A REVIEW ON IMPORTANCE OF *Artocarpus heterophyllus* L. (Jackfruit)

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**Abstract**

The Jackfruit (*Artocarpus heterophyllus* L.) is well-known as “poor man’s food” fruit in Bangladesh. It is widely consumed by most of the rural people and it is the national fruit of Bangladesh. The main aim of this review is to document the medicinal significance of jackfruit (*Artocarpus heterophyllus* L.), major parts and uses of the jackfruit in Bangladesh. This article was based on mostly a literature review. All parts of the fruit and plant are used as human food, animal feed and wood source for furniture. Although jackfruit is the main fruit of the tree, it is used as furniture for its beautiful texture and wood color. Jackfruit contains anti-bacterial, anti-diabetic, anti-oxidant, anti-inflammatory and anti-helminthic properties. The fruit is rich in carbohydrates, minerals, carboxylic acids, dietary fiber, vitamins and minerals. The seed is rich in manganese, magnesium, potassium, calcium iron and lectins and thus meets up nutritional requirements for the rural people. The present study attempted to review the medicinal importance, health-promoting effects of jackfruit and seeds with special emphasis on their applications in the food.

**Keywords:** jackfruit, medicinal importance, fruit and seed quality, health benefits, morphology

1. INTRODUCTION

*Artocarpus heterophyllus* is the scientific name of jackfruit which the fruit belong to the family of Moracea and native to Southeast Asia [1] –[3]. It is widely cultivated in most tropical countries like Bangladesh, India, Burma, Philippines, Pakistan, Sri Lanka, Malaysia, Thailand, and several areas in Brazil, Queensland, Africa and some other parts of Australia and America. Bangladesh is sanctified with a vast diversity of fruits. About 70 different types of fruits are grown in Bangladesh [4]. Jackfruit is the national fruit of Bangladesh [5][6] and mango is our national plant of Bangladesh [7]. It is the major fruit tree at Madhupur tract in Bangladesh [8]. The edible fruit of jackfruit is known as the “poor man’s food” [9][10]. It is the most popular fruit in rural and urban areas of Bangladesh. It ranks the 4th position as per production volume after banana, mango, and pineapple [11]. Jackfruit ranks the 3rd position with respect to fruit production in Bangladesh.

There are so many benefits from the fruit, tree, branches of jackfruit. The fruit is enriched with a diverse of nutrients and edible where the fruit can be consumed when its ripe and when its green part uses as vegetable. The edible bulbs of ripe jackfruit are usually consumed fresh or processed into canned products; 10-15 percent of the total fruit weight is considered as its seed weight. In Asia, folk consume the plants in medicine and used as anti-bacterial, anti-diabetic, anti-oxidant, anti-inflammatory and anti-helmintics properties [12]. Approximately, 2 Megajoule energy per kg/wet weight of ripe perianth. Besides, the fruit can supply at [13]. Phytonutrients contain in jackfruit such as lignans, flavones and saponins have the properties of anticancer, antiulcer, antihypertensive and antiaging [14]. The fruit is rich in carbohydrates, minerals, carboxylic acids, dietary fiber, vitamins and minerals. The seed is rich in manganese, magnesium, potassium, calcium iron and lectins and thus meets up nutritional requirements for the rural people. The jackfruit seed flour is not only a rich source of protein, starch and dietary fibers but can also be regarded as an abundant yet cheap source of nutrients. Lectin, a class of glycoprotein found in jackfruit seed, has been reported to possess antibacterial, antifungal
and anticarcinogenic properties [15]. Ripe jackfruit pulp is processed, dehydrated and sold as dry powder which is utilized for juice, biscuits, chutney, jam, jelly, toffee, paste, leather, bar, nectar, squash and pickle [16]. It is also canned in syrup, either plain or blended with dehydrated bulbs, chutney, preserves, candy and concentrate and powder. Now a days, consumer preferences have changed to diets with more natural antioxidants, dietary fibers, natural colorants, minerals, vitamins, reduced calories, low cholesterol and low sugar, free of chemicals, etc. The possibilities of utilizing jackfruit waste and by product of leaves and wood [17]. Jackfruit growth and development are directly depended on the source of nutrients and those nutrients improve the nutritional quality of jackfruit [18].

The qualitative jackfruit and some seeds are exported to UK [19]. The jackfruit is a cross pollinated fruit tree and is mainly propagated by seeds [20]. The tree as well can provide many other uses in environmental protection. The leaves of the jackfruit tree are used as nutritious food for cattle. The leaves are rich in vitamins and minerals which are important for the animal. Its remaining stalks are used as wood. However, the main stem enhances the beauty of the house as furniture. It is possible to earn income by selling wood as wood, just as it is possible to make a lot of profit by selling well shape wood. However, a lot of money is earned by selling ordinary jackfruit fruits. But the jackfruit trees cultivated around the village house are not taken care of but no fertilizer is given. By considering the above points, the present study was undertaken to collect information about the significance of the nutritional and medicinal importance of jackfruit in Bangladesh.

2. METHODOLOGY

To assess the current state of the research on importance of jackfruit (Artocarpus heterophyllus L.), a review of the existing journal literature, books, report, blogs and newspaper were carried out. Keywords (Jackfruit, medicinal importance, fruit and seed quality, health benefits, and morphology) search in the google, google scholar, web of science database (www.thomsonreuters.com/web-of-science) and a full-text search of the Science Direct (www.sciencedirect.com) database were carried out. Information was also collected from government organization and NGO’s by personal communication. The reviews or literature reviews will be examined to identify further studies for inclusion, and the results of meta-analyses will not be included in the analysis.

3. MORPHOLOGY OF JACKFRUIT

3.1. Size and Shape

Jackfruit grow as an evergreen tree that has a relatively short trunk with a dense treetop. It easily reaches heights of 10 to 20 m (33 to 66 feet) and trunk diameters of 30 to 80 cm (12 to 31 inches). The canopy shape is usually conical or pyramidal in young trees and becomes spreading and domed in older trees (Figure 1). It sometimes forms buttress roots. The bark of the jackfruit tree is reddish-brown and smooth. In the event of injury to the bark, a milky juice is released. In young trees, the leaf edges are irregularly lobed or split. The tree casts a very dense shade. Heavy side branching

| No. | Keyword Search                        | Articles Number |
|-----|---------------------------------------|-----------------|
| 1   | Artocarpus heterophyllus L. or Jackfruit | 215             |
| 2   | Medicinal importance                  | 188             |
| 3   | Fruit and seed quality                | 218             |
| 4   | Health benefits                       | 114             |
| 5   | Morphology                            | 225             |
| 6   | Limit of article                      | 201             |
| 7   | Manually screened                     | 87              |
| 8   | Articles included in the review        | 60              |

Table 1. Keyword search
usually begins near the ground. All parts of the tree exude sticky white latex when injured.

3.2. Flowers

This species is monoecious, having male and female inflorescences (or “spikes”) on the same tree. The flowers are small, sitting on a fleshy rachis. Male and female spikes are borne separately on short, stout stems that sprout from older branches and the trunk. The male flowers are greenish, some flowers are sterile (Figure 1). Male spikes are found on younger branches above female spikes. Male spikes are dense, fleshy, cylindrical to club shaped, and up to 10 cm (4 in) in length. Flowers are tiny, pale green when young, turning darker with age. The male flowers are less and small hairy and the perianth ends with two 1 to 1.5 mm (1/64 to 1/16 in) membrane. After the pollen distribution, the stamens become ash-gray and fall off after a few days.

Female flowers are larger, elliptic or rounded, tubular calyx, with hairy and tubular perianth, have a fleshy flower-like base. The female flowers contain an ovary with a broad, capitate or rarely bilobed scar (Figure 1). The flowers are reportedly pollinated by insects and wind, with a high percentage of crosspollination. The blooming time ranges from December until February or March [21].

3.3. Fruit

The inflorescences are formed on the trunk, branches or twigs (cauliflory). Jackfruit trees are monoecious, having both female and male flowers on a tree. Fruit of jackfruit has a compound or multiple fruit with a green to yellow brown exterior rind that is composed of hexagonal, bluntly conical carpel apices that cover a thick, rubbery, whitish to yellowish wall (Figure 1). The ellipsoidal to roundish fruit is a multiple fruit formed from the fusion of the ovaries of multiple flowers. The fruits grow on a long and thick stem on the trunk. The heavy fruit is held together by a central fibrous core. They vary in size and ripen from an initially yellowish-greenish to yellow, and then at maturity to yellowish-brown. They possess a hard, gummy shell with small pimples surrounded with hard, hexagonal tubercles. The large and variously shaped fruit have a length of 30 to 100 cm (10 to 40 inches) and a diameter of 15 to 50 cm (6 to 20 inches) and can weigh 10–25 kg (22–55 pounds) or more [22].

Figure 1. (a) Jackfruit tree with the fruits; (b) jackfruit tree with the fruits in different stages of fruiting; (c) club shaped spike male inflorescence; (d) female inflorescence; (e) leaf showing both side (f) Cut section of jackfruit; (g) the bulbs of jackfruit; (h) the jackfruit seed and (i) Jackfruit Chips
3.4. Leaves

Leaves are dark green, alternate, entire, simple, glossy, leathery, stiff, large (up to 16 cm [6 in] in length), and elliptic to oval in form. The leaves are alternate and spirally arranged (Figure 1). They are gummy and thick and are divided into a petiole and a leaf blade. On older trees, the leaves are rounded and dark green, with a smooth leaf margin. The petiole is 2.5 to 7.5 cm (1 to 3 inches) long. The leathery leaf blade is 20 to 40 cm (7 to 15 inches) long, and 7.5 to 18 cm (3 to 7 inches) wide and is oblong to ovate in shape. Leaves are often deeply lobed when juvenile and on young shoots.

3.5. Seeds

Seeds are light brown, rounded, 2–3 cm (0.8–1.2 in) in length by 1–1.5 cm (0.4–0.6 in) in diameter, and enclosed in a thin, whitish membrane. There may be about 100–500 seeds per fruit (Figure 1). Seeds are recalcitrant and can be stored up to a month in cool, humid conditions [21]. The seed coat consists of a thin, waxy, parchment-like and easily removable testa (husk) and a brownish, membranous tegmen. The cotyledons are usually unequal in size, and the endosperm is minimally present. An average fruit consists of 27% edible seed coat, 15% edible seeds, 20% white pulp (undeveloped perianth, rags) and bark and 10% core [7].

4. MAJOR PARTS OF A JACKFRUITS

Jackfruit has three main parts [2], the fruit axis, the perianth and the bulbs. The axis contains the core, latex and the arils (Figure 1). Jackfruit has lactiferous cells which are responsible for production of latex [23], which is sap that sticky in nature. The perianth contains the rind and the rags, the bulbs contain the edible part and the seeds. The inedible parts of jackfruit include prickly rind, non-edible perianth and a central core [24]. All these inedible jackfruit parts are potential raw materials for bioenergy and biochar production.

5. USES OF THE JACKFRUIT PARTS

All parts of the fruit and tree are used as human food, animal feed and wood source for furniture (Figure 2). The jackfruit pulp is processed for juice, biscuits, chutney, jam, jelly, toffee, paste, leather, bar, nectar, squash and pickle. The color and flavor are important for the jackfruit bulb [25]. Ice-cream prepared by using the jackfruit bulbs. The green fruit bulbs and seeds used as cooking materials in the farmers community. The leaves use as animal feed and the leaves are contain significant amount of nutrients. The wood materials are using as furniture of home and possibilities of utilizing jackfruit waste and by product of leaves and wood for production of biogas, briquettes and biochar which is applied in the farmer’s field. The jackfruit bulbs are using in bakery industry which is improve the food quality. The bakery products are increasingly gaining popularity since they are convenient, readily available in diverse tastes and textural profiles, less expensive and possess high nutritive value. The bakery products are as biscuits [26], cookies, bread [27], cake [28], muffins [29] etc. have been formulated by supplementation with different levels of jackfruit seed flour. So, there is scope to develop the industry which is help in employment sector in Bangladesh.

6. MEDICINAL SIGNIFICANCE OF JACKFRUIT

The *Artocarpus* species have been used as traditional medicines. The plants have been used as anti-bacterial, anti-diabetic, antioxidant, anti-inflammatory and anti-helminthic [31]. Jackfruit is
also a rich source of many minerals such as N, P, K, Ca, Mg, S, Zn, Cu, etc. [32]. The nutritional parameters of the jackfruit flesh, seeds and the meal are presented in Table 2. The water contents of the young, ripe fruit and seeds were (51.0-94.4) g; respectively. The available digestible carbohydrate contents of the young, ripe fruit and seeds were (16.0-38.40) g; respectively. Jackfruit seeds are underutilized and less acknowledged by people, but they have considerable nutritional benefits and constitute about 10% to 15% of the fruit weight [33]. The protein content of the meal was (0.40-2.60) g the young, ripe fruit and seeds of jackfruit; respectively with a higher contribution from the young fruit while the fat content of the meal was (0.10-0.60) g in the young, ripe fruit and seeds; respectively. The fiber content of the meal was (1.0-2.60) g the young, ripe fruit and seeds of jackfruit; respectively with a higher contribution from the young fruit while the mineral content of the meal was (0.87-0.90) g in the young, ripe fruit and seeds; respectively. The ripe fruit contains 20.60 g sugar in the meal. The jackfruit rich in calcium, magnesium, phosphorus, potassium, sodium, iron, vitamin A, thiamine, riboflavin and vitamin C (Table 2). Jack seeds contained high total dietary fiber (TDF) (11.1%) compared to flesh (2.6%). Jackfruit seeds also contained 8% resistant starch (undigestible starch).

It is a major source of carbohydrates, minerals and vitamins [34]. Hasan et al. [35] reported that the average annual net returns found more than the agriculture system. Alves et al. [36] observed that the fruit contains lignins, flavones and saponins which have the properties of anti-cancer, anti-ulcer, anti-hypertensive and anti-aging. It contains immense medicinal values and also considered a rich source of carbohydrates, minerals, carboxylic acids, dietary fiber and vitamins such as ascorbic acid and thiamine [13]. Manganese and magnesium [32], potassium, calcium and iron [37] elements are found in seed. Mukprasirt and Saijaanantakul [38] reported that the seeds contain lectins as jacalin and artocarpin. Jacalin has been shown to be useful for the evaluation of the immune status of patients infected with human immunodeficiency virus [39]. Seed nanoparticles were found effective against *Escherichia coli* and *Bacillus megaterium* bacteria [40]. It has anti-oxidant action [3], and acts against inflammation, malarial fever and skin diseases [41], anti-bacterial and anti-helminthic [42]. The tree leaves are commonly used as healing for ulcer. Its leaves have the potential of curing diabetics due to the presence of hypoglycemic and hypolipidemic substances [43]. The leaves and stems have sapogenins, cyclooctenone, cycloartenol, β-sitosterol and tannins. The latex yield artoasteron mixed with vinegar promotes healing of glandular

### Table 2. Nutrient composition of jackfruit (100 g edible portion)

| Nutrients       | Young fruit | Ripe fruit | Seed       |
|-----------------|-------------|------------|------------|
| Water (g)       | 76.20-85.20 | 72.0-94.0  | 51.0-64.50 |
| Protein (g)     | 2.0-2.60    | 1.20-1.90  | 0.40-0.43  |
| Fat (g)         | 0.10-0.60   | 0.10-0.40  | 0.40-0.43  |
| Carbohydrate (g)| 9.40-11.50  | 16.0-25.40 | 25.80-38.40|
| Fiber (g)       | 2.60-3.60   | 1.0-1.50   | 1.0-1.50   |
| Sugar (g)       | -           | 20.60      | -          |
| Minerals (g)    | 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       |

Source: Goswami and Chacrabati [34]
swelling and snake bites [44]. Long et al. [45] reported that the root extract is a therapy for asthma and skin disorder. The wood has sedative property and believed that it may cause promotion of abortioncure diarrhea and fever [46]. The fruits and roots are used for tapeworm infection [47]–[49]. The fruit is rich in carbohydrates, complex B vitamins, and minerals [50]. The freshly fruit is consumed. It can be processed to candies, sweeties, frozen pulps, juices and vegetable in immature fruit. Its seed can be consumed as baked or used in culinary to develop several menus. Now, there are studies concerning the use of seed meal for preparing cookies, sweeties and bread as an alternative source of carbohydrate. The jackfruit contains variable constituents of moisture (6.7%), glucosides (38.0%), lipids (0.7%), protein (1.7%) and cellulose (59.0 %) [50]. Jagtap and Bapat [51] observed that the ripe fruits are rich in nutritive value; every 100 g of ripe fruit contains 287-323 mg potassium, 30.0–73.2 mg calcium and 11–19 g carbohydrates. Chowdhury et al. [52] reported that the bark contains betullic acid and a flavone pigment, cycloheterophyllin (C_{30}H_{30}O_{7}). The fruit pulp also contains lycopene [53]. De-Faria et al. [54] reported that the fruit contain 18 carotenoids were successfully separated, identified and quantified and 14 were detected. The leaves and stem contain sapogenins, cycloartenone, cycloartenol, β-sitosterol and tannins show estrogentic activity. A root contains β-sitosterol, ursolic acid, betulinic acid and cycloartenone [4]. Jackfruit seed contains a thin brown spermoderm, the crude fiber (2.36 %), but the composition of flour depends on nature of seed [55].

7. HEALTH BENEFITS OF JACKFRUIT SEEDS

The phytonutrients such as lignans, saponins, and isoflavones present in the seeds, plays beneficial role in human health presented in Figure 3 [55]. The presence of high fiber content (3.6 g/100 g) in the jackfruit improve digestion system and produces smooth bowel movements. It also offers protection to the colon mucous membrane by removing carcinogetic chemicals from the large intestine [30].

The addition of the jackfruit seed flour to deep-fried products results in a reduction in fat absorption up to a certain limit [56]. The seeds are rich in dietary fiber and B-complex vitamins and due to their high fiber content, they help lower the risk of heart disease, prevent constipation and promote weight loss. Jackfruit seeds also contain resistant starch, which controls blood sugar and keeps the gut healthy. Jackfruit seeds possess antimicrobial activity, which prevents foodborne diseases [54] and the seeds contain an important lectin known as jacalin, used as a tool to evaluate the immune system of an HIV infected person. In China the seeds are known to be beneficial in overcoming the toxicity due to alcohol and likewise, in India, the seeds are a crucial component of an antidote produced for heavy drinkers [57]. The seeds contain an abundance of magnesium
which plays a vital role in lowering the blood pressure and maintaining bone health since it aids in calcium absorption and hence helps to strengthen the bones [2]. Furthermore, the seeds are rich in highly soluble protein resulting in the prevention and treatment of mental stress and anxiety. The seeds have low water and fat-absorption capacities, which helps in prevention of obesity [58]-[60].

8. CONCLUSION

Jackfruit is quite versatile. It can be eaten raw, cooked, ripe or unripe and tastes great in a variety of sweet and savory dishes. The consumption of jackfruit has grown in recent years due to its reported health benefits. Jackfruit and its pulp and seeds are rich sources of several high-value compounds with potential beneficial health benefits. The rich bioactive profile of jackfruit makes it a highly nutritious and desirable fruit crop. The review concluded that all the nutrients like vitamins and minerals fulfill malnutrition in the rural area of Bangladesh.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

[1] B. O. Ajiboye, O. Adeleke Ojo, O. Adeyonu, O. Imiere, B. Emmanuel Oyinloye, and O. Ogunmodede. (2018). “Ameliorative activity of ethanolic extract of artocarpus heterophyllus stem bark on alloxan-induced diabetic rats”. Advanced Pharmaceutical Bulletin. 8 (1): 141–147. 10.15171/apb.2018.017.

[2] R. A. S. N. Ranasinghe, S. D. T. Maduwanthi, and R. A. U. J. Marapana. (2019). “Nutritional and health benefits of jackfruit (Artocarpus heterophyllus lam.): a review”. International Journal of Food Science. 2019: 1–12. 10.1155/2019/4327183.

[3] A. K. Gupta, M. A. Rather, A. Kumar Jha, A. Shashank, S. Singhal, M. Sharma, U. Pathak, D. Sharma, and A. Mastinu. (2020). “Artocarpus lakoocha Roxb. and Artocarpus heterophyllus Lam. Flowers: New Sources of Bioactive Compounds”. Plants. 9 (10): 1329. 10.3390/plants9101329.

[4] R. Uddin, M. U. Thakur, M. Z. Uddin, and G. M. R. Islam. (2021). “Study of nitrate levels in fruits and vegetables to assess the potential health risks in Bangladesh”. Scientific Reports. 11 (1): 4704. 10.1038/s41598-021-84032-z.

[5] M. A. Rahaman, A. Rahman, M. G. Miah, M. A. Hoque, and M. M. Rahman. (2018).
“Productivity and profitability of jackfruit-eggplant agroforestry system in the terrace ecosystem of Bangladesh”. *Turkish Journal of Agriculture - Food Science and Technology*. 6 (2): 124. [10.24925/turja.f.v6i2.124-129.1330].

[6] S. Sarkar. (2017). “Jackfruit production in Tripura: a land for trip of jackfruits in Bangladesh”. *the Asian Journal of Horticulture*. 12 (1): 88–90. [10.15740/has/tajh/12.1/88-90].

[7] A. U. Khan. (2020). “Status of mango fruit infestation at home garden in Mymensingh, Bangladesh”. *Current Research in Agriculture and Farming*. 1 (4): 35–42. [10.18782/2582-7146.119].

[8] M. Sazib Uddin, M. Najmus Sayadat Pitol, and S. M Feroz. (2021). “Floristic composition and woody species diversity in National Park of Madhupur tract under Tangail North Forest division, Bangladesh”. *Journal of Forests*. 8 (1): 99–108. [10.18488/journal.101.2021.81.99.108].

[9] M. Balaji Rajkumar, B. Gundappa, M. M. Tripathi, and S. Rajan. (2018). In: “Omkar O (Ed) Pests and their management”. Springer Singapore, Singapore. [10.1007/978-981-10-8687-8_18].

[10] G. S. Chikkanna. (2021). “Technical Facts on the Current Scenario and Future Potential of Jackfruit Processing”. *Research Biotica*. 3 (2): 94–106.

[11] C. Saha, H. Mahmood, S. N. S. Nayan, M. R. H. Siddique, S. M. R. Abdulla, S. M. Z. Islam, M. Z. Iqbal, and M. Akhter. (2021). “Allometric biomass models for the most abundant fruit tree species of Bangladesh: A Non-destructive approach”. *Environmental Challenges*. 3 : 100047. [10.1016/j.envc.2021.100047].

[12] A. U. Khan, M. A. R. Choudhury, M. A. Maleque, C. K. Dash, M. S. A. Talucder, A. R. M. Maukeeb, I. J. Ema, M. Adnan. (2021). “Management of insect pests and diseases of jackfruit (Artocarpus heterophyllus L.) in agroforestry system: a review”. *Acta Entomology and Zoology*. 2 (1): 37–46. [10.33545/27080013.2021.v2.i1a.29].

[13] S. B. Swami and S. B. Kalse. (2018). In: “Mérillon J and Ramawat K (eds) Bioactive molecules in food”. Springer Cham, New York. [10.1007/978-3-319-54528-8_87-1].

[14] S. Palamthodi, S. Shimpi, and K. Tungare. (2021). “A study on nutritional composition and functional properties of wheat, ragi and jackfruit seed composite flour”. *Food Science and Applied Biotechnology*. 4 (1): 63. [10.30721/fsab.2021.v4.i1.107].

[15] A. N. M. Ramli, S. Z. S. Badrulzaman, H. A. Hamid, and P. Bhuyar. (2021). “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*. 45 (1). [10.1111/ifpp.14993].

[16] Y. Li, X. Duan, S. Liu, Y. Li, X. Zhang, and C. Ye. (2017). “Changes in soluble sugar accumulation and activities of sucrose-metabolizing enzymes during fruit ripening of jackfruit”. *Journal of Agricultural Science*. 9 (8): 155. [10.5539/jas.v9n8p155].

[17] N. S. B. Saha, N. Banadda, I. Kabenge, and K. D. Wydra. (2020). “Potential of jackfruit waste for biogas, briquettes and as a carbon dioxide sink—a review”. *Journal of Sustainable Development*. 13 (4): 60. [10.5539/jsd.v13n4p60].

[18] M. D. Toor. (2021). “Nutrients and their importance in agriculture crop production: a review”. *Indian Journal of Pure & Applied Biosciences*. 9 (1): 1–6. [10.18782/2582-2845.8527].

[19] Z. Al Riyadh, M. A. Rahman, M. G. Miah, S. R. Saha, M. A. Hoque, M. M. Rahman, and I. Miyajima. (2020). “Performance of spices as lower-storey crop in jackfruit–papaya multistorey agroforestry system in Bangladesh”. *Journal of the Faculty of Agriculture, Kyushu University*. 65 (2): 223–231. [10.5109/4103649].

[20] C. Witherup, M. I. Zuberi, S. Hossain, and N. J. C. Zerega. (2019). In: “Mérillon J and Ramawat K (eds) Bioactive molecules in food”. Springer Cham, New York. [10.1007/978-3-319-54528-8_87-1].
Variation in properties of tender jackfruit (Artocarpus heterophyllus, Moraceae) by a new species of gall midge, Clindoplosis ultracrepidata sp. nov. (diptera: cecidomyiidae). *International Journal of Plant Sciences.* **179** (5): 350–367. 10.1086/697115.

S. S. Rana, R. C. Pradhan, and S. Mishra. (2018). “Variation in properties of tender jackfruit during different stages of maturity”. *Journal of Food Science and Technology.* **55** (6): 2122–2129. 10.1007/s13197-018-3127-9.

S. Bhadra, N. Mohan, G. Parikh, and S. Nair. (2019). “Possibility of artocarpus heterophyllus latex as an alternative source for natural rubber”. *Polymer Testing.* **79**: 106066. 10.1016/j.polymertesting.2019.106066.

S.-Y. Xu, J.-P. Liu, X. Huang, L.-P. Du, F.-L. Shi, R. Dong, X.-T. Huang, K. Zheng, Y. Liu, and K.-L. Cheong. (2018). “Ultrasonic-microwave assisted extraction, characterization and biological activity of pectin from jackfruit peel”. *Lebensmittel – Wissenschaft and Technologie.* **90**: 577–582. 10.1016/j.lwt.2018.01.007.

V. L. Shinde, C. D. Pawar, O. S. Warang, V. S. Dandekar, M. M. Kulkarni, J. Josiya and M. S. Joshi. (2021). “Studies on preparation of ice-cream from jackfruit (Artocarpus heterophyllus) seed powder,” *International Journal of Chemical Studies.* **9** (1): 2710–2712. 10.22271/chemi.2021.v9.i1al.11636.

K. R. Barge and S. P. Divekar. (2018). “Development of coconut milk residue and jackfruit seed enriched biscuit”. *International Journal of Agricultural Engineering.* **11** (2): 373–378. 10.15740/HAS/IJAE/11.2/373-378.

V. Tulyathan, K. Tananuwong, P. Songjinda, and N. Jaiboon. (2002). “Some physicochemical properties of jackfruit (Artocarpus heterophyllus Lam) seed flour and starch”. *ScienceAsia.* **28** (1): 37. 10.2306/scienceasia1513-1874.2002.28.037.

M. Haque, R. Begum, A. Shibly, M. Sultana, and A. Khatun. (2015). “Influence of jackfruit pulp on the quality and shelf life of jackfruit cake”. *Journal of Environmental Science and Natural Resources.* **8** (1): 59–64. 10.3329/jesnr.v8i1.24672.

R. Waghmare, N. Memon, Y. Gat, S. Gandhi, V. Kumar, and A. Panghal. (2019). “Jackfruit seed: an accompaniment to functional foods”. *Brazilian Journal of Food Technology.* **22**: 10.1590/1981-6723.20718.

S. B. Swami, N. J. Thakor, P. M. Haldankar, and S. B. Kalse. (2012). “Jackfruit and its many functional components as related to human health: a review”. *Comprehensive Reviews in Food Science and Food Safety.* **11** (6): 565–576. 10.1111/j.1541-4337.2012.00210.x.

U. B. Jagtap, S. N. Panaskar, and V. A. Bapat. (2010). “Evaluation of antioxidant capacity and phenol content in jackfruit (Artocarpus heterophyllus Lam.) fruit pulp”, *Plant Foods for Human Nutrition.* **65** (2): 99–104. 10.1007/s11130-010-0155-7.

A. Ghain Barua and B. R. Boruah. (2004). “Minerals and functional groups present in the jackfruit seed: a spectroscopic investigation”. *International Journal of Food Sciences and Nutrition.* **55** (6): 479–483. 10.1080/09637480400015810.

M. T. Hossain. (2014). “Development and quality evaluation of bread supplemented with jackfruit seed flour”. *International Journal of Nutrition and Food Sciences.* **3** (5): 484. 10.11648/j.ijnfs.20140305.28.

C. Goswami and R. Chacrabati. (2016). In “M. S. J. Simmonds and V. R. Preedy (Eds) Functional foods”. Elsevier. 10.1016/B978-0-12-408117-8.00014-3.

M. Hasan, M. Ahmed, and M. Miah. (2008). “Agro-economic performance of jackfruit-pineapple agroforestry system in madhupur tract”. *Journal of Agriculture & Rural Development.* **6** (1): 147–156. 10.3329/jard.v6i1.1672.

J. L. F. Alves, J. C. G. da Silva, G. D. Mumbach, M. D. Domenico, V. F. da Silva Filho, R. F. de Sena, R. A. F. Machado, and
C. Marangoni. (2020). “Insights into the bioenergy potential of jackfruit wastes considering their physicochemical properties, bioenergy indicators, combustion behaviors, and emission characteristics”. Renewable Energy. 155 : 1328–1338. 10.1016/j.renene.2020.04.025.

[37] S. Syaribaini, A. Warsona, and D. Iskandar. (2014). “Natural radioactivity in some food crops from Bangka-Belitung islands, Indonesia”. Atom Indonesia. 40 (1): 29. 10.17146/aij.2014.260.

[38] A. Mukprasirt and K. Sajjaanantakul. (2004). “Physico-chemical properties of flour and starch from jackfruit seeds (Artocarpus heterophyllus Lam.) compared with modified starches”. International Journal of Food Science and Technology. 39 (3): 271–276. 10.1111/j.1365-2621.2004.00781.x.

[39] I. A. Ajayi. (2011). In: “V. R. Preedy, R. R. Watson, and V. B. Patel (Eds) Nuts and Seeds in Health and Disease Prevention”. Elsevier. 10.1016/B978-0-12-375688-6.10079-9.

[40] T. Theivasanthi, G. Venkadamanickam, M. Palanivelu, and M. Alagar. (2011). “Nano sized powder of jackfruit seed: Spectroscopic and anti-microbial investigative approach”. Nano Biomedicine and Engineering. 3 (4). 10.5101/nbc.v3i4.p215-221.

[41] K. Soumya, A. Krishnamoorthy, P. Patil, and M. G. Venkatesha. (2015). “Evaluation of jackfruit germplasm against jack shoot and fruit borer, Diaphania caesalis (Wlk.) (Lepidoptera: Pyralidae)”. Pest Management In Horticultural Ecosystems. 21 (1): 8–10.

[42] A. Soeksmanto, Y. Hapsari, and P. Simanjuntak. (2007). “Antioxidant content of parts of Mahkota dewa, Phaleria macrocarpa [Scheff] Boerl. (Thymelaceae)”. Biodiversitas Journal of Biological Diversity. 8 (2). 10.13057/biodiv/d080203.

[43] M. S. Baliga, A. R. Shivashankara, R. Haniadka, J. Dsouza, and H. P. Bhat. (2011) “Phytochemistry, nutritional and pharmacological properties of Artocarpus heterophyllus Lam (jackfruit): A review”. Food Research International. 44 (7): 1800–1811. 10.1016/j.foodres.2011.02.035.

[44] A. Mandhare, P. Banerjee, A. Pande, and A. Gondkar. (2020). “Jackfruit (Artocarpus heterophyllus): a comprehensive patent review”. Current Nutrition & Food Science. 16 (5): 644–665. 10.2174/1573401315666190730120759.

[45] H. B. Long, Y. F. Sun, C. Bai, and D. L. Peng. (2015). “First report of the root-knot nematode meloidogyne enterolobii infecting jackfruit tree in china”. Plant Disease. 99 (12): 1868–1868. 10.1094/PDIS-04-15-0406-PDN.

[46] A. W. Septama and P. Panichayupakarnant. (2017). “Antibacterial activity of artocarpanone isolated from Artocarpus heterophyllus heartwoods against gastrointestinal parasites and its mechanism of action on membrane permeability”. Journal of Applied Pharmaceutical Science. 7 (11): 64–68. 10.7324/JAPS.2017.71109.

[47] T. M. Nguyen, D. Van Binh, and E. R. Ørskov. (2005). “Effect of foliage containing condensed tannins and on gastrointestinal parasites”. Animal Feed Science and Technology. 121 (2): 77–87. 10.1016/j.anifeedsci.2005.02.013.

[48] M. P. M. Haleel, K. Rashid, and C. S. Kumar. (2018). “Artocarpus heterophyllus: review study on potential activities”. Research Journal of Pharmacology and Pharmacodynamics. 10 (1): 24. 10.5958/2321-5836.2018.00005.8.

[49] D. P. Tramontin, S. E. Cadena-Carrara, A. Bella-Cruz, C. C. Bella Cruz, A. Bolzan, and M. B. Quadri. (2019). “Biological activity and chemical profile of Brazilian jackfruit seed extracts obtained by supercritical CO2 and low pressure techniques”. The Journal of Supercritical Fluids. 152 : 104551. 10.1016/j.supflu.2019.104551.

[50] S. L. Jagadeesh, B. S. Reddy, G. S. K. Swamy, K. Gorbal, L. Hegde, and G. S. V. Raghavan. (2007). “Chemical composition of jackfruit (Artocarpus heterophyllus Lam.) selections of Western Ghats of India”. Food Chemistry. 102 (1): 361–365. 10.1016/j.foodchem.2006.05.027.
[51] U. B. Jagtap and V. A. Bapat. (2010). “Artocarpus: A review of its traditional uses, phytochemistry and pharmacology”. *Journal of Ethnopharmacology*. 129 (2): 142–166. 10.1016/j.jep.2010.03.031.

[52] F. A. Chowdhury, M. Azizur Raman, and A. Jabbar Mian. (1997). “Distribution of free sugars and fatty acids in jackfruit (Artocarpus heterophyllus)”. *Food Chemistry*. 60 (1): 25–28. 10.1016/S0308-8146(96)00294-4.

[53] B. Setiawan, A. Sulaeman, D. W. Giraud, and J. A. Driskell. (2001). “Carotenoid content of selected indonesian fruits”. *Journal of Food Composition and Analysis*. 14 (2): 169–176. 10.1006/jfca.2000.0969.

[54] A. F. de Faria, V. V. de Rosso, and A. Z. Mercadante. (2009). “Carotenoid composition of jackfruit (Artocarpus heterophyllus), determined by HPLC-PDA-MS/MS”. *Plant Foods for Human Nutrition*. 64 (2): 108–115. 10.1007/s11130-009-0111-6.

[55] F. Noor. (2014). “Physicochemical properties of flour and extraction of starch from jackfruit seed”. *International Journal of Nutrition and Food Sciences*. 3 (4): 347. 10.11648/j.ijnfss.20140304.27.

[56] S. Butool and M. Butool. (2013). “Nutritional quality on value addition to jack fruit seed flour”. *International Journal of Science and Research*. 4 (4): 2406–2411.

[57] V. Suryadevara, S. R. Lankapalli, L. H. Danda, V. Pendovala, and V. Katta. (2017). “Studies on jackfruit seed starch as a novel natural superdisintegrant for the design and evaluation of irbesartan fast dissolving tablets”. *Integrative Medicine Research*. 6 (3): 280–291. 10.1016/j.imr.2017.04.001.

[58] A.U. Khan and A.U. Khan. (2020). In “Infested and Healthy plant and fruit of Jackfruit”. 10.1080/19476337.2017.1301554.

[59] Y. Zhang, X. Zhou, J. Zhong, L. Tan, and C. Liu. (2019). “Effect of pH on emulsification performance of a new functional protein from jackfruit seeds”. *Food Hydrocolloids*. 93: 325–334. 10.1016/j.foodhyd.2019.02.032.