Asian Journal of Advances in Research

5(1): 298-307, 2022

A REVIEW ON TROPICAL FRUIT: JACKFRUIT (*Artocarpus heterophyllus*)

SUDIPTA SAHA [a*], MANOBENDRO SARKER [b], AHMED REDWAN HAQUE [c], TANVIR AHMED NAYEEM [d] AND ABU RASHED MD. MAUKEEB [e≡]

[a] Department of Silviculture, School of Forestry, Northeast Forestry University, China.
[b] Department of Bioengineering, University of Missouri, 1406 East Rollins Street, Columbia, Missouri 65211, United States.
[c] Department of Food Processing and Preservation, Hajee Mohammad Danesh Science and Technology University, Bangladesh.
[d] Projahnmo Research Foundation, Dhaka, Bangladesh.
[e] Department of Agricultural Chemistry, Khulna Agricultural University, Khulna-9100, Bangladesh.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Received: 05 December 2021
Accepted: 10 February 2022
Published: 17 February 2022

Mini-review Article

ABSTRACT

Jackfruit, a tropical fruit of the family Moraceae and genus Artocarpus, is usually preferred due to its subtle sweet taste and fruit flavor. However, this fruit has an impressive nutrient profile, which is comparable to shredded meat by Vegans and vegetarians. It contains a lot of fiber, vitamins, minerals, antioxidants, low fats, and protein (more than 3 gm/cup), making jackfruit unique from other fruits. Jackfruit also keeps for various medicinally important compounds, mainly antioxidants, carotenoids, flavanones, and vitamin C, and as a result, its consumption has a positive impact on human health. Various health benefits have been reported with jackfruit intake, such as immune health, preventing skin problems, cardiovascular disease prevention, blood sugar control, anti-aging, anti-cancer, anti-ulcer, antiviral, and anti-inflammatory. The present study attempted to review the morphology, production, consumption, nutritional value, and health-promoting benefits of jackfruit.

Keywords: Jackfruit; morphology; production; nutritional value; health benefits.

1. INTRODUCTION

1.1 Origin and Habitat

Jackfruit (*Artocarpus heterophyllus*) is a tropical fruit tree, exotic species native from Southeast Asia, especially India and Bangladesh, also have been cultivated in several parts of the country and confused with the species *Artocarpus integer* [1-4]. The name Artocarpus is derived from the Greek words "artos" (bread) and "carpos" (fruit), but the common name "jackfruit" was used by the physician and naturalist Garcia de Orta in his 1563 book Coloquios dos simples e drogas India [5]. In Bangla and Hindi, it is called as Kathal; Portuguese Jaca; Malayalam Chakka, Marathi Phanas; Canada Halasu; French Jacquier, etc. [6]. Jackfruit is a multipurpose tree bearing great importance for its multidimensional

≡ *Research Fellow;*
**Corresponding author: Email: saha.sudipta.sau10@gmail.com;*

benefits for the farmer as fruit, fodder, timber, food, medicine, aroma, vegetables, etc. It is often called poor man's fruit (Fig. 1) [7].

It is a cross-pollinated fruit tree mainly propagated by seeds [8]. The jackfruit thrives in the tropical low land with an elevation of 1000m. A warm, wet climate is the best for jackfruit cultivation and can grow almost all soil, prefers a deep, well-drained loam soil. It flourishes thrives in humid hill slopes even up to an elevation of 1500m, but the quality of the jackfruit deteriorates in higher altitudes [9].

1.2 Characteristics

The jackfruit tree is the largest tree-borne fruit in the world, evergreen, belongs to Moraceae family, monoecious, producing male and female flowers (small, sitting on a fleshy rachis, spikes, male and female flower born separately, flower blooming at December to February or March), the stem of the plan straight and rough, Bark is black or green color, 1.25 cm thick and exudes milky lates, obovate leaves, elliptic, decurrent, glabrous, entire, inflorescence solitary axillary, cauliferous and ramflours (up to 50 cm×100 cm and weight up to 50 Kg) (Fig. 2) [7,10,11]. It has a relatively short trunk (12 to 31 inches) with dense treetop (height 10 to 20m), and canopy shape is normally conical or pyramidal in young and become spreading and domed in the older tree. Jackfruit sometimes forms buttress roots [7]. Fruit of jackfruit is a multiple or compound fruit with green to yellow-brown exterior rind (composed of hexagonal, bluntly conical carpel apices), shape (length 10 to 40 inches), diameter (6 to 20 inches), and weight 10-25 Kg [12]. Seeds are light brown, rounded, length (0.8-1.2 inches), diameter (0.4-0.6 inches), enclosed with a thin whitish membrane, 100-150 seeds per fruit and seed are recalcitrant. The fruit consists of a 20%edible seed coat, 15% edible seeds, 20% white pulp and bark, and 10% core [11,13].

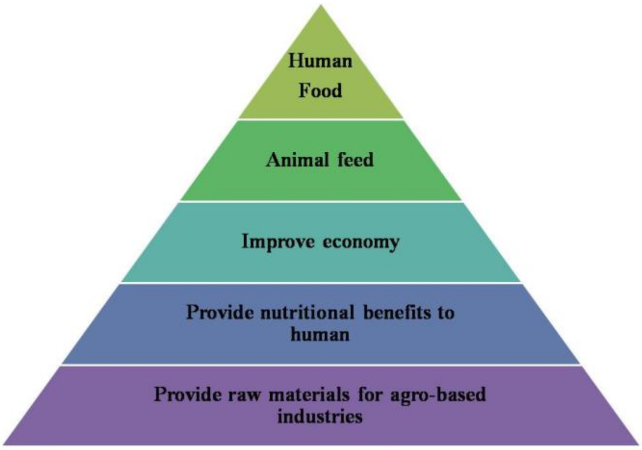

Fig. 1. Diversified uses of Jackfruit plant, fruits, and byproducts [5]

Fig. 2. Different Morphological parts of the Jackfruit tree

1.3 Productions, Consumption, and Taxonomy

List 1. Taxonomic classification of Jackfruit [5]

Taxonomic position	
Kingdom :	Plantae
Order :	Rosales
Family :	Moraceae
Tribe :	Artocarpeae
Genus :	*Artocarpus*
Species :	*Artocarpus heterophyllus*

Jackfruit is a multipurpose tree that is grown and cultivated economically in over 60 countries (Table 1), especially in Bangladesh, India, Nepal, Sri Lanka, Indonesia, China, Myanmar, Malaysia, Philippines, Thailand, Vietnam, as well as Latine American and East American countries (Fig. 3) [11,14,15]. Australia, Canada, China, Indonesia, Japan, New Zealand, the United States, and Vietnam are the top exporting countries [16-18]. Jackfruit is farmed in an equatorial to subtropical climate at elevations ranging from 1 to 1600 meters above sea level, with annual rainfall ranging from 1000 to 2400 millimeters [9,19]. On the other hand, Jackfruit bears blooms and fruits all year in areas with constant light and water [20,21]. Jackfruit is widely adaptable to climate conditions in many agro-ecological zones; however, because of their climatic diversity, Malaysia, Indonesia, Thailand, Australia, and China have reported year-round availability of jackfruit [20,22]. Jackfruit can tolerate shade conditions, but it needs light and space to develop during the early stages. In Asia, the fruit of jackfruit matures from July to August, and the seeds vary in size and weight range 4 to 14 gm [23,24]. The young jackfruit seedling should be fertilized with nitrogenous fertilizer during its bearing stages, and regular applications of phosphorous and potassium are also necessary. Still, applying organic fertilizer around the trees is recommended, although the water requirement is not critical during its production. Intercultural operations are required, especially if achieved two years of age (unwanted pruning branches, insect and disease branches [25-27].

Additionally, Fruit ripening indicators, including the leaf on the stalk turn yellow, fruit become dull, hollow sound during tapped, well-developed and widely spaced spines, etc., and harvesting is carried out from mid-morning to late afternoon of reducing latex flow. A high percentage of post-harvest loss is observed because of the high perishability of the jackfruit [28]. However, fruits and seeds are the edible part of jackfruit, which can be consumed either raw or cooked in various ways, and even pulp can be consumed naturally. When fruit becomes mature but not ripened, it can be cooked as a vegetable as it contains many carbohydrates. The rind can be used to produce jelly, and seeds can be eaten boiled, roasted, and as flour because of high contain starch and protein [29-32].

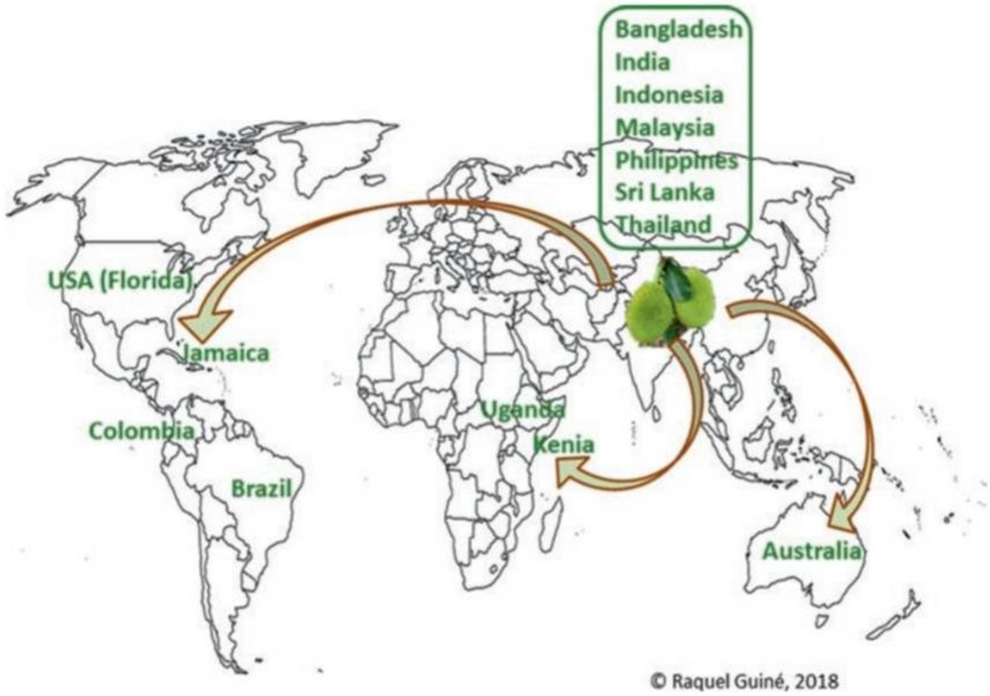

Fig. 3. Production of Jackfruit around the world [27]

Table 1. Jackfruit production in Asia

Country	Area (Ha)	Production (M. Ton)	Reference
Bangladesh	16550 ha	1001756 M. Ton	[33]
India	< 1,87,000 ha	18,57,000 M. Ton	[33]
Indonesia	-	802 M. Ton	[33]
Malaysia	4656.92 ha	31,281.30 M. Ton	[33]
Nepal	3265 ha	35,244 M. Ton	[33]

2. NUTRITIONAL VALUES AND CHEMICAL COMPOSITION

Jackfruit chemical composition varied on the variety, while compared with different tropical fruits, jackfruit fresh pulps and seeds contain more calcium, protein, iron, and thiamine [27,34-38]. Additionally, the ripe jackfruit contains richer vitamins and minerals (Table 2) than the apple, avocado, apricot, and banana found in some studies. Several researchers found that the chemical composition of jackfruit varied in different stages of maturity (Table 3) [34].

2.1 Carbohydrates

According to various chemical and histological studies, the jackfruit perianth and seed have a high starch content, and the dietary fiber and flesh content vary with maturity [34,39]. Chrips et al. reported that the carbohydrate percentage of different jackfruit seeds varies from 37.4-42.5 [40,41].

Table 2. Vitamins and minerals of jackfruit depend on several study findings that are given below [34]

Age of the fruit (in days)	Vitamin contents in flesh (mg/100gm)			Macro elements (mg/100 gm)		Micro elements (mg/100 gm)					
	B1	B2	C	Ca	Mg	Cd	Co	Cu	Fe	Mn	Pb
45	3.9	35.7	18.5	28.4	37.8	0.0	0.0	0.28	4.24	0.56	0.08
55	14.2	124.2	19.67	29.86	37.38	0.0	0.0	0.26	2.64	0.56	0.32
65	12.6	122.7	23.1	26.9	36.92	0.0	0.02	0.36	1.20	0.54	0.28
75	Trace	133	24.03	33.8	36.52	0.0	0.0	0.30	1.84	0.56	0.28
85	Trace	48.2	22.5	31.28	36.96	0.0	0.0	0.38	3.26	0.56	0.20

Table 3. Nutrients composition of jackfruit in 100gm edible portion [7]

Nutrients	Young fruit	Ripe fruit	Seed
Water (gm)	76.20-85.20	72.0-94.0	51.0-64.50
Protein (gm)	2.0-2.60	1.20-1.90	0.40-0.43
Fat (gm)	0.10-0.60	0.10-0.40	0.40-0.43
Carbohydrate (gm)	9.40-11.50	16.0-25.40	25.80-38.40
Fiber (gm)	2.60-3.60	1.0-1.50	1.0-1.50
Sugar (gm)	-	20.60	-
Minerals (gm)	0.90	0.87-0.90	0.90-1.20
Calcium (mg)	30.0-73.20	20.0-37.0	50.0
Magnesium (mg)	-	27.0	54.0
Phosphorus (mg)	20.0-57.20	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	63.20
Iron (mg)	0.40-1.90	0.50-1.10	1.50
Vitamin A (IU)	30	175-540	10-17
Thiamine (mg)	0.05-0.15	0.03=0.09	0.25
Riboflavin (mg)	0.05-0.20	0.05-0.40	0.11-0.30
Vitamin C (mg)	12.0-14.0	7.0-10.0	11.0

Table 4. The concentration of carotenoids in Jackfruit [34]

Carotenoids	Concentration (µg/100 gm fresh weight)
All-trans-neoxanthin	8.85
All-trans-luteoxanthin	2.06
9-cis-Neoxanthin	6.87
All-trans-neochrome	0.88
9-cis-Violaxanthin	7.05
Cis-Antheraxanthin	1.12
All-trans-zeaxanthin	0.96
All-trans-lutein	37.02
All-trans-zeinoxanthein	1.72
Cis-Zeinoxanthin	0.90
9-cis-β-Carotene	0.79
15-cis-β-Carotene	0.18
All-trans-β-carotene	29.55
All-trans-αcarotene	1.24
13-cis-β-carotene	2.45
All-trans-α-cryptoxanthin	0.35
All-trans-β-cryptoxanthin	1.21

2.2 Proteins

Cystine, arginine, leucine, histidine, lysine, threonine, methionine, and tryptophan are the amino acids found in jackfruit [7,42]. Ripe jackfruit has 1.9 gm of protein per 100 gm of flesh, and seeds have 5.3 to 6.8 percent protein. According to Goswami et al., the protein content of the flesh of different varieties of jackfruit (ripe) ranges from 0.57 to 0.97 percent [43,44].

2.3 Vitamins and Minerals

Jackfruit is a good source of vitamin C, and it's also one of the rare fruits high in B-complex vitamins, including B6, niacin, riboflavin, and folic acid [45,46]. According to Samaddar, fakes of ripe jackfruits have a high nutritional value, with 287-323 mg potassium, 30.0-73.2 mg calcium, and 11-19 gm carbohydrate per 100 gm [47].

2.4 Fiber

The fiber content of jackfruit varies between 0.33 to 0.4%, with no differences between ripening stages [32]. According to a study, immature and ripe jackfruit fiber content is 2.6 percent and 0.8 percent, respectively [48].

2.5 Phytochemical

Jackfruit contains many phytochemicals that depend on a variety of carotenoids, flavonoids, volatile acids, sterols, and tannins [49-51]. The total phenolic content of jackfruit is 0.36 mg GAE/g DW, according to Wongsa and Zamaluddien [34]. Carotenoids are natural pigments found in plants, animals, algae, and microbes that give them yellow-radish color. They include provitamin A activity in addition to their colorant qualities. They are known to have beneficial effects on various chronic degenerative disorders, including cancer, infection, cardiovascular disease, cataract, and age-related macular degeneration [52-56]. Jackfruit kernel is reported to present various carotenoids (Table 4).

3. HEALTH BENEFITS

Traditional medicines from Artocarpus species include anti-bacterial, anti-diabetic, anti-inflammatory, and anti-helminthic properties (Fig. 3)[42]. It is high in carbohydrates, minerals, and vitamins, and the fruit contains lignans, flavones, and saponins, which have anti-cancer, anti-ulcer, anti-hypertensive, and anti-aging properties [7]. It has a high medicinal value. The seeds contain lectins such as jacalin and artocarpin, which can be used to assess the immune status of patients infected with the human immunodeficiency virus [48].

3.1 Anti-inflammatory and Antiviral Activity

Jackfruit seeds have an important biological activity such as anti-inflammatory and cytotoxicity. Triterpenes and sterols from jackfruit seed could inhibit the inflammatory action induced in RAW 264.7 cells at a concentration of 30 $\mu g\ mL^{-1}$ of the extract [57]. However, Flavonoids are compounds that have immunomodulatory effects. Their derivatives can inhibit various transcriptional factors that can modulate the differentiation, proliferation, and activatiob of immune cells and increase T cell formation regulation [58,59]. Flavonoids from citrus and its derivatives phytochemicals have the potentiality of antiviral and anti-inflammatory activity, which can be used to treat 2019-nCoV infection [60]. Jackfruit (*Artocarpus heterophyllus*) seed contains flavonoids and is suggested for COVID-19 treatment [61]. Shanmugapriya's study found that the 100 mg ethanolic fraction of jackfruit seed extract contained higher flavonoids than the acetone fraction, ethyl acetate, and water [62]. Jackfruit seeds contain secondary metabolites called jacalin, which have anti-inflammatory and anti-angiogenic activity [63].

3.2 Antioxidant Activity

Jackfruit seed slimy sheath as a rich source of pectin, which demonstrated excellent antioxidant properties and phenolic content [64]. Its seed flour can produce value-added food products [65]. Jackfruit axis extract has the strongest antioxidant capacity, which can protect against alcohol-induced cytotoxicity and its efficacy more than vitamin C [66]. Jackfruit exhibits antioxidative activity via its phytonutrients such as carotenoids and defends tissues against oxidative damage [34,67]. One of the risk indicators for coronary heart disease is the high-density lipoprotein ratio [68]. However, LDL oxidation contributes to atherosclerosis, characterized by a cascade of inflammatory activity and free radical-induced tissue injury, protein oxidation, DNA damage, and pro-inflammatory responses [69]. Compounds known as antioxidants can slow or stop the oxidation process. Fresh jackfruit seed and flesh provide significant ascorbic acid equivalent antioxidant effects and Gallic acid, which accounts for approximately 70% of overall antioxidant activity [70,71].

3.3 Anti-cancerous Activity

Isoflavones, lignans, and saponins are phytonutrients found in jackfruit with anti-cancer, anti-hypertensive, anti-ulcer, and anti-aging activities. According to Ruiz-Montanez, the jackfruit has chemoprotective qualities that inhibit AFB1 (afatoxin B1) mutagenicity and cancer cell proliferation. The jackfruit flesh contains compounds that may help prevent pr treat lymphoma cancer [72,73].

3.4 Anti-bacterial and Anti-fungal Activity

Jackfruits leave extract to have the ability to act as antimicrobials that reduce antagonist effects and are used as traditional medicine in the treatment of foodborne diseases. Additionally, jackfruit nano-particles were found effective against *Bacillus megaterium*, and *Escherichia coli* bacteria and jackfruit tree leaves had antimicrobials action on *Escherichia coli*, ATCC 25922, E. coli EPEC, CDC 086H35, and *Salmonella enteric* bacteria [74,75]. Antibacterial and antioxidant activity observed during meat treated with jackfruit seed extract as the TBA value decreased that jackfruit extract can be used for meat shelf-life management [76]. Jackfruit has been used as folk medicine. Artocarpanone from the heartwood of jackfruit exhibited an antibacterial activity on diarrheal pathogenic bacteria in *Escherichia coli* (E. coli with MIC and MBC value of 3.9 and 7.8 µg/mL) and *Vibrio cholera* (moderate) by altering membrane cell [77]. However, jackfruit also has antifungal properties; jackin is found in jackfruit, which can inhibit the growth of *Saccharomyces cerevisiae* and *Fusarium moniliforme* fungus. It also exhibits hemagglutination activity against rabbit and human erythrocytes [78].

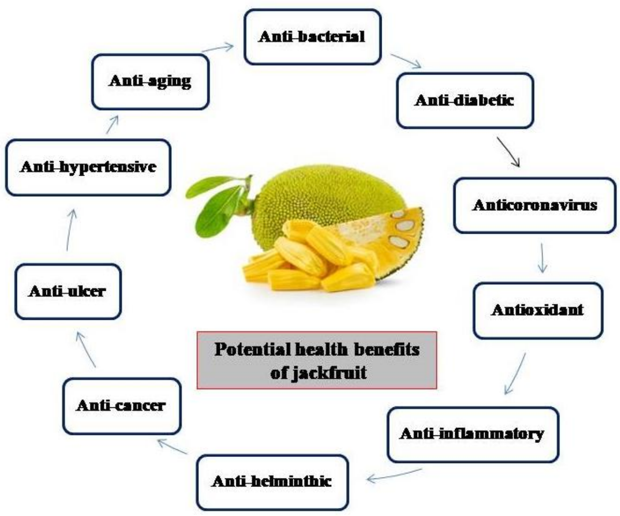

Fig. 3. Summary of the potential health benefits of jackfruit (*Artocarpus heterophyllus*)

3.5 Others Activity

All the parts of the jackfruit tree are used as a traditional medicine to treat malarial fever, kidney stones, infected wounds, diarrhea, asthma, dermatitis, and its seeds are used to heal sexual disorders due to its aphrodisiac properties [30,79-81]. Because of hypoglycemic and hypolipidemic chemicals in jackfruit leaves, they can help people with diabetes [72]. Artosterone from latex combined with vinegar promotes glandular swelling and snake bite recovery [82]. Root extract is a therapy for asthma and skin disorders, and root extract has soothing properties that may promote abortion cure, diarrhea, and fever. Seeds contain lectin (Jaclin), which assesses an HIV-positive person's immune system [83]. In Sri Lanka, the formulation of sausages together with jackfruit and different spices maintain the powerful immune-boosting ability [84]. However, traditionally jackfruit plants are used to treat various diseases (inflammation, malarial fever, diarrhea, diabetes, and tapeworm infection) as they contain various constituents such as protein, jacalin, flavonoids, stilbenoids, coloring matters, morin, dihydromorin, cynomacurin, artocarpin, isoartocarpin, carotene, essential amino acids. Artocarpus (from leaves, bark, stem) and several bioactive compounds (from fruit) are used in various biological activities, including anti-bacterial, anti-tubercular, anti-viral, anti-fungal, anti-platelet, anti-arthritic, tyrosinase inhibitory, and cytotoxicity [42].

4. CONCLUSION

Jackfruit is a quite versatile but tropical tree with high nutritional value sources (carbohydrates, proteins, vitamins and minerals, fiber, and photochemical). Jackfruit consumption has recently increased because of its health benefits revealed from previous studies, including anti-carcinogenic, anti-microbial, anti-inflammatory, anti-fungal, wound healing, and hypoglycemic properties. Nevertheless, it's an underutilized fruit commercially because of its big proportion of inedible parts, making waste generation even more difficult to peel. Some challenges include separating bulbs from the rind, lack of proper postharvest practices, and processing facilities in available regions. This review paper explains a brief explanation about their morphology, taxonomy, nutritional value, and chemical compounds present in jackfruit and its rich bioactive profile for the health benefits of the human being.

ACKNOWLEDGEMENTS

The author(s) appreciate Dr. Pallab Bhattacharjee**,** The Institute of Plant Protection, State Key Laboratory for Biology of Plant Diseases and Insect Pests, Chinese Academy of Agricultural Sciences, Beijing, China, and my wife Trishna Saha for support during the writing.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Sudheer K, Saranya S, Sankalpa K. Process protocol standardisation and shelf life study of minimally processed fresh cut tender jackfruit; 2019.
2. Taconi S, Pires AS. Vertebrate frugivory on jackfruit *Artocarpus heterophyllus* Lam. (Moraceae) in its native and exotic ranges. Tropical Ecology. 2021;1-10.
3. Moura CJRd, et al. Closing the snack bar: Developing methods for jackfruit tree (*Artocarpus heterophyllus* Lamk.) control in Brazil. Floresta e Ambiente. 2019;27.
4. Kamal NHM, et al. *In vitro* mass multiplication of *Artocarpus heterophyllus* lam var. Tekam yellow. Pertanika Journal of Tropical Agricultural Science. 2018;41(3).
5. Adnan M. Management of insect pests and diseases of jackfruit (*Artocarpus heterophyllus* L.) in agroforestry system: A review. Acta Entomology and Zoology. 2021;2(1):37-46.
6. Mitra S. Genetic resources of jackfruit in the world. in XXX International Horticultural Congress IHC2018: VII International symposium on tropical and subtropical fruits, Avocado, II 1299; 2018.
7. Khan AU, et al. A review on importance of *Artocarpus heterophyllus* L.(Jackfruit). Journal of Multidisciplinary Applied Natural Science; 2021.
8. Li X, Siddique KH. Future smart food. Rediscovering hidden treasures of neglected and underutilized species for Zero Hunger in Asia, Bangko; 2018.
9. Fathin A, et al. Flowering and fruiting phenology of jackfruit (*Artocarpus heterophyllus* Lam.) from Sumatra landraces in ex situ conservation area in Karangmojo, Yogyakarta. in IOP Conference Series: Earth and Environmental Science; 2021. IOP Publishing.
10. Xu SY, et al. Ultrasonic-microwave assisted extraction, characterization and biological activity of pectin from jackfruit peel. LWT. 2018;90:577-582.

11. Gardner EM, et al. A flower in fruit's clothing: Pollination of jackfruit (*Artocarpus heterophyllus*, Moraceae) by a new species of gall midge, Clinodiplosis ultracrepidata sp. nov.(Diptera: Cecidomyiidae). International Journal of Plant Sciences. 2018;179(5):350-367.
12. Rana SS, Pradhan RC, Mishra S. Variation in properties of tender jackfruit during different stages of maturity. Journal of food science and technology. 2018;55(6):2122-2129.
13. Khan1, et al. Status of mango fruit infestation at home garden in Mymensingh, Bangladesh; 2020.
14. Dhakar MK, et al. Diversity in jackfruit (*Artocarpus heterophyllus* Lam.): Insights into fruit characterization for the identification of superior genotypes. Plant Genetic Resources. 2020;18(5):307-315.
15. Witherup C, et al. Genetic diversity of Bangladeshi jackfruit (*Artocarpus heterophyllus*) over time and across seedling sources. Economic Botany. 2019;73(2):233-248.
16. Keat NS. High pressure processing of jackfruit (*Artocarpus heterophyllus* L.) BULB; 2018.
17. Shafie ZM, et al. Performance evaluation of vertijack (Jackfruit Opener) for commercial-scale fresh-cut fruit industry; 2019.
18. Vallath A, et al. Commercial utilization of jackfruit seed. Department of Processing and Food Engineering;; 2019.
19. Jadhav H, Mankar S, Bhosale M. A review on jackfruit: It is profitable to human beings. Research Journal of Pharmacognosy and Phytochemistry. 2021;13(1):51-54.
20. Nakintu J, et al. Ethno-varieties and distribution of jackfruit tree (*Artocarpus heterophyllus* Lam.) in Uganda: implications for trade, food security and germplasm conservation; 2019.
21. Ojwang RA, et al. Genetic diversity and relationships among populations of jackfruit, an underutilized nutrient-rich climate-smart fruit tree crop in Kenya and Uganda. Journal of Crop Improvement. 2021;1-19.
22. Joshi V. Indigenous fermented foods of South Asia; 2019. CRC press.
23. Gomes M, et al. Jackfruit trees as seed attractors and nurses of early recruitment of native plant species in a secondary forest in Brazil. Plant Ecology. 2021;222(10):1143-1155.
24. Balamaze J, Muyonga J, Byaruhanga Y. Production and utilization of jackfruit (*Artocarpus heterophyllus*) in Uganda. African Journal of Food, Agriculture, Nutrition and Development. 2019;19(2):14289-14302.
25. Kumar A. Unit-7 Sapota (*Achras zapota* L.) and Jackfruit (*Artocarpus Heterophyllus*). 2021, Indira Gandhi National Open University, New Delhi.
26. Kumar A. Block-2 sub tropical fruits. Indira Gandhi National Open University, New Delhi; 2021.
27. Guiné RP, e Florença SdG. *Artocarpus heterophyllus* (Jackfruit): Composition, Nutritional Value and Products, in Wild Fruits: Composition, Nutritional Value and Products. Springer. 2019;313-332.
28. Pua CK, NSAH, Tan CP, Mirhosseini H, Abd. Rahman R, Rusul G. Storage stability of jackfruit (*Artocarpus heterophyllus*) powder packaged in aluminium laminated polyethylene and metallized co-extruded biaxially oriented polypropylene during storage. Journal of Food Engineering. 2008;89(4):419-428.
29. Madruga MS, et al. Chemical, morphological and functional properties of Brazilian jackfruit (*Artocarpus heterophyllus* L.) seeds starch. Food Chem. 2014;143:440-5.
30. Fonseca CMB. Desidratação da jaca (*Artocarpus heterophyllus* Lam.) de São Tomé e Príncipe. Análise físico-química de amostras frescas e desidratadas. ISA-UL; 2016.
31. Borgis S, Bharati P. Mineral composition and antioxidant profile of jackfruit (*Artocarpus heterophyllus* Lam.) seed flour. EPRA International Journal of Research and Development (IJRD). 2020;5(11):159-162.
32. Amadi JA, Ihemeje A, Afam-Anene O. Nutrient and phytochemical composition of jackfruit (*Artocarpus heterophyllus*) pulp, seeds and leaves. International Journal of Innovative Food, Nutrition and Sustainable Agriculture. 2018;6(3):27-32.
33. FAO, FAO Statistical Yearbook – World Food and Agriculture. Rome, Italy: World Food and Agriculture. 2021;368.
34. Ranasinghe R, Maduwanthi S, Marapana R. Nutritional and health benefits of jackfruit (*Artocarpus heterophyllus* Lam.): A review. International journal of food science, 2019; 2019.
35. Waghmare R, et al. Jackfruit seed: An accompaniment to functional foods. Brazilian Journal of Food Technology. 2019;22.
36. Eyoh G. Effects of processing on nutrient composition of jackfruit (*Artocarpus heterophyllus*) seed meal. International Journal of Agric. and Rural Development. 2020; 23(2):5301-5306.

37. Adan A, et al. Phytochemical composition and essential mineral profile, antioxidant and antimicrobial potential of unutilized parts of jackfruit. Food Res. 2020;4:1125-1134.
38. Palamthodi S, Shimpi S, Tungare K. A study on nutritional composition and functional properties of wheat, ragi and jackfruit seed composite flour. Food Science and Applied Biotechnology. 2021;4(1):63-75.
39. Jagdale YD, et al. Nutritional profile and potential health benefits of super foods: a review. Sustainability. 2021;13(16):9240.
40. Chrips N, Balasingh R, Kingston C. Nutrient constituens of negleted varieties of *Artocarpus heterophyllus* Lam. from Kanyakumari district, South India. Journal of basic and applied biology. 2008;2(1):36-37.
41. Koppula T. Isolation of Starch from Jackfruit Seed and Evaluation of its Binding and Disintegrating Properties.
42. Haleel MP, Rashid K, Kumar CS. *Artocarpus heterophyllus*: Review study on potential activities. Research Journal of Pharmacology and Pharmacodynamics. 2018;10(1):24-28.
43. Tewari S, et al. The pharma therapeutic fruits: An overview; 2021.
44. Goswami CC, et al. Assessment of physicochemical properties of jackfruits' (*Artocarpus heterophyllus* Lam) pulps. Journal of Horticulture, Forestry and Biotechnology. 2011;15:26-31.
45. Swami SB, et al. Jackfruit and its many functional components as related to human health: A review. Comprehensive Reviews in Food Science and Food Safety. 2012;11:565-576.
46. Production and characterization of jackfruit jam devotha gabriel mushumbusi a dissertation submitted in partial fulfilment of the requirements for the degree of master of science in food; 2016.
47. Bose TK. Fruits of India: Tropical and subtropical. Naya Prokash; 1985.
48. Sowmyashree G, Devaraja S. Jackfruit and its beneficial effects in boosting digestion and immune-enhancing properties, in Nutrition and Functional Foods in Boosting Digestion, Metabolism and Immune Health. Elsevier. 2022;267-287.
49. Arung, E.T., K. Shimizu, and R. Kondo, Structure-activity relationship of prenyl-substituted polyphenols from *Artocarpus heterophyllus* as inhibitors of melanin biosynthesis in cultured melanoma cells. Chem Biodivers, 2007. 4(9): p. 2166-71.
50. Chandrika UG, Jansz ER, Warnasuriya ND. Analysis of carotenoids in ripe jackfruit (*Artocarpus heterophyllus*) kernel and study of their bioconversion in rats. Journal of the science of food and agriculture. 2005;85,2(no. 2):186-190.
51. Venkataraman K. Wood phenolics in the chemotaxonomy of the moraceae. Phytochemistry. 1972;11(5):1571-1586.
52. Fuad NIN, et al. Lutein: A comprehensive review on its chemical, biological activities and therapeutic potentials. Pharmacognosy Journal. 2020;12(6s).
53. Stanner SA, et al. A review of the epidemiological evidence for the 'antioxidant hypothesis'. Public Health Nutr. 2004;7(3):407-22.
54. Coyne T, et al. Diabetes mellitus and serum carotenoids: Findings of a population-based study in Queensland, Australia. The American Journal of Clinical Nutrition. 2005;82(3):685-693.
55. Stahl W, Sies H. Bioactivity and protective effects of natural carotenoids. Biochim Biophys Acta. 2005;1740(2):101-7.
56. de Faria AF, de Rosso VV, Mercadante AZ. Carotenoid composition of jackfruit (*Artocarpus heterophyllus*), determined by HPLC-PDA-MS/MS. Plant Foods Hum Nutr. 2009;64(2):108-15.
57. Tramontin D, et al. Response surface methodology (RSM) to evaluate both the extraction of triterpenes and sterols from jackfruit seed with supercritical CO 2 and the biological activity of the extracts. Journal of Food Science and Technology. 2021;1-11.
58. Lowery LA, et al. Characterization and classification of zebrafish brain morphology mutants. Anat Rec (Hoboken). 2009;292(1):94-106.
59. Hosseinzade A, et al. Immunomodulatory effects of flavonoids: Possible induction of T CD4+ regulatory cells through suppression of mTOR pathway signaling activity. Frontiers in immunology. 2019;10:51.
60. Cheng L, et al. Citrus fruits are rich in flavonoids for immunoregulation and potential targeting ACE2; 2020.
61. Kusumaningtyas AA, Retnoaji B. Jackfruit seed extract exposure on zebrafish embryos as initial screening model for Covid-19 treatment. in 3rd KOBI Congress, International and National Conferences (KOBICINC 2020). Atlantis Press; 2021.
62. Shanmugapriya K, et al. Antioxidant activity, total phenolic and flavonoid contents of *Artocarpus heterophyllus* and manilkara zapota seeds and its reduction potential Research Article; 2011.

63. Oktavia S, Wijayanti N, Retnoaji B. Anti-angiogenic effect of *Artocarpus heterophyllus* seed methanolic extract in ex ovo chicken chorioallantoic membrane. Asian Pacific Journal of Tropical Biomedicine. 2017;7(3):240-244.
64. Kumar M, et al. Jackfruit seed slimy sheath, a novel source of pectin: Studies on antioxidant activity, functional group, and structural morphology. Carbohydrate Polymer Technologies and Applications. 2021;2: 100054.
65. Kushwaha R, et al. Effect of cultivar and maturity on functional properties, low molecular weight carbohydrate, and antioxidant activity of Jackfruit seed flour. Journal of Food Processing and Preservation. 2021;45(2): e15146.
66. Li Z, et al. Phytochemicals, antioxidant capacity and cytoprotective effects of jackfruit (*Artocarpus heterophyllus* Lam.) axis extracts on HepG2 cells. Food Bioscience. 2021;41:100933.
67. Masibo M, He Q. Mango bioactive compounds and related nutraceutical properties—A review. Food Reviews International. 2009;25(4):346-370.
68. Ali KM, et al. Cardiovascular disease risk reduction by raising HDL cholesterol–current therapies and future opportunities. British journal of pharmacology. 2012;167(6):1177-1194.
69. Greig FH, Kennedy S, Spickett CM. Physiological effects of oxidized phospholipids and their cellular signaling mechanisms in inflammation. Free Radical Biology and Medicine. 2012;52(2):266-280.
70. Soong YY, Barlow PJ. Antioxidant activity and phenolic content of selected fruit seeds. Food chemistry. 2004;88(3):411-417.
71. Jagtap UB, Panaskar SN, Bapat V. Evaluation of antioxidant capacity and phenol content in jackfruit (*Artocarpus heterophyllus* Lam.) fruit pulp. Plant foods for human nutrition. 2010;65(2):99-104.
72. Baliga MS, et al. Phytochemistry, nutritional and pharmacological properties of *Artocarpus heterophyllus* Lam (jackfruit): A review. Food research international. 2011;44(7):1800-1811.
73. Ruiz-Montañez G, et al. Screening antimutagenic and antiproliferative properties of extracts isolated from Jackfruit pulp (*Artocarpus heterophyllus* Lam). Food chemistry. 2015;175:409-416.
74. Sousa DFd, Campos PC, Conceição AOd. Antibacterial activity of jackfruit leaves extracts and the interference on antimicrobial susceptibility of enteropathogen. Food Science and Technology; 2021.
75. Theivasanthi T, et al. Nano sized powder of jackfruit seed: spectroscopic and anti-microbial investigative approach. arXiv preprint arXiv:1111.1199; 2011.
76. Ramli ANM, et al. Antibacterial and antioxidative activity of the essential oil and seed extracts of *Artocarpus heterophyllus* for effective shelf- life enhancement of stored meat. Journal of Food Processing and Preservation. 2021;45(1):e14993.
77. Septama AW, Panichayupakaranant P. Antibacterial activity of artocarpanone isolated from *Artocarpus heterophyllus* heartwoods against diarrheal pathogens and its mechanism of action on membrane permeability. J. Appl. Pharm. Sci. 2017;7:64-8.
78. Trindade MB, et al. Structural characterization of novel chitin-binding lectins from the genus Artocarpus and their antifungal activity. Biochimica et Biophysica Acta (BBA)-Proteins and Proteomics. 2006;1764(1):146-152.
79. de Araújo NG, de Paes Lima LR. Utilização de *Artocarpus heterophyllus* no tratamento de cálculos de oxalato de cálcio. Infarma-Ciências Farmacêuticas. 2012;22(11/12):3-7.
80. Madaleno IM. Plantas da medicina popular de São Luís, Brasil. Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas. 2011;6:273-286.
81. Jagtap U, Bapat V. Artocarpus: A review of its traditional uses, phytochemistry and pharmacology. Journal of ethnopharmacology. 2010;129(2):142-166.
82. Mandhare A, et al. Jackfruit (*Artocarpus heterophyllus*): A comprehensive patent review. Current Nutrition & Food Science. 2020;16(5):644-665.
83. Suryadevara V, et al. Studies on jackfruit seed starch as a novel natural superdisintegrant for the design and evaluation of irbesartan fast dissolving tablets. Integrative medicine research. 2017;6(3):280-291.
84. Wijegunawardhana D, Madushani E, Gamage S. Development of immune-boosting vegan sausage utilizing baby jackfruit (*Artocarpus heterophyllus*) by replacing carcinogenic curing salts with natural pigment source. Energy (KJ). 2021;50(210):88-410.