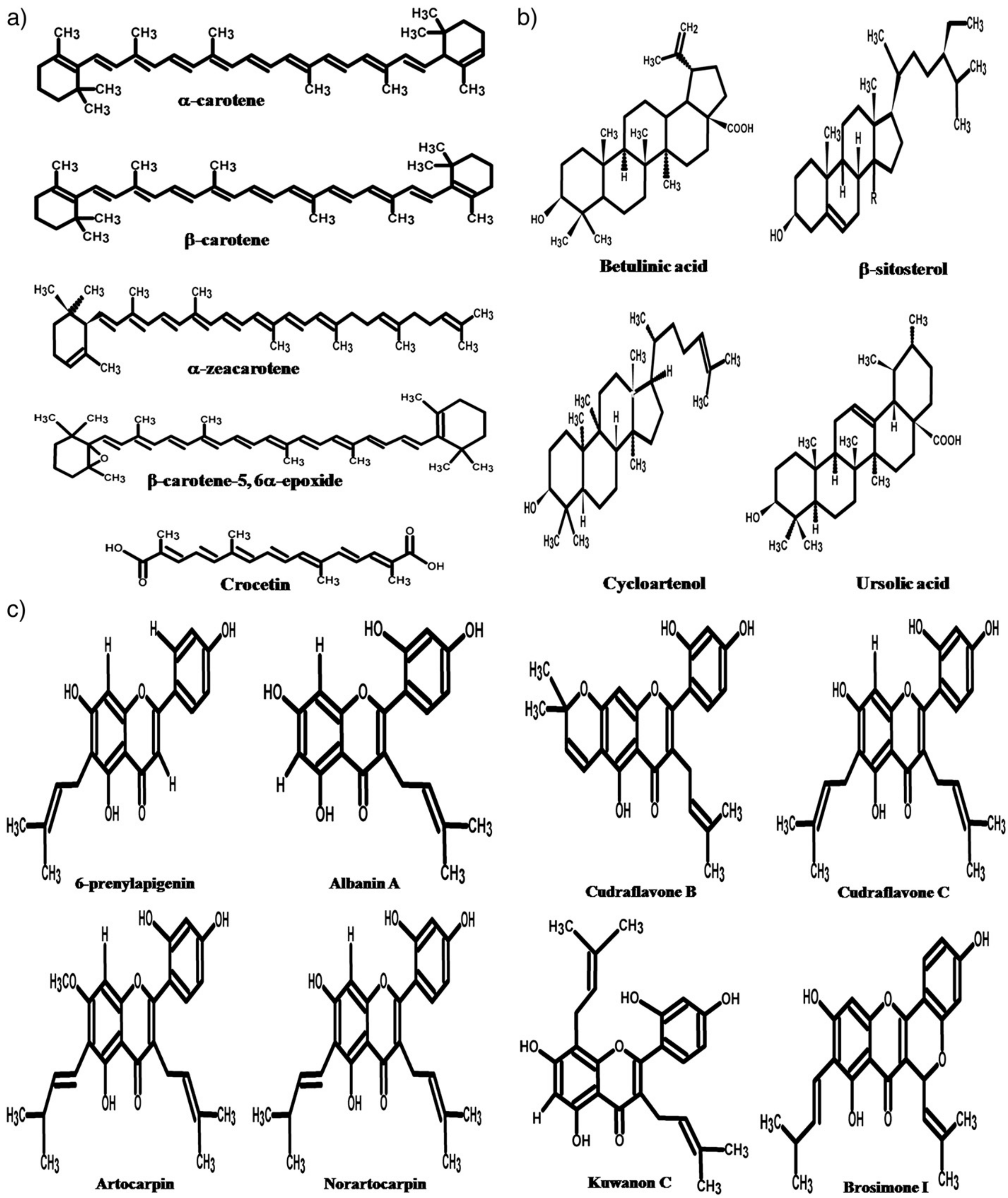

Fig. 2. a. The carotenoids present in the jackfruit. b. The sterols present in the jackfruit. c. The prenylflavones present in the jackfruit.

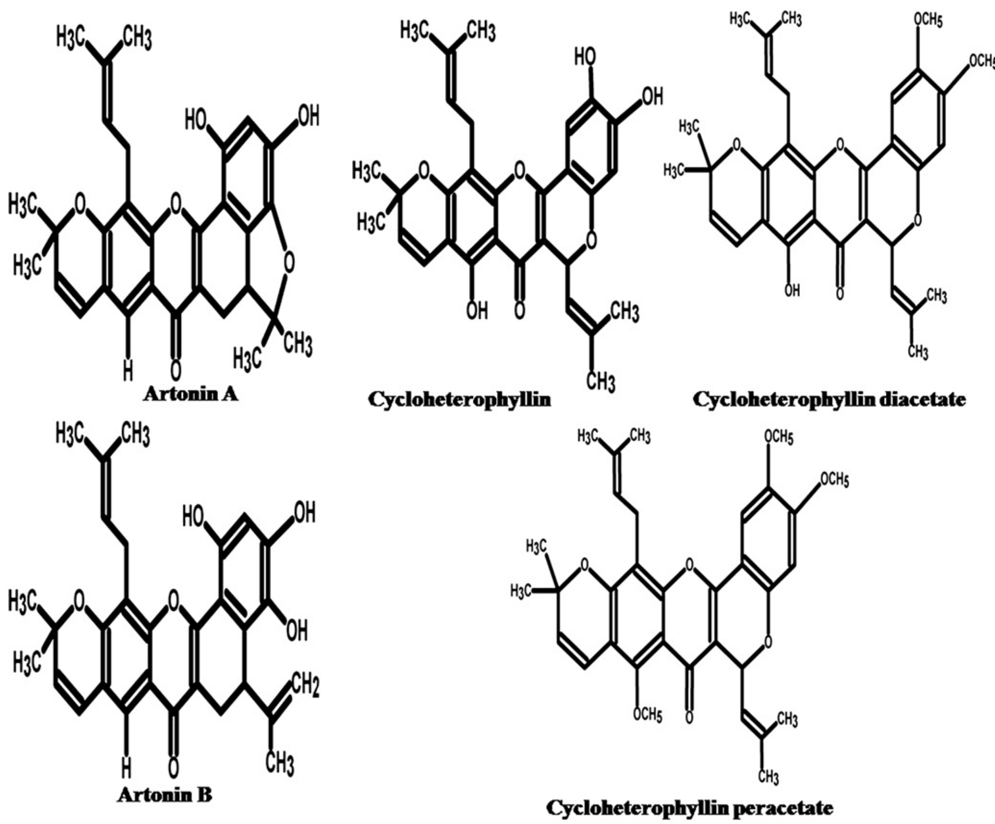

Fig. 2 (*continued*).

Detailed studies with artocarpesin have shown it to be also effective in inhibiting the production of PGE2, reactive oxygen species and to decrease the levels of COX-2 and iNOS protein expression in the LPS-stimulated RAW 264.7 cells (Fang et al., 2008). Together these observations clearly suggest the usefulness of artocarpesin in the amelioration of the inflammatory response. Future studies should emphasize on extending the anti-inflammatory effects to animal models of study as a realistic appraisal of the efficacy can be understood.

7.3. Antibacterial effects

Khan et al. (2003) studied the antibacterial effects of the crude methanolic extracts of bark of stem and root, heart wood of stem and roots, leaves, fruits and seeds as well as their petrol, dichloromethane, ethyl acetate and butanol partitioned fractions on *Bacillus cereus, B. coagulans, B. megaterium, B. subtilis, Lactobacillus casei, Micrococcus luteus, M. roseus, Staphylococcus albus, Staphylococcus 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 μg disc) 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 (Khan et al., 2003).

Recently, Loizzo et al. (2010) also investigated the antibacterial effects of the whole aqueous extract as well as the extract's aqueous and ethyl acetate fraction of jackfruit leaves against the foodborne pathogens *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 (Loizzo et al., 2010). 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 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) (Loizzo et al., 2010). The antibiotic streptomycin sulphate was observed to be more effective than any of the sample 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 (Loizzo et al., 2010). 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 >1000 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 (Loizzo et al., 2010).

Recently, Karthy et al. (2009) investigated the antibacterial activities of the ethanol, methanol, acetone, chloroform and petroleum ether extracts of the jackfruit seed powder on the clinical isolated multidrug resistant Methicillin Resistant *S. aureus* by the disc diffusion method *in vitro at* a uniform concentration of 30 mg/ml. It

Table 6
Validated pharmacological uses of Jack fruit tree.

Properties	Observations
Antioxidant effects	1. Ethanolic extract of the defatted jackfruit seed and the pulp shown to be effective in ABTS and FRAP assays (Soong & Barlow, 2004). 2. Ethanolic extract of the dried mature fruits scavenged DPPH radicals *in vitro* (Soubir, 2007). 3. The methanolic, ethanolic, acetone and aqueous extracts of ripe pulp shown to possess free radical scavenging effects in DPPH, FRAP, DMPD assays (Jagtap et al., 2010). 4. Cycloheterophyllin and artonins A and artonins B also inhibited the copper-catalyzed oxidation of human low-density lipoprotein, iron-induced lipid peroxidation in rat brain homogenate, scavenged the DPPH radicals, the peroxyl radicals and hydroxyl radicals (Ko et al., 1998).
Anti-inflammatory effect	1. Cycloheterohyllin, artonins B, and artocarpanone inhibited the superoxide anion formation in fMLP-stimulated rat neutrophils (Wei et al., 2005). 2. Dihydroisocycloartomunin inhibited release of beta-glucuronidase and histamine from rat peritoneal mast cells stimulated with P-methoxy-N-methylphenethylamine (Wei et al., 2005). 3. Artocarpanone inhibited the release of lysozyme from rat neutrophils stimulated with formyl-Met-Leu-Phe. Artocarpanone inhibited LPS-stimulated production of NO and expression of iNOS in RAW 264.7 cells (Wei et al., 2005). 4. Artocarpesin, norartocarpetin and oxyresveratrol isolated from the fruits caused a dose dependent decrease in the production of LPS-induced production of nitric oxide in vitro (Fang et al., 2008). Artocarpesin was effective in inhibiting the production of prostaglandin E2 (PGE2), reactive oxygen species and to decrease the levels of cyclooxygenase 2 (COX-2) and inducible nitric oxide synthase (iNOS) protein expression in the LPS-stimulated RAW 264.7 cells (Fang et al., 2008). 5. Protease fraction and artocarpain also possess anti-inflammatory effects in carrageenan induced rat paw oedema and Cotton pellet-induced granuloma model (Chanda et al., 2009).
Antibacterial effects	1. The methanolic extracts of stem, root, barks, heart wood, leaves, fruits and seeds as well as their various fractions evaluated for antibacterial effects. The butanol fractions of the root bark and fruits were most effective (Khan et al., 2003). 2. The aqueous extract as well the aqueous and ethyl acetate fraction of jackfruit leaves studied for the antibacterial effects by the agar diffusion and broth dilution methods. The activity varied from organism (Loizzo et al., 2010). 3. The ethanolic and methanolic extracts of the jackfruit seed powder were observed to be effective on multidrug resistant Methicillin Resistant *Staphylococcus aureus* (Karthy et al., 2009).
Anticariogenic effects	1. Methanolic extract of the leaves and the phytochemicals artocarpin and artocarpesin, possess inhibitory effects on the primary cariogenic bacteria *in vitro* (Sato et al., 1996).
Antifungal activity	1. The extract of the jackfruit leaf shown to be ineffective (Khan et al., 2003). However the chitin-binding lectin present in the seeds (denoted as jackin) is reported to inhibit growth of *Fusarium moniliforme* and *Saccharomyces cerevisiae* (Trindade et al., 2006).
Antineoplastic activity	1. Norartocarpin, cudraflavone C, artocarpin, brosimone I, cudraflavone B, kuwanon C and 6-prenylapigenin more active than the clinically used vinblastine, carmustine and 5-fluorouracil in the cytotoxic effects in B16 melanoma cells (Arung et al., 2010a). 2. Artocarpin also possess cytotoxic effects on cultured human T47D breast cancer cells *in vitro* (Arung et al., 2010b).
Inhibition of melanin biosynthesis	1. Jack fruit wood extract and the phytochemical artocarpanone was effective and inhibited both mushroom tyrosinase activity and melanin production in B16 melanoma cells (Arung et al., 2006a). Artoheterophyllin A, artoheterophyllin B, artoheterophyllin C, and artoheterophyllin D isolated from the twigs also possess tyrosinase inhibitory activity (Zheng et al., 2009). 2. Artocarpin, cudraflavone C, 6-prenylapigenin, kuwanon C, norartocarpin and albanin A also inhibited the biosynthesis of melanin in B16 melanoma cells without inhibiting tyrosinase (Arung et al., 2006b). 3. 3-prenyl luteolin also inhibits the tyrosinase activity (Arung et al., 2010b).
Effect on sexual performance	1. 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 (Ratnasooriya & Jayakody, 2002).
Hypoglycemic effects	1. Aqueous decoction of jackfruit leaf possesses hypoglycemic effects in rats, mice and health human volunteers (Fernando et al., 1990, 1991). 2. The aqueous leaf extract also inhibited α-amylase activity in the vitro (Kotowaroo et al., 2006).
Wound healing	1. The ethanol extract of dried leaves and its various fractions (petroleum ether, butanol, butanone and methanol) possess wound healing effects in rats. The methanol fraction was observed to possess the best effect (Patil, Jadhav, & Joshi, 2005).

was observed that of all the extracts studied, only ethanol, methanol and acetone extracts possessed good activity. The ethanol and methanolic extracts were active against all the twelve isolates while the acetone extract was effective only on four of the twelve isolates. The antimicrobial effects of the ethanolic and methanolic extract was also better than that of methicillin (5 µg) used as the positive control (Karthy et al., 2009). In milieu of these observations the seed is shown to be effective as antibacterial agent and studies should be extended to animal models. When performed these studies will clearly indicate the antibacterial efficacy in a living system and also validate its use.

7.4. Anticariogenic activity

Studies by Sato et al. (1996) have shown that the methanolic extract of the leaves possess significant inhibitory effects on the primary cariogenic bacteria. Bioactivity guided fractionated studies have shown that this effect was mediated by 6-(3-methyl-L-butenyl)-5,2′,4′-trihydroxy-3-isoprenyl-7-methoxyflavone (artocarpin) and 5,7,2′,4′-tetrahydroxy-6-isoprenylflavone (artocarpesin). Detailed evaluation have shown that both artocarpin and artocarpesin possess antimicrobial activities on various strains of *S. mutans*, *S. sobrinus*, *S. rattus, S. cricetus*, *S. sanguis, L. casei* and the Actinomyces in the range of 3.13–12.5 µg/ml (Sato et al., 1996). In milieu of these encouraging observations, studies should be extended to other microbes important in deteriorating the oral hygiene and also on assessing the toxicity of the extract on normal human epithelial cells, especially at the antibacterial concentrations for it to be of human use.

7.5. Antifungal activity

The extract of the leaf is reported to be ineffective on *Aspergillus niger*, *A. rubrum*, *A. versicolor*, *A. vitis*, *Candida albican*, *C. tropicalis*, *Cladosporium cladosporiods*, *Penicillium notatum*, *Trychophyton mentagrophytes* and *T. tronsurum* (Khan et al., 2003). However the chitin-binding lectin present in the seeds (denoted as jackin) is shown to inhibit the growth of *Fusarium moniliforme* and *Saccharomyces cerevisiae* (Trindade et al., 2006). Future studies should be extended to animal models as these studies will clearly indicate the antifungal efficacy in animal system of study.

7.6. Antineoplastic activity

Arung et al. (2006a) investigated the cytotoxic effects of the isoprenoid-substituted flavonoids isolated from the methanolic extract of the jackfruit wood on B16 melanoma cells. Culturing B16 melanoma cells in the presence of these phytochemicals (for 72 h) caused a concentration dependent cytotoxicity and the antineoplastic efficacy was as follows: norartocarpin (IC50 of 7.8 µM) > cudraflavone

C (IC50 of 9.2 μM) > artocarpin (IC50 of 10.3 μM) > brosimone I (IC50 of 10.7 μM) > cudraflavone B (IC50 of 12.5 μM) > kuwanon C (IC50 of 14.2 μM) > 6-prenylapigenin (IC50 of 32.5 μM) > albanin A (IC50 of 84.7 μM) > artocarpanone (IC50 of 122.2 μM). Except for the albanin A and artocarpanone all other phytochemicals were more active than the clinically used vinblastine (IC50 of 50 μM), carmustine (IC50 of 120 μM), and 5-fluorourasil (IC50 of 240 μM). The results clearly indicated that the flavonoids with an isoprenoid substituent were more effective than those without isoprenoid substituents and also that the cytotoxic potency was in proportion to the number of isoprenoid moiety substitutions (Arung et al., 2010a).

Studies have also shown that artocarpin exhibited potent cytotoxic activity on cultured human T47D breast cancer cells *in vitro*. Incubation of the cells with graded doses of artocarpin (5.7, 11.5, 20, and 28.7 mM) for 24 h resulted in a concentration-dependent cytotoxic effects (Arung et al., 2010b). The IC50 was calculated and observed to be 12.6 μM. Artocarpin caused concentration-dependent apoptosis and mechanistic studies showed that it was mediated by the activation of caspase 3 and caspase 8 but not caspase 9 or caspase 10 (Arung et al., 2010b). Together these observations clearly indicate that the isoprenoid-substituted flavonoids of jackfruit possess cytotoxic effects and that artocarpin is a potential candidate (Arung et al., 2010b). Future studies should be extended to animal models as these studies will clearly indicate the anticancer effects and whether this effect will be at a physiologically attainable concentration.

7.7. Inhibition of melanin biosynthesis

In their investigational studies, Arung et al. (2006a) observed that extract of jackfruit wood possesses significant tyrosinase-inhibitory effects and that the phytochemical artocarpanone was effective in inhibiting mushroom tyrosinase activity and melanin production in B16 melanoma cells (Arung et al., 2006a). Additionally, the isoprenylated 2-arylbenzofuran derivative artoheterophyllin A and three isoprenylated flavonoids, artoheterophyllin B, artoheterophyllin C, and artoheterophyllin D isolated from the twigs also possessed tyrosinase-inhibitory activity (Zheng et al., 2009). The isoprenoid-substituted flavonoids artocarpin, cudraflavone C, 6-prenylapigenin, kuwanon C, norartocarpin and albanin A inhibited the biosynthesis of melanin in B16 melanoma cells without inhibiting tyrosinase (Arung et al., 2006b). Additionally the prenylated flavone-based polyphenols were also found to be active inhibitors of the *in vivo* melanin biosynthesis in B16 melanoma cells, with little or no cytotoxicity but ineffective on tyrosinase (Arung et al., 2007).

Recently, 3-prenyl luteolin is also reported to inhibit the tyrosinase activity and the IC50 was observed to be 76.3 and 14.1 μM for 3-prenyl luteolin and Kojic acid, respectively. However in the melanin biosynthesis inhibitory activity using B16 melanoma cells, 3-prenyl luteolin (56.7 μM) was observed to be less effective than luteolin (10.1 μM). The most significant observations are that both 3-prenyl luteolin and luteolin are devoid of cell toxicity at their effective concentrations (Arung et al., 2010b). Together these observations suggest that jackfruit tree contain compounds that could be useful in the treatment of hyperpigmentation and useful as a skin-whitening agent when safety issues are thoroughly investigated in both cultured skin cells and in animal model.

7.8. Effect on sexual performance

Population explosion is a serious problem in many of the third world countries and search for an effective non toxic contraceptive agent or agents which decrease libido from dietary source is preferred. Preclinical studies have shown that feeding the seed (500 mg/kg) to rats decreased the sexual activities the number of mounts, number of intromissions, intromission ratio, copulatory efficiency, and increased the mount latency, intromissions latency, ejaculation latency and intercopulatory interval at early time point of two hour post administration but returned to normal at 6 h (Ratnasooriya & Jayakody, 2002). However the seed did not decrease the ejaculatory competence, libido and immediate fertility in terms of quantal pregnancy, number of uterine implants, implantation index and pre and post implantation loss (Ratnasooriya & Jayakody, 2002).

Behavioral studies have also shown that administering the jackfruit seed caused a concentration dependent impairment and reduced the number of rears and locomotary activities. Additionally, sub chronic treatment of high dose of jackfruit seed did not induce marked changes in the gross appearance or weight of the vital organs and did not alter the levels of AST and ALT, the liver marker enzymes. Together, these observations clearly suggest that the decrease in sexual activity caused by jackfruit seed at the early time point was transient and not due to general toxicity, liver toxicity, stress or reduction in blood testosterone level but due to noticeable sedative activity (Ratnasooriya & Jayakody, 2002). However, these observations have lesser human significance as the dose of 500 mg/kg when extrapolated to human dose amounts to approximately 35 to 40 g. It is highly unlikely that humans would appreciate consuming a high dose of the seed daily to cause a transient reduction in the sexual activity, while other effective measures are available for population control.

7.9. Hypoglycemic effects

Diabetes is globally a major health problem and search for effective hypoglycemic agents is a global priority. Fernando et al. (1990, 1991); Fernando et al. (1991) studied the hypoglycemic effects of the aqueous decoction of jackfruit leaf in both rats and humans and observed it to be effective. The authors observed that administering the decoction (10 ml/kg) to overnight-fasted animals caused progressive decrease in glycemic index through the various time points of study. A 25% and 34% decrease were observed at 3 and 5 h post administration. The hypoglycemic effect of the decoction was observed to be better than that of tolbutamide, used as positive control. A concentration-dependent effect was observed when 5, 10 and 20 ml/kg of the fresh decoction were administered. The authors also observed that storing the decoction at room temperature did not decrease the hypoglycaemic activity of the aqueous extracts suggesting its usefulness (Fernando et al., 1990).

The decoction was also observed to be effective in improving the utilization of the external glucose load in the glucose tolerance test in rats (Fernando et al., 1990) and this observation extended to both healthy human volunteers and non-insulin-dependent diabetic patients (Fernando et al., 1991). When compared to the placebo group, consumption of the decoction (10 ml/kg) by the overnight fasted individuals, 1 h before the oral glucose load decreased the blood glucose levels at all evaluated time points (30, 60, 90, 120, and 150 min post glucose administration) (Fernando et al., 1991). In the healthy volunteers, the blood glucose levels returned to normal levels by 90 min while in the placebo treated cohorts it was at 150 min. In the non-insulin-dependent diabetic patients it was observed that administration of the decoction caused an 11%, 15%, 24% and 36% decrease at 30, 60, 90, and 120 min post glucose administration, respectively (Fernando et al., 1991).

Studies by Kotowaroo et al. (2006) have also shown that aqueous leaf extract inhibited α-amylase activity in vitro. Incubation of graded concentrations of the aqueous leaf extract (0.104–1.666 mg/ml) with α-amylase and starch caused a significant decrease in the enzyme activity in the chemical assay. Studies also showed that the extract (125 to 2000 μg/ml) inhibited the α-amylase activity in rat plasma *in vitro*. The highest inhibitory activity was reported at a concentration of 1000 μg/ml and dose dependency was not observed (Kotowaroo et al., 2006). Detailed enzyme kinetic studies showed that the leaf extract behaved as a competitive inhibitor of α-amylase. Together these studies clearly indicate the extract could act as a starch blocker and reduce the post-prandial glucose peaks (Kotowaroo et al., 2006). Future studies should be aimed at understanding the mechanism/s by which the extract ensue these effects both in type 1 and 2 diabetes animal model and also on understanding the toxic effects of long term administration of the extract.

7.10. Wound healing effects

Recently, Patil et al. (2005) investigated the wound healing effects of the ethanol extract of dried leaves and its various fractions (petroleum ether, butanol, butanone and methanol) in the incision, excision and dead space (granulation) wound models in albino rats. The rats were orally administered the extracts at a uniform concentration of 100 mg/kg for ten consecutive days in the incision and dead space wound models, and for 18 days in the excision wound model with 1% gum acacia as the placebo control. In the resutured incision wound model it was observed that the administration of the extracts increased the mean breaking strength and was as follows methanol fraction (213.3 g) > butanone fraction (200.3 g) > ethanol extract (196.5 g) > butanol fraction (192.9 g) > petroleum ether (181.1 g) to that of the placebo treated control where the breaking strength was 122.3 g. Similar results were also observed in the breaking strength of the grass pith-induced granuloma (dead space model) and the results were as follows: methanol fraction (248 g) > butanol fraction (210.8 g) > ethanol extract (165 g) > petroleum ether (161 g) > butanone fraction (135 g) to that of the 129.8 g observed in the placebo treated control (Patil et al., 2005).

In the excision wound model, where wound closure, time of epithelization and size of scar are important end points the administration of the ethanolic extract and its various fractions were observed to be effective. The methanol fraction promoted better wound healing (95.3%) when compared to the control and other fractions (Patil et al., 2005). The epithelization period was observed to be 17, 17.7, 18.5, 19.5 and 19.2 days respectively, for the methanol fraction, butanone fraction, butanol fraction, ethanol extract and petroleum ether fraction, when it was 21.5 days for the placebo treated control (Patil et al., 2005). When compared with the control (28.2 mm^3), the extract and its factions were also effective in reducing the scar area which was as follows: methanol fraction (7.2 mm^3) = butanone fraction (7.2 mm^3) > butanol fraction (11.2 mm^3) > ethanol extract (19.7 mm^3) > petroleum ether (22.3 mm^3) (Patil et al., 2005). Together these reports clearly indicate that the methanol fraction of the ethanolic extract of the jackfruit leaves possess significant wound healing effects in the standard preclinical models of wound healing assays and merits detailed investigations, especially with the isolated compounds in both *in vitro* and animal model of studies.

8. Conclusions

Since antiquity jackfruit, a tree indigenous to the rainforests of the Western Ghats is an important source of nutritious food especially during the summer when food is scarce. Experimental studies performed in the past suggest that jackfruit possesses diverse medicinal uses including antioxidant, anti-inflammatory, antimicrobial, anticariogenic, antifungal, antineoplastic and hypoglycemic effects, inhibits melanin biosynthesis, possesses wound healing properties, and causes a transient decrease in the sexual performance. The observed pharmacological properties may be attributed to the presence of various phytochemicals.

The leaves are observed to be excellent adsorbents of the industrial dye methyleneblue. In milieu of the increased effluents being released in to environment and it affecting the living systems, these observations assume great significance. Jackfruit leaves could be an excellent bioadsorbent and could be utilized to remove dyes from the effluents. Emphasis should be given to optimize the effects for industrial scale as this could lead to prevention of the environmental pollution and its effects on both biotic and abiotic factors. Laboratory studies should also be performed to understand the bioadsorbent capacity of the leaves against other dyes and most importantly with the metal effluents like lead, cadmium, arsenic, mercury etc. that are highly dangerous. These studies if extended to reclamation will also be of use in recycling the dyes and metals for judicious usage and prevention of environmental pollution.

When compared to other tropical fruits like orange, banana, mango, pineapple papaya and ber, jackfruit pulp and seeds quantitatively contains more protein, calcium, iron and thiamine and are a good source for these essential nutrients. Regular consumption during the harsh summer season will provide the required RDA/AI at least in part. The pulps also contain biologically important neutraceuticals and its presence may have partly been responsible for the myriad beneficial effects.

Despite numerous advantages, the popularity of jackfruit as a commercial crop is very poor due to wide variation in fruit quality and the widespread belief that excessive consumption of jackfruit flakes leads to certain digestive ailments which is yet to be scientifically proved. Studies should be performed on standardizing the fruits and also on whether jackfruit really causes digestive ailments. If research indicates that jack fruit is devoid of digestive ailments, it will help in popularizing the use of the fruits and its products. The seed should also be subjected to detailed studies with emphasis being on understanding its dietary and nutritive advantages.

Endeavors should be directed at encouraging the food industry to process the good qualities of jackfruit and seeds for exporting of both canned and finished foods. This will directly help the growers and also increase their financial resources. The food industry should also attempt at optimizing the quality and develop novel finished products. Attempts should also be on the part of policymakers and the governmental agencies to support the integrated agricultural procedures involving jackfruit trees by providing necessary guidance and assistance to the growers as well as offering a minimal procurement price, especially to benefit the marginal farmers.

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