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Potential of jackfruit seed as a functional ingredient: A Review

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Abstract

The tropical fruit known as jackfruit (*Artocarpus heterophyllus*) is cultivated extensively, yet its seeds are often discarded as garbage. Nonetheless, these seeds have an array of nutritional and practical potential as they are high in fibre, proteins, carbohydrates, vitamins, and minerals. In this review, the underutilised jackfruit seed is examined with a focus on its nutritional makeup, bioactive components such as phenolics, flavonoids, terpenoids, steroids, glycosides, saponins, alkaloids, and tannins and numerous applications in the food and pharmaceutical sectors. The potential of jackfruit seeds as a natural source of nutraceuticals is highlighted by the presence of polyphenols, flavonoids, tannins, and other bioactive compounds. The present review aimed to provide an overview of health benefits of jackfruit seed, various processing techniques and their value added food products.

Keywords: Jackfruit seeds, bioactive compounds, functional, pharmaceutical, antioxidant, value-added

1. Introduction

Jackfruit, scientifically known as *Artocarpus heterophyllus*, is the largest fruit-bearing tree in the world and a member of the Moraceae family ^[1]. It is commonly found in tropical and subtropical countries such as Bangladesh, Indonesia, Malaysia, Sri Lanka, and Thailand ^[2]. Particularly in eastern and southern parts of India, the fruit is often referred to as the "poor man's fruit" ^[3]. Since it is a highly heterozygous and cross-pollinated crop, it exhibits an abundance of diversity in the population's production, fruit size, shape, quality, and maturity period. The taxonomical classification is given in Table 1. India is regarded as the jackfruit's motherland and is the world's second-largest producer ^[4]. The jackfruit is indigenous to parts of South and Southeast Asia and is believed to have originated in the rain forests of India's Western Ghats. It is cultivated throughout the lowlands of South and Southeast Asia ^[5]. The fruit is commonly referred to as "kata-hai" or "kathal" in Bengali and Hindi ^[6]. Around 35% of the jackfruit is considered edible, while the other 60% comprised of inedible components such as the prickly rind, fibres, latex, and seeds. The light brown hue and oval, oblong, ellipsoid, or circular form of these seeds set them apart ^[7]. Despite its immense potential and use, jackfruit is still an underutilised fruit, and it merits the essential push for research and development ^[8]. The fruit is categorised into three main groups, the persisting perianth, the fruit axis, and the true fruit. The axis and core of the fruit are inedible as they possess laticiferous cells that create latex, which seals the fruits together. The perianth consists of three parts, bulb and lowest mushy edible section, middle-fused part that forms the rind of the syncarp and the horny, inedible part known as the spikes ^[9]. The jackfruit varies in length from 22 to 90 cm and weigh between 2 and 36 kg ^[10]. The flesh can be consumed raw or processed. Typically, each fruit comprises between.

100 and 500 seeds ^[11] which account for approximately 8 to 15% of the fruit's overall weight. These seeds are recalcitrant and can be stored in cold, humid surroundings for up to a month. The thin, waxy, parchment-like testa (husk) and the brownish, membrane-like tegmen together form the seed coat. The endosperm is seldom noticeable, and the cotyledons are usually uneven in size. A typical fruit has 10% core, 20% white pulp (undeveloped perianth, rags, and bark), 15% edible seeds, and 27% edible seed coat ^[12]. Seeds are also an excellent source of vitamins, minerals, dietary fibre, and protein.

They can be consumed after simmering, roasting, or kept in syrup ^[13]. Jackfruit is also known as "*giant nutrition*" ^[11]. It is an energy-rich fruit and a powerful antioxidant, anti-inflammatory, antihypertensive, antibacterial, antifungal, anticariogenic, antineoplastic, cicatrizant, and hypoglycemic fruit because it is rich in phytochemicals including flavonoids, stilbenoids, morin, artocarpin, dihydromorin, cynomacurin, isoartocarpin, cyloartocarpin, artocarpesin, artocarpetin, artocarpinone, oxydihydroartocarpesin, norartocarpetin, and cycloartinone ^[14]. Major phytochemical components of jackfruit include carotenoids; prenylflavones and sterol ^[15]. All-trans lutein, all-trans- β -carotene, all-trans-neoxanthin, 9-cis-neoxanthin, and 9-cis-violaxanthin were identified as the primary carotenoids in jackfruit. Age-related macular degeneration, cancer, inflammation, cardiovascular disease, cataracts, and other chronic degenerative disorders can potentially be prevented by the carotenoids in jackfruit ^[9].

Table 1: Taxonomical classification of *Artocarpus heterophyllus* ^[16]

Kingdom	Plantae
Sub-kingdom	<i>Tracheobionta</i>
Super-division	<i>Spermatophyta</i>
Division	<i>Magnoliophyta</i>
Class	<i>Magnoliopsida</i>
Sub-class	<i>Asteridae</i>
Order	<i>Solanales</i>
Family	<i>Convolvulaceae</i>
Genus	<i>Convolvulus</i>
Species	<i>Pluricaulis</i>



Fig 1: Depicting Jackfruit and its parts

2. Jackfruit Seed

The jackfruit seeds are around 10-15% of the total fruit weight ^[17] and are part of non-leguminous plant having high carbohydrate and protein contents ^[10]. These seeds are spherical, light brown, approximately 2-3 cm in length and 1-1.5 cm width. A thin, white membrane envelops them. Despite being edible, they are difficult for humans to digest ^[16]. A single seed is surrounded by a slender brown spermoderm and a white aril that covers the fleshy white cotyledon ^[18]. Despite being consumed and utilised, seeds are usually thrown away, wasted, or destroyed due to their high moisture content. Regardless of being underutilised and undervalued by the general population, jackfruit seeds have substantial nutritional benefits and may be employed as a functional food ingredient ^[19]. It is also a good source of carbohydrate (22%) and dietary fibre (3.19%) and therefore maintain a healthy digestive system ^[10]. Jackfruit seeds also consist of phytonutrients such as isoflavones, and saponins that have numerous health benefits, including anticancer, antihypertensive, antiaging, antioxidant, and antiulcer qualities ^[22]. Jackfruit seeds possess a primary protein called jacalin, which has immunological capabilities ^[13]. The seeds have potential for value addition and nutraceutical advancements and can be consumed as a valuable source of antioxidant, antibacterial, mineral, and nutritional components ^[18]. It also contains various vital minerals: magnesium, potassium, phosphorus, calcium, sodium, iron, copper, zinc, and manganese are found in jackfruit seeds ^[23]. Additionally, jackfruit seeds contain resistant starch, which improves intestinal health and blood sugar regulation. Rich in two B vitamins, thiamine and riboflavin, it helps convert food into energy and maintains healthy skin, eyes, and hair ^[5]. The starch from jackfruit seeds offers assured use in the pharmaceutical sector. Jackfruit seed starch is utilised as a superdisintegrant in the production of fast-dissolving tablets (FDT). Additionally, starch has the ability to thicken, gel, and create films ^[24]. These attributes make them suitable for utilization as a functional remedy and a plant-derived ingredient in pharmaceutical applications ^[25].

2.1 Bioactive compounds in jackfruit seed

A bioactive compound is a compound having some biological activity. A bioactive substance has its direct physiological or cellular effects on a living organism ^[24]. Jackfruit seeds have shown to have potential as alternative treatments against malignant cells and regulate calorie intake while lowering pro-inflammatory states, oxidative stress, and metabolic diseases because they contain bioactive chemicals that have significant pharmacological capabilities as anti-tumour agents with potential therapeutic benefits ^[26]. Various bioactive compounds such as polyphenols, tannins, flavonoids, ferulic acid, gallic acid are found in jackfruit seeds ^[27]. These substances are vital for potential health benefit, including anti-inflammatory and antioxidant, antimicrobial qualities shown in Figure 2. Four phenolic acids (Gallic, tannic, caffeic and ferulic acids) were detected in raw fruit seeds where gallic acid was maximum followed by tannic, caffeic and ferulic acids. However, in ripe fruit seeds there was only three phenolic acids (gallic, ferulic and tannic acids) in which gallic acid was maximum followed by ferulic and tannic acid. Depicted in Table 2. Tannins are polyphenolic compounds with antioxidant and antimicrobial properties and anti-inflammatory properties. They have been studied for their potential role in preventing

and treating various diseases, including cancer and cardiovascular disorders. The bioactive compounds in jackfruit seeds, such as polyphenols, flavonoids, gallic acid,

and ferulic acid, are present in relatively higher concentrations compared to the other sample data.

Table 2: Bioactive components present in jackfruit seeds

Bioactive Compounds	Jackfruit seeds				
Polyphenols (mg GAE/100g)	243	-	-	-	-
Tannic Acid	0.06-0.229 mg/100g	-	6.59 µg/g	2.1 µg/g	-
Flavonoids	2.03 mg EC/100g	0.47±0.02 mg CE/ml	-	-	-
Gallic Acid	11.10 mg/100 mg	-	11.3 µg/g	11.3 µg/g	0.082-1.841 mg/ml
Ferulic Acid	0.216 mg/100g	-	2.38 µg/g	2.71 µg/g	0.041-0.068 mg/ml
Caffeic acid	-	-	2.84 µg/g	-	-
References	Kumoro <i>et al.</i> [27]	Shanooba <i>et al.</i> [28]	Singh <i>et al.</i> [29] (Raw seeds)	Singh <i>et al.</i> [29] (Ripe seeds)	Ravshanbek <i>et al.</i> [30]

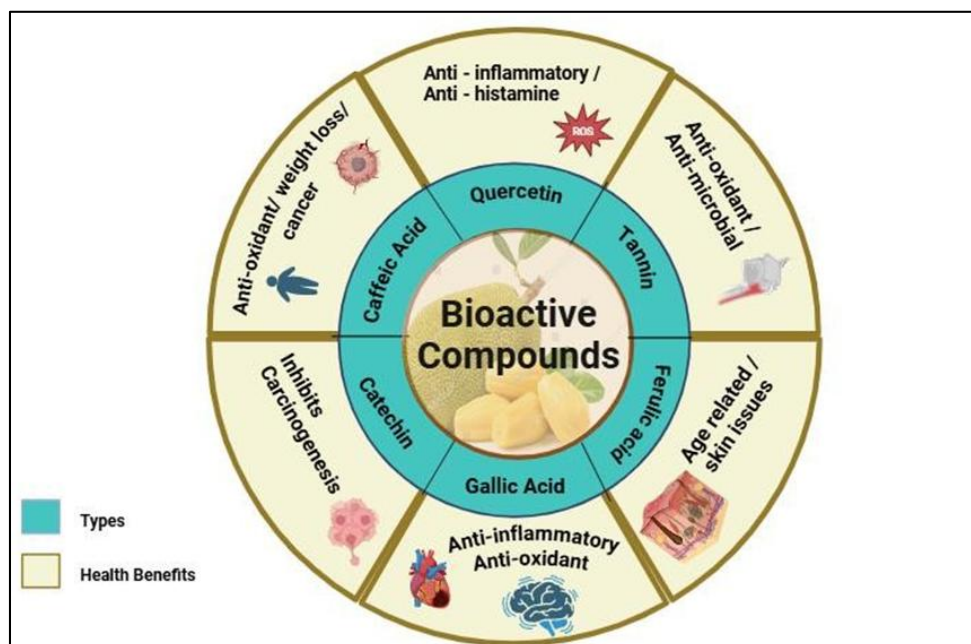


Fig 2: Different Bioactive compounds present in jackfruit seed and its health benefits

2.2 Nutritional composition of jackfruit seed

The nutritional composition of the jackfruit seed is shown in Table 3. Carbohydrate, protein, fat, crude fiber, ash and moisture contents were recorded in per 100 g of dry material samples. Raw jackfruit seeds are substantial source of both protein and carbohydrate, making them an excellent supplement to the diet. Jackfruit seeds contain the most carbohydrates and moisture and crude protein content indicating it as a potential source of protein enriched food

[31]. Out of the various studies carbohydrate content values was reported high as 78.65 % [8]. The range of protein levels, indicate a higher degree of protein availability. The seeds' usefulness for low-fat dietary formulations is highlighted by their comparatively low fat content, which help prevent weight gain in people. The distinct variations in the nutritional profile is due to different storage conditions, seed variety and seed maturity.

Table 3: Nutritional composition of jackfruit seed

Nutrient Composition	[31]	[32]	[35]	[24]	[36]	[12]	[8]	[37]	[38]	[23]
Carbohydrate	30.84±0.2%	7.9%	25.8-38.4%	-	26.2%	25.80-38.4 g	25.8-38.4 g	25.8 g	38.4 g	-
Protein	11.83±0.06%	10.1%	0.4%	-	11.85%	0.40-0.43 g	6.6-7.04 g	6.6 g	6.6 g	-
Fat	0.49±0.02%	4.3%	0.4%	-	1.006%	0.40-0.43 g	0.4-0.43 g	0.4 g	0.4 g	-
Crude Fiber	0.94±0.03%	3.9%	1.0-1.5%	-	-	-	1.0-1.5 g	1.5 g	1.5 g	-
Ash	3.16±0.15%	0.9%	-	-	0.15%	-	-	-	1.25-1.5 g	-
Moisture	52.74±0.24%	71.9%	51.0-64.5%	-	61.8%	-	-	64.5 g	51.6-57.7 g	-
Calcium (mg/100g)	-	40.0	-	50.0	29.5	50.0	-	50	-	50.0
Potassium (mg)	-	220.0	-	246	786.6	246	-	246	-	246
Manganese (mg)	-	9.50±0.71	-	-	-	-	-	-	-	-
Iron (mg)	-	18.25±0.35	-	1.5	-	1.50	-	1.5	0.002-1.2	1.5
Zinc (mg)	-	9.28±0.11	-	-	2.3	-	-	-	-	-
Vitamin C (mg)	-	0.11±0.0	-	11.0	-	11.0	-	-	-	11.0
Magnesium (mg)	-	-	-	-	-	54.0	-	54	-	54.0
Phosphorus (mg)	-	-	-	-	-	-	-	-	0.13-0.23 / 38-97	-
Sodium	-	-	-	-	-	-	-	-	-	63.2

Additional evidence of the nutritional benefits of jackfruit seeds comes from mineral analysis. Jackfruit seed contains variety of minerals such as calcium, potassium, manganese, iron, zinc, phosphorous and vitamin C providing antioxidant benefits.

3. Jackfruit seed flour

Jackfruit seed flour is a substitute for wheat that can be used to make bread, buttered cookies, cakes, vada, chapattis, noodles, and more [39]. Since fresh seeds cannot be stored for an extended period of time, seed flour is a substitute that can

be utilised in various dishes [24]. Jackfruit seed's bulk density, swelling power, and ability to absorb water and oil are all strong practical attributes and has high bulk density and water absorption capability, making it optimal for use as thickening and binding agent in baking industry. Therefore, it enhance the flavour, digestibility, and nutritional value of food [40]. The flour is relatively low in fat and high in proteins, carbs, and minerals (sodium, potassium, magnesium, and zinc). As a result, the seed flour is a valuable component in functional foods and poses no health risks when consumed [19].

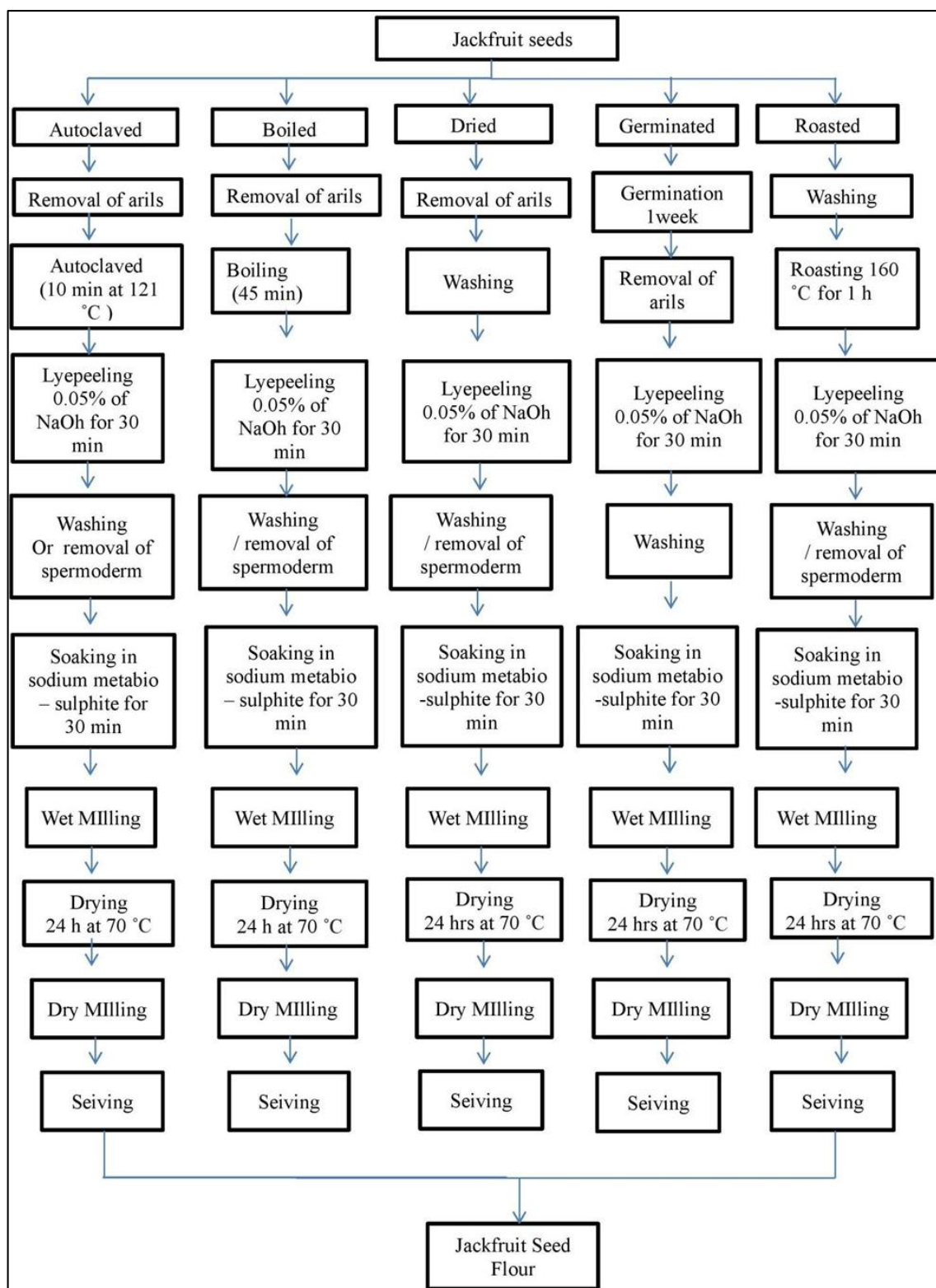


Fig 3: Different Processing techniques for processing of jackfruit seed flour [41]

3.1 Processing of jackfruit seed flour

These seeds can be processed to yield flour and other storage-friendly intermediate products. Various distinct processing techniques are used to produce jackfruit seed flour which includes autoclaving, boiling, drying, germination, and roasting is depicted in Fig 3. Though the methods in each approach are different but they all result in the same end product, which is jackfruit seed flour. These procedures improve the product's appearance, nutritional content, digestibility, antioxidant capacity, and storage qualities [13]. In autoclave method, the seeds are first separated from the plumules and then autoclaved for 10 minutes at 121°C followed by lye with 0.05% NaOH for 30 minutes. The seeds undergo wet milling after being thoroughly cleaned and soaked in 0.05% sodium metabisulfite for 30 minutes. The final flour is obtained by sieving and dry milling after a 24-hour drying process at 70°C. Boiling method is comparable to the autoclaved procedure, except that seeds are boiled for forty-five minutes before being processed further. In dried method, NaOH treatment is used to wash and peel the seeds. The final flour is produced via dry milling, sifting, and drying. The Germinated method involves a week long germination period after which the arils are entirely removed. The procedure is finished by lye peeling, washing, soaking in sodium metabisulphite, wet milling, drying, dry milling, and sieving. Roasting method include roasting of seeds at 160°C for 1 hr. The successive steps: peeling, washing, soaking, milling, drying, and sifting-remain identical with other

methods. In the end, all techniques result in the creation of jackfruit seed flour, nutritious and wholesome product [41]. Jackfruit seed flour made by roasting has a higher nutritional value because its moisture content is reduced. Applications for the seed flour have been discovered in bakery goods such as bread, cookies, and cakes, extruded goods such as snacks, noodles, and breakfast cereals, and infant food [4].

4. Value-added products prepared by incorporating jackfruit seed flour

The approach of modifying a food product to raise its inherent value is known as value addition. Breakfast cereals, jams, ice creams, juices, yoghurts, cheeses, pickles, concentrates, sauces, ketchup, extruded snacks, etc. are a few examples of items with added value [24, 42]. Due to its significant availability throughout the year, jackfruit trees typically yield an abundance of fruits around the fruiting season, and although many fruits and seeds are lost on a huge scale, people use jackfruit in a variety of ways and developed into products of added value [15]. Traditional products, extruded products, and baked goods were among the foods made with jackfruit seed flour. Addition of jackfruit seed flour at optimum concentration helped improve the physicochemical, textural, colour, and sensory attributes of a variety of products [42]. Studies on various product kinds and added benefits brought about by the inclusion of jackfruit flour are listed in Table 4.

Table 4: Value added products of Jackfruit seed flour

Product	Percentage of JSF	Outcome	References
Bread	25	Bread fortified with 25% jackfruit seed flour had a good overall acceptability and was more nutritious than whole wheat bread due to its higher concentrations of carbohydrates, lipids, protein, and crude fibre.	[39]
Chocolate Cake	10	Incorporation of 10% jackfruit seed flour resulted in an increase in protein and a decrease in fat content.	[43]
Composite Cake	10, 20, 30	The 10% cake sample exhibits the most acceptable colour, while samples with 10% and 20% fortification are the most acceptable in terms of flavour, texture, crumb characteristics, and enhanced nutritional properties.	[44]
Cookies	0-50	A nutritionally enhanced product with minimal anti-nutritional components is produced when 12.5% jackfruit seed flour is concentrated without negatively affecting sensory qualities.	[45]
Noodles	0-20	Incorporation of 5% jackfruit seed flour in composite flour (soy flour and refined wheat flour) results in higher sensory attributes and increased nutritional value.	[46]
Waffle Ice Cream	0-80	It was determined that the cone supplemented with 60% JSF had greater levels of crispiness and overall acceptance.	[47]
Crackers	0-50	The best hardness and crispness are achieved in crackers made with a 70% wheat and 30% jackfruit seed flour blend.	[48]

5. Conclusion

Jackfruit seeds, generally discarded as waste contain tremendous untapped potential as a great dietary and functional element. Using various processing techniques, jackfruit seed flour provides a flexible, gluten-free substitute for wheat flour, making it a great choice for the increasing demand for gluten-free diets and functional foods and a nutritious substitute for people with celiac disease. Additionally, jackfruit seed flour has proven to be an invaluable ingredient in the production of products with added value, including bread, cakes, cookies, noodles, and snacks. It is highly nutritious and consists of various health benefits such as anticarcinogenic, antimicrobial, anti-inflammatory, hypoglycemic, antioxidant and antiageing effects. Therefore further study is needed to fully understand

its potential in the food and pharmaceutical sectors. In order to establish jackfruit seeds as a sustainable, health-promoting component of a variety of industries, future research should concentrate on improving bioactive compound extraction, streamlining processing techniques, and investigating potential applications.

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