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The jackfruit renaissance: A holistic review of value addition, processing and global market potential

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Abstract
The jackfruit (*Artocarpus heterophyllus*), a particular member of the Moraceae family, is abundantly found in Asia's tropical and subtropical regions. It is a versatile tropical fruit renowned for its nutritional richness-including high fiber, vitamins, minerals and antioxidants-and unique physio-chemical properties such as high moisture content, natural sweetness and fibrous texture. Despite its large size, sticky latex and high perishability, jackfruit presents significant opportunities for value addition, which aims to enhance shelf life, diversify products, improve marketability and increase profitability for farmers and entrepreneurs. Value-added products-including chips, pickles, ready-to-cook packs, vegan meat alternatives and nutraceuticals-can significantly enhance profitability while reducing post-harvest losses. Global market trends indicate rising demand for plant-based, gluten-free and functional foods, with increasing export potential to Europe, North America and the Middle East. This article integrates physio-chemical characterization, economic analysis, market trends, processing methods, marketing strategies, export potential and research projects, highlighting jackfruit as a nutritionally rich, economically viable and globally promising fruit for the modern food industry.

Keywords: Jackfruit, *Artocarpus heterophyllus*, Value addition, post-harvest processing, Plant-based foods, Nutraceuticals, Export potential, GI tagging

1. Introduction
Jackfruit (*Artocarpus heterophyllus*), a tropical fruit native to South and Southeast Asia, is often referred to as a "poor man's fruit." India is the second biggest producer of the fruit in the world and is considered as the motherland of jackfruit. In India, it has a wide distribution in Assam, Tripura, Bihar, Uttar Pradesh, the foothills of the Himalayas and the south Indian states of Kerala, Tamil Nadu and Karnataka, as well as most rural areas of other states and warm countries. Jackfruit plays a significant role in Indian agriculture; it was cultivated in India 3,000-6,000 years ago.
The potential to transform jackfruit from a seasonal crop into an economically viable product year-round has sparked interest in value addition processes. In recent years, jackfruit has gained attention for its role in food security, as it can be processed into a variety of value-added products that not only contribute to nutritional needs but also offer economic opportunities, especially for rural women. This review explores the role of jackfruit in promoting food security in rural areas, focusing on the fruit's nutritional benefits, its importance in ensuring a stable food supply and the critical role of value addition in transforming jackfruit into products that can empower rural women economically. It can be intercropped with other staple crops, providing farmers with an additional source of income and food security. It is known for its large size, sweet aroma and distinctive flavor, as well as its high nutritional value.

2. Concept Of Value Addition
In simple terms, value addition means increasing the value of a raw product through processing, packaging, branding, or improving quality so that it can fetch a higher price in the market. In agriculture, value addition transforms a low-cost raw commodity into a high-value product; instead of selling produce in bulk at low prices, farmers and entrepreneurs can earn more by processing and marketing in improved forms. For example, raw jackfruit has a

limited shelf life and market demand, but when processed into chips, flour, or canned products, its market value increases significantly.

2.1 Objectives of Value Addition

1. Increase farmers' income - products fetch higher prices compared to raw fruit.
2. Reduce post-harvest losses - processing helps prevent spoilage and wastage.
3. Extend shelf life - converting fresh fruits into chips or flour increases storage life.
4. Create employment opportunities - processing activities generate jobs.
5. Improve consumer convenience.
6. Enhance export potential - proper packaging and processing improve quality and marketability in international markets.

3. Nutritional Benefits of Jackfruit

Artocarpus heterophyllus is a highly nutritious tropical fruit valued for its rich composition of carbohydrates, vitamins, minerals and dietary fiber. Jackfruit is a good source of Vitamin C, which boosts immunity and acts as an antioxidant to protect cells from damage and Vitamin A, which promotes healthy vision and supports skin health. Jackfruit seeds are rich in protein, starch and micronutrients. The fruit is gluten-free and, when used as flour, is suitable for people with gluten intolerance. It is high in dietary fiber, which aids digestion, prevents constipation and supports gut health.

Jackfruit contains phytonutrients-lignans, isoflavones and saponins-that have wide-ranging health benefits, including anticancer, antihypertensive, antiulcer and anti-aging properties (Soobrattee *et al*., 2005) [27]. A portion of 100 g jackfruit pulp provides 4 mg niacin; the recommended daily amount is 16 mg for males and 14 mg for females (Institute of Medicine, 2000). The fruit contains many carotenoids (Faria *et al*., 2009) [9], including β-carotene, an important antioxidant for human health (Cadenas and Packer, 1996). It is also one of the rare fruits rich in B-complex vitamins, including Vitamin B-6 (pyridoxine), niacin, riboflavin and folic acid. Kumar *et al*. (2021) [17] reported that dried jackfruit seeds contain carbohydrate (76.1%), protein (17.8%) and lipid (2.1%).

4. Pharmaceuticals and Beauty Aids

Starch and protein found in jackfruit seeds can be used in pharmaceuticals. Jackfruit seed starch serves as a super-disintegrant in the production of fast-acting tablets that dissolve in the mouth without the need for water. Jackfruit latex may be useful for treating dental problems because of its high resin content. Bioactive compounds in jackfruit help reduce inflammatory markers, benefiting conditions such as arthritis, inflammatory bowel disease and chronic inflammatory conditions.

Jackfruit is also emerging as a natural ingredient source for skincare and haircare. Its rich antioxidants and vitamins make it useful in anti-aging creams, brightening serums and UV protection boosters. Vitamin C and carotenoids support collagen synthesis and skin elasticity, while antimicrobial and astringent properties support spot treatments. Jackfruit peel pectin, when used to make bio-nanocomposite materials for bone healing, has demonstrated better antimicrobial properties (Ranasinghe *et al*., 2019) [24]. Pathak *et al*. reviewed the therapeutic use of biopolymeric materials for disease treatment. Extracts from the pulp and leaves can be formulated into lotions and moisturizers; natural polysaccharides help retain skin hydration.

5. Jackfruit - Parts and Their Uses (Zero-Waste Fruit Crop)

The jackfruit consists of several parts, each having different uses. The fruit bulbs (pulp) are the yellow, fleshy edible portions, commonly consumed fresh or processed into jam, jelly, candy, squash, ice cream and fruit leather. The seeds, present inside the bulbs, are rich in starch and protein and can be boiled or roasted as snacks, or processed into flour for bakery products and traditional sweets. The rind (peel) is the thick outer covering and is mainly used as animal feed. The core, the central axis of the fruit that holds the bulbs together, is utilized as cattle feed or organic manure (Gupta, 2021) [10]. Proper utilization of all fruit parts helps reduce waste and supports value addition in jackfruit processing.

6. Physio-Chemical Properties of Jackfruit

6.1 Raw (Tender) Jackfruit Pulp

The physical and chemical properties of raw jackfruit pulp are summarized in Table 1 below. These parameters are critical for designing appropriate processing protocols and value-added products.

Table 1: Physical and Chemical Properties of Raw Jackfruit Pulp

Parameter	Typical Range	Significance
Moisture content (%)	72 - 78	Affects shelf life
pH	5.2 - 6.0	Slightly acidic
Total soluble solids (Brix)	8 - 12	Sugar level indicator
Ascorbic acid (mg/100 g)	5 - 10	Nutritional and health importance
Crude protein (%)	1.5 - 2.5	Nutritional value
Crude fiber (%)	2 - 4	Digestive health
Total carbohydrates (%)	18 - 25	Energy source
Vitamin C (mg/100 g)	7 - 12	Antioxidant
Ash content (%)	0.8 - 1.5	Mineral content
Starch (%)	10 - 15	Energy
Reducing sugars (%)	2 - 5	Sweetness

7. Types of Value-Added Jackfruit Products

7.1 Products from Raw (Tender) Jackfruit

Jackfruit Chips

Chips are prepared from raw (unripe) jackfruit. Mature, unripe jackfruits are selected, cut and the bulbs removed. Seeds are discarded and bulbs sliced into thin pieces. The slices are blanched in hot water at 95 °C for 5 minutes, dried at 60 °C for 1 hour followed by 70 °C for 6 hours, then deep-fried in hot oil at 170-180 °C until crisp and golden. After draining excess oil, the chips are seasoned with salt, pepper and chili powder (Bhuyan *et al*., 2013) [7] and packed in airtight, moisture-proof pouches. Jackfruit chips are rich in Vitamin E, γ-oryzanol and phytosterols, which provide health and nutritional benefits.

Jackfruit Pickle

Unripe jackfruits are used for preparing pickle. Firm, undamaged fruits are cut into small pieces with seeds removed if required, boiled in salted water for 5-10 minutes (Sultana, 2019) [29], drained, then mixed with oil, salt and spices before packing.

Canned Tender Jackfruit
Firm, unripe jackfruit free from blemishes is selected. Edible oil is applied to hands and knife to reduce sticky latex. The outer rind is removed, bulbs separated, seeds discarded and pieces washed in clean water. Pieces are blanched briefly to inactivate enzymes and maintain texture and color, placed into sterilized cans, covered with brine or salted water, sealed airtight and autoclaved to ensure long shelf life.

Jackfruit Flour
Processing begins with selection of mature, healthy fruits, followed by washing, peeling and removal of bulbs and seeds. Bulbs are sliced thinly; to prevent enzymatic browning, slices may be treated with a mild salt solution or blanching. The slices are dried at 50-60 °C until moisture content falls below 10% (Kumari *et al*., 2024) [18]. Dried slices are pulverized and sieved to obtain fine flour, then packed in moisture-proof, airtight packaging.

Ready-to-Cook (RTC) Jackfruit Products
Processing involves converting fresh produce into partially processed, convenient food items requiring minimal preparation. Firm, disease-free fruits are washed, peeled, cut into uniform pieces and briefly blanched. The material is cooled, drained and treated with mild salt solution, preservatives, or spices as appropriate. Vacuum packaging, modified atmosphere packaging (MAP), or quick freezing are applied to extend shelf life (Srivastava and Singh, 2020) [28]. Common RTC products include peeled and cut raw jackfruit cubes, vacuum-packed tender jackfruit chunks, jackfruit curry base mix, marinated jackfruit pieces, jackfruit biryani mix and jackfruit flour-based instant dosa/roti mix.

Jackfruit Papad
Jackfruit papads of different taste and flavor were standardized by Ukkuru and Pandey (2005). Mature, unripe jackfruit is washed, cut and bulbs separated. The bulbs are boiled or steamed until soft, mashed into a smooth paste, spiced for flavor, spread in thin circular layers on sheets and sun-dried until completely crisp. After drying, the papads are peeled off, packed in moisture-proof covers and stored.

Vegan/Vegetarian Meat Alternatives
Raw (unripe) jackfruit is widely used as a plant-based meat substitute because of its fibrous, meat-like texture. Mature raw jackfruit is washed, peeled, cut and pressure-cooked or boiled until soft. The cooked flesh is shredded and sautéed with oil, spices and seasonings such as soya sauce and chili sauce. The mixture is used for burgers, tacos and curries, or made into kebabs, nuggets, or packed as ready-to-eat plant-based meat alternatives.

7.2 Products from Ripe Jackfruit
Jackfruit Jam
Ripe jackfruit bulbs are cleaned, deseeded and pulped into a smooth puree. The pulp is cooked with sugar and citric acid or lemon juice, stirring continuously until jam consistency is reached (about 68-70°Brix). Pectin may be added if needed for proper setting. The hot jam is filled into sterilized bottles, sealed, cooled and stored (Bhuyan *et al*., 2013) [7].

Jackfruit Jelly
Ripe jackfruit pulp is crushed, mixed with water, heated and filtered through muslin cloth to extract clear juice. The juice is cooked with sugar and citric acid; pectin is added if required. The mixture is boiled until it reaches jelly stage (about 65-68°Brix), poured into sterilized glass bottles, sealed and stored (Ahiduzzaman *et al*., 2024) [1].

Jackfruit Squash
Ripe jackfruit bulbs are cleaned, deseeded and pulped to extract juice. The juice is filtered, mixed with prepared sugar syrup and citric acid added to adjust acidity. A permitted preservative (e.g., sodium benzoate) may be added to increase shelf life (Jagadeesh *et al*., 2006) [14]. The squash is filled into sterilized bottles, sealed and stored.

Jackfruit Candy
Ripe jackfruit bulbs are cleaned, deseeded, cut into uniform pieces and briefly blanched. They are soaked in concentrated sugar syrup with gradually increasing concentration over 2-3 days to allow proper sugar absorption. After sufficient impregnation, pieces are drained and dried until firm and non-sticky (Jagadeesh *et al*., 2006) [14], then packed in moisture-proof containers.

Jackfruit Ice Cream
Ripe jackfruit bulbs are cleaned, deseeded and blended into smooth pulp. Milk, cream and sugar are mixed and gently heated until the sugar dissolves, then cooled. Jackfruit pulp is added to the cooled mixture and churned in an ice cream maker or frozen with intermittent stirring to prevent ice crystal formation. The finished product is packed and stored at freezing temperature.

Jackfruit Wine
Ripe jackfruit bulbs are cleaned, deseeded and crushed to extract juice. The juice is filtered, sugar adjusted to 20-24°Brix and wine yeast (Saccharomyces cerevisiae) added. Fermentation is carried out at room temperature for 7-14 days. After fermentation, the wine is filtered or siphoned to remove sediments, aged for several weeks to improve flavor and bottled in sterilized containers.

Jackfruit Vinegar
Ripe jackfruit juice is first subjected to alcoholic fermentation using Saccharomyces cerevisiae for 7-10 days to produce wine. The alcoholic liquid is then exposed to air and inoculated with acetic acid bacteria (Acetobacter species) for acetic fermentation over 2-4 weeks. After complete transformation (about 4-8% acetic acid), the vinegar is filtered, pasteurized if needed, bottled and stored.

Jackfruit Leather
Ripe jackfruit bulbs are cleaned, deseeded and blended into smooth pulp. Sugar and a small amount of citric acid or lemon juice may be added (Islam *et al*., 2021). The pulp is spread in thin, uniform layers on greased trays and sun-dried or dehydrated at 50-60 °C until dry, flexible and non-sticky (Thomas and Dharmapalan). The leather is then peeled off, cut into strips or rolls and packed in moisture-proof packaging.

Jackfruit Muffins: Ripe jackfruit bulbs are cleaned, deseeded and blended into smooth pulp. Dry ingredients

(wheat flour, baking powder and salt) are mixed separately. Sugar, butter or oil, milk and jackfruit pulp are blended, then the dry mixture is gradually added to form a smooth batter. The batter is poured into greased muffin molds and baked at 180 °C for 18-25 minutes until golden brown.

7.3 Products from Jackfruit Seeds

Jackfruit Seed Flour

Mature seeds are washed and boiled or pressure-cooked to soften the outer coat. The brown seed coat is removed and kernels sliced into small pieces. Pieces are dried at 55-60 °C until completely dry, ground into fine powder, sieved (Airani, 2007) [3] and packed in airtight containers. Addition of 25% jackfruit seed flour has been found to be nutritionally superior to whole wheat bread owing to higher fat, protein and crude fiber content (Hossain *et al*., 2014) [12]. Addition of 5% jackfruit seed flour to chapatis increased overall protein content by 11%.

Roasted Jackfruit Seeds

Seeds are washed and boiled for 15-20 minutes, then roasted in a pan or oven until the outer layer becomes dry and slightly crispy. Roasted seeds are peeled and consumed as a nutritious snack.

Jackfruit Seed Halwa

Boiled and peeled seeds are ground into smooth paste. The paste is cooked with sugar and ghee on a low flame with continuous stirring until it thickens and leaves the sides of the pan. Flavoring agents such as cardamom may be added before cooling and cutting into pieces.

8. Processing Techniques for Value Addition

Jackfruit is a highly perishable tropical fruit and efficient processing techniques are essential to reduce post-harvest losses and enhance market value. Various traditional and modern processing methods are used to convert raw fruit, ripe bulbs and seeds into diversified value-added products.

Blanching

Blanching is a preliminary heat treatment given to jackfruit pieces before further processing such as drying, freezing, or canning. Cleaned and cut pieces are immersed in hot water (80-100 °C) or exposed to steam for 2-5 minutes to inactivate browning enzymes and reduce surface microorganisms (Babu and Sudheer, 2012) [5].

Drying and Dehydration

Jackfruit bulbs or slices are sun-dried or mechanically dried at controlled temperatures (50-60 °C) to reduce moisture content. This method is used to produce chips, flour, candy and fruit leather, extending shelf life and improving storage stability.

Freezing

Cleaned bulbs are packed in airtight containers and stored at −18 °C. This method retains flavor, color and nutrients for extended periods and supports export potential (Shamsudin *et al*., 2009) [25].

Canning and Bottling

Mature ripe bulbs are cleaned, deseeded, graded and filled into sterilized cans or glass bottles. Sugar syrup of suitable concentration is poured over the fruit, containers are sealed, processed, cooled, labeled and stored in a cool, dry place. This technique extends shelf life for several months while maintaining flavor and quality.

Vacuum Frying

Thin slices of raw jackfruit are placed in a vacuum fryer and fried at low pressure and temperature (about 80-120°C). The reduced pressure allows water to evaporate at lower temperatures, helping retain natural color, flavor and nutrients. Excess oil is removed using a centrifuge inside the vacuum system (Pathak *et al*., 2022) [22].

Spray Drying

Fresh jackfruit pulp is filtered, mixed with a carrier agent such as maltodextrin and fed into a spray dryer where it is atomized into tiny droplets and exposed to hot air (around 150-180 °C inlet temperature). The resulting fine dry powder has good solubility, flavor retention and a longer shelf life. It is widely used in beverages, baby foods, bakery products and instant mixes.

High Pressure Processing (HPP)

Packaged products are subjected to pressures of 400-600 MPa for a few minutes inside a pressure chamber filled with water. High pressure inactivates harmful microorganisms and enzymes without the use of high temperature. After treatment, the product is stored under refrigeration (Pathak *et al*., 2022) [22]. HPP maintains fresh-like quality and is suitable for premium and export markets.

Osmotic Dehydration

Fresh jackfruit bulbs are immersed in concentrated sugar syrup (50-70°Brix) or salt solution, which creates osmotic pressure that draws water out of the fruit tissues while allowing some solutes to enter. This partial removal of moisture reduces water activity, improves shelf life and helps retain natural color, flavor and nutrients. It reduces drying time and energy consumption while producing high-quality intermediate moisture products such as jackfruit candy, sweetened dried slices and ready-to-eat snacks (Rahman *et al*., 2012) [23].

9. Global Market Trends (USA and Europe)

Growing Demand for Plant-Based and Sustainable Foods

Jackfruit has become a key ingredient in plant-based diets due to its fibrous, meat-like texture and nutritional profile, appealing to vegans, vegetarians, flexitarians and health-focused consumers in both the USA and Europe. This trend is boosting demand for value-added products such as jackfruit meat alternatives, ready-to-eat meals and processed foods.

Market Expansion and Growth Projections

North America (primarily the USA) is one of the fastest-growing markets for jackfruit products, driven by increasing vegan and vegetarian populations and strong distribution networks through supermarkets, health food stores and online retail. The global jackfruit products market is projected to grow from approximately USD 1.17 billion in 2025 to over USD 2.07 billion by 2035, with the USA exhibiting strong growth (~6.3% CAGR) through that period.

Diverse Formats Gaining Traction

USA and European consumers are adopting a range of value-added products, including canned jackfruit (shelf-stable and convenient), frozen jackfruit pieces for home cooking, IQF (Individually Quick-Frozen) for food service and retail and jackfruit powder for baking and functional ingredient applications.

Steady Market Growth Across Europe

The European jackfruit market is expanding significantly, with projections showing continued growth in value-added products such as canned, frozen and processed jackfruit for culinary and meat alternative uses. Forecasts suggest the market will grow at a moderate to strong CAGR through 2030+, driven by plant-based demand and sustainability trends. Countries leading adoption include Germany (largest share of jackfruit product demand, strong processing infrastructure, consumer interest in plant proteins), the United Kingdom (high acceptance of vegan foods and use in meat alternatives), France (culinary innovation driving jackfruit product offerings) and the Netherlands (significant trade hub and distribution channels for imported jackfruit).

Table 2: Global Market Trends in India, USA and Europe (2018-2030)

Year	India / Asia-Pacific (USD M)	USA / North America (USD M)	Europe (USD M)
2018	150	22	70
2019	160	25	71
2020	175	29	71.5
2021	190	34	72
2022	205	38	72
2023	220	42	72
2024	223	47-54	42-72
2025 (est.)	240	55-60	75
2030* (proj.)	300+	85+	82+

* Projected values. Source: Compiled from market research reports and industry analyses.

10. Export and GI Potential of Jackfruit

Artocarpus heterophyllus has significant export and Geographical Indication (GI) potential due to its unique regional varieties, nutritional value and increasing global demand for plant-based foods.

Region-Specific Varieties with GI Potential

1. Kerala - known for high-quality jackfruit varieties; declared jackfruit as state fruit.
2. Karnataka - coastal and Malnad regions produce premium varieties.
3. Tamil Nadu - known for specific traditional jackfruit types.

Jackfruit has significant export potential due to its high nutritional value, versatility and increasing global demand for plant-based foods. Countries such as India, Bangladesh, Thailand and Vietnam are major producers and exporters of jackfruit to international markets including the USA, EU and UK. India exports jackfruit in various forms including fresh fruit, frozen pulp, canned jackfruit, dehydrated chips, jackfruit flour and ready-to-cook products (Gunasena *et al*.). In India, the Sindhura Jackfruit from Tumakuru district of Karnataka received GI status in 2019, known for its distinctive reddish-orange flakes, strong aroma, sweetness and soft texture. Sindhudurg and Ratnagiri Jackfruit from Maharashtra and Panruti Jackfruit (2025) from Cuddalore district, Tamil Nadu have received GI recognition for their distinctive taste, aroma and quality. GI tagging helps increase market value, export recognition and consumer trust while also promoting regional farmers and traditional cultivation practices.

Export Enabling Agencies

1. Agricultural and Processed Food Products Export Development Authority (APEDA): the primary agency promoting export of fruits and processed food products including jackfruit; provides infrastructure support, quality certification, market promotion, training and export facilitation.
2. Ministry of Food Processing Industries (MOFPI): encourages value-added jackfruit products such as chips, flour, pulp and ready-to-cook items through processing and export support schemes.
3. National Horticulture Mission (NHM): promotes cultivation, productivity improvement and supply chain development for horticultural crops including jackfruit.
4. National Horticulture Board (NHB): supports post-harvest management, cold storage and processing infrastructure.
5. Food Safety and Standards Authority of India (FSSAI): establishes food safety standards and certification required for exporting processed jackfruit products.

Table 3: Government Schemes Supporting Value Addition of Jackfruit

Sl. No.	Scheme	Implementing Agency	Support Provided
1	Pradhan Mantri Formalization of Micro Food Processing Enterprises (PM-FME)	Ministry of Food Processing Industries	Promotes micro food processing units under One District One Product (ODOP). Provides 35% credit-linked subsidy (up to ₹10 lakh) for processing units producing jackfruit chips, flour, jam and other products.
2	One District One Product Scheme (ODOP)	Ministry of Food Processing Industries	Identifies region-specific crops such as jackfruit to develop processing clusters, branding and marketing of value-added products.
3	Mission for Integrated Development of Horticulture (MIDH)	Ministry of Agriculture and Farmers Welfare	Supports cultivation, post-harvest management, pack houses and processing infrastructure for horticultural crops including jackfruit.
4	Agriculture and Processed Foods Export Promotion Scheme	Agricultural and Processed Food Products Export Development Authority (APEDA)	Provides financial assistance for pack houses, cold storage, grading, processing facilities and export promotion of fruit products such as processed jackfruit.
5	Operation Greens Scheme	Ministry of Food Processing Industries	Supports processing, storage and transport infrastructure for perishable crops and promotes value-added processing to reduce post-harvest losses.

11. Varietal Improvement of Jackfruit

The basic understanding of existing clones is an essential prerequisite for further improvement in jackfruit. Some trees produce sweet aromatic fruits; others are nearly dry and sour. Better selection and vegetative propagation of clones is practicable and efforts should be made to extend the fruiting season. Although little work has been done on rootstock and scion compatibility, evidence so far indicates wide variability in scion performance with different rootstocks.

Traditionally, jackfruit cultivation has relied on seedling trees, which show large variability in fruit size, pulp quality, sweetness and yield (Chikkanna, 2021) [8]. Therefore, the development and promotion of improved varieties through selection, hybridization and vegetative propagation are essential for commercial production. Breeding programs focus on traits such as high pulp recovery, low latex content, firm and attractive bulbs, uniform fruit size, early bearing and resistance to pests and diseases.

12. Post-Harvest Handling, Processing and Product Development

Proper post-harvest management of jackfruit is essential to maintain fruit quality, reduce losses and facilitate the development of value-added products. There is a high degree of wastage because seasonal production causes gluts in the market and low prices. A major constraint is the lack of accessible practical information, particularly on post-harvest handling and processing.

After harvesting at the appropriate maturity stage, fruits should be carefully handled to avoid mechanical damage and latex contamination. Both ripe and raw jackfruit can be processed using techniques such as blanching, dehydration, vacuum frying, canning, freezing and fermentation (Maheshwari and Valsan). Raw jackfruit is commonly processed into ready-to-cook products, canned vegetables and pickles, while ripe jackfruit bulbs are used for the preparation of jams, jellies, nectar and desserts.

Overall, improved post-harvest handling, efficient processing technologies and innovative product development can significantly enhance the economic potential and global demand for jackfruit products (Bala *et al*., 2022) [6]. Key recommendations include: developing appropriate processing and packaging methods for local and regional markets; maintaining hygiene and food safety standards during processing; promoting jackfruit-based products through branding and awareness campaigns; and making greater efforts in processing, value addition and product development.

13. Applications of Jackfruit Bioproducts

Lignocellulosic biomass from jackfruit represents one of the major renewable and cost-effective resources for bioproduct development. Valorization is an environmentally friendly and sustainable approach in which waste biomass is recycled or converted into valuable products.

13.1 Bio-oil / Fuels

Jackfruit peel waste can be used to produce bio-oil via pyrolysis in a fixed-bed reactor (Soetardji *et al*.). A high number of volatile compounds were found in the peel after pyrolysis at 400-700 °C, suggesting the biomass is a good resource for bio-oil production. At 550 °C, when the organic content was 85.2% and water content was 14.8%, biofuel quality was found to be optimal. The produced bio-oil, containing only trace amounts of sulfur (0.03%) and nitrogen (0.61%), can be used as a substitute for fossil fuels in boilers, furnaces and power generation systems after suitable upgrading.

13.2 Bioplastics

The use of plastics developed from carbohydrate-rich biomass can be an eco-friendly option compared to synthetic plastic. Kahar *et al*. (2019) [16] reported that plastic from jackfruit seed starch has thermal stability as well as desirable tensile properties. Lubis *et al*. (2018) [20] investigated bioplastics made of jackfruit seed starch plasticized with glycerol. Cellulose extraction from jackfruit peel and rind offers another approach, where cellulose fibers are blended with biodegradable polymers to form bioplastic materials with improved strength and flexibility.

13.3 Animal Feed

The jackfruit peel is highly recommended as a valuable raw material for animal feed due to its high levels of carbohydrate, protein and fiber. Jackfruit waste supplementation improves feed intake and digestibility in ruminants (Ajay, 2013) [4]. Fermentation using a combination of yeast and lactic acid bacteria supplemented with 2% ammonium sulfate yielded the highest crude protein and fiber content (Munishamanna *et al*., 2020) [21]. According to Kusmartono *et al*. (2002) [19], jackfruit waste including peel and axis has great potential as ruminant feed.

13.4 Jackfruit Waste as Adsorbent

Jackfruit peel has been investigated for remediation of dyes from aquatic environments (Hameed, 2008; Jayarajan *et al*., 2011) [11, 15]. Hameed investigated jackfruit peel for methylene blue dye removal, reporting an adsorption efficiency of 285.713 mg/g. Ahmed and Nasar (2021) [2] confirmed the fruit peel as a low-cost, promising adsorbent for removing methylene blue from aqueous solutions. Activated carbon derived from jackfruit peel can also adsorb heavy metals such as lead, cadmium and chromium from industrial wastewater, as well as organic dyes and toxic compounds from textile and chemical industries.

14. Challenges and Solutions

Challenges

Value addition of jackfruit faces several challenges. Major constraints include the large fruit size and high latex content, which make harvesting, cutting and processing difficult and labor-intensive. The fruit also has a short shelf life and high perishability, leading to significant post-harvest losses during peak production seasons (Bala *et al*., 2022) [6]. In many jackfruit-growing regions, there is a lack of modern processing facilities, cold storage infrastructure and efficient supply chains, which restricts the development of diversified value-added products. Limited awareness among farmers and entrepreneurs about processing technologies and market opportunities further reduces the adoption of value addition practices. Seasonal availability, inadequate standardization, poor marketing, weak branding and limited export infrastructure collectively hinder global market expansion.

Solutions

Improved post-harvest management practices such as proper harvesting methods, grading, hygienic handling and efficient packaging can significantly reduce post-harvest losses. The establishment of cold storage facilities, refrigerated transportation and integrated supply chains can extend shelf life and ensure a steady supply of raw materials. Adoption of modern processing technologies such as vacuum frying, spray drying, freeze drying and high-pressure processing can facilitate the development of diverse value-added products.

Encouraging small- and medium-scale processing units in jackfruit-growing regions can promote rural entrepreneurship and generate employment. Training programs and extension services can improve awareness about processing techniques, product development, quality control and market opportunities. Research efforts should focus on developing improved jackfruit varieties with better pulp quality, uniform size and longer shelf life. Efficient marketing strategies, branding and promotion of GI-tagged varieties can enhance domestic and international demand. Furthermore, adopting waste valorization technologies to convert jackfruit peel, core and seeds into useful products can improve sustainability and profitability in the jackfruit value chain.

15. Future Scope of Jackfruit Value Addition

The future scope of jackfruit value addition represents a transformative opportunity to revolutionize the global agri-food sector by evolving from a seasonal fruit into a versatile, year-round commodity through comprehensive circular economy practices. While the fruit is currently gaining traction as a plant-based meat alternative, the true economic potential lies in maximizing the utility of every component: the seeds can be milled into nutrient-dense, gluten-free flour; the fibrous rind can be converted into pectin, eco-friendly packaging, or crispy snacks; and the core can be fermented into vinegar or utilized for biofuel production, effectively eliminating post-harvest waste (Pathak *et al*., 2022) [22].

As advancements in cold-chain logistics, preservation technology and standardized quality protocols continue to mature, jackfruit is poised to penetrate high-value international markets with shelf-stable products ranging from dehydrated chips and ready-to-eat meals to nutraceutical supplements and cosmetic extracts. Government support, entrepreneurship development and promotion of GI-tagged varieties can increase export potential and international market recognition. Integrating technological innovations, sustainable processing practices and market-driven product development will play a crucial role in unlocking the full potential of jackfruit value addition in the future.

16. Real-World Impact

16.1 The Kerala Jackfruit Mission (Government Policy Success)

In Kerala, India, the state government launched the "Jackfruit Mission" to address massive post-harvest waste and low farmer income. Previously, farmers sold raw jackfruit at throwaway prices of ₹2-5 per kilogram during peak season, leading to tons of fruit being discarded. The government responded by providing subsidies for processing units and training farmers to create value-added products such as chips, pickles and flour. This initiative successfully established over 1,000 new processing units across the state, driving the price of raw fruit up to ₹15-20 per kilogram and increasing income by an estimated 30-50%. Before the mission, nearly 30-40% of Kerala's 320 million jackfruits went to waste annually. Recent reports indicate that local processing and industrial demand have reduced this to less than 10% in some clusters.

16.2 The "Jackfruit Meat" Startup (Bangalore, India) - Innovation Success

In Bangalore, Karnataka, a startup known as "The Jackfruit Company" has successfully positioned jackfruit as a sustainable meat alternative. Launched around December 2020, the company began processing young, unripe jackfruit to mimic the texture of pulled pork. They developed ready-to-cook, marinated products now stocked in major online grocery platforms and select supermarkets. The venture has secured venture capital funding and begun exporting to the Middle East and Europe, demonstrating that jackfruit can command high-value prices in the international vegan market.

16.3 The Thai Fruit Chip Exporter (Thailand) - Processing Success

In Thailand, a leading fruit processing unit invested in vacuum frying technology to produce high-quality, crunchy jackfruit chips. Fresh jackfruit spoils within three days, but this innovation extended the shelf life of the product to 12 months while preserving natural color and texture. The resulting products are exported to high-value international markets including Japan, Germany and the USA. The facility employs over 50 local workers for sorting, peeling and packaging, demonstrating how processing technology can turn a highly perishable crop into a stable, high-value export commodity. The company now exports to more than 30 countries.

16.4 Waste-to-Energy Project (Brazil) - Sustainability Success

Brazil has increasingly adopted waste-to-energy (WtE) technologies as a sustainable solution for managing municipal solid waste while generating renewable energy. These projects convert organic and solid waste into electricity, biogas, or biomethane, helping reduce landfill use, greenhouse gas emissions and environmental pollution. One notable initiative is the Energy Recovery Power Plant being developed in Barueri (São Paulo region). WtE projects in Brazil create employment in waste collection, plant operation and technology development while improving waste-management infrastructure in densely populated regions. These initiatives illustrate a successful sustainability model integrating waste management, renewable energy production and environmental protection.

16.5 Jackfruit Flour Export Success (Karnataka and Kerala)

The commercial success of jackfruit flour in India is anchored in the 2018 launch of the Kerala State Horticulture Mission's "Jackfruit Mission," which pioneered standardized processing units in Wayanad and Idukki. By 2021, this model was replicated in Karnataka's Chikkaballapur district, where Farmer Producer Organizations (FPOs) adopted solar drying technology to ensure the flour met international

moisture and quality standards. This strategic value addition has unlocked lucrative markets in Germany, the UK and the USA, where the flour is marketed as a premium gluten-free and low-glycemic alternative to wheat.

The economic impact is profound: through contract farming models, farmers now receive guaranteed buy-back prices that are 10-20 times higher than the traditional mandi rate for raw green jackfruit. Furthermore, processing units are predominantly managed by women's Self-Help Groups, which has not only reduced post-harvest waste by nearly 40% but also empowered rural women with technical skills and financial independence, solidifying jackfruit flour as a cornerstone of India's sustainable agricultural export strategy.

17. Conclusion

In conclusion, the journey of jackfruit from a perishable local fruit to a globally recognized superfood exemplifies the transformative power of agricultural value addition. By integrating scientific insights into its nutritional, pharmaceutical and physio-chemical properties with advanced processing techniques, India is successfully converting post-harvest waste into high-value economic assets. The robust market demand in the USA and Europe, coupled with the strategic advantage of GI tags and favorable cost-benefit analyses, validates jackfruit as a cornerstone of export-led agricultural growth. While challenges in supply chain and technology persist, the synergy of government schemes, varietal improvements and innovative product development offers a clear roadmap for sustainability.

As the sector moves towards innovative product development and sustainable practices, jackfruit stands poised not just as a food source, but as a catalyst for rural empowerment, food security and India's growing leadership in the global plant-based economy. Ultimately, the jackfruit value chain represents a holistic model for food security, rural empowerment and economic resilience, positioning India as a leader in the global plant-based economy. The future of this 'poor man's fruit' is not just bright, but essential for a sustainable agricultural renaissance.

Author's Declaration

Artificial Intelligence: Author(s) hereby declare that NO generative AI technologies such as large language models (ChatGPT, COPILOT etc.) and text-to-image generators have been used during writing or editing of this manuscript.

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