A review on jackfruit and its by-products

Kunika Ahlawat

Abstract
The jackfruit, or Artocarpus heterophyllus Lam., is a tropical fruit from India's Western Ghats that is also widely grown in Asia, Africa, and some parts of South America. It is a member of the Moraceae family and is native to tropical climates. It is well known that it is the world's largest edible fruit. The jackfruit is full of vitamins, minerals, phytochemicals, carbs, proteins, and other nutrients. The jackfruit's meat and seeds are both eaten in curries and other cooked forms, but when the meat is fully ripe, it can be eaten like a fruit. Using pureed jackfruit, several nations have created a variety of food items including jams, jellies, marmalades, and ice creams. Due to the jack tree's anticarcinogenic, antibacterial, antifungal, anti-inflammatory, wound-healing, and hypoglycemic properties, several of its parts, including fruits, leaves, and bark, have been extensively used in traditional medicine. However, despite all these advantages, commercial scale processing of the fruit is not utilised in the developing regions. The goal of this review's conclusion is to spread awareness of the jackfruit's nutritional and health benefits in order to promote its use in commercial food production.

Keywords: Jackfruit, physical properties, jackfruit powder, seeds

Introduction
The tropical fruit known as the jackfruit (Artocarpus heterophyllus Lam) is a member of the Moraceae family. It is native to the Western Ghats of India and is widely cultivated in Asia, Africa, and some regions of South America. (Ranasinghe et al., 2019) [1]. About 25.71 t/ha of jackfruit are produced annually (Loizzo et al., 2010) [2]. Both the tree's main branch and its side branches bear fruit (Mushumbusi et al., 2015) [3]. Jackfruit constitute of 3 major components: pulp (30-32%), seeds (18%), and rind (5-55%). Golden-yellow pulp is arranged in fleshy bulbs that account for 30–35% of the fruit's weight and each include a single seed inside (Swami et al. 2014) [4]. In addition to its pulp, the jackfruit’s under-utilized sections like the seed and rind have been said to contain great nutritional qualities. Nutrients such as starch and dietary fiber are observed to be abundant in jackfruit seed and makeup to 22 & 3.19 percent of it. The major protein in jackfruit seed is jacalin which possesses immunological properties. Apart from that, jackfruit seed is said to be a rich source of lignins, isoflavones, saponins, all phytonutrients, and their health benefits are wide ranging from anti-cancer to antihypertensive, anti-aging, antioxidants, anti- ulcer and so on (Swami et al., 2012) [5]. Pectin is abundant in the slimy coating of jackfruit seeds, which has high antioxidant and phenolic characteristics (Kumar M et al., 2021) [6] its seed flour can result in culinary products with enhanced value (Kushwaha R et al., 2021) [7]. The strongest antioxidant ability is seen in jackfruit axis extract, which is more effective than vitamin C at preventing cytotoxicity brought on by alcohol. Through its phytonutrients, such as carotenoids, jackfruit demonstrates antioxidative action and protects tissues from oxidative damage (Ranasinghe et al., 2019) [1]. Perianth and seeds of jackfruit contains a high starch content, and the amount of dietary fiber and flesh varies with maturity, according to several chemical and histological investigations (Ranasinghe et al., 2019; Jagdale et al., 2021) [1, 8]. In addition to this, Jackfruit’s rind also possesses antioxidant properties. Jackfruit’s rind extracts are observed to contain more polyphenols and flavonoids compared to that of its spine and skin. Additionally, it was discovered that its rind had a higher polyphenol concentration than the fruit peels of pineapple, pomegranate, and orange. There are no changes in jackfruit fibre content according to the stage of ripeness; it ranges from 0.33 to 0.4% (Amadi et al., 2018) [9]. A study found that the fibre content of immature and ripe jackfruits was 2.6% and 0.8%, respectively. The importance that nutrition plays in the prevention and treatment of many illnesses has gained widespread acceptance, and consumers, food industry and researchers have all shown
an increased interest in recent years in how food products might assist sustain health. This review’s objective was to provide a summary of the jackfruit’s physiological, therapeutic, and functional characteristics.

Nutritional composition
The jackfruit is a rich source of several high-value compounds that could have beneficial physiological effects. It is known for having anti-inflammatory, anti-bacterial, anti-antidiabetic, and antioxidant effects. The jackfruit tree yields the largest oval shaped-cylindrical edible ellipsoid shape, measuring 1-2 cm in diameter and 2-3 cm long, with a thin, white cotyledon coating with a light brown exterior layer. The ripe fruit bulbs are consumed in huge quantities; the seeds, on the other hand, are used occasionally as dessert, as minor ingredients in recipes, or as a snack after boiling, steaming, or roasting. Seeds are typically left untreated or thrown away as trash because of their unappealing flavour and texture.

The rind of the jackfruit has antioxidant qualities as well. Jackfruit rind extracts contain more polyphenols and flavonoids than extracts from the fruit’s skin or spine. More polyphenols were also discovered in its skin compared to the fruit peels of orange, pomegranate, and pineapple. Amino acids present in jackfruit include cystine, arginine, leucine, histidine, lysine, threonine, methionine, and tryptophan (Khan et al., 2021; Haleel et al., 2018) [10]. According to the level of maturity, the amount of fibre in jackfruit remains constant and can vary from 0.33 to 0.4% (Amadi et al., 2018) [9].

According to a study, ripe and immature jackfruits had fibre contents of 2.6% and 0.8%, respectively. Consumers, researchers, and the food industry have all recently demonstrated an increased interest in how food products might assist in sustaining health as the role that nutrition plays a role in the prevention and treatment of many illnesses and gained widespread acceptance (Vinuda-Martos and others 2010) [12].

Jackfruit bulbs
Jackfruit is hefty and dense and about 20% to 25% of its edible portions, or bulbs are really recovered. The edible section of Jackfruit which ranges from 20% to 25% of the overall weight and mass, is easily digestible but is also hefty and thick. Around 13.7 mg of vitamin C and 95 calories, making it a good source of antioxidants.

The fruits are also aged source of potassium, calcium, iron, and vitamin B6. Ripe jackfruit bulb is used in FRUI salads and eaten raw. It has a high nutritional value, 100 g of ripe fruit pulp includes 84 calories, 20 mg of calcium, 30 mg of phosphorus, 500 mg of iron, 540 IU of vitamin A, 30 mg of thiamine, 1.9 g of protein, 0.1 g of fat, 77% moisture, 1.1 g of fibre, and 0.8 g of total mineral matter. The bulbs of the jackfruit contains beta-carotene which is necessary antioxidant for human health (Shedge et al., 2022) [13].

### Composition of jackfruit bulb; (100 g edible portion)

<table>
<thead>
<tr>
<th>Composition</th>
<th>Carbohydrates (g)</th>
<th>Protein (%)</th>
<th>Fat (g)</th>
<th>Fiber (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16.0-25.4</td>
<td>1.2-1.9</td>
<td>0.1-0.4</td>
<td>1.0-1.5</td>
</tr>
<tr>
<td></td>
<td>18.9</td>
<td>1.9g</td>
<td>0.1g</td>
<td>1.1g</td>
</tr>
<tr>
<td></td>
<td>7.74</td>
<td>10.6</td>
<td>1.49</td>
<td>3.01</td>
</tr>
<tr>
<td></td>
<td>9.4-11.5</td>
<td>2.0-2.6</td>
<td>0.1-0.6</td>
<td>2.6-3.6</td>
</tr>
</tbody>
</table>

(Sedge et al., 2022) [14], (Amadi et al., 2018) [9]

### Composition of jackfruit seed; (100 g of edible portion)

<table>
<thead>
<tr>
<th>Composition</th>
<th>Carbohydrates</th>
<th>Protein</th>
<th>Fat</th>
<th>Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25.8-38.4</td>
<td>6.6-7.04</td>
<td>0.40-0.43</td>
<td>1.0-1.5</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>7.89</td>
<td>10.09</td>
<td>4.29</td>
<td>3.92</td>
</tr>
<tr>
<td></td>
<td>38.4</td>
<td>606</td>
<td>0.4</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>30.84</td>
<td>11.83</td>
<td>0.49</td>
<td>0.94</td>
</tr>
</tbody>
</table>

(Gupta et al., 2011) [15], (Thatanasuwan et al., 2022) [16]

### Bioactive components and health benefits of jackfruit
Fruits can be eaten at all stages of growth as it can be baked, roasted, fried or steamed. The seed is also cooked and used for cooking. The bark and leaves are excellent cattle feed. The tree provides food, fodder, fuel wood, timber and 70% of timber, 90% of fuel wood and 48% sawn (Khan et al., 2020) [17].

The jackfruit has been used as traditional medicines. The plant has been used as anti-bacterial, anti-diabetic, antioxidant, anti-inflammatory (Hwang et al., 2017) [18]. It is

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[14] Sedge et al., 2022
[9] Amadi et al., 2018
[16] Thatanasuwan et al., 2022
[17] Khan et al., 2020
[18] Hwang et al., 2017
major source of carbohydrates, minerals and vitamins (Deivanai et al., 2010) [19]. The fruit contains lignins, flavones and saponins which have the properties of anti-aging (Gapasin et al., 2014) [20].

Bioactive components and health benefits of jackfruit

<table>
<thead>
<tr>
<th>Bioactive compounds</th>
<th>Health benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytonutrients- Lignans, isoflavones, niacin &amp; saponins</td>
<td>Cancer, Hypertensive, Ulcer, Aging, Nerve function, Asthma</td>
</tr>
<tr>
<td>Phenolic Compounds</td>
<td>Chronic diseases, hyperglycaemia</td>
</tr>
<tr>
<td>Carotenoid- All-trans- beta, alpha, lutein, neoxanthin, 9-cis- violaxanthin carotene</td>
<td>Inflammation, cardiovascular diseases, cataract, age-related macular degeneration</td>
</tr>
</tbody>
</table>

(Swami et al., 2018) [21]

Fig 1: Health benefits of jackfruit

**Anticancer**
Recent studies have demonstrated the anticancer benefits of all phytonutrients found in jackfruit bulbs. These nutrients’ primary function is to fend off dangerous free radicals, which have been linked to the development of cancer and numerous other serious disorders. The phytonutrients stop the creation of cancer cells from their very beginning. Additionally effective anticancer agents, saponins. A study found that saponins had the ability to prevent colon cancer. In the case of leukaemia cells, it has been discovered that these phytonutrients promote mitotic arrest. The study also discovered that it occasionally assisted in bringing about remission. According to Oktavia et al. (2017) [22], saponins have been observed to react with cancer cells’ outer coats. Isoflavones and lignans are two significant categories of phytoestrogens found in jackfruit pulp (Swami et al., 2012) [23]. These vitamins and minerals assist in lowering the risk of endometrial cancer. Fibre is abundant in jackfruit. Moreover, it has a distinct sticky form. These two qualities come together to make a powerful colon cleanser. It aids in cleansing your digestive system of impurities. Additionally, this lowers the risk of colon cancer.

**Dental Health**
When tested for antibacterial and antifungal capabilities, the jackfruit latex extracts, which are high in flavonoids and alkaloids, performed rather well and much better than typical antibacterial and antifungal medications. They came to the conclusion that this information reveals a number of significant uses of jackfruit latex or resin, or both, which can be used as a cementing medium, irrigation solution (washing a wound or cavity by a stream), denture cleaning solution, resin, and other potentially cost-effective dental filling material (Rao et al., 2014) [24].

**Improve Digestion**
High fibre content (3.6 g/100 g) found in jackfruit helps with smooth bowel movements and prevents constipation. By eliminating or driving away the carcinogenic, these fibres also provide protection for the colon mucosal membrane (Shedge et al., 2022) [13].

**Antidiabetics**
Hyperglycemia, a metabolic condition caused by abnormalities in insulin action, secretion, or both, characterises diabetes mellitus. Kind 2 diabetes mellitus is the most prevalent kind of the condition, accounting for 85–95% of all cases and posing a serious public health issue (Cheplick et al., 2010) [25].

**Fast-Dissolving Tablet**
The main carbohydrate that plants use for storage is starch. Worldwide, more than 66.5 million tonnes of starch are produced each year. The starch and protein content of the cotyledons of the jackfruit seed is average. The starches derived from jackfruit seeds are utilised as super disintegrates when creating fast dissolving tablets, or FDT. According to the Food and Drug Administration (FDA), FDT formulations are “a solid dosage form from containing medical substance which disintegrates rapidly, typically within a second, when place upon tounge.” Jackfruit can be viewed as a functional fruit since it has useful chemicals with functional and

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therapeutic benefits in many regions of the fruit (Shedge et al., 2022) [13].

**Product developments**

**Ripe jackfruit products**
The by-products of jackfruit have a broad range of possible applications in the food industry. They are used in foods like bread, biscuits, cakes, cookies, and ice creams to boost the nutritional value of the items. Additionally, the by-products of jackfruit are used to extract useful molecules. Babu (2017) [26] discovered that the oil of jackfruit seeds was rich in linoleic and alpha-linolenic acids, two important fatty acids. Jackfruit seed flour has a lot of protein, per studies on its nutritional properties (Abedin et al., 2012) [27]. Starch of jackfruit seed contains a higher proportion of amylose, it could be used in place of modified starch. Jackfruit seeds have a high concentration of saponins and phytochemicals. Jackfruit seeds can be used as a medicine and pharmaceutical plant-based product since they have a high flavonoid concentration and reduction potential (Shanmugapriya et al., 2011) [28]. The sensory panel approved of dinner wine made from jackfruit byproducts including seed coat, pith, rags, peel and overripe pulp. After only two weeks of unrest, there is a good chance that wine-related accessories will arrive. Low-glycemic diets are frequently advised to the general populace and provide therapeutic benefits for diabetic individuals. Using jackfruit seeds in place of cocoa powder to create a low-glycaemic-index diet chocolate and get the positive outcomes. Meat alternative that is healthful using jackfruit by-products. Seed powder, cloths, and rinses were used. The produced meat analogue's nutritional makeup revealed high levels of protein and dietary fibre. According to research on the textural characteristics of meat analogues, chewiness and hardness significantly decreased as wheat gluten level was reduced (Hamid et al., 2020) [29]. Babu (2017) [26] conducted study on the traditional milling method of extracting oil from jackfruit seeds. It took about 6kg of the seeds to produce 2L of oil. He claimed that linoleic acid and alpha-linolenic acid, two essential fatty acids, were abundant in the oil of jackfruit seeds. They calculated the oil from jackfruit seeds to have 1.35g/100g free fatty acids.

![Image of product development](https://www.thepharmajournal.com)

**Preparation of products using jackfruit seeds and pulp:**

**Bakery product**
In order to effectively distribute powerful ingredients with health advantages to people, bakery products are a good option. Recent research has shown that a variety of bakery goods, including biscuits, cookies, cakes, and muffins, have been created by adding jackfruit seed flour at varying quantities (Islam et al., 2015; Arpit & John, 2015; Siti Faridah & Noor Aziah, 2012) [30, 31, 32].

![Image of bakery products](https://www.thepharmajournal.com)

**Table 1: Baked products prepared by Jackfruit seed fortification in different forms and at different concentrations**

<table>
<thead>
<tr>
<th>Product</th>
<th>Amount of Supplementation (%)</th>
<th>Outcome</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread</td>
<td>25</td>
<td>Increased crude fiber content</td>
<td>Butool &amp; Butool (2015) [13]</td>
</tr>
<tr>
<td>Bread</td>
<td>25</td>
<td>Nutritional higher carbohydrate, fat, protein, and crude fiber content</td>
<td>Hossain (2014) [14]</td>
</tr>
<tr>
<td>Biscuit</td>
<td>20</td>
<td>Swelling power, percent solubility, flour dispersibility and viscosity</td>
<td>Butool &amp; Butool (2015) [33]</td>
</tr>
<tr>
<td>Biscuit</td>
<td>10-40</td>
<td>Moisture, fat, crude fiber and ash content increased</td>
<td>Islam et al., (2015) [30]</td>
</tr>
<tr>
<td>Cake</td>
<td>5-15</td>
<td>Increase in protein and reduction in fat content</td>
<td>Arpit &amp; John (2015) [31]</td>
</tr>
<tr>
<td>Cake</td>
<td>10-30</td>
<td>Better crumb, texture and nutritional characteristics</td>
<td>Khan et al., (2016)</td>
</tr>
<tr>
<td>Muffins</td>
<td>10-20</td>
<td>Specific gravity increased and viscosity decreased</td>
<td>Siti Faridah &amp; Noor Aziah (2012) [32]</td>
</tr>
</tbody>
</table>
Bread and biscuits
The availability of jackfruit seed flour and its considerable nutritional and practical value have caught the interest of scientists and bakeries. In order to make bread and biscuits, Butool and Butool (2015) [133] successfully added flour made from jackfruit seeds. The colour and texture of bread and biscuit formulations with 10% and 20% jackfruit seed flour added an outstanding eating quality. The products’ crude fiber content was boosted by the addition of jackfruit seed flour. Biscuits made with jackfruit seed flour had slightly higher ash and crude fiber levels but lower carbohydrate levels. Hossain et al. (2014) [34] experimented with different ratios of jackfruit seed flour to wheat flour to determine the ideal mixture for making bread. The breads contained 25%, 35%, 45%, and 55% of jackfruit seed flour, respectively. According to their findings, the bread that included 25% jackfruit seed flour as a replacement was the most palatable in terms of its nutritional content and general appeal.

Cake
Khan et al. (2016) made cake by replacing 10%, 20%, and 30% of the wheat flour with jackfruit seed flour. In comparison to the other cakes, the specific volume of the cake for the 20% substitution was larger. However, the cake with a 10% addition of jackfruit seeds to the flour was the most well-liked by the panel. Because jackfruit seed flour was used, the crust and crumb qualities differed (Faridah and Aziah, 2012; Arpit and John, 2015) [132, 31]. The jackfruit seed also gave rise to other pastry goods, including biscuits, muffins, masala vada, flour, and chapathi. Pectin, which was taken out of the rind, is another excellent source (Swami et al., 2012) [35]. The jackfruit seed also gave rise to other pastry goods, including biscuits, muffins, masala vada, flour, and chapathi. According to Santos et al. (2011) [36], cereal bars made with 30% and 40% jackfruit seed meal exhibited high fibre contents, better sensory qualities, and nutritional values that were comparable to those of other bars available for purchase.

<table>
<thead>
<tr>
<th>Product</th>
<th>Amount of supplementation</th>
<th>Outcome</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal bar</td>
<td>30 &amp; 40</td>
<td>high fiber content, better sensorial characteristic</td>
<td>Santos et al., 2011 [36]</td>
</tr>
<tr>
<td>Cereal bar</td>
<td>15</td>
<td>Preserved hardness and crispness</td>
<td>Torres et al., 2011</td>
</tr>
<tr>
<td>Snack bar</td>
<td>35-45</td>
<td>increased protein content</td>
<td>Meethal et al., 2017</td>
</tr>
</tbody>
</table>

(Physically modified from Waghmare et al., 2019) [37]

Ready to eat products
Jackfruit Jam
Jam can be made using the pulp from the fruit. A synthetic flavouring ingredient, such as ethyl or n-butyl ester of 4-hydroxybutyric acid at 100 and 120 ppm, will greatly enhance the flavour of jackfruit products (Technical Manual for Small-Scale Fruit Processors, 2004).
The risk of developing diabetes is raised by the large amount of sugar that is added to many other fruit jams sold in shops. Instead, jackfruit jam is a great food source for losing weight because it is high in natural sugars and low in calories (Swami et al., 2012) [35].

Instant powder
Hema (2015) [38] explored how jackfruit seeds and bulbs may be combined to create a nutrient-rich quick dried powder. According to the study, adding more jackfruit seed powder to the mix made the instant powder’s protein content higher and its moisture content lower.

Jackfruit Candy
The jackfruit was split in two along its length. The pulp of the fruit was removed after the core was cut out. The pulp was separated from the seeds. A brine solution comprising 15% sodium chloride (150g/L) and 1% calcium chloride (10g/L) was used to soak the pulp for two days. In order to eliminate the salt, the pulp was taken out of the brine, drained, and then washed with water. It was stored at room temperature (28.30C) for 24 hours after being boiled in 140 brix sugar syrup for 5 minutes. The pulp was taken out of the syrup and dried in a tray dryer for roughly a day (24 hours). Cardboard cartons were used to package the Jackfruit candies.

Jackfruit leather
The leather is made from dried jackfruit pulp sheets. It tastes sweet and has a soft, rubbery feel. It can also be produced from a combination of fruits, and the flavour can be altered by adding sugar, chopped nuts, or spices. In place of a boiled sweet, it can be consumed as a snack item. Additionally, it can be used as a component in the creation of desserts like cakes and ice cream (International Centre for Underutilized Crops, UK, 2004).

Preparation of Jackfruit Beverage / Drink
Wine
The riped jackfruit has a sizable amount of fermented sugar that can be used to make vinegar and wine for sale. Jack wine had a maximum alcohol percentage of 10% (v/v) and utilised 14% of the total sugar solids. These first findings indicate that this fruit has potential for application in the creation of commercial wines. For jackfruit to be used in the creation of jackfruit wine, it must be at a specific stage of maturity and ripeness (29 to 30 Brix).
The jackfruit wine may offer protection from antioxidant and DNA damage and may prove to be a valuable source of nutraceuticals with a high concentration of antioxidants. Additionally, the wine can be a useful by-product for the jackfruit growers from a business perspective.

Conclusion
A great source of vitamins, minerals, dietary fibre, phytochemicals, proteins, and other nutrients is tropical trees
like the jackfruit. Jackfruit has a wide range of health advantages, including, antibacterial, antifungal, anti-inflammatory, and hypoglycemic characteristics. It is believed that this fruit is underutilised on a commercial scale, primarily due to the fruit's high proportion of edible parts, which leads to waste generation, difficulty peeling and separating the edible bulb from the rind, ignorance of proper postharvest procedures, and a lack of processing facilities in the regions where they are grown. Therefore, according to proper postharvest practise and turning jackfruit into minimally processed products, like precut jackfruit, might get more people to eat jackfruit and may aid in waste management.

Only a small number of recent studies have focused on expanding the shelf life of jackfruit and generating value from waste by converting it into other products and renewable energy sources. In order to determine possible industrial applications for jackfruit and to figure out how to handle the trash generated during jackfruit processing, more research is needed.

References
24. Rao J, Kalpana S, Shweta S, Kumar MS, Manish B. Artocarpus heterophyllus (Jackfruit) potential


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