Jackfruit (Artocarpus heterophyllus): Biodiversity, Nutritional Contents, and Health

Chapter · January 2018

DOI: 10.1007/978-3-319-54528-8_87-1

2 authors:

Shrikant Baslingappa Swami
Dr. Balasaheb Sawant Konkan Krishi Vidypeeth, Dapoli Dist Ratnagiri
42 PUBLICATIONS **661** CITATIONS
SEE PROFILE

Sandeep Kalse
Dr. Balasaheb Sawant Konkan Krishi Vidypeeth
15 PUBLICATIONS **348** CITATIONS
SEE PROFILE

Jackfruit (*Artocarpus heterophyllus*): Biodiversity, Nutritional Contents, and Health

Shrikant Baslingappa Swami and Sandeep Baban Kalse

Contents

1 Introduction 2
2 Biodiversity 4
2.1 Genetic Diversity 5
3 Nutritional Characteristics of Jackfruit 7
3.1 Jackfruit Bulbs 7
3.2 Jackfruit Seed 9
4 Physicochemical Properties 10
5 Phytochemical Analysis 11
5.1 Primary Metabolites in Jackfruit Seed 11
6 Health Benefits 13
6.1 Anticancer 14
6.2 Diabetics 15
6.3 Immune System 16
6.4 Improve Digestion 16
6.5 Cardiovascular Health 16
6.6 Fast-Dissolving Tablets 17
6.7 Dental Health 18
7 Conclusion 19
References 19

Abstract

Jackfruit (*Artocarpus heterophyllus Lam.*) is an ancient fruit and is consumed either raw or processed into different value-added products. Jackfruit seeds are normally discarded or steamed and eaten as a snack or used in some local dishes; seed flour is used in some biscuit factories in various bakery products, etc. The use of jackfruit bulbs, seeds, and its other parts has also been reported since

S. B. Swami (✉) · S. B. Kalse
Department of Post Harvest Engineering, Post Graduate Institute of Post Harvest Management, Killa Roha, MS, India
e-mail: swami_shrikant1975@yahoo.co.in; sandeep.kalse@gmail.com

J.-M. Mérillon, K. G. Ramawat (eds.), *Bioactive Molecules in Food*, Reference Series in Phytochemistry, https://doi.org/10.1007/978-3-319-54528-8_87-1

ancient times for their therapeutic qualities. The health benefits of jackfruit have been attributed to its wide range of physicochemical applications. It contains high levels of carbohydrates, protein, starch, calcium, vitamins, free sugar (sucrose), fatty acids, ellagic acid, and amino acids like arginine, cystine, histidine, leucine, lysine, methionine, theanine, and tryptophan. The jackfruit has diverse medicinal uses especially antioxidant, anti-inflammatory, antimicrobial, anticancer, and antifungal activity. This chapter describes an overview of the functional, medicinal, nutritional, and health aspects of jackfruit.

Keywords
Jackfruit · Antioxidant · Jacalin

Abbreviations

Caf-A	Caffeic acid
FA	Ferulic acid
FDA	Food and Drug Administration
FDT	Fast-dissolving tablets
GA	Gallic acid
GL	Glycemic load
HbA1c	Hemoglobin A1c
HDL-C	High-density lipoprotein cholesterol
IAUC	Incremental area under curve
LDL-C	Low-density lipoprotein cholesterol
NO	Nitric oxide
NSS	Normal serving size
TA	Tannic acid
UDL	Under detection limit

1 Introduction

Jackfruit (*Artocarpus heterophyllus*) belongs to the Moraceae family, native to India and seen abundant in Western Ghats, a biodiversity spot of India [1–5]. Besides India, jackfruit is commonly grown in home gardens of tropical and subtropical countries especially in Sri Lanka, Bangladesh, Burma, Philippines, Indonesia, Thailand, Malaysia, and Brazil [2, 6–10]. In India, it is widely distributed in the states of Assam, West Bengal, Uttar Pradesh, Maharashtra, Kerala, Tamil Nadu, and Karnataka [5] and considered to be the "poor man's food" [1, 4]. It is a medium-size tree typically reaching 28–80 ft. in height that is easily accessible for its fruit. The fruit is borne on side branches and main branches of the tree. The average weight of a fruit is 3.5–10 kg, and sometimes a fruit may reach up to 25 kg. The ripe jackfruits consisted 29% pulp, 12% seeds, and 54% rind [11]. Figure 1 shows the various parts of a jackfruit. The jackfruit seed is 2–3 cm long and 1–2 cm in diameter, and each fruit contains 100–500 seeds.

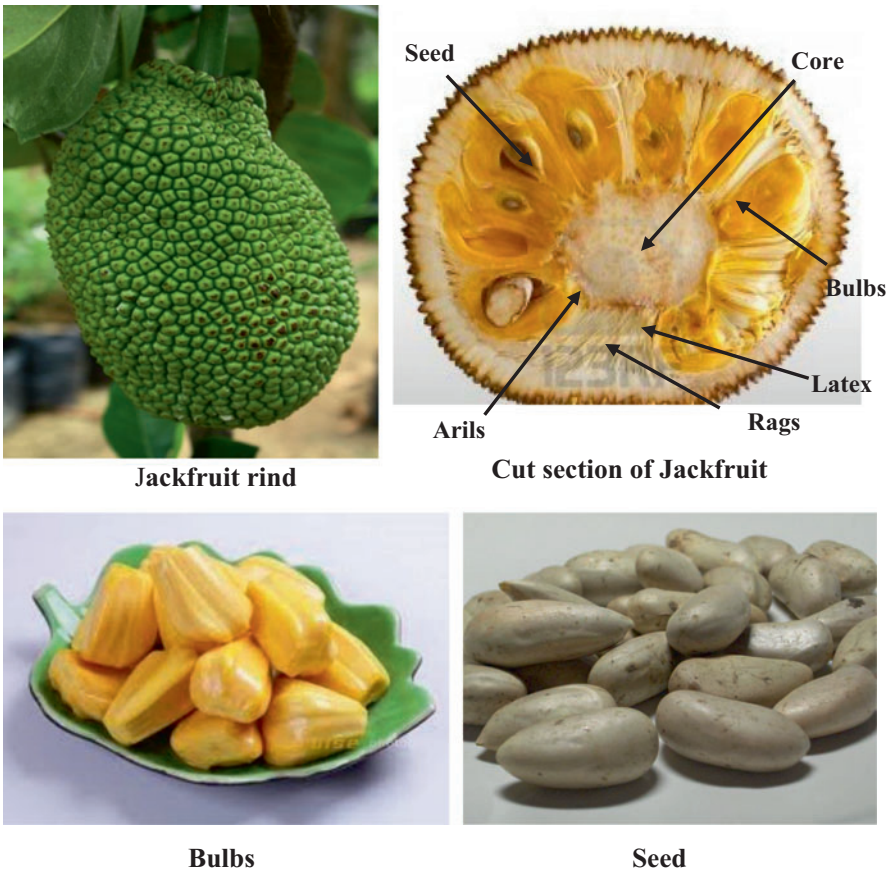

Fig. 1 Different parts of jackfruit

There are two varieties of jackfruit in India: one is small, fibrous, soft, and mushy, with sweet carpels and a texture like that of raw oysters, and is called *Barka*, and the other variety is crisp and crunchy, but not very sweet, and is called *Kapa* [12]. In Bangladesh, *Khaja*, *Gala*, and *Durasha* are the main varieties [13]. *Khaja* is characterized by its hard and crispy bulb; *Gala* is soft and juicy and mostly melting bulb. On the other hand, *Durasha* is an intermediate between *Khaja* and *Gala* [14].

Jackfruit is reported to possess many medicinal properties. The phenolic compounds isolated from jackfruit are reported to exhibit anti-inflammatory effect [4]. The prenylflavonoids present in jackfruit had shown strong antioxidant properties [43] and is expected to act against lipid peroxidation of biological membranes [15]. The hot water extract of mature leaves are utilized in *Ayurvedic* treatment for hyperglycemia and diabetes [4]. The flavonoids present in the extract have been identified to be responsible for the nontoxic hypoglycemic action [16]. Lectins present in the seeds have shown antifungal properties, while the crude methanolic

extracts from root bark and stems have shown broad-spectrum antibacterial activity [17].

Resveratrol (trans-3,5,4-trihydroxystilbene, RES) is one of the polyphenols naturally present in jackfruit [18, 19] and is well-known for its health-promoting activities of antioxidant, cardioprotect, and anti-inflammatory [19]. Compounds that can inhibit angiogenesis have great potential for cancer treatment [20]. Jackfruit seeds contain secondary metabolites that display anticancer effects, especially anti-angiogenesis, and belong to the flavonoid group [21]. The jackfruit seed starch as superdisintegrant is suitable for the preparation of fast-dissolving tablets [22]. Extracts of jackfruit pulp show considerable anti-inflammatory activity by suppressing the production of nitric oxide (NO) and prostaglandin E2 (PGE2) [23], its leaf extracts also give remarkable antioxidant activity [43] and exhibit attenuation on hyperglycemia and hyperlipidemia [24]. Its wood was reported to be used as antioxidant, antiaging, anti-inflammatory, and skin care agents [25]. The leaf, root, bark, and fresh fruit of this plant have been certified to contain various compounds like flavonoids, phenolic acids, organic acids, carotenoids, stilbenes, triterpenes, and sterols, especially prenylflavonoids [2, 26, 27].

Jackfruit is also used for further processing. For instance, jackfruit leather and jackfruit chips can be made from dried jackfruit pulp [28]. Pureed jackfruit is also manufactured into baby food, juice, jam, jelly, and base for cordials [29]. Jackfruits are made into candies, fruit-rolls, marmalades, and ice cream [80]. Other than canning, advances in processing technologies too have pushed toward more new products [30]. Freeze-dried, vacuum-fried, and cryogenic processing are new preservation methods for modern jackfruit-based products. Various parts of the jackfruit tree have been used in medicine, and its wood is an important source in timber industries [29].

Nowadays, it is widely accepted that the beneficial health effects of fruits and vegetables in the prevention of disease are due to the bioactive compounds they contain [31]. In recent years, there has seen increased interest on the part of consumers, researchers, and the food industries into how food products can help maintain health; and the role that diet plays in the prevention and treatment of many illnesses has become widely accepted. This chapter describes an overview of the biodiversity of the tree and functional, medicinal, nutritional, and health aspects of jackfruit and its various parts.

2 Biodiversity

Jackfruit is an important crop of India, Burma, China, Sri Lanka, Malaysia, Indonesia, Thailand, and the Philippines. It is also grown in parts of Africa, Brazil, Suriname, the Caribbean, Florida, and Australia. Jackfruit has been cultivated since prehistoric times and has been introduced to many Pacific islands since post-European contact and is of particular importance in Fiji [32].

Despite numerous advantages, the popularity of jackfruit as a commercial crop is very poor owing to wide variations in fruit quality, the long seed dormancy, and the

widespread belief that excessive consumption of jackfruit bulbs leads to certain digestive ailments [33].

The jackfruit has innumerable types in the Western Ghats with varying fruit characteristics. The types differ among themselves in the shape and density of spikes on the rind, bearing, size, shape, latex, flake size, flake color, quality, and period of maturity. Innumerable variations in bulb sweetness, acidity, flavor, and taste are observed in jackfruit growing areas. Such a wide diversity among jackfruit types in Western Ghats offers tremendous scope for improvement of this crop by selection [33, 34]. Due to crosspollination and predominance of seed propagation over a long period of time, there is high degree of variability within the species.

Jagadeesh and others [1] selected 95 jackfruit types from the hilly (65 types) and coastal (30 types) zones of Karnataka situated in Western Ghats, a biodiversity spot of India. The Western Ghats falling in two agroclimatic regions of the state, viz., hilly and coastal, studied the physicochemical characters at edible ripe stage. It was apparent that the majority of selections (19), irrespective of their agroclimatic zone, were grouped in cluster "A," whereas clusters "B," "C," "D," and "E" were monotree type. It was found that the genetic drift and natural selection under different environmental conditions could cause considerable diversity than geographical distance. Highest values for TSS (34.33 °B), carotenoids (0.857 mg/100 g), total sugar (31.33%), and reducing sugars (13.37%) were observed in cluster "B," while cluster "D" exhibited highest values for TSS/acid ratio (123.29). Single-bulb mass (26.42 g) was the highest in cluster "A" with the majority of selections, whereas the solitary cluster "C" showed the highest edible portion (37.81%). With regard to fruit mass (14.86 kg) and flake mass (5.62 kg), cluster "C" exhibited the highest value, while titratable acidity (0.768%) was found highest in cluster "E." They conclude that jackfruit, being indigenous and a highly cross-pollinated crop, displays vast diversity in the Western Ghats of India. This wide range of variation existing in nature aids in the selection of superior desirable types.

2.1 Genetic Diversity

Jackfruit is a tetraploid; its somatic chromosome number is (4n) 56. Therefore, the basic chromosome number is 14 [35]. Only one study until now by Schnell and others [36] looked at the genetic diversity of 26 accessions from different parts of the world, using amplified fragment length polymorphism (AFLP) markers, and provided an actual picture of diversity and genetic relatedness in jackfruit. This study included only two accessions from India, and they scored a small number of markers (87), of which 92 (49.2%) were found to be polymorphic. The most recent study by Azad and others [37] looked at isozyme variation in jackfruit in Bangladesh. A total of 50 accessions were evaluated for four enzyme systems, and isozyme patterns were determined on the basis of number and position of bands. They discovered that morphological traits such as weight, length, girth of the fruits, and percentage of pulp correlated poorly with environmental factors, suggesting that these characters are more likely genetically controlled. However, isozyme markers are also known to be

Table 1 Variation in morpho-agronomic characters [40]

Characteristic	Range of variation
Tree habit	Open, spreading, low spreading, sparse upright
Tree growth rate	Fast, moderate, slow
Canopy	Dense, mostly dome-shaped, slightly pyramidal, or flat-toped. It ranges from 3.5 to 6.7 m
Leaf shape	Elliptic, elliptic-obovate, obovate, oblong, lanceolate, oval
Leaf size	4–25 cm in length; 2–12 cm in width
Leaf petiole	1.2–4.0 cm long
Fruit maturity	Variable
Fruiting seasons	Variable
Fruit shape	Oblong, ellipsoid, triangular, spheroid, claviform, round
Number of fruits/tree	15–1450
Fruit weight (kg)	1.2–22.0
Fruit thickness	Thin, medium, thick
Fruit texture	Fibrous, firm, coarse, melting, crisp
Seed shape	Oblong, ellipsoid, irregular, reniform, elongated, spheroid
100 – seed weight (g)	250–1230
Flakes aroma	Mild, strong
Flakes color	Creamy white, light yellow, deep yellow, yellow, reddish, red golden
Flakes texture	Crisp, coarse, fibrous/coarse, fibrous, smooth
Quantity of fiber	Scarce, medium, abundant
Juiciness of pulp	Very juicy, juicy, medium juicy, less juicy, dry
Fruit weight (kg)	1.2–22.0
Fruit length (cm)	20.5–60.6
Fruit diameter (cm)	16.4–29.5
Fruit girth (cm)	50.5–95.8
No. of bulbs/fruit	24.2–580.2
Pulp (%)	18.3–60.9
Seed (%)	2.6–23.1
Rachis (%)	1.5–21.4
Rind (%)	20.6–72.0
TSS Brix (°)	13.8–25.3

affected by both environment and posttranslation modification, and their practical use is limited [38].

Jackfruit shows a considerable range of variation in morpho-agronomic characters, and this may be because jackfruit trees are cross-pollinated and are mostly propagated by seed. A considerable variation between trees has been observed for the traits such as growth habit, canopy structure, leaf size, fruit shape, size, color, fruit bearing (age and seasonality), and maturity (Table 1). The International Plant Genetic Resources Institute (IPGRI; now Biodiversity International) in 2000 issued a

list of descriptor and descriptor states both for characterization of germplasm and for further evaluation. Variation also exists in density, size, and shape of spines on rind, fruit-bearing sensory quality, flesh types, sweetness, flavor, and taste [39].

3 Nutritional Characteristics of Jackfruit

Studies have proved that the nutritional and phytochemical composition among jackfruit varies depending on the cultivar as well as region [2, 30, 39–41]. It is a good source of vitamins (A, C, thiamine, riboflavin, niacin) and minerals (calcium, potassium, iron, sodium, zinc) (Swami and others) [12, 30, 39–41]. Protein and carbohydrate concentration also varied in seeds across India were some varieties contain 6.8% of protein in seeds [2]. The nutritional characteristics of jackfruit bulb, seed, and other part are discussed below.

3.1 Jackfruit Bulbs

Jackfruit is heavy and bulky, and actual recovery of bulbs or edible portion varies from 20 to 25% which is easily digestible. A 100 g portion of edible raw jackfruit provides about 95 calories and is a good source of the antioxidants and vitamin C, providing about 13.7 mg. The fruit is also rich in vitamin B_6, potassium, calcium, and iron.

The bulb of ripe jackfruit is eaten fresh and used in fruit salads. It possesses high nutritional value; every 100 g of ripe fruit pulp contains 18.9 g carbohydrate, 1.9 g protein, 0.1 g fat, 77% moisture, 1.1 g fiber, 0.8 g total mineral matter, 20 mg calcium, 30 mg phosphorus, 500 mg iron, 540 IU vitamin A, 30 mg thiamin, and 84 calories [33]. The jackfruit also contains useful antioxidant compounds [15]. Table 2 shows the composition of jackfruit edible portion of young fruit and ripe fruit. Figure 2 shows the nutraceutical characteristics of jackfruit bulb (pulp) and its effects on various diseases. Figure 3 shows principal functional and medicinal effects of jackfruit. The jackfruit could be considered a functional food because it has valuable compounds in different parts of the fruit that display functional and medicinal effects.

3.1.1 Carotenoid Composition

The jackfruit bulb consists of 107.98 total carotenoids [27]. Jackfruit consists all-trans-β-carotene which is an important antioxidant for human health [40]. Jackfruit contains carotenoids that are important for prevention of several chronic degenerative diseases, such as cancer, inflammation, cardiovascular disease, cataract, and age-related macular degeneration [44, 45]. The total carotenoids present in jackfruit are shown in Table 3.

The main carotenoids in jackfruit were 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%). Jackfruit is a good source of provitamin A carotenoids,

Table 2 Composition of jackfruit bulb (100 g edible portion) [30, 41, 42]

Sr.No	Composition	Young fruit	Ripe fruit
A	**Proximate analysis**		
1	Water (g)	76.2–85.2	72.0–94.0
2	Protein (g)	2.0–2.6	1.2–1.9
3	Fat (g)	0.1–0.6	0.1–0.4
4	Carbohydrate (g)	9.4–11.5	16.0–25.4
5	Fiber (g)	2.6–3.6	1.0–1.5
6	Total sugars (g)	–	20.6
B	**Minerals and vitamins**		
1	Total minerals (g)	0.9	0.87–0.9
2	Calcium (mg)	30.0–73.2	20.0–37.0
3	Magnesium (mg)	–	27.0
4	Phosphorus (mg)	20.0–57.2	38.0–41.0
5	Potassium (mg)	287–323	191–407
6	Sodium (mg)	3.0–35.0	2.0–41.0
7	Iron (mg)	0.4–1.9	0.5–1.1
8	Vitamin A (IU)	30	175–540
9	Thiamine (mg)	0.05–0.15	0.03–0.09
10	Riboflavin (mg)	0.05–0.2	0.05–0.4
11	Vitamin C (mg)	12.0–14.0	7.0–10.0

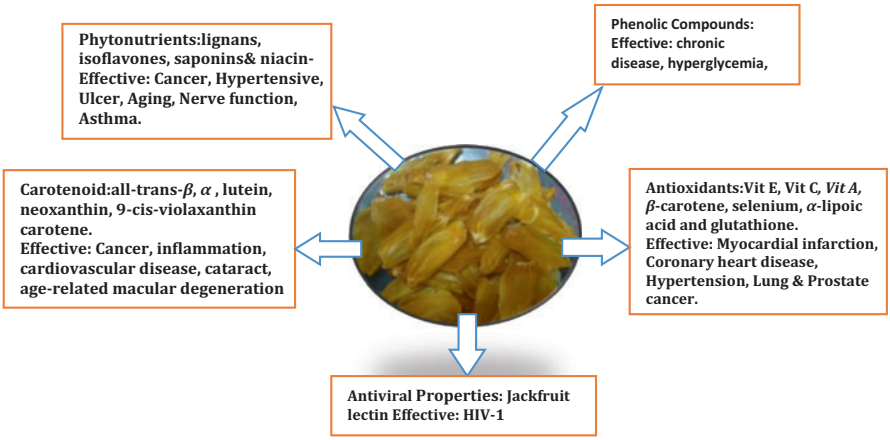

Fig. 2 Nutraceutical characteristics of jackfruit bulb (pulp) and its effect on various diseases

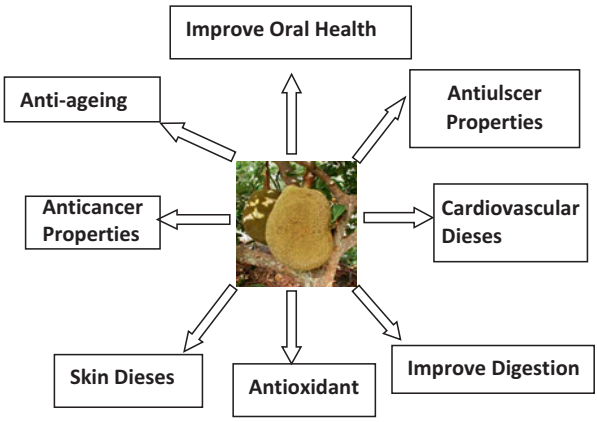

Fig. 3 Principal functional and medicinal effects of jackfruit

Table 3 Concentration (μg/100 g fresh weight) of different carotenoids in jackfruit [27]

Carotenoids	Values	Carotenoids	Values
All-trans-neoxanthin	8.85 ± 5.73	All-trans-zeinoxanthin	1.72 ± 1.20
9-cis-Neoxanthin	6.87 ± 4.25	9-cis-Zeinoxanthin	0.90 ± 1.12
All-trans-neochrome	0.88 ± 1.11	All-trans-α-cryptoxanthin	0.35 ± 0.60
All-trans-luteoxanthin	2.06 ± 0.90	All-trans-β-cryptoxanthin	1.21 ± 0.45
cis-Antheraxanthin	1.12 ± 0.36	15-cis-β-carotene	0.18 ± 0.31
9-cis-Violaxanthin	7.05 ± 5.97	13-cis-β-carotene	2.45 ± 1.40
cis-Luteoxanthin	0.34 ± 0.42	All-trans-α-carotene	1.24 ± 0.93
All-trans-lutein	37.02 ± 20.34	All-trans-β-carotene	29.55 ± 15.46
All-trans-zeaxanthin	0.96 ± 1.20	9-cis-β-carotene	0.79 ± 0.30
Total carotenoids			**107.98 ± 51.46**

though not as good as papaya [46]. Thus increased consumption of ripe jackfruit could be advocated as part of a strategy to prevent and control vitamin A deficiency.

3.2 Jackfruit Seed

The jackfruit seeds are around 10–15% of the total fruit weight and have high carbohydrate and protein contents [47]. There are 100–500 seeds in a single fruit. Seeds are normally discarded or steamed and eaten as a snack or used in some local dishes. The fresh seeds cannot be kept for a long time, seed flour can be an alternative product, which can be used in some food products.

The jackfruit seeds are a good source of starch (22%) and dietary fiber (3.19%) [48]. Jackfruit seeds contain lignans, isoflavones, and saponins that are called phytonutrients, and their health benefits are wide-ranging from anticancer to antihypertensive, antiaging, antioxidant, antiulcer, etc. [49].

Table 4 Composition of jackfruit seed (100 g edible portion) [30, 39, 41, 42]

Sr. no.	Composition	Value	Sr. no.	Composition	Value
A	**Proximate analysis**		**B**	**Minerals and vitamins**	
1	Water (g)	51.0–64.5	1	Total minerals (g)	0.9–1.2
2	Protein (g)	6.6–7.04	2	Calcium (mg)	50.0
3	Fat (g)	0.40–0.43	3	Magnesium (mg)	54.0
4	Carbohydrate (g)	25.8–38.4	4	Phosphorus (mg)	38.0–97.0
5	Fiber (g)	1.0–1.5	5	Potassium (mg)	246
6	Total sugars (g)	–	6	Sodium (mg)	63.2
			7	Iron (mg)	1.5
			8	Vitamin A (IU)	10–17
			9	Thiamine (mg)	0.25
			10	Riboflavin (mg)	0.11–0.3
			11	Vitamin C (mg)	11.0

The jackfruit seeds have medicinal properties. The oval, oblong, or oblong ellipsoid or rounded-shape, light brown color jackfruit seeds are nutritious and rich in potassium, fat, carbohydrates, and minerals. Manganese and magnesium elements have also been detected in seed powder [50]. Table 4 shows the composition of jackfruit seed. Seeds contain two lectins, namely, jacalin and artocarpin. Jacalin has been proved to be useful for the evaluation of the immune status of patients infected with human immunodeficiency virus-1 [40].

Amylose content of jackfruit seed starch was 32% [51]. Jackfruit seed extract was found to inhibit the proteolytic activities of different animal pancreatic preparations effectively [52]. The fresh seed contains crude proteins (606 g), fat (0.4 g), carbohydrates (38.4 g), fiber (1.5 g), ash (1.25–1.50 g), and moisture (51.6–57.77 g), respectively [53].

4 Physicochemical Properties

There have been few studies on physicochemical properties of jackfruit seeds. The physicochemical properties of jackfruit seed is shown in Table 5. Jackfruit seeds are fairly rich in starch [54]. The pasting properties of the jackfruit seed starch against corn and potato starch were studied, and it is reported that the pasting temperature of jackfruit seed starch was higher than those of corn starch and potato starch. The jackfruit seed starch has lower swelling properties because of high amylose content. Jackfruit seed starch was more resistant to heat and mechanical shear and hence less prone to loss viscosity upon holding and shearing. Mukprasirt and Sajjaanantakul [55] also reported that the breakdown viscosity of jackfruit seed starch was lower than that of the commercial starch.

Fat absorption is an important property in food formulations because fats improve the flavor and mouthfeel of foods [57]. The jackfruit flour has 2.8 g/ml fat absorption

Table 5 Some physicochemical and functional properties of jackfruit seed flour [56]

Sr. no.	Particular	Value (% dry matter)
	Physicochemical properties	
1.	Moisture	6.09 ± 0.01
2.	Crude fat	1.27 ± 0.01
3.	Ash	2.70 ± 0.02
4.	Protein	13.50 ± 0.06
5.	Fiber	3.19 ± 0.01
6.	Carbohydrate	79.34 ± 0.06
7.	Energy (Kcal/100 g)	382.79 ± 1.20
8.	pH	5.78 ± 0.01
	Functional properties	
9.	Titratable acidity (as, lactic acid)	1.12 ± 0.03
10.	Water absorption capacity (%)	25.00 ± 1.67
11	Fat absorption capacity (%)	17.00 ± 1.37
12.	Bulk density (g/cm^3)	0.80 ± 0.02
13.	Foaming capacity (%)	25.34 ± 0.02
14.	Foam stability (%)	33.00 ± 0.01
15.	Swelling power (g/g)	4.77 ± 0.10

characteristic. Jackfruit seed flour has a lot of potential in the food industry, especially its uses as thickener and binding agent in the food systems.

Kumar and others [58] studied the proximate compositions of two varieties of jackfruit seeds and reported considerable biochemical difference between the two varieties. The starch content of the seed increases with maturity [59].

5 Phytochemical Analysis

Gupta and others [60] analyzed phytochemical content of jackfruit seeds found high quantity of saponins (6.32 ± 0.098 g/100 g). Saponins have been known for their medicinal uses, including antispasmodic activity and toxicity to cancer cells. Some alkaloids function as spasmolytic, anticholinergic, and anesthetic agents. The alkaloid content in jackfruit seeds was found to be 1.16 ± 0.09 g/100 g. Polyphenolics are known to function as antioxidants through a number of mechanisms including radical scavenging by H-donation, prevention of chain initiation by donating electrons, or binding of transition metal ion catalysts. Flavonoids prevent platelet stickiness and hence platelet aggregation.

5.1 Primary Metabolites in Jackfruit Seed

Organic acids control acetic-alkali equilibrium, which affects human health and all the reactions in the body. Table 6 shows the various organic acid content of jackfruit

Table 6 Organic acid content in jackfruit seed kernel (SK) and seed coating membrane (SCM) [61]

Sr. no.	Compounds (mg/kg dry matter)	SK	SCM
1	Oxalic	649.45 ± 26.38	122.38 ± 12.36
2	Aconitic	650.51 ± 6.93	96.52 ± 6.53
3	Citric	8086.95 ± 807.60	1745.72 ± 120.31
4	Pyruvic	–	59.32 ± 6.25
5	Malic	3539.64 ± 335.53	877.97 ± 137.97
6	Quinic	460.84 ± 10.50	230.38 ± 44.69
7	Shikimic	–	12.95 ± 0.30
8	Acetic	–	84.28 ± 5.82
9	Fumaric	535.88 ± 1.37	26.33 ± 1.47
	Total	**13923.26 ± 1188.30**	**3255.85 ± 335.70**

seed kernel (SK) and seed coating membrane (SCM). In addition, they have a disinfecting function, and affect metabolism, etc. By interacting with other substances, organic acids affect the acetic-alkali balance, alkalizing the whole body. As a result, the person's health improves. Also the organic acids are involved in digestion, stimulate the stomach and pancreas, and increase intestine motor function.

Oxalic acid that is a normal element in the blood has been reported to have a mean value of 288 mcg of anhydrous oxalic acid/100 ml of blood. Oxalic acid must be available for the immune system to fight the diseases such as cancer and viral, bacterial, and vascular conditions. When oxalic acid falls below an effective level, the immune system can no longer protect the body from various diseases. When the immune system can no longer eliminate abnormal cells, radical cells are allowed to develop and give rise to a detectable tumor.

Amino acids build proteins, and proteins are life-sustaining macronutrients. Table 7 shows the amino acid content in jackfruit seed kernel and seed coating membrane (SCM). When cells need protein, they follow instructions from DNA that define the specific amino acids and the order in which they must connect to build the protein. DNA depends on another macromolecule RNA to make the protein. RNA takes a copy of the code from your DNA, leaves the cell, finds the amino acids, and brings them back to the cell, where they bind into a chain. Each amino acid must be available at the time it's needed or the protein won't be synthesized. When the chain is complete, it twists and folds into a specialized shape. The chemical structure of each amino acid controls the final shape, and the shape determines the function of the protein. Several amino acids produce neurotransmitters, but two well-known examples are the amino acids tryptophan and tyrosine. Tryptophan is available in jackfruit seed in fair quantity which produces serotonin, regulates your moods, and makes the hormone melatonin. Food proteins vary depending on their amino acid content and contain varying concentrations of essential and nonessential amino acids [61].

Fernandes and others [61] identified 67 compounds and reported for the first time in jackfruit seed. Table 8 shows fatty acid content in jackfruit seed kernel (SK) and seed coating membrane (SCM).

Table 7 Amino acid content in jackfruit seed kernel (SK) and seed coating membrane (SCM) (mg/kg dry matter) [61]

Amino acids		SK	SCM
A. Essential			
1	Threonine	387.00 ± 1.40	48.20 ± 0.11
2	Valine	290.54 ± 3.62	37.43 ± 0.44
3	Isoleucine	157.01 ± 0.79	11.82 ± 0.29
4	Leucine	396.43 ± 7.61	71.39 ± 0.60
5	Tryptophan	94.69 ± 0.91	8.30 ± 0.14
6	Phenylalanine	210.92 ± 2.56	29.51 ± 0.10
7	Lysine	242.59 ± 0.63	29.04 ± 0.24
8	Histidine	104.90 ± 0.04	32.08 ± 0.25
	Total	**1884.08 (17.56)**	**267.76 ± 2.18**
B. Nonessential			
1	Aspartic acid	247.64 ± 20.35	25.83 ± 0.02
2	Glutamic acid	703.31 ± 30.18	20.39 ± 6.03
3	Asparagine	759.79 ± 14.07	158.01 ± 0.16
4	Glutamine	2670.13 ± 4.00	338.52 ± 0.73
5	Serine	309.86 ± 2.83	26.60 ± 0.13
6	Glycine	154.17 ± 4.81	18.46 ± 0.11
7	Alanine	241.32 ± 2.23	32.08 ± 0.07
8	Proline	2585.93 ± 10.58	194.38 ± 0.52
9	Arginine	1250.50 ± 3.64	63.36 ± 1.26
10	Cysteine	395.73 ± 0.64	147.36 ± 0.28
11	Ornithine	27.74 ± 0.67	9.18 ± 0.02
12	Tyrosine	504.10 ± 2.07	42.70 ± 0.14
	Total	**9850.21 ± 96.07**	**1076.87 ± 9.47**

The seed kernel is significantly richer in all metabolites. As expected, the accumulation of primary metabolites was higher, organic and amino acids being predominant in jackfruit seed kernel and seed coating material. Phenolic compounds allowed a more clear distinction of the two materials, being mainly accumulated in the seed kernel. Seed kernel and seed coating membrane showed antioxidant capacity.

The jackfruit leaves and stem show the presence of sapogenins, cycloartenone, cycloartenol, β-sitosterol, and tannins; they show estrogenic activity. A root contains β-sitosterol, ursolic acid, betulinic acid, and cycloartenone [62].

6 Health Benefits

The health benefits of jackfruit are still underway. The jackfruit bulb and jackfruit seeds are good sources of protein, starch, and minerals. Jackfruits also contain phytonutrients, i.e., lignans, isoflavones, and saponins, and they have numerous

Table 8 Fatty acid content in jackfruit seed kernel (SK) and seed coating membrane (SCM) (mg/kg dry matter) [61]

Sr. no.	Fatty acids	SK	SCM
1	Dodecanoic (C12:0)	–	12.69 ± 0.27
2	Tridecanoic (C13:0)	–	1.70 ± 0.06
3	Tetradecanoic (C14:0)	20.17 ± 0.22	53.38 ± 0.48
4	*cis*-10-Pentadecenoic (C15:1*n*-5c)	3.43 ± 0.10	–
5	Pentadecanoic (C15:0)	24.55 ± 0.26	31.93 ± 0.94
6	*cis*-9-Hexadecenoic (C16:1*n*-7c)	21.57 ± 0.41	40.41 ± 0.85
7	Hexadecanoic (C16:0)	836.70 ± 11.94	864.79 ± 15.42
8	*cis*-10-Heptadecenoic (C17:1 *n*-7c)	9.29 ± 0.08	11.17 ± 0.27
9	Heptadecanoic (C17:0)	23.42 ± 0.28	24.14 ± 0.33
10	*cis-9,12-Octadecadienoic (C18:2n-6c))*	*801.19 ± 10.44*	*147.59 ± 1.02*
11	*cis*-9-Octadecenoic (C18:1*n*-9c)	109.81 ± 2.48	189.42 ± 1.55
12	*trans-9-Octadecenoic (C18:1n-9 t)*	*17.62 ± 1.92*	*23.31 ± 0.51*
13	*Octadecanoic (C18:0)*	*181.62 ± 4.52*	*254.75 ± 1.80*
14	*cis-9,12,15-Octadecatrienoic (C18:3n-3c)*	*2.17 ± 0.33*	*3.91 ± 0.11*
15	*Eicosanoic (C20:0)*	*74.71 ± 3.79*	*78.52 ± 1.03*
16	*Heneicosanoic (C21:0)*	*24.13 ± 0.68*	*20.79 ± 0.60*
17	*Docosanoic (C22:0)*	*112.41 ± 4.96*	*91.12 ± 1.58*
18	*Tricosanoic (C23:0)*	*20.65 ± 1.06*	*25.60 ± 0.07*
19	*Tetracosanoic (C24:0)*	*64.62 ± 4.30*	*85.98 ± 0.63*
	TOTAL	**2348.06 ± 47.77**	**1961.20 ± 27.52**

health benefits such as anticancer, antiaging, and antioxidant. Fig. 2 shows the nutraceutical characteristics of jackfruit bulb and its effect on various diseases.

6.1 Anticancer

Angiogenesis is the outgrowth of new blood vessels from preexisting vessels. It commonly occurs during the normal physiological process of blood vessel formation and during cancer growth [63].

The recent studies show all phytonutrients in jackfruit bulb shave anticancer benefits. The main role of these nutrients is to help prevent the harmful free radicals that have been known to develop cancer and many other chronic diseases. The phytonutrients prevent the very initial stage of cancer cell formation. Saponins are also strong anticancer agents. According to a study, saponins show colon cancer preventative properties. These phytonutrients have been found to induce mitotic arrest in the case of leukemia cells. The study also found that it helped in some cases to cause remission. Saponins were found to react to the outer layers of cancer cells. They bound the cells and prevented their further growth [64]. Swastika and others [21] reported that the effective dose of jackfruit seed methanolic extract for angiogenesis inhibition is 35.00 mg/ml.

Phytoestrogens are naturally occurring polycyclic phenols found in certain plants that may, when ingested and metabolized, have weak estrogenic effects. Two important groups of phytoestrogens that are present in jackfruit pulp are isoflavones and lignans (Swami and others) [12]. According to studies, these nutrients help in reducing the risk of endometrial cancer.

Jackfruit is rich in fiber. It also has a unique sticky form. Both these properties combine together to work as a great colon cleanser. It helps in removing toxins from your digestive tract. This further helps in reducing the risk of colon cancer. Three phenolic anticancer compounds of jackfruit were characterized as artocarpesin [5,7,2′,4′-tetrahydroxy-6-βmethylbut-3-enyl) flavones] [65], norartocarpetin (5,7,2′,4′-tetrahydroxyflavone), and oxyresveratrol [trans-2,4,3′,5′tetrahydroxystilbene] [66]. Gowri and others [66] also reported that the reactive oxygen species (ROS) production is a common feature of tumor promotion. The Cressa critica aqueous extract (CCAE) showed higher antioxidant activity than single plant extracts of *P. zeylanica* (45%) [67], *L. acidissima* (19%) [68], and *A. heterophyllus* (36%) [69].

6.2 Diabetics

Diabetes mellitus is a metabolic disorder characterized by hyperglycemia resulting from defects in insulin action, insulin secretion, or both. The most common type of diabetes mellitus is type 2 diabetes mellitus, which accounts for 85–95% of all cases and constitutes a major public health problem [70]. Hot water extract of mature jack leaves is recommended by Ayurvedic and traditional medical practitioners as a treatment for diabetes mellitus (Fernando et al. 1991 [71]. It is already indicated that an extract of jackfruit improves the glucose tolerance in normal human subjects and diabetic patients [72]. The leaves and stem show the presence of sapogenins, cycloartenone, ß-sitosterol, and tannins [73]. Jackfruit contains vitamin A, vitamin C, thiamin, riboflavin, niacin, calcium, potassium, iron, manganese, and magnesium among many other nutrients. It is good for diabetes as they improve insulin resistance.

Ajaiya Kumar and others [74] reported that consuming 100 g of the jackfruit meal per day for 4 months leads to quantitative reduction in fasting blood glucose (FBG), postprandial blood glucose (PBG), and hemoglobin A1c (HbA1c) compared with the baseline. The HbA1c decreased by 13.59%, FBG by 22.68%, and PBG by 25.69%. They have concluded that the dietary supplementation of the jackfruit raw fruit meal preparation has an impact in reducing type 2 diabetes.

Hettiaratchi and others [75] studied Nutritional assessment of a jackfruit meal. The total energy contribution of the jackfruit meal is 1370 kJ. Jackfruit meal provides 20% of daily energy requirement of a moderately active individual. Jackfruit seeds contained high amount of resistant starch (RS) (undigestible starch). Resistant starch is categorized into four types (RS_1–RS_4) [76], and jackfruit seeds may contain RS_1 type. The undigestible starch escapes digestion in the small intestine, passes into the colon, and is reported to act like dietary fiber (Hettiaratchi

Table 9 Nutritional parameters of jackfruit flesh, seed, meal, and the standard [75]

Parameter	Jackfruit flesh	Jackfruit seeds	Jackfruit meal	Standard
Carbohydrate	10.0 ± 0.3	21.9 ± 0.8	50 g	50 g
Insoluble dietary fiber	1.5 ± 0.1	7.9 ± 0.5	13.5	0.8
Soluble dietary fiber	1.1 ± 0.1	3.2 ± 0.3	6.5	2.4
Total dietary fiber	2.6	11.1	20.0	3.2
Protein	0.9	4.7	6.8	8.2
Fat	0.8 ± 0.1	1.3 ± 0.3	11.5	3.2
Resistant starch	0.3	8.0	5.2	0.7
Slowly available glucose %	17%	33%	30%	16%
Amylose	29	54	31	15
Glycemic index (SEM)	–	–	75 ± 11	100
IAUC (SEM)	–	–	132 ± 19	181 ± 18
GL (NSS)	–	–	13	20

and others) [75]. The postprandial glycemic response and glycemic index (GI) of the jackfruit meal were determined. Jackfruit meal elicited a low GI (Table 9). This is the first reported data on GI of a jackfruit meal in spite of having 2487 data on GI of different foods in the recent "International Tables of Glycaemic Indices and Glycaemic Load Values" [77]. Jackfruit has beneficial nutritional parameters and a low GI. This could be due to the collective contributions of dietary fiber, slowly available glucose, intact starch granules in seeds, and influence of different sources of carbohydrates. Table 10 shows phenolic acids in different parts of jackfruit.

6.3 Immune System

Jacalin, the major protein from the *Artocarpus heterophyllus* seeds, is a tetrameric two-chain lectin combining a heavy chain of 133 amino acid residues with a light β chain of 20–21 amino acid residues [78]. Jacalin's uniqueness in being strongly mitogenic for human CD4 + T lymphocytes has made it a useful tool for the evaluation of the immune status of patients infected with human immunodeficiency virus HIV-1 [79].

6.4 Improve Digestion

The presence of high fiber (3.6 g/100 g) in the jackfruit prevents constipation and helps in smooth bowel movements. These fibers also offer protection against colon mucous membrane by removing or driving away the carcinogenic.

Table 10 HPLC analysis of various phenolic acids in different parts of jackfruit [54]

Plant parts	Phenolic acids (μg/g fresh wt.)			
	TA	**GA**	**FA**	**Caf – A**
Raw fruit skin	6.70 ± 0.05	22.73 ± 2.04	4.64 ± 0.02	UDL
Ripe fruit skin	5.73 ± 0.04	12.08 ± 1.03	13.41 ± 1.2	UDL
Raw fruit flesh	4.87 ± 0.05	9.70 ± 0.09	8.04 ± 0.07	UDL
Ripe fruit flesh	5.24 ± 0.06	19.31 ± 1.8	2.66 ± 0.06	UDL
Raw fruit pulp of seed	2.29 ± 0.01	11.05 ± 1.02	2.16 ± 0.05	UDL
Ripe fruit pulp of seed	UDL	6.26 ± 0.04	2.56 ± 0.02	UDL
Raw fruit seed	6.59 ± 0.07	11.3 ± 1.6	2.38 ± 0.01	2.84 ± 0.02
Ripe fruit seed	2.21 ± 0.01	11.30 ± 1.07	2.71 ± 0.01	UDL

6.5 Cardiovascular Health

One of the major risk factors for the development of coronary heart disease is dyslipidemia, which is mainly characterized by elevated levels of low-density lipoprotein cholesterol (LDL-C) and/or reduced high-density lipoprotein cholesterol (HDL-C) [81].

Epidemiological studies have shown that high concentrations of serum total cholesterol and LDL-C are independent risk factors for cardiovascular disease [82] and could produce atherosclerosis. Atherosclerosis, a major degenerative disease of the arteries, involves a series of inflammatory and oxidative modifications within the arterial wall [83]. Oxidative excess in the vasculature reduces levels of the vasodilator nitric oxide, causes tissue injury, promotes protein oxidation and DNA damage, and induces proinflammatory responses [84]. Oxidative stress induces inflammation by acting on the pathways that generate inflammatory mediators like adhesion molecules and proinflammatory cytokines [85].

6.6 Fast-Dissolving Tablets

The major storage carbohydrate in plants is starch. The annual worldwide production of starch is 66.5 million tons (FAOSTAT) [86]. Growing demand for starches in the industry has created interest in new sources of this polysaccharide, such as leaves, legume seeds, and fruits [87]. It has immense industrial use in the manufacture of products such as food, textile, paper, adhesives, and pharmaceuticals. Starch can also serve as a thickening, gelling, and film-forming properties [88, 89].

Jackfruit seed cotyledons are fairly rich in starch and protein. The recent investigation shows that the jackfruit seed starch has potential in pharmaceutical industries. The starches extracted from jackfruit seeds are used as superdisintegrants for the formulation of fast-dissolving tablets (FDT).

The FDT technology makes tablets dissolve or disintegrate in the mouth without additional water intake. The FDT formulation is defined by the Food and Drug Administration (FDA) as "A solid dosage form containing medical substances whish

disintegrates rapidly, usually within a seconds, when placed upon the tongue." Fast-dissolving tablets are also called mouth-dissolving tablets, melt-in-mouth tablets, orodispersible tablets, rapidmelts, porous tablets, quick dissolving, etc. [90]. The basic approach in the development of FDT is the use of superdisintegrants, which provide instantaneous disintegration of tablet after putting on tongue, thereby releasing the drug in saliva [91]. The fast-dissolving tablets are rapidly dissolved or disintegrate by the use of superdisintegrants.

Vidyadhara and others [22] reported as Irbesartan (IRB), which is anangiotensin II type, receptor antagonist, is selected as a model drug. IRB and FDT formulations that contained various concentrations of jackfruit starch extracts and CCS (croscarmellose sodium) were prepared by wet granulation technique using IPA (Isopropyl alcohol) as granulating fluid. The evaluated pre-compression parameters indicated that the granules exhibited good flow properties. In vitro dissolution studies were performed on all prepared matrix tablets using the USP apparatus II with 900 mL of 0.1 N HCl. From the results of dissolution studies, it was observed that the type of starch as superdisintegrant and the proportion of superdisintegrant have considerably influenced the dissolution parameters of various formulations. The tablets prepared from jackfruit seed starch as superdisintegrant were found to be suitable for preparation of fast-dissolving tablets.

Jackfruit is well known to have antibacterial property against 24 species of bacteria [92]. A jackfruit lectin, i.e., jacalin, inhibits DNA viruses such as herpes simplex virus type II (HSV-2), varicella-zoster virus (VZV), and cytomegalovirus (CMV) [93].

The jackfruit could be considered a functional food because it has valuable compounds in different parts of the fruit that display functional and medicinal effects (Fig. 2).

"Functional foods" are those that provide more than simple nutrition; they supply additional physiological benefit to the consumer. Because dietary habits are specific to populations and vary widely, it is necessary to study the disease-preventive potential of functional micronutrients in the regional diets.

6.7 Dental Health

In jackfruit tree, latex or resin are found on the trunk of tree as well as the fruit. All parts of jackfruit tree contain sticky white latex which produced from special secretory cells called laticifers. Latex is an aqueous emulsion containing many ingredients, for instance, lipids, rubbers, resins, sugars, and proteins including proteolytic enzymes [94].

Rao and others [95] reported that the jackfruit latex extract which is rich in flavonoids and alkaloids was checked for antibacterial and antifungal properties which shows fairly well and significant comparison with standard antibacterial and antifungal drugs. They concluded that this information gives about the several important uses of jackfruit latex or resin, or both can be utilized as the cementing medium, irrigation solution (washing of a body cavity or wound by a stream of

fluid), denture cleaning solution, resin, and other future dental filling material in terms of cost-effectiveness.

7 Conclusion

There is a need for commercial utilization of the jackfruit in developing countries and can serve as a possible alternative of many vitamins in the body. An activity of certain phytochemicals along with their antioxidant properties further supports the cause of commercial utilization of the fruit. The antioxidant constituents present in the fruits play important role in scavenging free radicals and reactive oxygen species which are responsible for a number of human disorders. The jackfruits and fruit products hold potential in the diet as they possess not only pleasant taste but also source of naturally and readily available source of instant energy.

In Ayurveda the jackfruit is used as a cooling tonic and pectorial, roots in diarrhea and fever, leaves to activate milk in women and animals, as a source to treat antisyphilic and vermifuge, leaf ash applied to ulcers wounds and the warmed leaves have healing properties if pasted on the wounds. The richness of jackfruit in bioactive natural metabolites encourages their consumption. Furthermore, the aqueous extracts activity suggests that it may be useful for food and pharmaceutical industries. The valued jackfruit material, which nowadays is largely discarded by the population, might have an important economic impact for the producers.

References

1. Jagadeesh SL, Reddy BS, Basavaraj N, Swamy GSK, Kirankumar G (2007) Inter tree variability for fruit quality in jackfruit selections of Western Ghats of India. J Sci Hortic 112 (4):382–387
2. Baliga MS, Shivashankara AR, Haniadka R, Dsouza J, Bhat HP (2011) Phytochemistry, nutritional and pharmacological properties of *Artocarpusheterophyllus Lam* (jackfruit): a review. Food Res Int 44(7):1800–1811
3. Reddy BMC, Patil P, Kumar SS, Govindaraju LR (2014) Studies on physico-chemical characteristics of jackfruit clones of South Karnataka. Karnataka J Agric Sci 17(2):279–282
4. Prakash O, Kumar R, Mishra A, Gupta R (2009) *Artocarpusheterophyllus* (jackfruit): an overview. Pharmacogn Rev 3(6):353–358
5. Wangchu L, Singh D, SK M (2013) Studies on the diversity and selection of superior types in jackfruit (*Artocarpusheterophyllus Lam.*). Genet Resour Crop Evol 60(5):1749–1762
6. Dutta H, Paul SK, Kalita D, Mahanta CL (2011) Effect of acid concentration and treatment time on acid-alcohol modified jackfruit seed starch properties. Food Chem 128(2):284–291
7. Siti BZ, Rosma A (2011) *Artocarpus* integer leaf protease: purification and characterisation. Food Chem 129(4):1523–1529
8. Lin KW, Liu CH, Tu HY, Ko HH, Wei BL (2009) Antioxidant prenylflavonoids from *Artocarpus communis* and *Artocarpus elasticus*. Food Chem 115(2):558–562
9. Maia JGS, Andrade EHA, Zoghbi MDGB (2004) Aroma volatiles from two fruit varieties of jackfruit (*Artocarpusheterophyllus Lam.*). Food Chem 85(2):195–197
10. Hameed BH (2009) Removal of cationic dye from aqueous solution using jackfruit peel as nonconventional low-cost adsorbent. J Hazard Mater 162(1):344–350

11. Aziz A (2006) Development of an innovative ingredient from jackfruit seed flour in health bakery products. Universiti Sains Malaysia
12. Swami SB, Thakor NJ, Haldankar PM, Kalse SB (2012) Jackfruit and its many functional components as related to human health: a review. Compr Rev Food Sci Food Saf 11:565–576
13. Haque MA (1991) Village and forestry in Bangladesh. Joint Publication of Bangladesh Agricultural University and SAARC Documentation Center, New Delhi
14. Noor F, Rahman MJ, Mahomud MS, Akter MS, Talukder MAI, Ahmed M (2014) Physico-chemical properties of flour and extraction of starch from jackfruit seed. Int J Nutr Food Sci 3 (4):347–354
15. Ko FN, Cheng ZJ, Lin CN, Teng CM (1998) Scavenger and antioxidant properties of prenylflavones isolated from *Artocarpusheterophyllus*. Free Radic Biol Med 25:160–168
16. Chandrika UG, Wedage WS, Wickramasinghe SMDN, Fernando WS (2006) Hypoglycaemic action of the flavonoid fraction of *Artocarpus heterophyllus* leaf. Afr J Tradit Complement Altern Med 3:42–50
17. Trindade MB, Lopes JL, Costa SCA (2006) Structural characterization of novel chitin-binding lectins from the genes *Artocarpus* and their fungal activity. Biochim Biophys Acta 1764:146–152
18. Lagouge M, Argmann C, Zachary G, Meziane H, Lerin C, Daussin F, Messadeq N, Milne J, Lambert P, Elliott P, Geny B, Laakso M, Puigserver P, Auwerx J (2006) Resveratrol improves mitochondrial function and protects against metabolic disease by activating SIRT1 and PGC-1a. Cell 127:1109–1122
19. Shen T, Wang XN, Lou HX (2009) Natural stilbenes: an overview. Nat Prod Rep 26:916–935
20. Ribatti D, Gulandris A, Bastaki M, Vacca A, Iurlaro M, Roncali L (1997) New model for the study of angiogenesis and antiangiogenesis in the chick embryo chorioallantoic membrane: the gelatin sponge/chorioallantoic membrane assay. J Vasc Res 34:455–463
21. Oktavia S, Wijayanti N, Retnoaji B (2017) Anti-angiogenic effect of *Artocarpusheterophyllus* seed methanolic extract in *ex ovo* chicken chorioallantoic membrane. Asian Pac J Trop Biomed 7(3):240–244
22. Vidyadhara S, Sasidhar RL, Lakshmi HD, P V, Vijetha K (2017) Studies on jackfruit seed starch as a novel natural superdisintegrant for the design and evaluation of irbesartan fast dissolving tablets. Integr Med Res 6(3):280–291. https://doi.org/10.1016/j.imr.2017.04.001
23. Fang SC, Hsu CL, Yen GC (2008) Anti-inflammatory effects of phenolic compounds isolated from the fruits of *Artocarpusheterophyllus*. J Agric Food Chem 56(12):4463–4468
24. Omar HS, El-Beshbishy HA, Moussa Z, Taha KF, Singab ANB (2011) Antioxidant activity of *Artocarpusheterophyllus Lam*. (Jack fruit) leaf extracts: remarkable attenuations of hyperglycemia and hyperlipidemia in streptozotocin-diabetic rats. Sci World J 11:788–800
25. Nguyen NT, Nguyen MHK, Nguyen HX, Bui NKN, Nguyen MTT (2012) Tyrosinase inhibitors from the wood of *Artocarpusheterophyllus*. J Nat Prod 75(11):1951–1955
26. Arung ET, Yoshikawa K, Shimizu K, Kondo R (2010) Isoprenoid-substituted flavonoids from wood of *Artocarpusheterophyllus* on B16 melanoma cells: cytotoxicity and structural criteria. Fitoterapia 81(2):120–123
27. De Faria AF, de Rosso VV, Mercadante AZ (2009) Carotenoid composition of jackfruit (*Artocarpusheterophyllus*), determined by HPLC-PDA-MS/MS. Plant Foods Hum Nutr 64 (2):108–115
28. Nakasone HY, Paull RE (1998) Tropical fruits. CAB International, New York
29. Roy SK, Joshi GD (1995) Minor fruits-tropical. In: Salunkhe DK (ed) Handbook of fruit science and technology. Marcel Dekker, Inc., New York, pp 570–573
30. Narasimham P (1990) Breadfruit and jackfruit. In: Nagy S, Shaw PE, Wardowski WF (eds) Fruits of tropical and subtropical origin. Florida Science Source, Lake Alfred, pp 193–259
31. Galaverna G, Di Silvestro G, Cassano A, Sforza S, Doceana A, Drioli E, Marchelli R (2008) A new integrated membrane process for the production of concentrated blood orange juice: effect on bioactive compounds and antioxidant activity. Food Chem 106:1021–1030

32. Thaman RR, Ali I (1993) Agroforestry on smallholder sugarcane farms in Fiji. In: Clarke WC, Thaman RR (eds) Agroforestry in the Pacifi Islands: Systems for Sustainability. United Nations University Press, Tokyo
33. Sammadar HM (1985) Jackfruit. In: Bose TK, Mitra SK (eds) Fruits of India: tropical and subtropical. Naya Prokash, Calcutta, pp 638–649
34. Guruprasad TR (1981) Studies on systematic selection of jackfruit (*Artocarpus heterophyllus Lam.*) types. M.Sc.(Hort.)Thesis, University Agriculture Science, Bangalore, Karnataka, India
35. Darlington CD, Wylie AP (1956) Chromosome atlas of flowering plants. Allen and Unwin, London
36. Schnell RJ, Olano CT, Campbell RJ, Brown JS (2001) AFLP analysis of genetic diversity within a jackfruit germplasm collection. Sci Hortic 91:261–274
37. Azad AK, Jones JG, Haq N (2007) Assessing morphological and isozyme variation of jackfruit (*Artocarpusheterophyllus Lam.*) in Bangladesh. Agrofor Syst 71:109–125
38. Akashi Y, Fukuda N, Wako T, Masuda M (2002) Genetic variation and phylogenetic relationships in east and south Asian melons, *Cucumis melo L*., based on the analysis of fie isozymes. Euphytica 125:385–396
39. Azad AK (2000) Genetic diversity of jackfruit in Bangladesh and development of propagation methods. Ph.D Thesis, Universityof Southampton, UK. 200 p
40. Haq N (2006) Jackfruit, Artocarpusheterophyllus, Southampton Center for Underutilised Crops, University of Southampton, Southampton. 192 p
41. Arkroyd WR, Gopalan C, 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, p 42
42. Gunasena HPM, Ariyadasa KP, Wikramasinghe A, Herath HMW, Wikramasinghe P, Rajakaruna SB (1996) Manual of Jack cultivation in Sri Lanka. Forest Information Service, Forest Department: 48
43. Cadenas E, Packer L (1996) Hand book of antioxidants. Plenum Publishers, New York
44. Krinsky NI, Landrum JT, Bone RA (2003) Biologic mechanisms of the protective role of lutein and zeaxanthin in the eye. Annu Rev Nutr 23:171–201
45. Stahl W, Sies H (2005) Bioactivity and protective effects of natural carotenoids. Biochim Biophys Acta Mol basis Dis 1740:101–107
46. Chandrika UG, Jansz ER, Warnasuriya ND (2005) Analysis of carotenoids in ripe jackfruit (*Artocarpusheterophyllus*) kernel and study of their bioconversion in rats. J Sci Food Agric 85:186–190
47. Bobbio FO, El-Dash AA, Bobbio PA, Rodrigues LR (1978) Isolation and characterization of the physicochemical properties of starch of jackfruit seeds (*Artocarpusheterophyllus*). J Cereal Chem 55:505–511
48. Hettiarchi UPK, Ekanayake S, Welihinda J (2010) Nutritional assessment of jackfruit (*Artocarpusheterophyllus*) meal. Ceylon Med J 56(2):54–58
49. James O, Friday E (2010) Phytochemical composition, Bioactivity and wound healing potential of euphorbia Heterophylla (euphorbiaceae) leaf extract. Int J Pharm Biomed Res 1(1):54–63
50. Barua AG, Boruah BR (2004) Minerals and functional groups present in the jackfruit seed: a spectroscopic investigation. J Food Sci Nutr 55:479–483. https://doi.org/10.1080/09637480400015810
51. Tulyathan V, Tananuwong K, Songjinda P, Jaiboon N (2002) Some physicochemical properties of jackfruit (Artocarpusheterophyllus lam) seed flour and starch. Sci Asia 28:37–41
52. Bhat AV, Pattabiraman TN (1989) Protease inhibitors from jackfruit seed (*Artocarpus integrifolia*). J Food Sci Technol 14(4):351–365
53. Morton J (1987) Jackfruit (Artocarpusheterophyllus). In: Fruits of warm climates. Creative Resource Systems, Winterville, pp 58–64
54. Singh A, Maurya S, Singh M, Singh U (2015) Studies on the phenolic acid contents in different parts of raw and ripe jackfruit and their importance in human health. Int J Appl Sci Res Rev 2:69–73

55. Mukprasirt A, Sajjaanantakul K (2004) Physico-chemical properties of flour and starch from jackfruit seeds. Int J Food Sci Technol 39(3):271–276
56. Ocloo FCK, Bansa D, Boatin R, Adom T, Agbemavor WS (2010) Physico-chemical, functional and pasting characteristics of flour produced from jackfruits (*Artocarpusheterophyllus*) seeds. Agric Biol J N Am 1(5):903–908
57. Kinsella JE (1976) Functional properties of proteins in food – a survey. Crit Rev Food Sci Nutr 7:219–280
58. Kumar S, Singh AB, Abidi AB, Upadhyay RG, Singh A (1988) Proximate composition of jack fruit seeds. J Food Sci Technol 25:308–309
59. Rahman MA, Nahar N, Mian AJ, Mosihuzzaman M (1999) Variation of carbohydrate composition of two forms of fruit from jack tree (*Artocarpus heterophyllus L*) with maturity and climatic conditions. Food Chem 65:91–97
60. Gupta D, Mann S, Sood A, Gupta RK (2011) Phytochemical, nutritional and antioxidant activity evaluation of seeds of jackfruit (*Artocarpus heterophyllus lam*.). Int J Pharm Bio Sci 2(1):336–345
61. Fernandes F, Ferreres F, Gil-Izquierdo A, Oliveira A, Valentão P, Andrade PB (2017) Accumulation of primary and secondary metabolites in edible jackfruit seed tissues and scavenging of reactive nitrogen species. J Food Chem 233:85–95
62. Dayal R, Seshadri TR (1974) Colourless compounds of the roots of Artocarpusheterophyllus. Isolation of new compound artoflavone. Indian J Chem 12:895–896
63. Spano D, Zollo M (2012) Tumor microenvironment: a main actor in the metastasis process. Clin Exp Metastasis 29:381–395
64. Sagar SM, Yance D, Wong RK (2006) Natural health products that inhibit angiogenesis: a potential source for investigational new agents to treat cancer – part 1. Curr Oncol 13:14–26
65. Rowe DP, Garner RJ, Chaudhri SA (1985) *Artocarpus Heterophyllus* jackfruit. The propagation of tropical fruit trees, commonwealth bureau of horticulture and plantation crops. FAO, Rome, pp 269–290
66. Gowri SK, Divya S, Ignacimuthu S, James AP, Albin TF (2017) In vitro and in silico anticancer effect of combined crude acetone extracts of *Plumbago zeylanica L*., *Limonia acidissima L*. and *Artocarpusheterophyllus Lam*. J Synergy 5:15–23
67. Eldhose B, Notario V, Latha MS (2013) Evaluation of phytochemical constituents and in vitro antioxidant activities of *Plumbago indica* root extracts. J Pharm 2:157–161
68. Attarde DL, Chaudhari BJ, Bhambar RS (2011) Phytochemical investigation and in vitro antioxidant activity of extracts from leaves of *Limonia acidissima linn*. (Rutaceae). J Pharm Res 4(3):766–768
69. Thapa N, Thapa P, Bhandari J, Niraula P, Shrestha N, Shrestha BG (2016) Study of phytochemical, antioxidant and antimicrobial activity of *Artocarpusheterophyllus*. Nepal J Biotechnol 4:47–53
70. Cheplick S, Kwon YI, Bhowmik P, Shetty K (2010) Phenolic linked variation in strawberry cultivars for potential dietary management of hyperglycemia and related complications of hypertension. Bioresour Technol 101:404–413
71. Fernando MR, Wickramasinghe SM, Thabrew MI, Ariyaratne PL, Karunanayake EH (1991) J Ethnopharmacol 31:277–282
72. Chackrewarthy S, Thabrew MI, Weerasuriya M, Jayasekera S (2010) Evaluation of the hypoglycemic and hypolipidemic effects of an ethyl acetate fraction of *Artocarpus heterophyllus* (jak) leaves in streptozotocin-induced diabetic rats. Phcog Mag 6:186–190
73. Sathyavathi GV, Gupta AK, Tandon N (1987) Medicinal plants of India. ICMR, New Delhi
74. Ajaiya Kumar SK, Merlin RS, Athira CR (2017) Control of blood glucose level ond glycated Haemoglobin (Hbalc) with dietary jackfruit meal taken by type-II diabetic patients. Int J Sci Res 6(3):43–46
75. Hettiaratchi UPK, Ekanayake S, Welihinda J (2011) Nutritional assessment of a jackfruit (*Artocarpusheterophyllus*) meal. Ceylon Med J 56:54–58

76. Sajilata M, Singhal S, Kulkarni P (2006) Resistant starch – a review. Compr Rev Food Sci Food Saf 5(1):1
77. Atkinson F, Foster-Powell K, Brand-Miller (2008) International tables of glycaemic index and glycaemic load values. Diabetes Care 31:2281–2283
78. Suresh Kumar G, Appukttan PS, Basu DK (1982) D-Galactose – specific lectin from jack fruit seed. J Biosci 4:257–261
79. Pereira-da-Silva GAN, Moreno F, Marques C, Jamur A, Panunto-Castelo MC (2006) Neutrophil activation induced by the lectin KM+ involves binding to CXCR2. Biochim Biophys Acta 1(1):86–94
80. Siddappa GS (1957) Development of products from jackfruit – canned jackfruit, frozen canned jackfruit and jackfruit jam. J Sci Ind Res 11:166–199
81. Esmaillzadeh A, Azadbakht L (2008) Food intake patterns may explain the high prevalence of cardiovascular risk factors among Iranian women. J Nutr 138(8):1469–1475
82. Russo F, Chimienti G, Riezzo G, Pepe G, Petrosillo G, Chiloiro M, Marconi E (2008) Inulin-enriched pasta affects lipid profile and Lp(a) concentrations in Italian young healthy male volunteers. Eur J Nutr 47(8):453–459
83. Fan J, Watanabe T (2003) Inflammatory reactions in the pathogenesis of atherosclerosis. J Atheroscler Thromb 10:63–71
84. Xu S, Touyz RM (2006) Reactive oxygen species and vascular remodeling in hypertension: still alive. Can J Cardiol 22(11):947–951
85. Valko M, Leibfritz D, Moncol J, Cronin MT, Mazur M, Telser J (2007) Free radicals and antioxidants in normal physiological functions and human disease. Int J Biochem Cell Biol 39:44–84
86. FAOSTAT (2002) Database FAO. Food and Agriculture Organisation of the United Nations, Rome, 19.2
87. Betancur-Ancona D, Gallegos-Tintore S, Chel Guerrero L (2004) Wet-fractionation of *Phaseolus lunatus* seeds: partial characterization of starch and protein. Sci Food Agr 84:1193–1201
88. Gebre-Mariam T, Schmidt PC (1996) Isolation and physicochemical properties of Enset starch. Starch-Starke 48:208–214
89. Aldana DLM, Gómez BT, Oca MMM, Ayerdi SGS, Meraz FG, Pérez LAB (2011) Isolation and characterization of Mexican jackfruit (*Artocarpus heterophyllus* L) seeds starch in two mature stages. Starch/Stärke 63:364–372
90. Debjit B, Chiranjib B, Krishna K, Pankaj RMC (2009) Fast dissolving tablet: an overview. J Chem Pharm Res 1(1):163–177
91. Mohanachandran PS, Sindhumol PG, Kiran TS (2011) Superdisintegrants: An overview. Int J Pharm Sci Rev Res 6:105–109
92. Septama AW, Panichayupakaranant P (2015) Antibacterial assay-guided isolation of active compounds from *Artocarpusheterophyllus* heartwoods. Pharm Biol 53(11):1608–1613
93. Wetprasit N, Threesangsri W, Klamklai N, Chulavatnatol M (2000) Jackfruit lectin, properties of mitogenicity and the inhibition of herpesvirus infection. Jpn J Infect Dis 53(4):156–161
94. Fonseca KC, Morais NC, Queiroz MR, Silva MC, Gomes MS, Costa JO (2010) Purification and biochemical characterization of eumiliin from *Euphorbia milii var. hislopii latex*. Phytochemistry 71:708–715
95. Jitendra R, Kalpana S, Shweta S, Kumar MS, Manish B (2014) *Artocarpusheterophyllus* (jackfruit) potential unexplored in dentistry – an overview. Univers J Pharm 03(01):50–55