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Research Article

CHEMISTRY AND MEDICINAL PROPERTIES OF JACKFRUIT (*ARTOCARPUS HETEROPHYLLUS*): A REVIEW ON CURRENT STATUS OF KNOWLEDGE

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ABSTRACT
Jackfruit (*Artocarpus heterophyllus*) is commonly grown in home gardens of tropical and sub-tropical countries. The fruit provide 2 MJ per kg/wet weight of ripe perianth and contain high levels of carbohydrates, protein, starch, calcium and vitamins. Jackfruit has diverse medicinal uses especially anti-oxidant, anti-inflammatory, antimicrobial, anti-cancer and anti-fungal activity. Jackfruit is considered to be an underutilized fruit where most of the fruits get wasted due to ignorance, lack of post harvest technology and gaps in supply chain systems. Jackfruit contains more protein, calcium, iron, vitamins and other essential nutrients when compared to the common fruits. A wide gap in the marketing of jack fruits and its processed value added products which can be fully explored for additional income as well as food security. Encouragements should be done to the marketing as well as value added food products from this underutilized fruit tree.

Keywords: *Anti-oxidant; Jackfruit; Jackalin; Monecious; Underutilized Fruit*

INTRODUCTION
Artocarpus heterophyllus belong to the Moraceae family, colloquially jack fruit in English is native to India and seen abundant in Western Ghats (Jagadeesh *et al.*, 2007a; Baliga *et al.*, 2011; Reddy *et al.*, 2004; Jagadeesh *et al.*, 2007b; Prakash *et al.*, 2009; Wangchu *et al.*, 2013). Besides India, jackfruit is commonly grown in home gardens of tropical and sub-tropical countries especially Sri Lanka; Bangladesh, Burma, Philippines, Indonesia, Thailand, Malaysia and Brazil (Jagadeesh *et al.*, 2007b; Baliga *et al.*, 2011; Dutta *et al.*, 2011; Siti Balqis and Rosma, 2011; Lin *et al.*, 2009; Saxena *et al.*, 2009a Maia *et al.*, 2004; Hameed, 2009). In India, it widely distributed in the states of Assam, West Bengal, Uttar Pradesh, Maharashtra, Kerala, Tamil Nadu and Karnataka (Wangchu et., 2013) and considered to be the 'Poor man's food' (Jagadeesh *et al.*, 2007a; Prakash *et al.*, 2009). In Malayalam (regional language in Kerala, India) jack fruit is called as "Chakka" while the ancient Indian language Sanskrit refers as Atibruhatphala (Baliga *et al.*, 2011; Haq, 2006; Prakash *et al.*, 2009). The morphology of the tree varies with 10-30 m tall; with long tap root and desne crown (Wangchu *et al.*, 2013) producing the largest tree born fruit in the world (Baliga *et al.*, 2011; Prakash *et al.*, 2009). The fruit weight up to 50 kg, but average weigh is considered to be 10 kg, while only 30-35% of the bulb is edible (Jagadeesh *et al.*, 2007a; Baliga *et al.*, 2011; Saxena *et al.*, 2009b; Hameed, 2009; Swami *et al.*, 2012; Selvaraj and Pal,1989).
Jack fruit is considered as national fruit in Bangladesh and highly appreciated in India due to cheap and availability in summer seasons were food is scarce (Muralidharan *et al.*, 1997; Morton, 1987; Schnell *et al.*, 2001). The fruit provide 2 MJ per kg/wet weight of ripe perianth and contain high levels of carbohydrates, protein, starch, calcium and vitamins (Swami *et al.*, 2012; Ahmed *et al.*, 1986; Burkill, 1997; Saxena *et al.*, 2009a). Boiled and cooked jackfruit seeds are included in the diets which have 77% starch content, which is exploited as a potent source of starch (Bobbio *et al.*, 1978; Tulyathan *et al.*, 2002; Mukprasirt and Sajjaanantakul, 2004; Odoemelam, 2005). Jackfruit is widely used in culinary preparation, baking, candid jackfruit, baby food, jams, jellies, juice, chips, deserts and the advances in food processing technologies further expanded the possibilities (Burkill, 1997; Swami *et al.*, 2012; Selvaraj and Pal, 1989; Narasimham, 1990; Roy and Joshi, 1995; Haq, 2006). Jackfruit is widely accepted

by consumers, researchers and food industries due to the presence of bioactive compounds and diversity products made out of it (Swami *et al.*, 2012; Saxena *et al.*, 2009a; Dutta *et al.*, 2011; Lin *et al.*, 2009; Devalaraja *et al.*, 2011). Various parts of jackfruit tree have been used for medicine and the hard wood used for construction (Roy and Joshi, 1995; Alagiapillai *et al.*, 1996). The aim of this review paper was to improve the current knowledge, medicinal and industrial application properties of jackfruit.

MATERIALS AND METHODS

Botanical Description and Varieties

Artocarpus species (15 edible fruits) are known to occupy various niches and habitats, comprise mainly bread fruit and jackfruit (Jagtap and Bapat, 2010; Wangchu *et al.*, 2013). Jackfruit is monecious and pollinated flowers develop several months to develop into ripe fruit, depending on climatic and soil conditions (Morton, 1987; Baliga *et al.*, 2011). According to Prakash et al (2009) jackfruit consist of lower fleshy edible region (bulb), middle fused region (syncarp) and out spiney region (spike). When ripe the fruit get fleshy, outer spines widened and flesh get soft and yellow (Saxena *et al.*, 2009). Except the thorny outer bark and axis are not edible (Baliga *et al.*, 2011). The jackfruits were classified based on their phonotypical and organoleptic characteristics with variation in bulb colour as well as shape, size, odour, flake size, flake colour and period of maturity (Haq, 2006; Prakash *et al.*, 2009; Jagadeesh *et al.*, 2007b; Jagadeesh *et al.*, 2007a). Two types of ecotypes are recognised flake characteristics, one with soft and spongy while other with firm carpels which called different in regional languages (Baliga *et al.*, 2011; Amma *et al.*, 2011; Shyamalamma *et al.*, 2008; Muralidharan *et al.*, 1997; Odoemelam, 2005).

Nutritional and Vitamin Composition

Studies have proved that the nutritional and photochemical composition among jackfruit varies depending on the cultivar as well as region (Baliga *et al.*, 2011; Arkroyd *et al.*, 1966; Azad, 2000; Haq, 2006; Narasimham, 1990). It is a good source of vitamins (A, C, thiamine, riboflavin, niacin) and minerals (calcium, potassium, iron, sodium, zinc) (Swami *et al.*, 2012; Haq, 2006; Narasimham, 1990; Arkroyd *et al.*, 1966; Azad, 2000). Protein and carbohydrate concentration also varied in seeds across India were some varieties contain 6.8% of protein content in seeds (Baliga *et al.*, 2011; Chrips *et al.*, 2008).

Table 1: Phenolic, flavinoid content and antioxidant activity of araticum, papaya and jackfruit in undigested and digested extracts (Modified after; Pavan *et al.*, 2011)

Parameters	Araticum		Papaya		Jackfruit	
	Undigested	Digested	Undigested	Digested	Undigested	Digested
Total phenol content	215 ± 9.5	178. 2 ± 11	79.5 ± 0.13	28.6 ± 2.2	23.3 ± 3.5	33.9 ± 0.8
Flavonoid content	405 ± 6.6	399 ± 44	15.9 ± 2.6	26.4 ± 3.7	33 ± 9.5	28.4 ± 1.2
TEAC	142.6 ± 3.7	1647.7 ± 5.5	447.5 ± 18	383.3 ± 17	56 ± 2	318 ± 12
ORAC	10038 ± 984	31165 ± 4113	3112 ± 866	2017 ± 393	2117 ± 388	3047 ± 455

Table 2: Biochemical difference various jackfruit varieties in South India (Chrips *et al.*, 2008)

Name of variety	Flake		Seed	
	Total sugar (%)	Total carbohydrate (%)	Total protein (%)	Total carbohydrate (%)	Total protein (%)
Valayan	21.3 ± 1.02	23.8 ± 2.6	1.4 ± 2.2	42.5 ± 0.6	5.9 ± 0.7
Nettadivarika	17.5 ± 0.9	28.4 ± 1.7	2.3 ± 1.5	40.3 ± 2.3	6.8 ± 2.3
Chemparethy	20.7 ± 0.4	26.1 ± 0.8	1.9 ± 2.7	37.4 ± 1.1	5.3 ± 1.4
Mondan	18.6 ± 1.9	31.2 ± 2.0	2.0 ± 1.4	42.8 ± 0.9	6.5 ± 1.8
Venkanni	15.3 ± 1.15	28.4 ± 1.3	1.7 ± 2.3	40.2 ± 1.5	6.0 ± 1.5

Numbers represent means ± one standard deviation (SD) of the mean

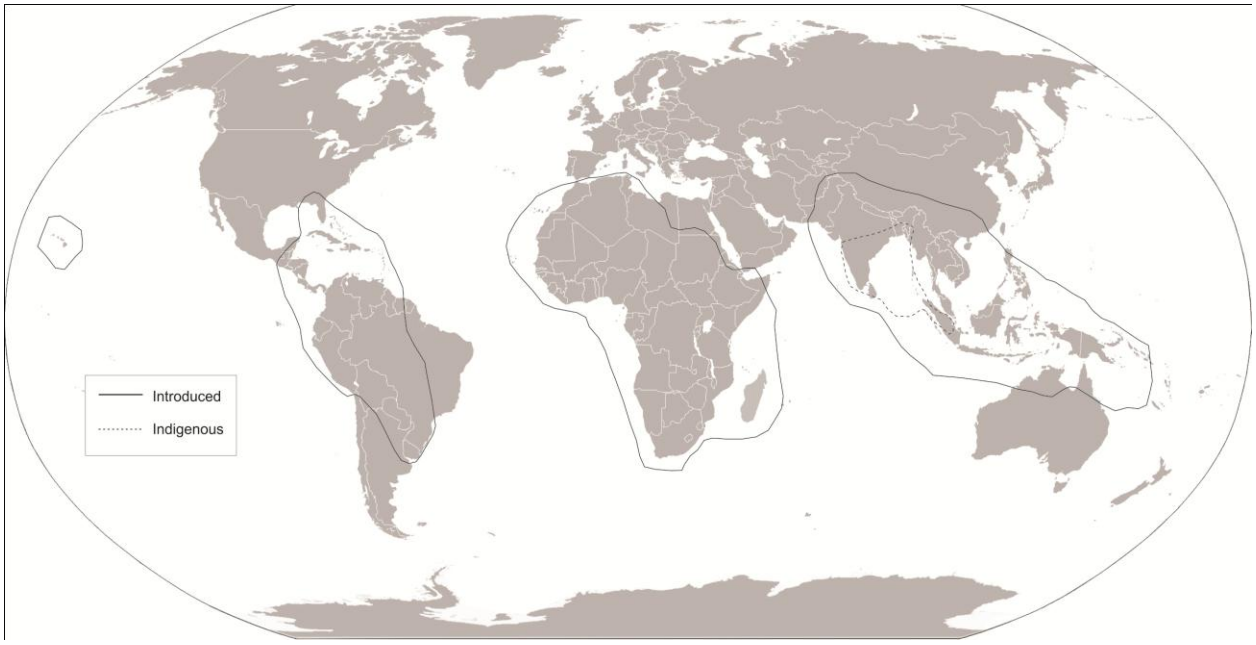

Figure 1: Introduced and indigenous regions of *Artocarpus heterophyllus* around the world (Modified after; Haq, 2006)

Table 3: Uses of different jackfruit parts (Swami *et al.*, 2012; Jagtap and Bapat, 2010)

Plant part	Use	Reference
Fruit	Food: Vegetable, pickle, chutney, jam, jelly, paste, candies, juice, power, confectionery	Burkill, 1997; Swami *et al.*, 2012; Selvaraj and Pal, 1989; Narasimham, 1990; Roy and Joshi, 1995 Haq, 2006; Verheij and Coronel, 1992
Seed	Eaten boiled, roasted and salted as table nuts, flour for baking, substrate for solid state fermentation, animal feed	Bobbio *et al.*, 1978; Tulyathan *et al.*, 2002; Mukprasirt and Sajjaanantakul, 2004; Odoemelam, 2005; Verheij and Coronel, 1992; Babitha *et al.*, 2006; Babitha *et al.*, 2007
Wood	Furniture, musical instruments, bee hives, boats, dye	Haq, 2006; Verheij and Coronel, 1992
Latex	Varnishes, glue, caulking for boats and buckets,	Haq, 2006;
Root	Carving and picture framing	
Leaves	Fodder for cattle and goats, making spoon to take rice kanji, removal of methylene blue	Uddin *et al.*, 2009a; Uddin *et al.*, 2009b
Jackfruit peel	Adsorbent for the removal of cadmium	Hameed, 2009

Table 4: Uses of different jackfruit Lectins (Swami *et al.*, 2012; Jagtap and Bapat, 2010)

Lectin	Study focus	Reference
Jacalin	Inhibition and activation studies on human B and T-suppressor cells	Saxon *et al.*, 1987; Kabir, 1998
Jacalin	Interaction with human IgA1	Hagiwara *et al.*, 1988
α-D-Galactose specific lectin	Crystallographic study	Basu *et al.*, 1988
Anti-T lectin	X-ray studies	Dhanaraj *et al.*, 1988
Jacalin	Purification of C1 inhibitor	Pilatte *et al.*, 1989
Jacalin	Interaction with ant egg glycoprotein	Ray and Chatterjee, 1989
Jacalin	X-ray characterization	Banerjee *et al.*, 1991; Banerjee *et al.*, 1991
Jacalin and artocarpin	Activation studies on B and T cells	Miranda Santos *et al.*, 1991
Jacalin	Binding studies	Sahasrabuddhe *et al.*, 2004
Artocarpin	Interactions with monosaccharide	Barre *et al.*, 2004; Basu *et al.*, 1988

Table 5: Different vernacular names of *Artocarpus heterophyllus* in India (Modified after; Baliga *et al.*, 2011)

Language	Names
Scientific names	*Artocarpus heterophyllus* Lam. *Artocarpus brasiliensis* Gomez. *Artocarpus hetrophylla* Lam. *Artocarpus maxima* Bianco *Artocarpus philippensis* Lam.
Name in various Indian languages	
Sanskrit	Panasa, Atibruhatphala, Kantaphal
Hindi	Kathal, Panas
Bengali	Kanthal
Guajarati	Phanas
Kannada	Halasu
Konkani	Phanas
Malayalam	Chakka
Tamil	Palaa
Telugu	Panasa

Table 6: Common names, uses and distribution of major Artocarpus species (Modified after; Jagtap and Bapat, 2010)

Scientific name	Common name	Uses	Distribution
Artocarpus altilis (Parkinson) Fosberg	Breadfruit	Hypertension, diabetes, liver cirrhosis	Pacific, Tropical Asia, Indonesia, Papua New Guinea
Artocarpus chama Buch.-Ham.	Chaplasha	-	India, Burma
Artocarpus chempeden Spreng	Chempedak	Diarrhoea, malaria,	South-East Asia, Indonesia
Artocarpus elasticus Reinw. Ex Blume	-	Inflammation, dysentery, tuberculosis	South-East Asia, West Malaysia
Artocarpus heterophyllus Lam.	Jackfruit	Diarrhoea, fever, dermatitis, cough	India, South-East Asia
Artocarpus hirsutus Lam.			South India
Artocarpus odoratissimus Blanco.	Marang, Terap	Fruits edible	Borneo, Philippines

Table 7: Chemical composition of jackfruit (Modified after; Jagtap and Bapat, 2010)

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	01-04	0.40-0.43
Carbohydrate (g)	9.4-11.5	16.0-25.4	25.8-38.4
Fibre (g)	2.6-3.6	1.0-1.5	1.0-1.5
Total sugars (g)	-	20.6	-
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
Phosphorous (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
Vitamin A (IU)	30	175-540	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

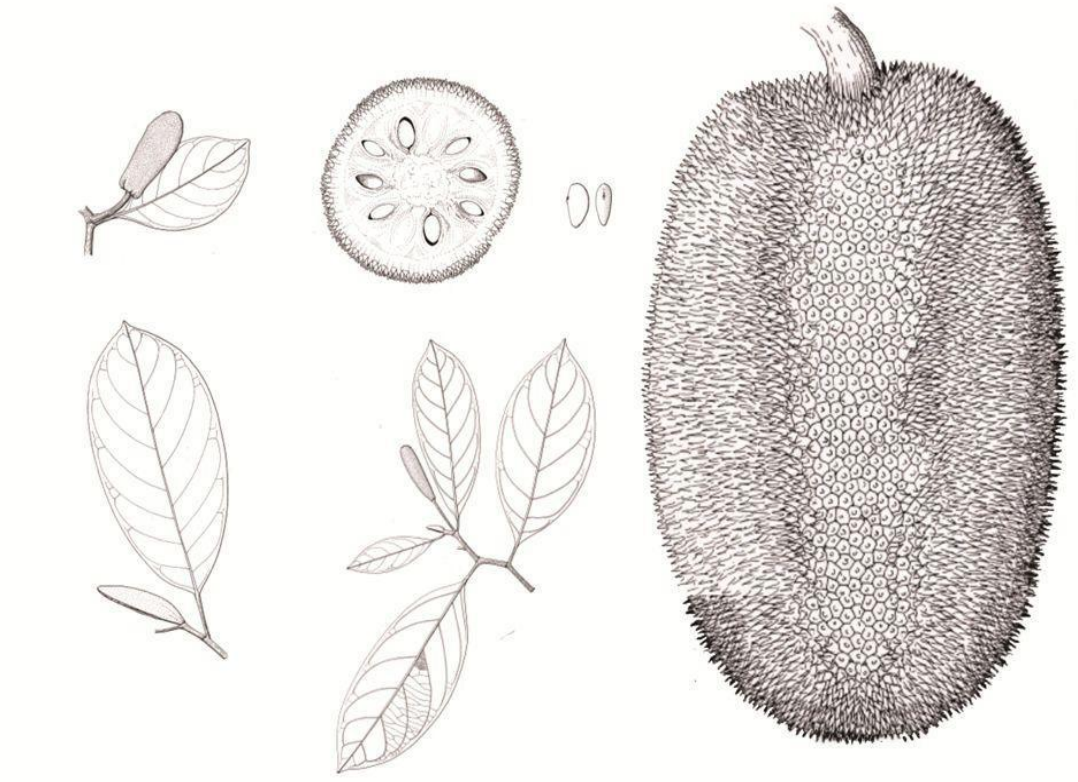

Figure 2: Morphological characters of jackfruit (*Artocarpus heterophyllus* Lam.) (Modified after; Haq, 2006)

Phytochemical Composition

The Artocarpus species contain a diversity of compounds especially phenolic compounds, flavonoids, stilbenoids, arylbenzofurons, carotenoids, volatile acid sterols and tannins which varies depending on the variety (Jagtap and Bapat, 2010; Baliga *et al.*, 2011; Hakim *et al.*, 2006; Arung *et al.*, 2006; Chandrika *et*

al., 2005; De Faria *et al.,* 2009; Ko *et al.,* 1998; Venkataraman, 1972; Wong *et al.,* 1992; Maia *et al.,* 2004). Fructose, glucose and sucrose were the major sugars in jackfruit, while capric, myristic, lauric, palmitic, oleic, stearic, linoleic and arachidic acids were the major fatty acids (Chowdhury *et al.,* 1991; Chowdhury *et al.,* 1997; Jagtap and Bapat, 2010; Rahman *et al.,* 1999; Ong *et al.,* 2006).

The seeds contain β-carotene, α-carotene, β-zeacarotene, α-zeacarotene and crocetin which are mostly present in trans form (Baliga *et al.,* 2011; Chandrika *et al.,* 2005; Jagtap and Bapat, 2010; De Faria *et al.,* 2009). The occurrence of Jacalin (lectin) in the jackfruit seeds was first reported in 1979 which is a tetrameric two chain lectin molecular mass 65 KDa combining a heavy α-chain (133 amino acid) with light β-chain (20-21 amino acid) (Jagtap and Bapat, 2010; Chatterjee *et al.,* 1979; Young *et al.,* 1991). Jacalin is the major protein representing over 50% in jackfruit seeds (Kabir *et al.,* 1993) and can bind to human IgA (Chatterjee *et al.,* 1979; Pereira *et al.,* 1980; Saxon *et al.,* 1987) and T-antigen (Sastry *et al.,* 1986). In addition to Jacalin, Artocarpin, a polyspecfic lectin which can react with a variety of monosaccharide is also present in jackfruit seeds (Chowdhury *et al.,* 1991; Barre *et al.,* 2004). Artocarpin is a 159 amino acid polypeptide chain which is a non glycosylated version of Jacalin, showing 52% identity in sequences (Rosa *et al.,* 1999; Jagtap and Bapat, 2010). The seeds have high protein than from beef and fishes, with high carbohydrate content and 11.4% oil content which make an alternate source for animal diet (Ajayi, 2008).

These phyto-nutrients have a wide range of health benefits especially antimicrobial, anticancer, antihypertensive, antiulcer, antioxidant and anti-ageing properties (Swami *et al.,* 2012; Haq, 2006; Loizzo *et al.,* 2010; Siritapetawee *et al.,* 2012; Ko *et al.,* 1998). Root has been found affective effective against asthma, skin diseases, diarrhoea and fever (Samaddar, 1985). The presence of phyto-nutrients further enhances the opportunities for development of value added products (Umesh *et al.,* 2010; Jagtap and Bapat, 2013).

Biological Activities

Antibacterial Activity

The methanolic extracts of stem, roots, bark and leaves and seeds exhibit broad spectrum antibacterial properties against various gram positive and negative bacteria (Jagtap and Bapat, 2010). However the butanol fractions of root bark and fruit have much promising antibacterial activity (Khan *et al.,* 2003).

Antimalarial Activities

The flavonoids especially artonin, artocapones show antiplasmodial activity.

Anticariogenic activities

The studies on methonlic extracts of leaves posses inhibitory effect on various cariogenic bacteria (Sato *et al.,* 1996).

Antifungal Activities

The studies jackfruit seeds shown to inhibit growth of *Fusarium moniliforme* and *Saccharomyces cerevisiae* (Trinade *et al.,* 2006).

Table 8: Free sugars in soft and firm varieties of jackfruit (Modified after; Rahman *et al.,* 1999)

Samples	Glucose	Fructose	Surcose	Inositol
Soft variety				
JES	69	63	8	Trace
DES	158	104	Trace	6
CES	148	96	Trace	Trace
Firm variety				
JEF	ND	-	-	-
DEF	101	159	63	36
CEF	381	302	18	18

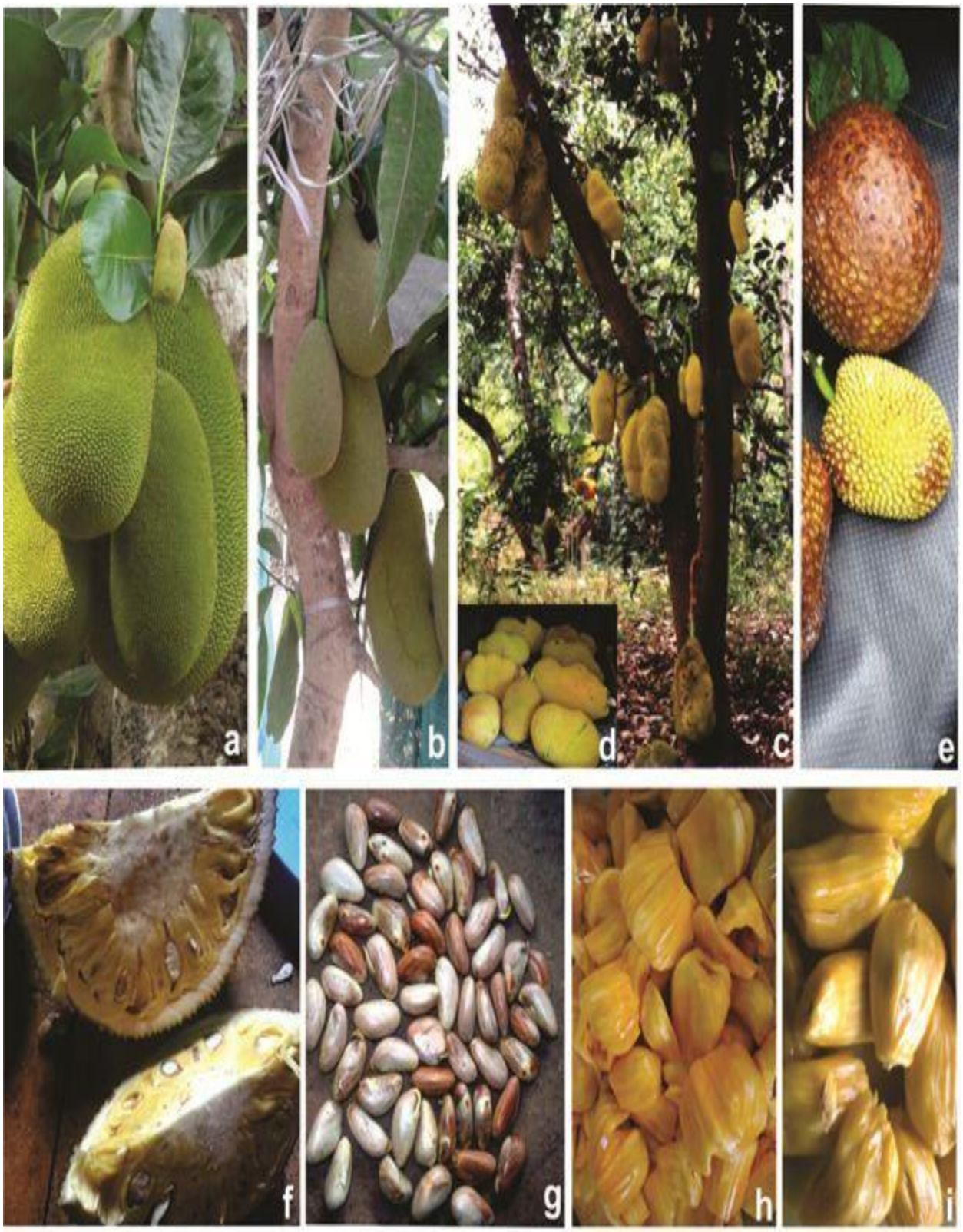

Figure 3: Jackfruit trees a) jackfruit with varying sizes; b) different stages of fruiting; c) tree bearing fruits; d) fruits plucked; e) small type of jackfruit; f) jackfruit cut opened; g) jackfruit seeds; h) opened jackfruit flakes; i) flakes unopened

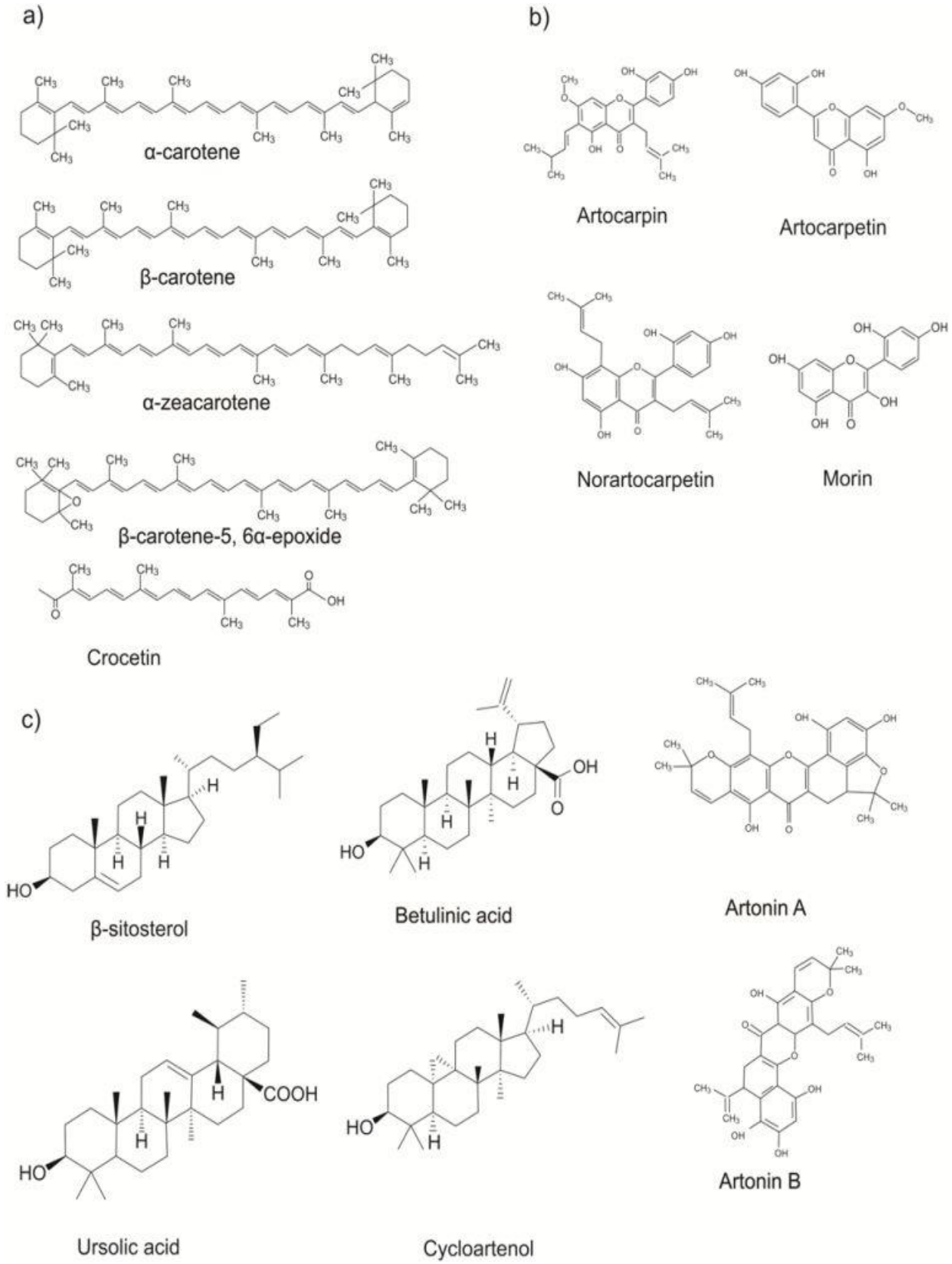

Figure 4: Major phytochemical components of jackfruit a) carotenoids; b) prenylflavones; c) sterols

Table 9: Starch and dietary fiber content in soft and firm varieties of jackfruit (Modified after; Rahman *et al.*, 1999)

Samples	Starch	SDF	IDF	Total dietary fibre
Soft variety				
JES	7.8	4.5	38.6	43.4
DES	8.7	3.8	39.9	43.7
CES	9.9	4.9	42.2	47.1
Firm variety				
JEF	9.0	3.5	38.9	42.5
DEF	11.1	3.3	41.7	45.0
CEF	11.1	3.5	42.6	46.0

Conclusion

Being one of the underutilized fruits in India, *Artocarpus heterophyllus* Lam. has promising leads to further scientific researches and livelihood strategies. The tree indigenous to the Western Ghats is an important source of nutritious food during summer season. Encouragements should be done to the marketing as well as value added food products from this underutilized fruit tree.

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REFERENCES

Ahmed K, Malek M, Jahan K and Salamatullah K (1986). *Nutritive Value of Food Stuff*, 3rd edition, Institute of Nutrition and Food Science. Bangladesh: University of Dhaka.

Ajayi IA (2008). Comparative study of the chemical composition and mineral element content of *Artocarpus heterophyllus* and *Treculia Africana* seeds and seed oils. *Bioresource Technology* **99**(11) 5125-5129.

Alagiapillai OA, Kuttalam PS, Subramanian V and Jayasekhar M (1996). PPI-I jack: A new high yielding, regular bearing jack variety for Tamil Nadu. *Madras Agricultural Journal* **83**(1) 310-312.

Amma SP, Kumaran K, Valavi SG, Peter KV and Thottappilly G (2011). Jackfruit in South India. *The jackfruit*, Studium Press LLC, Houston, USA.

Arkroyd WR, Gopalan C and Balasubramanuyam SC (1996). The nutritive value of Indian food and the planning of satisfaction diet. *September Report Series*, New Delhi: Indian Council of medical Research **42**.

Arung ET, Shimizu K and Kondo R (2006). Inhibitory effect of artocarpanone from *Artocarpus heterophyllus* on melanin biosynthesis. *Biological and Pharmaceutical Bulletin* **29**(9) 1966-1969.

Azad AK (2000). Genetic diversity of jackfruits in Bangladesh and development of propagation methods. Ph.D thesis, University of Southampton, UK.

Babitha S, Soccol CR and Pandey A (2006). Jackfruit Seed- A Novel Substrate for the Production of Monascus Pigments through Solid-State Fermentation. *Food Technology and Biotechnology* **44**(4) 465-471.

Babitha S, Soccol CR and Pandey A (2007). Solid-state fermentation for the production of *Monascus* pigments from jackfruit seed. *Bioresource Technology* **98**(8) 1554-1560.

Baliga MS, Shivashankara AR, Haniadka R, Dsouza J and Bhat HP (2011). Phytochemistry, nutritional and pharmacological properties of *Artocarpus heterophyllus* Lam (jackfruit): A review. *Food Research International* **44**(7) 1800-1811.

Banerjee R, Dhanaraj V, Mahanta SK, Surolia A and Vijayan M (1991). Preparation and x-ray characterization of four new crystal forms of Jacalin, a lectin from *Artocarpus integrifolia*. *Journal of Molecular Biology* **221**(3) 773-776.

Barre A, Peumans WJ, Rossignol M, Borderies G, Culerrier R, Van Damme EJ and Rougé P (2004). Artocarpin is a polyspecific jacalin-related lectin with a monosaccharide preference for mannose. *Biochimie* **86**(9) 685-691.

Basu D, Delucas L, Parks EH and Suddath FL (1988). Preliminary crystallographic study of the α-d-galactose-specific lectin from jack fruit (*Artocarpus integra*) seeds. *Journal of Molecular Biology* **201**(3) 661-662.

Bobbio FO, el Dash AA, Bobbio PA and Rodrigues LR (1978). Isolation and characterization of the physicochemical properties of the starch of jackfruit seeds (*Artocarpus heterophyllus*). *Cereal Chemistry* **55**(4) 505-511.

Burkill HM (1997). *The Useful Plants of West Tropical Africa*, 2nd edition (Royal Botanic Gardens: Kew, U.K.) **4**.

Chandrika UG, Jansz ER and Warnasuriya ND (2005). Analysis of carotenoids in ripe jackfruit (*Artocarpus heterophyllus*) kernel and study of their bioconversion in rats. *Journal of the Science of Food and Agriculture* **85**(2) 186-190.

Chatterjee B, Vaith P, Chatterjee S, Karduck D and Uhlenbruck G (1979). Comparative studies of new marker lectins for alkali-labile and alkali-stable carbohydrate chains in glycoproteins. *International Journal of Biochemistry* **10**(4) 321-327.

Chowdhury FA, Raman A and Jabbar Mian A (1997). Distribution of free sugars and fatty acids in jackfruit (*Artocarpus heterophyllus*). *Food Chemistry* **60**(1) 25-28.

Chowdhury S, Ahmed H and Chatterjee BP (1991). Chemical modification studies of *Artocarpus lakoocha* lectin artocarpin. *Biochimie* **73**(5) 563-571.

Chrips, NR, Balasingh GR and Kingston C (2008). Nutrient constituents of neglected varieties of *Artocarpus heterophyllus* Lam. from Kanyakumari district, South India. *Journal of Basic and Applied Biology* **2**(3&4) 36-37.

De Faria AF, De Rosso VV and Mercadante AZ (2009). Carotenoid composition of jackfruit (*Artocarpus heterophyllus*), determined by HPLC-PDA-MS/MS. *Plant Foods for Human Nutrition* **64**(2) 108-115.

Devalaraja S, Jain S and Yadav H (2011). Exotic fruits as therapeutic complements for diabetes, obesity and metabolic syndrome. *Food Research International* **44**(7) 1856-1865.

Dhanaraj V, Patanjali SR, Surolia A and Vijayan M (1988). Preparation and preliminary X-ray studies of two crystal forms of Jacalin, a lectin from *Artocarpus integrifolia*. *Journal of Molecular Biology* **203**(4) 1135–1136.

Dutta H, Paul SK, Kalita D and Mahanta CL (2011). Effect of acid concentration and treatment time on acid-alcohol modified jackfruit seed starch properties. *Food Chemistry* **128**(2) 284-291.

Hagiwara K, Collet-Cassart D, Kunihiko K and Vaerman JP (1988). Jacalin: isolation, characterization, and influence of various factors on its interaction with human IgA1, as assessed by precipitation and latex agglutination. *Molecular Immunology* **25**(1) 69-83.

Hakim EH, Achmad SA, Juliawaty LD, Makmur L, Syah YM, Aimi N, Kitajima M and Takayama H, Ghisalberti EL (2006). Prenylated flavonoids and related compounds of the Indonesian Artocarpus (Moraceae). *Journal of Natural Medicines* **60**(3) 161-184.

Hameed BH (2009). Removal of cationic dye from aqueous solution using jackfruit peel as non-conventional low-cost adsorbent. *Journal of Hazardous Materials* **162**(1) 344-350.

Haq N (2006). Jackfruit (Artocarpus heterophyllus). In: *Tropical Fruit Trees*, edited by Williams JT, Smith RW and Dunsiger Z, Southampton, UK: Southampton Centre for Underutilised Crops, University of Southampton.

Jagadeesh SL, Reddy BS, Basavaraj N, Swamy GSK, Gorbal K, Hegde L, Raghavan GSV and Kajjidoni ST (2007a). Inter tree variability for fruit quality in jackfruit selections of Western Ghats of India. *Scientia Horticulturae* **112**(4) 382-387.

Jagadeesh SL, Reddy BS, Swamy GSK, Gorbal K, Hegde L and Raghavan GSV (2007b). Chemical composition of jackfruit (*Artocarpus heterophyllus* Lam.) selections of Western Ghats of India. *Food Chemistry* **102**(1) 361-365.

Jagtap UB and Bapat VA (2010). *Artocarpus*: A review of its traditional uses, phytochemistry and pharmacology. *Journal of Ethnopharmacology* **129**(2) 142-166.

Jagtap UB and Bapat VA (2013). Green synthesis of silver nanoparticles using *Artocarpus heterophyllus* Lam. seed extract and its antibacterial activity. *Industrial Crops and Products* **46**(1) 132-137.

Kabir S (1998). Jacalin: a jackfruit (*Artocarpus heterophyllus*) seed-derived lectin of versatile applications in immunobiological research. *Journal of Immunological Methods* **212**(2) 193-211.

Kabir S, Aebersold R and Daar AS (1993). Identification of a novel 4 kDa immunoglobulin-A-binding peptide obtained by the limited proteolysis of jacalin. *Biochimica et Biophysica Acta (BBA)-Protein Structure and Molecular Enzymology* **1161**(2) 194-200.

Khan MR, Omoloso AD and Kihara M (2003). Antibacterial activity of *Artocarpus heterophyllus*. *Fitoterapia* **74**(5) 501-505.

Ko FN, Cheng ZJ, Lin CN and Teng CM (1998). Scavenger and Antioxidant Properties of Prenylflavones Isolated from *Artocarpus heterophyllus*. *Free Radical Biology and Medicine* **25**(2) 160-168.

Lin KW, Liu CH, Tu HY, Ko HH and Wei BL (2009). Antioxidant prenylflavonoids from *Artocarpus communis* and *Artocarpus elasticus*. *Food Chemistry* **115**(2) 558-562.

Loizzo MR, Tundis R, Chandrika UG, Abeysekera AM, Menichini F and Frega NG (2010). Antioxidant and antibacterial activities on food borne pathogens of *Artocarpus heterophyllus* Lam.(Moraceae) leaves extracts. *Journal of Food Science* **75**(5) M291-M295.

Maia JGS, Andrade EHA and Zoghbi MDGB (2004). Aroma volatiles from two fruit varieties of jackfruit (*Artocarpus heterophyllus* Lam.). *Food Chemistry* **85**(2) 195-197.

Miranda Santos IKFD, Mengel Jr J, Bunn-Moreno MM and Campos-Neto A (1991). Activation of T and B cells by a crude extract of *Artocarpus integrifolia* is mediated by a lectin distinct from jacalin. *Journal of Immunological Methods* **140**(2) 197-203.

Morton JF (1987). *Fruits of Warm Climates* (Creative Resources Systems, Inc.) Winterville, USA

Mukprasirt A and Sajjaanantakul K (2004). Physico-chemical properties of flour and starch from jackfruit seeds (*Artocarpus heterophyllus* Lam.) compared with modified starches. *International Journal of Food Science & Technology* **39**(3) 271-276.

Muralidharan VK, Ganapathy MM, Velayudhan KC and Amalraj VA (1997). Collecting jackfruit germplasm in Western Ghats. *Indian Journal of Plant Genetic Resources* **10**(2) 227-231.

Narasimham P (1990). Breadfruit and jackfruit. In: *Fruits of Tropical and Subtropical Origin Lake Alfred, FL: Florida Science Source*, edited by Nagy S, Shaw PE and Wardowski WF 193–259.

Odoemelam SA (2005). Functional properties of raw and heat processed jackfruit (*Artocarpus heterophyllus*) flour. *Pakistan Journal of Nutrition* **4**(6) 366-370.

Ong BT, Nazimah SAH, Osman A, Quek SY, Voon YY, Hashim D, Chew PM and Kong YW (2006). Chemical and flavour changes in jackfruit (*Artocarpus heterophyllus* Lam.) cultivar J3 during ripening. *Postharvest Biology and Technology* **40**(3) 279-286.

Pavan V, Sancho RAS and Pastore GM (2014). The effect of *in vitro* digestion on the antioxidant activity of fruit extracts (*Carica papaya, Artocarpus heterophillus* and *Annona marcgravii*). *LWT-Food Science and Technology* **59**(2) 1247-1251.

Pereira ME, Loures MA, Villalta F and Andrade AF (1980). Lectin receptors as markers for *Trypanosoma cruzi*. Developmental stages and a study of the interaction of wheat germ agglutinin with sialic acid residues on epimastigote cells. *The Journal of Experimental Medicine* **152**(5) 1375-1392.

Pilatte Y, Hammer CH, Frank MM and Fries LF (1989). A new simplified procedure for C1 inhibitor purification: a novel use for jacalin-agarose. *Journal of Immunological Methods* **120**(1) 37-43.

Prakash O, Kumar R, Mishra A and Gupta R (2009). *Artocarpus heterophyllus* (Jackfruit): an overview. *Pharmacognosy Reviews* **3**(6) 353-358.

Rahman MA, Nahar N, Mian AJ and Mosihuzzaman M (1999). Variation of carbohydrate composition of two forms of fruit from jack tree (*Artocarpus heterophyllus* L.) with maturity and climatic conditions. *Food Chemistry* **65**(1) 91-97.

Ray S and Chatterjee BP (1989). Purification of ant-egg glycoprotein and its interaction with jacalin. *Carbohydrate Research* **191**(2) 305-314.

Reddy BMC, Patil P, Kumar SS and Govindaraju LR (2014). Studies on physico-chemical characteristics of jackfruit clones of south Karnataka. *Karnataka Journal of Agricultural Sciences* **17**(2) 279-282.

Rosa JC, Garrat R, Beltramini L, Resing K, Roque-Barreira MC and Greene LJ (1999). KM+, a mannose-binding lectin from *Artocarpus integrifolia*: amino acid sequence, predicted tertiary structure, carbohydrate recognition and analysis of the beta-prism fold. *Protein Science* **8**(1) 13–24.

Roy SK and Joshi GD (1995). Minor fruits-tropical. In: *Handbook of Fruit Science and Technology*, edited by Salunkhe DK (Marcel Dekker, Inc.) New York, USA.

Sahasrabuddhe AA, Ahmed N and Krishnasastry MV (2006). Stress-induced phosphorylation of caveolin-1 and p38, and down-regulation of EGFr and ERK by the dietary lectin jacalin in two human carcinoma cell lines. *Cell Stress & Chaperones* **11**(2) 135-147.

Samaddar HM (1985). Jackfruit. In: *Fruits of India: Tropical and Subtropical*, edited by Bose TK and Mishra SK, Culcutta, India.

Sastry MV, Banarjee P, Patanjali SR, Swamy MJ, Swarnalatha GV and Surolia A (1986). Analysis of saccharide binding to *Artocarpus integrifolia* lectin reveals specific recognition of T-antigen (α-D-Gal(1–3)D-GalNAc). *Journal of Biological Chemistry* **261**(1) 11726–11733.

Sato M, Fujiwara S, Tsuchiya H, Fujii T, Iinuma M, Tosa H and Ohkawa Y (1996). Flavones with antibacterial activity against cariogenic bacteria. *Journal of Ethnopharmacology* **54**(2) 171-176.

Saxena A, Bawa AS and Raju PS (2009). Optimization of a multitarget preservation technique for jackfruit (*Artocarpus heterophyllus* L.) bulbs. *Journal of Food Engineering* **91**(1) 18-28.

Saxena A, Bawa AS and Raju PS (2009). Phytochemical changes in fresh-cut jackfruit (*Artocarpus heterophyllus* L) bulbs during modified atmosphere storage. *Food Chemistry* **115**(4) 1443-1449.

Saxon A, Tsui F and Martinez-Maza O (1987). Jacalin, an IgA-binding lectin, inhibits differentiation of human B cells by both a direct effect and by activating T-suppressor cells. *Cellular Immunology* **104**(1) 134-141.

Schnell RJ, Olano CT, Campbell RJ and Brown JS (2001). AFLP analysis of genetic diversity within a jackfruit germplasm collection. *Scientia Horticulturae* **91**(3) 261-274.

Selvaraj Y and Pal DK (1989). Biochemical changes during the ripening of jackfruit (*Artocarpus heterophyllus* L.). *Journal of Food Science Technology* **26**(6) 304-307.

Shyamalamma S, Chandra SBC, Hegde M and Naryanswamy P (2008). Evaluation of genetic diversity in jackfruit (*Artocarpus heterophyllus* Lam.) based on amplified fragment length polymorphism markers. *Genetics and Molecular Research* **7**(3) 645-656.

Siritapetawee J, Thammasirirak S and Samosornsuk W (2012). Antimicrobial activity of a 48-kDa protease (AMP48) from *Artocarpus heterophyllus* latex. *European Review for Medical and Pharmacological Sciences* **16**(1) 132-137.

Siti Balqis Z and Rosma A (2011). *Artocarpus integer* leaf protease: Purification and characterisation. *Food Chemistry* **129**(4) 1523-1529.

Swami SB, Thakor NJ, Haldankar PM and Kalse SB (2012). Jackfruit and its many functional components as related to human health: a review. *Comprehensive Reviews in Food Science and Food Safety* **11**(6) 565-576.

Trindade MB, Lopes JL, Soares-Costa A, Monteiro-Moreira AC, Moreira RA, Oliva MLV and Beltramini LM (2006). Structural characterization of novel chitin-binding lectins from the genus *Artocarpus* and their antifungal activity. *Biochimica et Biophysica Acta (BBA)-Proteins and Proteomics* **1764**(1) 146-152.

Tulyathan V, Tananuwong K, Songjinda P and Jaiboon N (2002). Some physicochemical properties of jackfruit (*Artocarpus heterophyllus* Lam) seed flour and starch. *Science Asia* **28**(2002) 37-41.

Uddin MT, Rukanuzzaman M, Khan MMR and Islam MA (2009b). Jackfruit (*Artocarpus heterophyllus*) leaf powder: An effective adsorbent for removal of methylene blue from aqueous solutions. *Indian Journal of Chemical Technology* **16**(2) 142-149.

Uddin MT, Rukanuzzaman M, Maksudur Rahman Khan M and Akhtarul Islam M (2009a). Adsorption of methylene blue from aqueous solution by jackfruit (*Artocarpus heteropyllus*) leaf powder: A fixed-bed column study. *Journal of Environmental Management* **90**(11) 3443-3450.

Umesh JB, Panaskar Shrimant N and Bapat VA (2010). Evaluation of antioxidant capacity and phenol content in jackfruit (*Artocarpus heterophyllus* Lam.) fruit pulp. *Plant Foods for Human Nutrition* **65**(2) 99-104.

Venkataraman K (1972). Wood phenolics in the chemotaxonomy of the Moraceae. *Phytochemistry* **11**(5) 1571-1586.

Verheij EWM and Coronel RE (1992). Plant resources of South-East Asia No. 2. Edible fruits and nut, Prosea, Bogor, Indonesia.

Wangchu L, Singh D and Mitra SK (2013). Studies on the diversity and selection of superior types in jackfruit (*Artocarpus heterophyllus* Lam.). *Genetic Resources and Crop Evolution* **60**(5) 1749-1762.

Wong KC, Lim CL and Wong LL (1992). Volatile flavour constituents of chempedak (*Artocarpus polyphema* Pers.) fruit and jackfruit (*Artocarpus heterophyllus* Lam.) from Malaysia. *Flavour and Fragrance Journal* **7**(6) 307-311.

Young NM, Johnston RA and Watson DC (1991). The amino acid sequences of jacalin and the *Maclura pomifera* agglutinin. *FEBS Letters* **282**(2) 382-384.