



## A Comprehensive Review of the Nutritional Composition, Bioactive Phytochemicals, and Therapeutic Potential of Jackfruit Seeds (*Artocarpus heterophyllus* Lam.): Implications for Functional Foods and Waste Valorization

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### ABSTRACT

Jackfruit (*Artocarpus heterophyllus* Lam.) is widely cultivated in tropical regions, however, its seeds, which constitute up to 15% of the fruit's total mass, are often discarded as waste. Despite this, jackfruit seeds are rich in macronutrients such as carbohydrates and proteins, essential minerals including potassium and magnesium, and a wide range of bioactive phytochemicals such as flavonoids, tannins, saponins, and lectins. This review consolidates current knowledge on the nutritional composition, phytochemical profile, therapeutic properties, and industrial applications of jackfruit seeds. Drawing on evidence from in vitro, in vivo, and in silico studies, the review highlights their antioxidant, antidiabetic, antimicrobial, anti-inflammatory, and prebiotic activities. Special emphasis is placed on their role in sustainable food systems through waste valorization and circular bioeconomy strategies. Although jackfruit seeds show significant promise as functional food ingredients and nutraceuticals, challenges related to bioavailability, standardization, safety, and industrial scalability remain. Further research is required to fully harness their nutritional, therapeutic, and commercial potential.

### INTRODUCTION

Jackfruit is the largest tree-borne tropical fruit (*Artocarpus heterophyllus* Lam.), a native species that grew in India before spreading to other parts of the world. It is now grown in many areas of Asia, Africa, and South America where it is used for food, fuel, timber, fodder, and medicine. In the Pacific Islands, this plant has many names, such as jack, jack tree, and jackfruit. (Dhani *et al.*, 2025) The Government of India's Department of Agriculture and Farmers' Welfare estimates the area under jackfruit cultivation in India to be 185,479.86 hectares and jackfruit production to be 3,198,848.003 Metric tons for 2024. In mature jackfruit trees, growth rates are higher during the first year (1.5 meters per year), tapering off after that (approximately 0.5 meters per year). The seeds of jackfruit are oval to ellipsoid

or round, and are considered waste; however, they can grow between 2 and 4 cm long and between 1.5 and 2.5 cm thick, as seen in Figure 1.

The majority of people utilize the sweet and aromatic pulp of the jackfruit for its value, but the seeds account for about 10% to 15% of the mass of the fruit. Most commonly, during processing, jackfruit seeds are discarded (Karelia, 2019). However, the seeds that people discard are an excellent, nutrient-rich, and bioactive compound-rich source of nutrition and health applications (Akter & Haque, 2018). Recent studies have shown that jackfruit seeds are rich in several essential minerals including calcium, potassium, magnesium and multiple macronutrients including proteins, lipids and carbohydrates (Amadi *et al.*, 2018). In addition, jackfruit seeds contain many

phytochemicals, including lectins, flavonoids, tannins and saponins. Laboratory and animal studies have shown that these phytochemical compounds provide anti-diabetic, anti-bacterial, anti-oxidant and anti-inflammatory effects (Dwitiyanti *et al.* 2019; Ray *et al.*, 2021; Fernandes *et al.*, 2017). As such, jackfruit seeds represent a significant opportunity for use as therapeutic agents and have the potential to be processed into edible or pharmaceutical products and/or nutraceutical formulations (Bantilan, 2018; Rahman *et al.*, 1999). Despite the fact that jackfruit seeds have many uses that are yet to be fully investigated, most of the time, jackfruit seeds are under-utilized due to a lack of standardized research regarding their microbiological safety and shelf life as well as their

functional properties (Hossain, 2014; Akter & Haque, 2018). Moreover, very few efforts have been made to bring together existing studies on their industrial applications within sustainable development frameworks such as waste valorization and strengthening food security (Ranasinghe *et al.*, 2019; Jagtap & Bapat, 2010).

In this review, we aim to bridge that gap by offering a comprehensive exploration of jackfruit seeds' nutritional composition, medicinal potential, microbiological stability, and industrial applications. By drawing together insights from the latest studies (Choudhury *et al.*, 2025; Kamal *et al.*, 2024), we highlight how circular bioeconomy approaches in agro-based sectors can promote sustainable practices and bolster public health.



Figure 1: Morphological structure of jackfruit showing whole fruit, cut section, bulbs and seeds. (Swami, S. B., & Kalse, S. B., 2018)

### Carbohydrates composition

Recent studies have shown that jackfruit seeds contain approximately 63-85 percent of their dry weight as total carbohydrates, the majority of which is in the form of starch. Therefore, jackfruit seeds may serve as a source for the extraction and use of starch in a variety of different industries. Additionally, jackfruit seeds also contain high levels of dietary fibre, and thus, may contribute significantly to both their nutritional value and potential health benefits (Kamal *et al.*, 2024).

The composition of macronutrients supports the potential of jackfruit seeds to be a valuable dietary energy source. In addition to being a primary food source, jackfruit seeds have been documented to contain up to 80% of total starch

content when isolated from seeds; factors affecting the variability of compositional content [due to the processes and methods of extraction used] have been documented in numerous studies (Suryadevara *et al.* 2017). Due to their nutritional properties, jackfruit seed starch can be used in the production of foods that are suitable for those with diabetes, and in developing functional foods for improved metabolic health. The presence of slowly digestible starch may also aid in the feeling of fullness after eating as well as assist in maintaining a healthy balance of energy throughout the day (i.e., satiety), which are associated with weight management and the prevention of chronic diseases (Dilworth *et al.* 2024). It is important to note that starch comprises a significant portion of the diet of many

people around the world, being a principal energy source of most people (Zhang *et al.* 2024). Starch is (wet/dry) (i.e., from a chemical viewpoint) a complex carbohydrate. In addition to its role as a source of energy, starch must also be able to resist changes in temperature, acidity, and shear stress, and must also have the ability to retain water and provide for the gelling properties needed for use in food. In addition to providing nutrition, jackfruit seed starch is becoming increasingly popular for its functional utility in both the food and pharmaceutical industries. Its swelling ability and ability to break down have been shown to be successful as a natural disintegrant in formulations, presenting an eco-friendly and economically viable substitute for synthetic excipients (Dwitiyanti, *et al.* 2019). Another key carbohydrate type of jackfruit seeds is dietary fiber; it is essential in keeping the digestive system functioning properly. It will increase peristalsis, increase the amounts of beneficial bacteria in the intestines, and provide prebiotic properties to the fiber, which improves the function of the GI tract and decreases the risk of gastrointestinal disorders (Swami, *et al.* 2012). Dietary fiber combined with starch contributes to the overall contribution of the seed as a holistic food source with immediate and long-term health benefits. There are differences in carbohydrate compositions among the different types of jackfruit seeds. The Gala variety has the greatest starch content at 17.90%; the Khaja comes in at 15.61% and the Durosha at 12.86% (Abedin, *et al.* 2012). This creates an opportunity for breeding for specific cultivars and uses. The carbohydrate profile of jackfruit seeds together provides insight into the major use for energy and a food product with potential medicinal value as a functional food. However, further investigation of both the changes made to the jackfruit seeds structure and extraction of jackfruit seeds on an industrial scale may provide opportunities for multiple industries.

### Profile of Protein and Amino Acids

Jackfruit seeds provide a moderate source of plant-based protein at around 13-18% protein content (Chhotaray & Priyadarshini, 2022) stated that the protein found in jackfruit seeds contain high amounts of amino acids (such as arginine, methionine, tryptophan, and lysine) that are essential for the human body. Amino acids like lysine and tryptophan, along with other amino acids, play an important role in the growth and repair of tissue, the regulation of human enzyme function, and the generation of collagen (Roy Chowdhury *et al.*, 2012). Arginine, when at higher concentrations, has been linked to improvements in cardiovascular health and immune function (Bose *et al.*, 2024) This amino acid profile is particularly appealing due to the combined and balanced nature of both essential and conditionally essential amino acids found in jackfruit seed proteins (Suryadevara *et al.*, 2017). In addition to the nutritional aspect of jackfruit seed proteins, they have

demonstrated bioactive properties. This is additional value that could be used in nutritional supplements and other health and wellness products. They have a number of functional values, which have supported evidence for arginine, an amino acid whose increased levels improve cardiovascular health, immune function and also show a relationship with these proteins (Bose *et al.*, 2024). Enzymatic digestion of the protein provides protein hydrolysates with antibacterial and antioxidant activities. With those functions being evident, they are now considered as potential sources for functional food and nutraceutical development (Sharma *et al.* 2025). Jackfruit seeds (*Artocarpus heterophyllus*) are also a source of jacalin, a lectin protein that has been extensively studied due to its ability to specifically bind O-linked glycoproteins, particularly those containing the Thomsen-Friedenreich Ag. Studies have investigated the immunomodulatory and antiviral abilities of jacalin, and have shown that jacalin may have therapeutic as well as preventative applications. Jacalin's unique property is that it shows strong mitogenic activity towards CD4+ T cells and exhibits a strong binding affinity for CD4 glycans on human host cells, which have been shown to block HIV-1 infection. Jacalin is also being studied as an antiviral agent, beyond its antiviral properties against HIV (Tripathi *et al.*, 2023).

An *in silico* study reported that jacalin, a lectin derived from jackfruit seeds, binds to the glycosylated receptor binding domain (RBD) of SARS-CoV-2, with potential for altering RBD/ACE2 interaction via conformation changes (Rajendran *et al.*, 2020). This would stop the virus from binding to the human ACE2 receptor, and provides a promising avenue for developing antiviral therapies using lectin-based compounds (Senthilnathan *et al.*, 2020). Although these findings are promising, comprehensive proteome profiling and structure-function studies on the proteins found in jackfruit seeds are still quite limited. Advancing research in this area could unlock new opportunities in pharmaceutical sciences, food technology, and health.

### Lipid and Fatty Acid Content

According to recent studies, Jackfruit Seed contains a low amount of lipids (1.3–1.7% dry weight) and therefore cannot be classified as an oilseed. The oil yield from Jackfruit Seed is lower than that of other oilseed crops, however its oil quality is still considered excellent (Bose *et al.*, 2025). The lipid composition of Jackfruit Seed includes high levels of unsaturated fatty acids such as omega 6 (linoleic acid) and omega 9 (oleic acid), which have cardio-protective properties through their ability to reduce levels of LDL cholesterol and inflammation (Dabas *et al.*, 2017; Fernandes *et al.*, 2019). The fatty acid composition and the biocompatibility of jackfruit seed lipids indicate great promise for possible uses as delivery vehicles in pharmaceutical lipid-based drug delivery systems.

Although much work remains to fully characterize the lipid profile of jackfruit seed oil, lipidomic profiling will provide further insight into the full recovery and characterization of jackfruit seed oil; additional studies are needed to evaluate the kinetics of lipid oxidation, to elucidate the composition of the trace lipids, and to optimize the methods of oil extraction. The commercial potential for jackfruit seed lipids in terms of nutritional and functional food systems can be enhanced by the exploration of extraction processes, such as cold-pressing, enzymatic extraction, and solvent free methods (Suryadevara *et al.*, 2017; Bose *et al.*, 2024). Although these properties are

advantageous, there has not been an extensive lipidomic analysis of Jam fruit seed oil that has been published. Advanced analytical research to establish lipid oxidation kinetics, to identify trace lipid components, and to develop a methodology for standardization for oil extraction will help in both enhancing the recovery as well as the quality of the oils. Advancements related to cold pressing, enzymatic extraction, and solvent-free approaches would increase the commercial viability of Jam fruit seed lipid for nutritional and functional food application (Suryadevara *et al.*, 2017, Bose *et al.*, 2024).

**Table 1: Nutritional Profile of Jackfruit Seeds Macronutrients**

Nutrient	Value per 100g
Moisture	10.2–13.0%
Protein	6.8–18.0%
Carbohydrates	40.0–50.0%
Starch	22.0–32.0%
Dietary Fiber	1.5–3.9%
Fat	0.4–1.7%
Ash	1.2–2.0%

Journal of Agriculture and Food Research, 2025.

### Mineral Analysis and Micronutrients

Jackfruit seeds have medium to high levels of mineralization (calcium, magnesium, potassium, zinc, iron, and copper) which provide many of the minerals and nutrients needed for many physiological processes. In addition to having high levels of the four aforementioned minerals, jackfruit seed studies report that jackfruit seeds are a source of fairly substantial amounts of magnesium (210 mg/100 g), phosphorus (170.7 mg/100 g), and potassium (1.42%) (Abedin *et al.*, 2012; Saha *et al.*, 2023). All minerals mentioned above are thought to play key roles in regulating blood pressure, enacting enzymatic reactions, and maintaining healthy bones. Potassium is associated with regulating the balance of fluids (electrolytes) in the human body, regulating cardiovascular function, and facilitating muscle contractions, while magnesium and calcium are critical for the formation of bones and the functioning of the neuromuscular systems (Maurya & Mogra, 2016). Because jackfruit seeds have a relatively higher than average concentration of potassium, they are believed to provide unique benefits to individuals with high blood pressure through their potential antihypertensive properties (Saha *et al.*, 2023).

Phosphorus is critical for synthesizing adenosine triphosphate (ATP), creating energy, and mineralizing bones. Copper and zinc, for example, are trace metals needed to produce red blood cells and provide antioxidant defences, while, in addition to binding to oxygen, iron is critical for the treatment of iron-deficiency anemia in at-

risk populations, and zinc supports the synthesis of DNA and the repairing of cells. Gupta *et al.* (2011) and Sharma *et al.* (2015) Several recent studies found that jackfruit seed minerals consume a substantial portion of adult phytate resorption at the time of absorption, suggesting that they may be an effective natural nutritional supplement for providing missed minerals in malnourished/under-nutrition populations (Kumoro *et al.* 2020). They are of particular concern to developing countries where micronutrient deficiencies are common and nutrition comes from plant-based diets. Although jackfruit is a valuable food source nutritionally, research on the bioavailability and kinetic factors of mineral absorption through food, and their combined effects with antinutritional agents such as phytates remain dismal (Gupta *et al.* 2011; Kumoro *et al.* 2020). Jackfruit seeds, like other plant foods, contain dietary fiber, which influences mineral absorption. Phytic acid, commonly found in cereals and legumes, can chelate with essential minerals (e.g., calcium, zinc, iron), thus forming indeterminate complexes, which inhibit bioavailability in the gut. It is possible that certain dietary fibers might also bind with minerals, and thereby alter their respective rates of absorption. However, the relationship between dietary fiber and mineral absorption varies widely and depends on the particular type and solubility of the respective dietary fiber. In order to understand fully how phytates and dietary fibers influence the absorption of minerals; further *in vitro* and *in vivo* studies are needed (A. Kumari & A. Roy 2023; A.S Sandberg 2023).

**Table 2: Nutritional Profile of Jackfruit Seeds**

Nutrient	Value per 100g
Calcium	30–54 mg
Phosphorus	38–97 mg
Potassium	287–448 mg
Magnesium	54–102 mg
Iron	0.5–1.5 mg
Zinc	0.2–0.5 mg
Sodium	1–3 mg
B1 Vitamins (thiamine)	0.03–0.05 mg
B2 Vitamin (Riboflavin)	0.05–0.06 mg
B3 Vitamin (Niacin)	0.5–0.9 mg
Vitamin C (ascorbic acid)	7.0–13.0 mg

Journal of Agriculture and Food Research, 2025.

**Table 3: Elemental Composition of Jackfruit Seeds across Different Varieties**

Variety	Mastura	Khaja	Gala	Durosha
Phosphorus (g/100g)	0.12883	0.1239	0.1707	0.1193
Potassium (g/100g)	0.76932	1.30	1.34	1.42
Aluminum (g/100g)	1.67	-	-	-
Calcium (g/100g)	40.86	0.02	0.11	0.38
Magnesium (g/100g)	0.10294	0.1507	0.1687	0.210
Sodium (g/100g)	5.39	-	-	-
Zinc (g/100g)	1.36	1.5	2.333	3.1

Brahma, R., & Ray, S. (2023).

### Health Benefits

Jackfruit seeds, which contain an extraordinary abundance of phenolic compounds, particularly flavonoids, tannins, saponins, and phenolic acids, are starting to become recognized for their health-promoting properties (*Artocarpus heterophyllus*) (Fernandes *et al.*, 2017). This means that these compounds have a significant role to play in this aspect of the seeds. Gallic acid and ferulic acid are very common examples of flavonoids and phenolic acids that have antioxidant properties, among others. The antioxidant effects of flavonoids and phenolic compounds neutralize free radicals and reduce the amount of oxidative damage that can occur, which are both major contributors to chronic diseases (Siddique *et al.*, 2023). Saponin and tannin compounds also have antibacterial and anti-inflammatory activities, which encourage the body's natural equilibrium and promote overall health by providing a higher quantity of primary nutrients (Fernandes *et al.*, 2017).

Recent advances in the extraction of phenolic compounds from jackfruit seed (via subcritical water extraction) acknowledge the effectiveness of this approach compared to traditional methods, and have been shown to produce higher quantities of phenolic compounds while enhancing their degree of antioxidant potential (Siddique *et al.*, 2023). The strong relationship between total phenolic content and antioxidant activity demonstrates how medicinally active these bioactive tensors may be, and it is likely that other phytonutrients, such as lignan and flavone

compounds, will further improve the medicinal activity of jackfruit seeds and provide additional anti-aging, anti-cancer, anti-ulcer, and antihypertensive effects (Fernandes *et al.*, 2017). Incorporating jackfruit seeds into the diet or utilizing their extracts in functional foods and nutraceuticals offers a natural approach to enhancing health and preventing disease. By recognizing the value of this often-overlooked byproduct of jackfruit consumption, their rich bioactive profile not only supports immune and metabolic functions but also aligns with sustainable and eco-conscious practices (Siddique *et al.*, 2023).

### Flavonoids and Essential Phenolic Acids

The phenolic acids and flavonoids contained in jackfruit seeds may reduce the incidence and/or development of oxidative-stress-related diseases, including cancer, cardiovascular disease, and neurodegenerative disorders, by counteracting free radicals and limiting oxidative damage to cellular components (Bose *et al.*, 2024). Additionally, they can enhance the effectiveness of the body's natural defenses and repair mechanisms by preventing the peroxidation of lipids and modulating catalase and superoxide dismutase (SOD), which are antioxidant enzymes. The presence of tannins and saponins (two common plant phytochemicals) indicates that jackfruit seeds may also provide antibacterial activity and increase immunity. Tannins act by inflicting cellular damage to microbial organisms through disruption of cell walls and inhibiting microbial enzyme functions

(Fernandes *et al.*, 2017). This and other synergistic relationships among phytochemicals lead to potential applications for jackfruit seeds as a source of nutraceuticals. The bioactive properties of jackfruit seeds help maintain the immune balance around the body and support digestive health, with evidence that they may have anticancer effects as well (Bose *et al.*, 2024). Because of their high content of phenolic compounds, jackfruit seeds are a prime candidate for being included in functional foods developed for improving health and mitigating the occurrence of lifestyle-induced diseases. The phytochemical profiling of jackfruit seeds using advanced technologies such as LC-MS/MS and NMR is currently not performed in an extensive manner, though there have been several promising findings regarding their bioactivity (Manianga *et al.*, 2024). To better understand the bioavailability of the various compounds in jackfruit seeds and evaluate their usefulness in clinical studies, additional research must be conducted to identify the specific molecular structures responsible for their biological activity (Manianga *et al.*, 2024). Many of the health benefits attributed to jackfruit seeds are a result of the seeds' high concentration of dietary fiber, alkaloids, and other phytochemical constituents that have exhibited bioactivity. The many physiological and therapeutic effects attributed to these compounds emphasize the potential of jackfruit seeds to provide a valuable source for functional foods and natural health products (Manianga *et al.*, 2024).

### Properties of Antioxidants

Not only does processing jackfruit seeds make food look better and improve the nutritional value of food, it increases digestibility, antioxidant potential, and shelf life and decreases the antinutrients (Khan *et al.*, 2021). Jackfruit seeds contain phenolic compounds like quercetin and gallic acid, which are two strong antioxidants. These antioxidants protect the health of the cells by neutralizing free radicals, decreasing lipid peroxidation, and decreasing oxidative stress. Antioxidants play a key role in decreasing the risk of chronic diseases such as cancer, diabetes, and cardiovascular disease and are therefore one of the reasons jackfruit seeds are considered to be a functional food source that provides health benefits (Fernandes *et al.*, 2017; Ranasinghe *et al.*, 2019). Recent advances in nutritional research utilizing both the *in vitro* and *in vivo* study methods have increased our understanding of jackfruit seed extracts' therapeutic benefits as they have very high antioxidant activity (Baliga *et al.*, 2011; Saha *et al.*, 2023). This data suggests that jackfruit seeds are becoming increasingly relevant in the development of nutraceuticals and have the potential to serve as valuable ingredients in functional foods.

### Antimicrobial Impact

Jackfruit seeds are rich in flavonoids, tannins, and other secondary metabolites that exhibit broad-spectrum antimicrobial properties. These compounds work by disrupting microbial cell membranes and inhibiting the growth of harmful bacteria and fungi. As a result, they hold promise for use in natural food preservation and alternative infection-control strategies (Maurya & Mogra, 2016; Mustikasari & Ariyani, 2016). Their ability to target both Gram-positive and Gram-negative bacteria supports their promising applications in the medical field. Rich in flavonoids, tannins, and other secondary metabolites, jackfruit seeds exhibit strong antibacterial activity effective against a range of pathogens, including certain fungi. Their broad-spectrum antimicrobial effect is largely attributed to their ability to disrupt microbial cell membranes, destabilize proteins, and inhibit key enzymatic pathways ultimately suppressing microbial growth and leading to cell death (Manianga *et al.*, 2024). Beyond serving as a natural defense mechanism for the seeds themselves, these bioactive compounds show considerable potential for incorporation into pharmaceutical formulations designed to combat bacterial infections. Their effectiveness is especially relevant in the current landscape of rising antibiotic resistance, offering a natural alternative for therapeutic intervention (Maurya & Mogra, 2016). Recent studies have demonstrated that these phytochemicals are particularly effective against food borne pathogens like *Escherichia coli* and *Staphylococcus aureus*, suggesting their use in natural food preservation strategies (Mustikasari & Ariyani, 2016). Flavonoids, in particular, exert inhibitory effects on bacterial replication by binding to critical enzymes and blocking substrate interaction, while tannins precipitate microbial proteins, reducing pathogenic activity. The dual-action nature of these compounds ensures enhanced efficacy, paving the way for them to be used as biodegradable preservatives in minimally processed foods and beverages. The same action of apriary compounds (such as those derived from jackfruit seed) also has potential applications for agricultural and food preservation. Specifically, the flavonoids and tannins derived from jackfruit seed have been shown to have antifungal properties, which has the potential to provide more ecologically sustainable farming methods. Researchers have also explored the use of these natural compounds as edible film/coating products to extend the shelf life of perishable products, while preserving the safety and quality of the product (Manleka *et al.*, 2024). As the scientific and consumer popularity of jackfruit seed tannins and flavonoids has increased, many personal care and skin care products (for example lotions and soaps) are utilizing the antimicrobial properties of these natural compounds to help reduce the risk of developing skin infections caused by microbial agents (Sharma *et al.*,

2017). These applications highlight the versatility of jackfruit seeds in fulfilling both industrial and medicinal needs, supporting ongoing efforts to develop environmentally friendly solutions.

### Anti-Inflammatory Properties

A key component of Jackfruit seed's antioxidant capacity; however, flavonoid and phenolic compound found in Jackfruit have been identified as having the potential to inhibit many of the pathways that lead to the inflammatory response in the body. The promise shown by flavonoids and phenolics is tied directly to the fact that they have been shown to significantly reduce the levels of both TNF- $\alpha$  and IL-6, two major proinflammatory cytokines. For instance, TNF- $\alpha$  and IL-6 work together during the inflammatory cascade as alarm bells that signal for a full-blown response to the threat to health. While the physiological function of these cytokines is critical for the body's initial reaction to injury or infection, when the levels of these cytokines are elevated, this has been correlated with the development and/or worsening of chronic inflammatory diseases including arthritis, inflammatory bowel disease, and the chronic inflammation associated with oxidative stress. By significantly reducing the levels of these cytokines, flavonoids and polyphenols have the potential to relieve the symptoms of inflammation and minimize the amount of tissue damage caused by attachment of the inflammatory mediators (Manianga *et al.*, 2024; Fernandes *et al.*, 2017). Moreover, flavonoids and phenolic compounds have also been identified to play a role in modulating the immune response of the body. Quercetin, one of the flavonoids in Jackfruit seed, has shown the ability to stabilise, modulate the way that the immune cells, specifically mast cells and macrophages operate during the inflammatory response. By acting in this dual manner, flavonoids and phenolic compounds support the overall balance of the immune system and also help to facilitate a more balanced response to an infection (Saha *et al.*, 2023). In addition to preventing the body from developing an immune system that is overly activated due to a chronic inflammatory response (Ranasinghe *et al.*, 2019). New research demonstrates that these bioactive components possess significant variety and numerous other medicinal uses. For example, phenolic compounds possess strong antioxidant activity and they both protect against free radicals and prevent oxidative stress that ultimately leads to tissue damage and chronic inflammatory conditions. Thus, jackfruit seed extracts have the potential to serve as future functional foods and nutraceuticals to support healthy immune responses and manage chronic inflammatory diseases (Gupta *et al.*, 2011). In preclinical and clinical studies, there is growing evidence supporting the use of jackfruit seed extracts as anti-inflammatory agents. Specific to arthritis, for instance, jackfruit products decrease edema and

inflammatory markers in animal model systems (Fernandes *et al.*, 2017). Ultimately, these research results suggest the utility of jackfruit seed extracts providing alternative therapeutic options to support health, with limited side effects compared to synthetic pharmaceuticals. The expanding body of research supporting the development of using bioactive materials derived from jackfruit seeds for pharmacological and nutritional purposes, particularly in the treatment of inflammation-related illnesses, coincides with international efforts to develop sustainable, plant-based treatment options for chronic disease management and improving health and wellness. The hypoglycaemic (anti-diabetic) effects of jackfruit seeds appear to be mediated by alkaloids (especially the alkaloids) and/or tannins and flavonoids derived from jackfruit seeds via enhancing insulin sensitivity and/or lowering postprandial blood glucose concentrations. The significant impact of jackfruit seed extract(s) in controlling glucose levels may be attributed to the compound's action on enzymes involved in glucose regulation. In experimental models, jackfruit seed extracts have also demonstrated potential as an adjunct therapy in controlling glucose levels and may help to promote the management of diabetes (Manleka *et al.*, 2024; Saha *et al.*, 2023). Animal studies have also demonstrated the hypoglycaemic activity of jackfruit seed extract, suggesting a benefit on the overall health of animals with diabetes, by lowering fasting blood glucose levels (Ranasinghe *et al.*, 2019; Dwitiyanti *et al.*, 2019).

### Healthy Digestive and Prebiotic Conditions

Jackfruit seeds contain a high concentration of dietary fiber, which is an essential nutrient found in many foods. Many individuals consume jackfruit seeds for the sole purpose of their high fibre content due to the various health benefits associated with dietary fiber consumption, especially in regards to digestive health. According to the study performed by Swami and others (2012) on jackfruit seeds, dietary fiber is responsible for maintaining normal bowel movement, as well as reducing constipation. The researchers also explain that dietary fiber acts as a prebiotic, meaning that it will support the growth and activity of good gut bacteria, which are necessary for maintaining a healthy balance of gut microbiota for proper digestion, absorption, and other important aspects of supporting gut health (Trejo-Rodriguez *et al.* 2021). Currently, there is emerging evidence demonstrating the effect that jackfruit seed dietary fibre can have on gastrointestinal disorders such as dysbiosis an imbalance in the gut microbiome in addition to promoting the growth of good gut bacteria (e.g., *Lactobacillus* and *Bifidobacterium*) and promoting a more balanced gut environment. Additionally, the beneficial microbial replacement that occurs through consumption of dietary fibre from jackfruit seeds promotes the production of

metabolic byproducts that inhibit the growth of harmful pathogens (Manianga et al. (2024) indicates that dietary fibre from jackfruit seeds may also improve regulation of intestinal motility, which is particularly useful for persons who suffer from disorders such as IBS). (GG need for attributes). Recent research has shown that jackfruit seed flour can be incorporated into a number of functional food products. Jackfruit seed flour contains a high level of dietary fiber; therefore, it is becoming increasingly popular as an ingredient in a variety of different product categories, including snacks, extruded foods and fortified breads. All three of these product categories are being developed with the intention of increasing the nutritional quality of the total foods produced and sold (Brahma & Ray, 2023). Furthermore, these findings not only provide an approach to the issue of sustainability in the food supply chain, but also meet the demand for healthier food options from consumers who are increasingly interested in eating healthy but who do not have access to healthy food items that are made from under-utilized materials from the processing of jackfruit. Dietary fiber present in jackfruit seeds plays a key role in maintaining good metabolic health by regulating blood sugar levels. Jackfruit seed fiber is particularly useful for people who are diabetic or prediabetic; because it delays carbohydrate digestion and absorption postprandially, the carbohydrate digestion and absorption process occurs over a longer time period. Therefore, by delaying carbohydrate digestion and absorption, jackfruit seed fiber minimizes sharp increases and spikes in blood glucose concentrations after meals.

Abedin *et al.* (2022) concluded that including jackfruit seed fiber as a functional dietary ingredient can improve glycemic control and insulin sensitivity of individuals eating this type of ingredient.

**Potential and Mechanisms of Therapy**

In addition to these beneficial antidiabetic compounds, jackfruit seeds are known to contain many other bioactive compounds that have significant therapeutic benefits in the treatment of several chronic conditions (diabetes, cancer, and hypertension). Some of the most common compounds in jackfruit seeds are flavonoids, tannins, alkaloids, and phenolic acids. The phytochemical compounds found in jackfruit seeds can have many different types of pharmacologic effects, including antioxidant activity, modulation of the immune system, inhibition of metabolic enzymes, and anti-inflammatory activity. Oxidative stress causes chronic diseases, and both flavonoids and phenolic acids are well known for their ability to scavenge free radicals and reduce oxidative stress and damage to cells (Brahma & Ray, 2023; Manianga *et al.*, 2024). Jackfruit seeds are known for their ability to lower blood sugar levels in diabetic animal models. They improve insulin sensitivity by stimulating the pancreas to produce more insulin, thus, resulting in lower fasting blood glucose levels (Saha *et al.*, 2023). The high levels of bioactive compounds, such as phenolic acids, tannins, and alkaloids found in jackfruit seeds make them an excellent candidate for use as nutraceuticals and functional food products in treating chronic diseases.

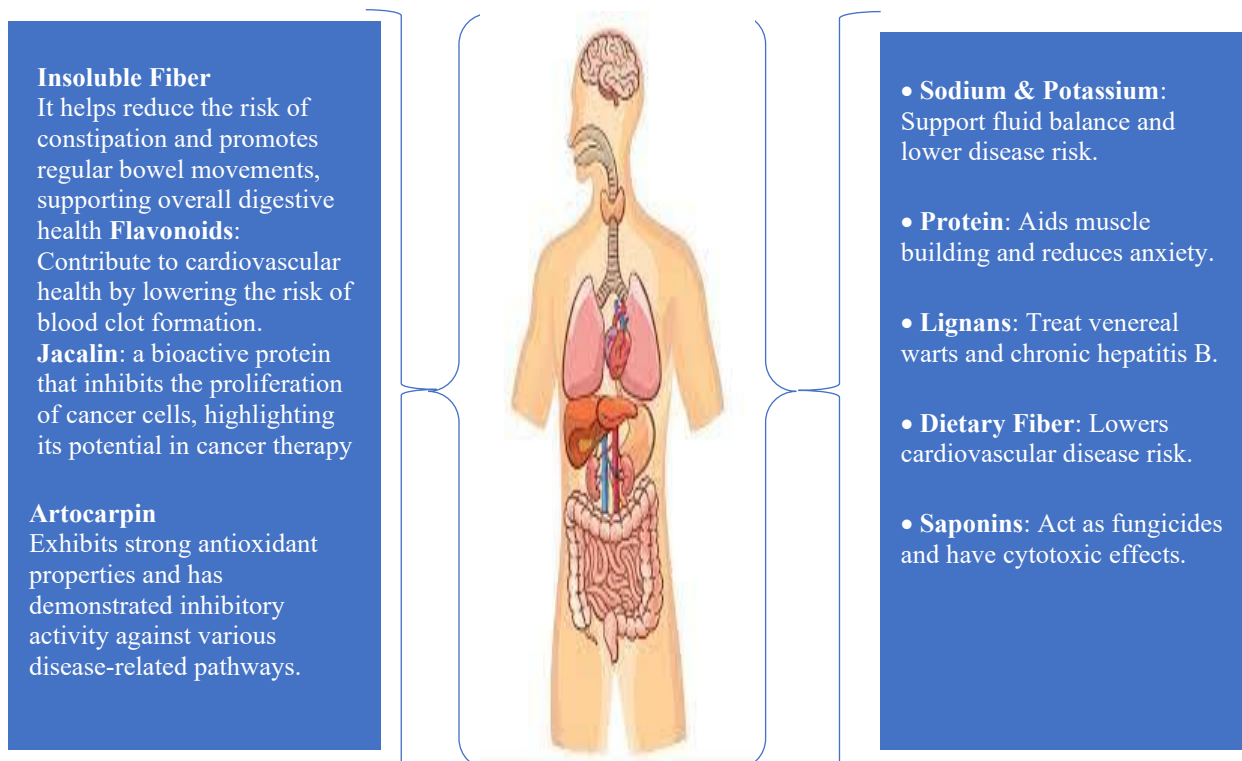


Figure 2: Health Benefits and Bioactive Components of Flaxseed

### **The Antidiabetic Mechanism and Enzyme Inhibition**

Evidence supports this claim by showing that phenolic acids, tannins, and alkaloids are capable of inhibiting the carbohydrate-digesting enzymes  $\alpha$ -amylase and  $\alpha$ -glucosidase. This means that jackfruit seed extracts may also help maintain healthy post-meal blood sugar levels (Maradesha *et al.*, 2020). By inhibiting the digestion of carbohydrates into glucose at a faster rate, jackfruit seed extracts create a slower and steadier release of glucose into the bloodstream. This mechanism not only improves glucose control, but it also allows for better insulin sensitivity, thus providing a natural method for controlling diabetes (Saha *et al.*, 2023). Furthermore, the role of jackfruit seed extracts in activating cell death (apoptosis) and inhibiting the growth of cancerous cells was established in research conducted with many different human cancer cell lines and animal models (Brahma and Ray, 2023). Animal studies verifying the above have been undertaken in recent times. For instance, jackfruit seed extracts were shown to have a positive effect on improving glucose tolerance and lowering fasting blood glucose levels in diabetic rats. Alkaloids and tannins in jackfruit seed extracts are believed to play an important role in controlling glucose metabolism and decreasing oxidative stress. Therefore, these extracts hold promise as a sustainable, plant-based source of potential antidiabetic treatments, as well as a functional ingredient for the food industry.

### **Immune modulation and anti-inflammatory effects**

Jackfruit seeds are a rich source of bioactive components including several lectins (e.g., jacalin) which possess potent immunoregulation activities (Brahma & Ray, 2023). Studies conducted have indicated that jacalin has potentiality to be utilized as a therapy for enhancing immunological activity through its ability to stimulate cytokine production and induce activation of different types of immunity producing cells (T-cells, NK cells, and macrophages) while also providing antimicrobial properties (antiviral) indicating potential usage of Jacalin in the augmentation of immunity during viral infections (Brahma & Ray, 2023). Evidence suggests the presence of flavonoids and tannins; their bioactive phytochemicals found in jackfruit seed are responsible for producing the majority of the anti-inflammatory properties of jackfruit seed, including suppression of cytokines such as TNF- $\alpha$ , IL-6, and pro-inflammatory mediators (Trejo Rodríguez *et al.*, 2021). Flavonoids stabilizing T-cells, regulating inflammatory pathways, and Tannins preventing acute inflammatory conditions associated with oxidative stress (Gupta *et al.*, 2011) indicate the potentiality for jackfruit seed acting as a nutraceutical and functional-based ingredients to maintain/healthcare to individuals with inflammatory and/or autoimmune disease conditions (Fernandes *et al.*, 2017). According to Trejo Rodríguez and

co-workers (2021) and Fernandes *et al.* (2017), jackfruit (*Artocarpus heterophyllus*) seeds contain a large quantity of phenolic acids such as gallic acid, and flavonoids such as quercetin, which exhibit significant antioxidant activity, primarily through the down-regulation of oxidative stress associated with chronic diseases and cancer. Because of their ability to neutralize free radicals, maintain the integrity of cellular membranes, and to reduce DNA damage, these bioactive compounds have anticancer properties (Brahma and Ray, 2023; Baliga *et al.*, 2011)

### **Management of Hypertension and Cardiovascular Health**

Jackfruit seeds may enhance the regulation of blood pressure and the overall health and functioning of blood vessels through their ability to act as naturally occurring angiotensin-converting enzyme (ACE) inhibitors. The ACE-inhibiting agents produced by jackfruit seeds can help to control blood pressure levels and decrease the risk of developing cardiovascular disease (Maradesha *et al.*, 2022). Furthermore, the fatty acid composition of jackfruit seeds (which is predominantly oleic and linoleic acid), has also been associated with improved heart health by providing help in lipid metabolism and decreasing levels of low-density lipoprotein (LDL) cholesterol (Trejo Rodríguez *et al.*, 2021; Fernandes *et al.*, 2017). Therefore, the use of jackfruit seeds may serve as a natural approach for supporting cardiovascular health.

### **Digestive and Prebiotic Support**

As a high-source of dietary fibre, jackfruit seeds are also beneficial to the intestinal microbiome. By contributing to the growth of health-promoting bacteria (specifically *Lactobacillus* and *Bifidobacterium* species), the soluble fibre derived from jackfruit seeds can help to improve nutrient absorption, decrease intestinal inflammation and promote overall digestive health. Research supports the use of jackfruit seed soluble fibre as a prebiotic and to alleviate a variety of gastrointestinal problems such as dysbiosis and constipation (Trejo Rodríguez *et al.*, 2021; Abedin *et al.*, 2022). Therefore, jackfruit seeds may be functional dietary factors for enhancing a person's digestive system.

### **CONCLUSION**

Jackfruit seeds represent a highly valuable yet underutilized resource with significant nutritional and therapeutic potential. Rich in essential amino acids, dietary fiber, minerals, and diverse bioactive compounds, jackfruit seeds exhibit a wide range of health-promoting effects, including antidiabetic, antioxidant, antibacterial, and anti-inflammatory activities. These multifunctional properties support their potential application in the management of chronic diseases such as diabetes, cardiovascular disorders, and inflammatory conditions.

Additionally, their high fiber content and phytochemical richness make them ideal candidates for incorporation into functional foods, prebiotic products, and nutraceutical formulations. From a sustainability perspective, the valorization of jackfruit seeds aligns with circular economy principles and contributes to the reduction of food waste. However, limitations such as inconsistent processing methods, limited clinical evidence, incomplete bioavailability data, and underdeveloped industrial applications must be addressed. Future research should focus on clinical validation, bioactive compound isolation, safety assessment, and scalable extraction technologies to support the broader adoption of jackfruit seeds in food, pharmaceutical, and nutraceutical industries.

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