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JACKFRUIT SEEDS: A COMPREHENSIVE REVIEW OF NUTRITIONAL COMPOSITION, FUNCTIONAL PROPERTIES, AND POTENTIAL APPLICATIONS

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ABSTRACT

Jackfruit (Artocarpus heterophyllus Lam.) is one of the most abundant tropical fruit trees, which produces the largest known edible fruit by any tree. While its pulp is commonly consumed, the seeds—which contribute to nearly 18–25% of the total fruit weight—are often underutilized or discarded in spite of their rich nutritional and functional potential. This review delivers a comprehensive overview of jackfruit seeds, pointing out their nutritional composition, bioactive constituents, functional properties, and prospective applications across various sectors. Jackfruit seeds contain carbohydrates, proteins, dietary fiber, essential amino acids, vitamins, and minerals, along with phytochemicals such as flavonoids, tannins, phenolic acids, and saponins. These compounds have antioxidant, antimicrobial, anti-inflammatory, antidiabetic, and immunomodulatory properties that contribute to the prevention and management of chronic and lifestyle-related disorders, such as cardiovascular disease, diabetes, gastrointestinal complications, and certain cancers. Functionally, jackfruit seed flour, starch, and protein isolates showcase promising emulsifying, foaming, and binding properties, substantiating their integration into bakery products, snacks, nutraceuticals, and cosmetic. Despite these advantages, the large-scale utilization of jackfruit seeds remains limited by factors such as post-harvest perishability, the presence of antinutritional compounds, and the limited availability of processing technologies. Addressing these obstacles through optimized storage, innovative processing, and extraction techniques could enhance the bioavailability as well as reduce the anti-nutrient content.

Overall, jackfruit seeds represent a sustainable and underexploited resource that can reduce food waste, provide health-promoting ingredients, and support the development of functional foods, pharmaceuticals, and cosmetics, thereby contributing to nutrition security and sustainable food innovation.

KEYWORD: Jackfruit, Nutraceuticals.

INTRODUCTION

The Artocarpus heterophyllus, a type of tree in the mulberry family (Moraceae), is commonly referred to by various names such as jackfruit (English), Kathal, Panas (Hindi), Kanthal (Bengali), Palaa (Tamil), Phanas (Gujarati & Marathi), and Chakka (Malayalam). It is originally from the Western Ghats of India and is also found in central and eastern Africa, southeastern Asia, the Caribbean, Florida, Brazil, Australia, Puerto Rico, and several Pacific Islands. The plant is known to have antibacterial, anti-inflammatory, antidiabetic, antioxidant, and immunomodulatory effects. Artocarpus heterophyllus serves as a significant source of compounds such as morin, dihydromorin, cynomacurin, artocarpin, isoartocarpin, cyloartocarpin, artocarpesin, oxydihydroartocarpesin, artocarpetin, norartocarpetin, cycloartinone, betulinic acid, artocarpanone, and heterophylol, which are beneficial for treating fever, boils, wounds, skin ailments, convulsions, as well as functioning as a diuretic, addressing constipation, ophthalmic issues, and snake bites, among others. This large, evergreen tree typically reaches a height of 10-15 meters and is native to the evergreen forests at altitudes of 450-1,200 meters, being cultivated in various hotter regions of India. This tree has a straight, rough stem and 1.25 cm thick, milky latex-producing bark that can be either green or black. Its broad, oblong, elliptic, glabrous leaves have a decurrent margin. Short leafy shoots give rise to the cauliflorous, solitary, and axillary inflorescence. Female flower heads are oblong, ovoid receptacles that are cylindrical and syncarpous in shape, whereas male flower heads are either sessile or found on short peduncles, occasionally growing on the ultimate twigs. The horny endocarp that envelopes the seeds is covered in the sub-gelationous exocarp that is oblong and ellipsoid in shape and about 1mm thick. The seeds are surrounded by sweet yellow sheaths that range in thickness from 3 to 5 mm and have a flavor akin to pineapple, but softer and less juicy.[1]

The jackfruit tree (Artocarpus heterophyllus Lam) generates more yield than any other tree species and bears the largest known edible fruit, which can weigh up to 35 kg. This tree has several uses. Ripe fruit flakes are very nutritious; for every 100 g of ripe flakes, there are

287-323 mg of potassium, 30.0-73.2 mg of calcium, and 11-19 g of carbohydrates. In Bangladesh, it is often called “poor man’s food” because it is affordable and widely available during its season. The nutrient-rich seeds can be boiled or roasted and consumed similar to chestnuts, mixed into flour for baking, or prepared in various dishes. The tree is also recognized for its robust timber, which matures to a reddish-orange hue and possesses anti-termite qualities. The leaves and leftover fruit are valuable as fodder for livestock such as cattle, pigs, and goats. Additionally, wood chips from the jackfruit tree can produce a dye that is used to color the traditional orange-red robes worn by Buddhist priests. Moreover, various parts of the plant, including the bark, roots, leaves, and fruits, have medicinal benefits.

It thrives in well-drained but moist soil, with a pH range of 4.3 to 8.0 and moderate soil fertility. The ideal temperature for growth is between 19 and 29°C, at an altitude of approximately 1,600 meters above sea level, and it requires annual rainfall of 1,000 to 2,400 mm.[2]

Taxonomical Classification

Kingdom: Plantae -- planta, plantes, plants, vegetal
Subkingdom: Tracheobionta—vascular plants
Division: Magnoliophyta -- angiosperms, flowering plants, phanérogames
Class: Magnoliopsida -- dicots, dicotylédones, dicotyledons
Subclass: Hamamelidae
Order: Urticales
Family: Moraceae – mulberries
Genus: Artocarpus – breadfruit
Species: Artocarpus heterophyllus Lam.[3]

Like any other seeds, jackfruit seeds can be used several ways. Jackfruit seeds have long been used in South Asian curries as a vegetable substitute. These nutty seeds can be ground into flour, cooked, or roasted for consumption. Some food companies also use seed flour as a binding agent in some meal preparations. It is also well known for appearing in a wide range of delicious desserts. People can make healthy salads and hummus. The seeds of jackfruit flour can be used in baking and cooking. You can also make healthy butter from these seeds.[4] It also boosts male libido and helps with a variety of male sexual issues. In ancient times, jackfruit seed powder was frequently used to treat wounds and illnesses, and it is highly valued for its strong antibacterial properties.[5]

Despite being regarded as edible, jackfruit seeds are rarely used in large-scale food production, with the exception of certain Asian households that roast them for consumption. Because of their perishable nature, these seeds are frequently thrown away as waste, but if kept in a cool, damp place, they can be kept for up to a month. To increase the nutritional content and prolong the shelf life of a variety of products, roasted seeds can be ground into a powder and added. Jackfruit seed powder can be used as a flour substitute in baking and confections by combining it with wheat flour and other inexpensive flours. The nutritional benefits and consumer acceptance of food products made with jackfruit seed flour have been the subject of numerous studies.

A thin layer of brown endosperm covers the fleshy white cotyledon, which is encased in a white aril that envelops the seed. The edible portions of jackfruit are the bulbs that encase the seed, which can weigh up to 45 kg.[6] Each jackfruit typically contains between 100 and 500 seeds, which make up around 18 to 25 percent of the total weight of the fruit.[7] According to research, jackfruit seeds contain a variety of antioxidant peptides that could be used as preservatives or dietary supplements in protein-rich food systems.[8] When evaluated for its emulsifying performance, protein isolates made from jackfruit seeds showed a higher emulsifying index value in neutral conditions.[9,10] Supercritically extracted jackfruit extracts demonstrated antifungal qualities, whereas extracts derived from low-pressure methods displayed photoprotective effects.[11] These characteristics could be used for developing natural products for the food, pharmaceutical, and cosmetic industries. With the exception of sucrose and maltose, jackfruit seed flour contains a variety of compounds, such as inositol, sorbitol, glucose, fructose, sucrose, maltose, and raffinose, all of which become more concentrated as the fruit ages or matures.[12,13] Polypeptides with a molecular weight of 17–26 kDa make up the majority of the proteins found in jackfruit seeds. Their main secondary structures are β-sheet and random coil configurations.[14] Jackfruit seed proteins could serve as beneficial and nutrient-dense food additives, as evidenced by the notable foaming and emulsifying properties of jackfruit seed protein isolates and their fractions.

Morphological Characteristics

The seeds are rounded, light brown, measuring 2–3 cm (0.8–1.2 in) long and 1–1.5 cm (0.4–0.6 in) wide, and they are surrounded by a delicate, whitish membrane. Each fruit can contain as many as 500 seeds. These seeds are recalcitrant and can be kept for up to a month in cool, humid environments. Around ten to fifteen percent of a jackfruit's overall weight is made up

of seeds. These seeds are contained within the fruit's pulp and are located inside a white aril. This aril encompasses a soft brown seed coat, which in turn houses the fleshy, white cotyledon.[15]

- Shape: Jackfruit seeds tend to be oval or elongated, although there are some variations.
- Size: Their length usually ranges from 2 to 4 cm.
- Color: The outer layer of the seed is a light brown hue.
- Texture: The surface feels smooth.[16]

Fig. No. 01: Jackfruit seed.

Bioactive compounds and mineral composition

It is widely accepted that by-products of fruits are valuable sources of bioactive compounds and can be utilized to develop various value-added products. In addition to lowering oxidative stress, inflammation, and the risk of metabolic disorders, bioactive compounds are known to aid in controlling calorie consumption and may have therapeutic benefits. Consuming foods high in bioactive substances, such as vitamins and phenolic compounds (including flavonoids) with antioxidant qualities, has been shown in numerous epidemiological studies to help prevent a number of diseases, including diabetes, cancer, heart disease, and stroke.[17]

The seeds of jackfruit are rich in fibre, starch, and protein, with approximately 55% moisture content, making them valuable sources of starch and protein. Jacalin, a type of lectin found in these seeds, accounts for about 50% of the fruit's protein and may negatively impact on the digestive tract. Additionally, jackfruit is a significant source of several minerals, such as zinc, phosphorus, copper, calcium, sulfur, nitrogen, magnesium, and potassium. Amines, amides, and amino acids make up the seeds' proteins, whereas polysaccharides and lipids make up their carbohydrate content. Flavonoids are suggested by the presence of aromatic compounds,

and sulfur and its derivatives are implicated in the seeds' antimicrobial qualities. The soft and hard parts of the jackfruit seed contain 92.8% and 94.5% starch and 2.49% crude fiber, respectively. Crucially, jackfruit seeds are a significant source of thiamine and riboflavin, two B vitamins essential for energy metabolism and overall health. Additionally, they provide a good amount of fiber and resistant starch, which travels through the digestive system, undigested, and thus being able to supply nutrients for beneficial gut flora. The seeds contain around 76.1% carbohydrates, while their protein levels usually range from 5.3% to 6.8%. Researchers have endeavored to extract a compound from jackfruit seeds to explore a novel and valuable protein source with emulsifying characteristics. The seeds have a lot of soluble protein, which is known to help with mental stress and anxiety. People know that protein isolates from jackfruit seeds can help keep food fresh. Jackfruit is abundant in Vitamins, especially vitamin C.

Moreover, it is a distinctive fruit with a significant amount of B-complex vitamins, including noteworthy levels of riboflavin, folic acid, niacin, and pyridoxine. The seeds contain minerals such as sulfur, potassium, copper, magnesium, phosphorus, zinc, calcium, and nitrogen. They are recognized for having a substantial amount of dietary fiber. Due to the high dietary fiber content, they contribute to the prevention of cardiovascular diseases and lower mortality rates. The fiber content is approximately 3.19%. The fatty acids present include linoleic and linolenic acids.[18]

Table no 01: Nutritional Composition- Jackfruit seed.

Nutrient	Content
Carbohydrate	76.1%
Moisture	50%
Proteins	5.3-6.8%
Fibre	3.19%
Ash	3.14%
Crude Fibre	2.49%
Fat	0.70%

The seeds of jackfruit contain key minerals including magnesium, potassium, phosphorus, calcium, sodium, iron, copper, zinc, and manganese. The seeds are also a rich source of riboflavin (vitamin B2). Fresh seeds possess a significant level of ascorbic acid, a high quantity of phenolic compounds, and exhibit antioxidant activity, which accounts for approximately 70 percent of the total antioxidant effect. Jackfruit seeds are made up of sulfur and its derivatives, which contribute to their antimicrobial properties. For promoting healthy

hair growth, jackfruit seeds are extremely beneficial, in addition to supporting healthy blood circulation and digestion. They contain a high level of starch, while being low in calcium and iron, and serve as a rich source of vitamin B2. These seeds contribute to bone health due to their high magnesium content, which is a crucial mineral required for calcium absorption, working in conjunction with calcium to strengthen bones and help prevent conditions such as Osteoporosis.[19]

The jackfruit seed contains two varieties of lectins, one of which is jacalin; this lectin aids in preventing the herpes simplex virus type two and enhances the immune status of individuals infected with human immunodeficiency virus-1 (HIV- Ⅰ). Jacalin is also used for isolating glycoproteins from human plasma, studying IgA nephropathy, analyzing O-linked glycoproteins, and detecting tumors. Many researchers have recognized jackfruit seeds as a promising functional ingredient because they are packed with phytonutrients. The seeds contain a significant amount of saponins, accounting 6.32 g for every 100 g of seeds. Various antioxidant tests, such as free radical scavenging and metal chelation, have shown that jackfruit seeds have strong antioxidant properties. This can be attributed to their moderate levels of phytochemicals. A study examining various extracts of jackfruit seeds revealed elevated levels of phenolic compounds and flavonoids, correlating with significant antioxidant capabilities. These results suggest that jackfruit seed extract has potential applications as a valuable plant-based product in pharmaceuticals and weight functional medicines. Given its high flavonoid content (ranging from 0.86 to 4.05) and notable reducing potential (ranging from 9.56 to 13.12). Benefits of jackfruit seeds include reducing cholesterol, helping to relieve constipation, preventing cancer, and managing weight.

Table No. 02: Phytochemical Composition- Jackfruit seeds.

S.L. No	Test	Inference
1.	Alkaloids	8.85±0.08 mg/100g
2.	Tannins	0.06±0.01 mg/100g
3.	Saponins	6.32 mg/100 g
4.	Flavonoids	2.03 ±0.06 mg/100g
5.	Phenolic Acids	4.52 ± 0.01 mg GAE/g
6.	Phytic Acid	8.11 ±0.06 mg/100g
7.	Oxalate	5.53 ±0.06 mg/100g

Bioactive substances like polyphenols, tannins, flavonoids, ferulic acid, gallic acid, and caffeic acid are present in jackfruit seeds. Various extraction techniques can be employed to obtain these compounds. Gupta et al. utilized a solvent extraction method using acetone for

isolating bioactive components, while Islam et al. implemented enzymes and pressurized hot water extraction. Conversely, Tramontin et al. recommended the use of a Soxhlet extraction method. Additionally, Gupta et al. documented the isolation of rutin from jackfruit seeds applying a dichloromethane: methanol (1:1) extraction technique.

Jackfruit seeds are rich in several amino acids, including arginine, leucine, histidine, cystine, lysine, methionine, threonine, and tryptophan, which are essential for our diet, as illustrated in Fig. 2. Research by Chowdhury et al. indicates that extracting protein from jackfruit seeds enhances protein quality by boosting the levels of crucial amino acids. Amino acids play a significant role in enhancing the nutritional value of food, making their presence very important. The amino acid profiles of three varieties of seeds dried, acidified, and fermented—were analyzed, with acidified seeds showing the highest levels of both essential and non-essential amino acids. Among the essential amino acids found in jackfruit seeds are lysine (7.0µmol/g), isoleucine (6.1µmol/g), leucine (12.3µmol/g), valine (12.5µmol/g), threonine (8.1 µmol/g), along with non-essential amino acids such as aspartic acid (10.3µmol/g), serine (9.2µmol/g), glycine (10.3µmol/g), and tyrosine (8.4 µmol/g). Amaechi and Ngozi compared the levels of essential and non-essential amino acids in boiled and raw jackfruit seeds. Essential amino acids rise while non-essential amino acids fall when the amino acids from the seeds are ground into flour.[20]

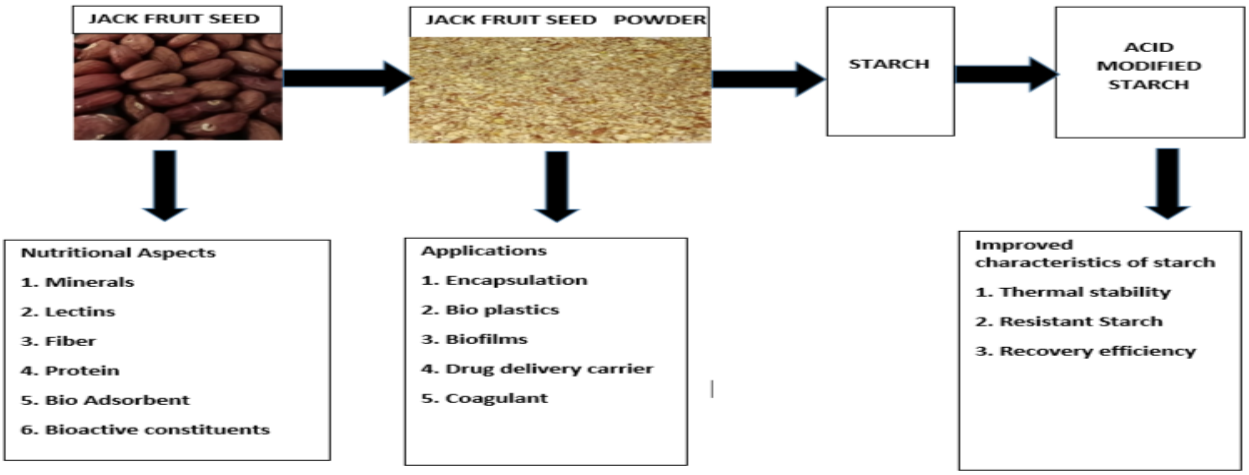

Fig.No.02: Schematic representation of nutritional, applications of Jackfruit seed.

Anti-nutritional Properties of Jackfruit seeds

Antinutritional compounds are natural substances found in food that may inhibit the absorption or utilization of nutrients, which critically affects gastrointestinal functions and metabolic processes. Anti-nutrients are chemicals found in plants that inhibit the body's ability to utilize nutrients. A number of antinutrients, such as hydrogen cyanide, alkaloids, flavonoids, oxalate, phytic acid and tannin are present in jackfruit seeds. According to research, roasting jackfruit seeds as a food processing technique greatly reduces the anti-nutrient levels in the seeds, increasing the nutrient bioavailability. As a result, when incorporated into people's diets, roasted jackfruit seeds can be a useful nutritional supplement. To find the best processing techniques that can maximize nutrient preservation and reduce anti-nutrient levels, more research on jackfruit seeds is advised.[21]

Health benefits of Jackfruit seeds

Although jackfruit seeds are usually considered waste, they are known to have many health benefits that can help treat a variety of ailments. Studies revealed the antibacterial properties of jackfruit seed nanoparticles against E. coli and B. megaterium, demonstrating these nanoparticles' potential as potent antibacterial agents.[22] Jackfruit seed nanoparticles have been shown to have an antibacterial effect on their host material based on studies on their specific surface area (SSA). As a result, jackfruit seeds may be transformed into medicinal substances that can treat infectious illnesses and stop foodborne infections. It may be possible to turn jackfruit seeds into multifunctional food items with antimicrobial properties. Because of their remarkable fiber content, these seeds help lower the chances of heart disease, prevent constipation, and may help in weight loss; they also provide a good amount of B-complex vitamins. These seeds are well known in China for their ability to lessen the negative effects of alcohol, and in India, they are an essential component of an antidote for heavy drinkers.. Incorporating jackfruit seed flour into fried foods can lower fat absorption up to a certain level. When jackfruit seed flour and starch are used, secondary metabolites called jacalin are produced. These metabolites have anti-inflammatory and anti-new blood vessel-forming properties. The substantial fiber content of jackfruit (3.6 g/100 g) supports digestion and facilitates regular bowel movements.[23] Furthermore, it safeguards the colon's mucous membrane by eliminating carcinogenic substances from the large intestine.[24]

Brain

• Prevent and treat mental stress and nervousness

• Promote circulation to keep the brain strong

Skin

• Healthy skin, hair, and eyes: Thiamine and Riboflavin

• Stimulate hair growth

• Keeps skin hydrated, smooth, and glowing

Thyroid

• Copper: Promotes thyroid metabolism, hormone production, and absorption

Heart

• Lowers risk of heart disease

Lungs

• Prevent asthma and respiratory disorders

• Prevent lung and oral cavity cancer

Liver

• Decrease LDL

• Prevents formation of plaque in arteries

• Prevents blockage of arteries

• Lowers risk of high cholesterol

Stomach

• Good protein source

• Muscle building

Intestines

• Insoluble fiber: Prevents constipation and indigestion

• Low water and fat absorption: Prevents obesity

• Used in treatment of diarrhea and dysentery

• Low in calories and fat: Manages weight

Colon

• Lowers toxin effects in the colon

• Protects the body from colon cancer cells

Pancreas

• Magnesium: Maintains sugar levels by regulating insulin

• Improves blood sugar control as it contains resistant starch

Kidneys

• Maintains electrolyte balance

Blood

• Flavonoids: Limit the risk of blood clots

• Antihypertensive

• Potassium: Maintains proper blood pressure

Cells

• Antioxidant activity: Prevents damage to cells from free radicals

• DPPH and ABTS scavenging activity

• Prevents wrinkles and delays aging

• Anti-aging

• Anticancer activity: Saponins

Bones

• Iron and copper: Increases red blood cell production

• Prevents anemia

• Calcium: Strengthens bones and prevents osteoporosis

Other Benefits

• Metal ion chelating activity

• Thickening and binding agent

• Reducing potential

• Bulk density

• Gelling agent

• Least gelatinization

• Foaming capacity and stability

• Emulsification

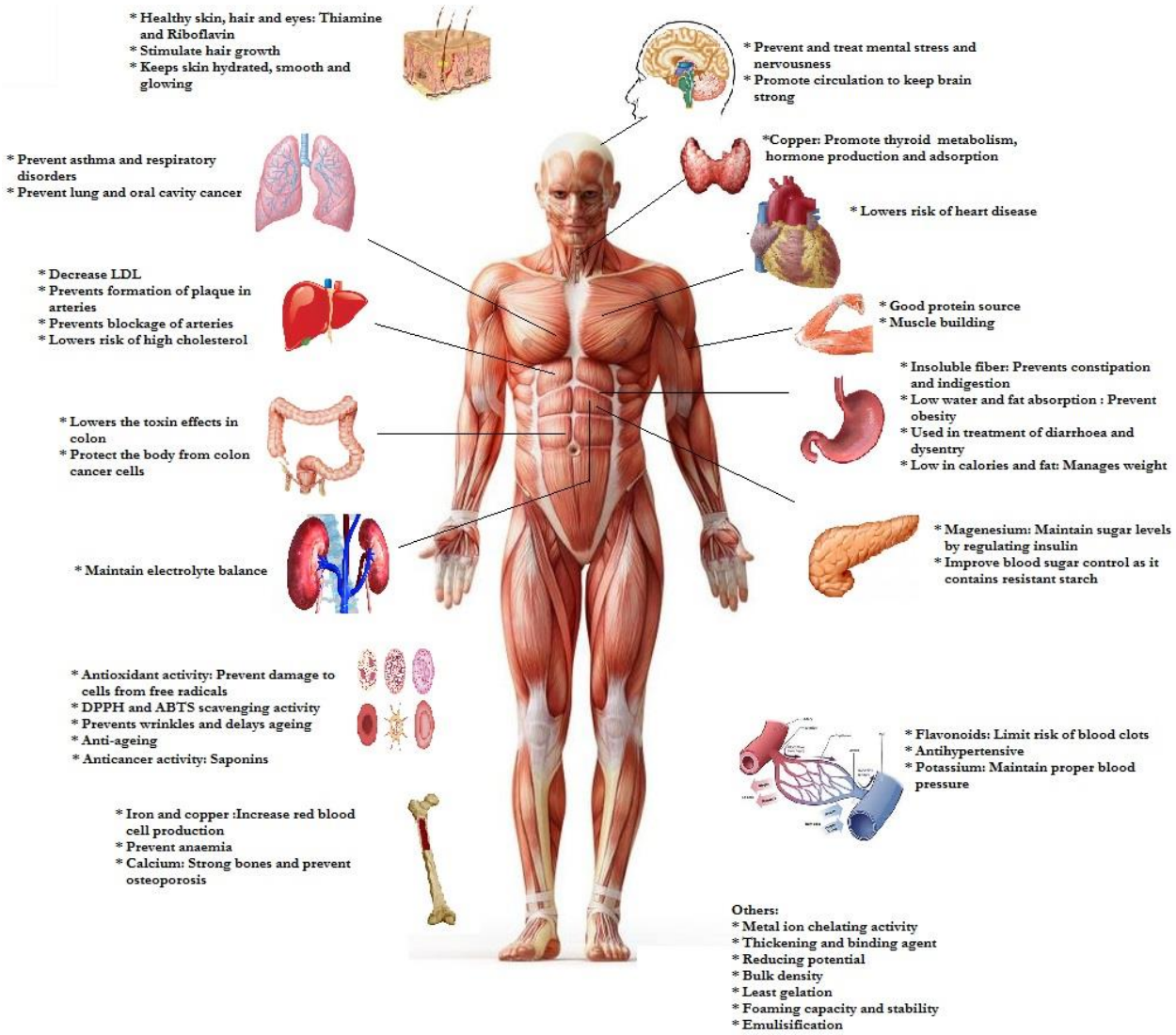

Fig. No. 03: Schematic representation of Health benefits of Jackfruit seed.

CONCLUSION

Jackfruit seeds, often regarded as agricultural waste, are in fact a rich source of nutrients, bioactive compounds, and functional properties that hold significant potential for food, pharmaceutical, and cosmetic industries. They are an underutilized but extremely valuable resource for creating functional foods and nutraceuticals because of their composition, which is high in proteins, carbohydrates, dietary fiber, essential amino acids, and vital minerals. Additionally, the seeds exhibit exceptional antimicrobial, antioxidant, and therapeutic qualities that help prevent and treat lifestyle-related illnesses like diabetes, heart disease, and digestive problems. Large-scale use of jackfruit seeds is still restricted despite their nutritional and functional potential because of issues like perishability, the existence of antinutritional factors, and a lack of processing technologies. In order to incorporate jackfruit seed flour, starch, and protein isolates into conventional food systems, future research should

concentrate on minimizing antinutritional compounds, improving processing techniques to increase nutrient bioavailability, and investigating novel product formulations. All things considered, jackfruit seeds offer a fantastic chance to lower food waste, enhance health outcomes, and encourage sustainable food innovation.

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