



RESEARCH ARTICLE

Value chain analysis of jackfruit: Production dynamics, post-harvest losses and processing opportunities in Panruti, Cuddalore District

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Abstract

Jackfruit (*Artocarpus heterophyllus* Lam.) is a nutritionally rich and economically important tropical fruit crop that plays a vital role in supporting small and marginal farmers. This study focuses on the production trends, cultivation practices, post-harvest challenges and value addition opportunities of jackfruit in the Panruti region of Cuddalore District, Tamil Nadu. Primary data were collected from 120 farmers using a structured interview schedule, along with secondary data were collected from official sources. The results indicate that jackfruit cultivation has expanded over time; however, fluctuations in production and productivity are observed due to climatic variations, pest issues and inconsistent farm management practices. Panruti remains the dominant cultivation hub due to its favourable agro-climatic conditions and recognised fruit quality. Despite its potential, farmers face several challenges, including mechanical damage during harvesting, high perishability, lack of storage facilities, high transportation costs and price fluctuations. The socio-economic analysis reveals that most farmers are smallholders with limited adoption of improved varieties and modern technologies. Most farmers market jackfruit in fresh form with minimal value addition, limiting income generation. The study highlights value addition as a key solution to enhance profitability and reduce post-harvest losses. Products such as jackfruit leather and jackfruit-based noodles show high economic viability, while freeze-dried products have potential in premium markets. Overall, improving post-harvest infrastructure, promoting value addition and strengthening market linkages can significantly enhance farmer income and support sustainable agricultural development.

Keywords: agro processing; jackfruit cultivation; Panruti; post-harvest losses; socio-economic analysis; value-added products

Introduction

Jackfruit (*Artocarpus heterophyllus* Lam.), an important tropical fruit crop in the Moraceae family, possessing significant nutritional, economic and ecological value. The plant is endemic to the Western Ghats region in India and has been cultivated in South and Southeast Asia. Its ability to thrive in humid tropical climates has led to its cultivation in countries like Bangladesh, India, Sri Lanka and Thailand. Its ease of growth, low maintenance requirements and perennial nature make it important to the sustainability of small and marginal farmers (1).

Jackfruit is known to be the world's largest tree-borne fruit, with individual fruits weighing up to 50 kg. A productive lifespan of 40–60 years ensures its viability and sustainable fruit tree. Its low maintenance requirements and suitability for rain-fed conditions make jackfruit well-suited to agroforestry systems, where it provides shade, supports soil conservation by reducing erosion and promotes farm diversification, thereby enhancing overall system

sustainability (2).

The versatility of jackfruit is one of its special characteristics. The fruit is employed in its unripe and ripe forms for a range of uses. Although the ripe bulbs are consumed raw or processed into food products like jam, jelly, nectar and sweets, the unripe fruit is frequently employed as a vegetable in conventional food products. Additionally, the seeds of jackfruit are employed in their roasted form or processed as flour products like baked goods due to their high protein and carbohydrate content. The waste-free potential of the crop is exemplified by the reality that even the peel and waste pieces can be employed as compost and feed (3).

Nutritional studies indicate that jackfruit is rich in dietary fibre, carbohydrates, vitamins A and C and essential minerals like calcium, magnesium and potassium (4). Moreover, it is rich in bioactive compounds with antioxidant properties, which have been shown to have positive health effects, like flavonoids, carotenoids and phenolic compounds. These properties have generated

consumer interest in the product, considering the trend towards plant-based diets and health awareness (4).

Jackfruit as a meat substitute, as well as its use in the processed food industry, has captured the interest of countries across the world. The market for products made of jackfruit, like ready-to-cook curries, frozen bulbs, flour, as well as dried products, has increased with the growing demand for plant-based as well as vegan foods. Value addition through processing increases profitability, which in turn has contributed to the growth of the global market for jackfruit products. These trends indicate significant opportunities for emerging countries such as India (5). India is the largest producer of jackfruit in the world. With an estimated size of 150–160 thousand hectares and an output of 1.4–1.5 million metric tons, India produces the largest quantity of jackfruit. However, owing to poor post-harvest practices, lack of structured agricultural practices and absence of processing facilities, the potential of this crop is yet to be harnessed. Unlike other crops that are grown on plantations, jackfruit is mostly grown on homesteads and in mixed cropping systems, which hinders the productivity and integration of the crop (6, 7).

Because of the suitable climatic conditions for growing jackfruit plants, Tamil Nadu is one of the prominent states in India that cultivates large quantities of jackfruit. The cultivation of jackfruit is well recognised in districts such as Cuddalore, Dindigul, Pudukkottai and Kanyakumari. Among these districts, the "Panruti" area in the Cuddalore District is now recognised as a prominent area in the production and supply of high-grade jackfruit. Due to the unique characteristics of the soil and the suitable agro-climatic conditions that help in enhancing the quality, fragrance and taste of the fruits, the area is sometimes referred to as the "jackfruit belt."

There are various challenges facing Jackfruit growth in the Cuddalore region despite the potential for yield. The absence of scientific procedures for harvesting is one of the main challenges. Inappropriate harvesting techniques result in mechanical damage to the fruit, latex exudation and rapid decay due to the large size of the fruit. All these factors contribute to reduced marketable yield for farmers due to large post-harvest losses (1).

The absence of appropriate transportation and storage infrastructure is another important constraint. Jackfruit requires proper handling and storage to maintain quality because it has a limited shelf life, especially in tropical countries. Nevertheless, most farmers cannot access appropriate supply chain infrastructure. As a result of this, some farmers may be forced to sell their products at very low prices soon after harvesting their crops, mainly at a discounted price during the peak season. The price that farmers receive is further reduced due to price variations and the involvement of middlemen.

Furthermore, farmers lack sufficient awareness and motivation regarding techniques of value addition. This is because, despite the vast opportunities available for processing the fruits into various products such as chips, flour, papad and dried products, most of the fruits are sold at the fresh fruit stage. This reduces the efficiency of the entire value chain. This limits the scope of the entire value chain to attain greater efficiency. The use of value addition techniques is hindered by a lack of skills, financial constraints and poor linkages with markets (8).

The main factor that will enhance the economic sustainability of jackfruit farming is value addition. Value addition will enable farmers to increase the shelf life of their products and reduce

post-harvest losses through processing of raw jackfruits into processed products. Value addition will also enable farmers to respond to the changing demands of consumers regarding ready-to-eat foods. Furthermore, value addition of jackfruits will promote the development of agro-based industries that will provide employment opportunities in rural areas (9).

Global scenario of jackfruit

The nutritional value, versatility and increasing interest in plant-based foods have positioned jackfruit as an emerging tropical commodity the global marketplace. In tropical and subtropical regions, particularly in South and Southeast Asian countries, jackfruit cultivation is common. In recent years, jackfruit has gained popularity worldwide as an environment-friendly food product and an excellent substitute for meat in vegetarian and vegan diets.

In recent times, the jackfruit market has been rising steadily on a global level. The market is expected to rise at a compound annual growth rate (CAGR) of about 3.5 % between 2025 and 2034, from its current value of 543.1 million US dollars in 2024 to 781.8 million US dollars in 2034. Moreover, it is also expected that the market for processed jackfruit products, which includes canned, frozen, flour-based and ready-to-cook products, will also grow at a higher rate. With a CAGR of about 5.9 %, it is expected to grow from about 1.17 billion US dollars in 2025 to about 2.08 billion US dollars in 2035. The main reason behind the rise in the jackfruit market is the rise in food processing industries, awareness of the health benefits of jackfruit and the increase in the demand for convenient food products (10).

India is the world's top producer of jackfruit, followed by Bangladesh, Thailand, Indonesia and Nepal. Table 1 shows the output levels of the major jackfruit-producing regions.

Indian scenario of jackfruit

India is the world's largest producer of jackfruit, contributing a substantial proportion to world production. The tropical and subtropical areas of the country, like Kerala, Tamil Nadu, Karnataka, West Bengal, Assam and Odisha, are where this crop is cultivated on

Table 1. Major jackfruit producing countries in the world

Rank	Country	Production ('000 tonnes)
1	India	1436
2	Bangladesh	926
3	Thailand	392
4	Indonesia	340
5	Nepal	18.97

a large scale. Jackfruit cultivation in India is predominantly practiced in homesteads, small farms and mixed cropping systems.

An estimated 150–160 thousand hectares were under jackfruit cultivation in India during 2023–24. The yield would be 1.4–1.5 million metric tons annually. This crop is a cost-effective option for small and marginal farmers. This crop is mainly rain-fed and requires fewer inputs. However, owing to differences in soil characteristics, management practices and climatic conditions, the levels of production vary considerably across states (6, 11).

The awareness of the nutritional value and potential of jackfruit as a cash crop is reflected in an increase in production as well as area under cultivation over the years. From the graphical representation given above (Fig. 1). The findings suggest that despite minor fluctuations in some years, there has been an overall increasing trend in the production as well as area under jackfruit

cultivation. This has been due to the expansion of market opportunities for value-added products as well as the growing demand for jackfruit.

Fig. 2 illustrates the state-wise distribution of the area under jackfruit farming in India, covering the years 2022–23 and 2023–24. The extent of agriculture differs considerably across states (12).

In India, the highest area is in the state of Kerala, which had an area of 92.18 thousand hectares in 2023–24, while in 2022–23, the area under cultivation was 89.66 thousand hectares. This shows a constant increase in the area under cultivation, thus proving that Kerala is the state where the highest area of jackfruit is produced (13). The next highest area is in the state of Assam, which has shown a slight fall in the area under cultivation, from 22.59 thousand hectares in 2022–23 to 21.26 thousand hectares in 2023–24 (13).

Jharkhand and Odisha are also contributing to the cultivation of jackfruit, with relatively stable areas over the last two

years. The area under jackfruit cultivation in Jharkhand is 15.59 thousand hectares in 2023–24, while in Odisha, the area is 13.81 thousand hectares. Similarly, in West Bengal, the area under jackfruit cultivation is relatively stable, with around 13.5 thousand hectares being cultivated.

States such as Chhattisgarh and Madhya Pradesh display moderate levels of cultivation. Madhya Pradesh also recorded significant growth in the cultivated area. It increased from 7.58 thousand hectares in 2022–23 to 8.28 thousand hectares in 2023–24. Tripura recorded a stable cultivated area of about 5.8 thousand hectares (12).

Even though Tamil Nadu was a major jackfruit producer, it had a lesser area under cultivation compared to other states. In 2023–24, Tamil Nadu had 3.42 thousand hectares under jackfruit cultivation, which was slightly less than 3.59 thousand hectares in 2022–23. This suggests that jackfruit cultivation in Tamil Nadu was not as widespread as in other states but was more region-specific to

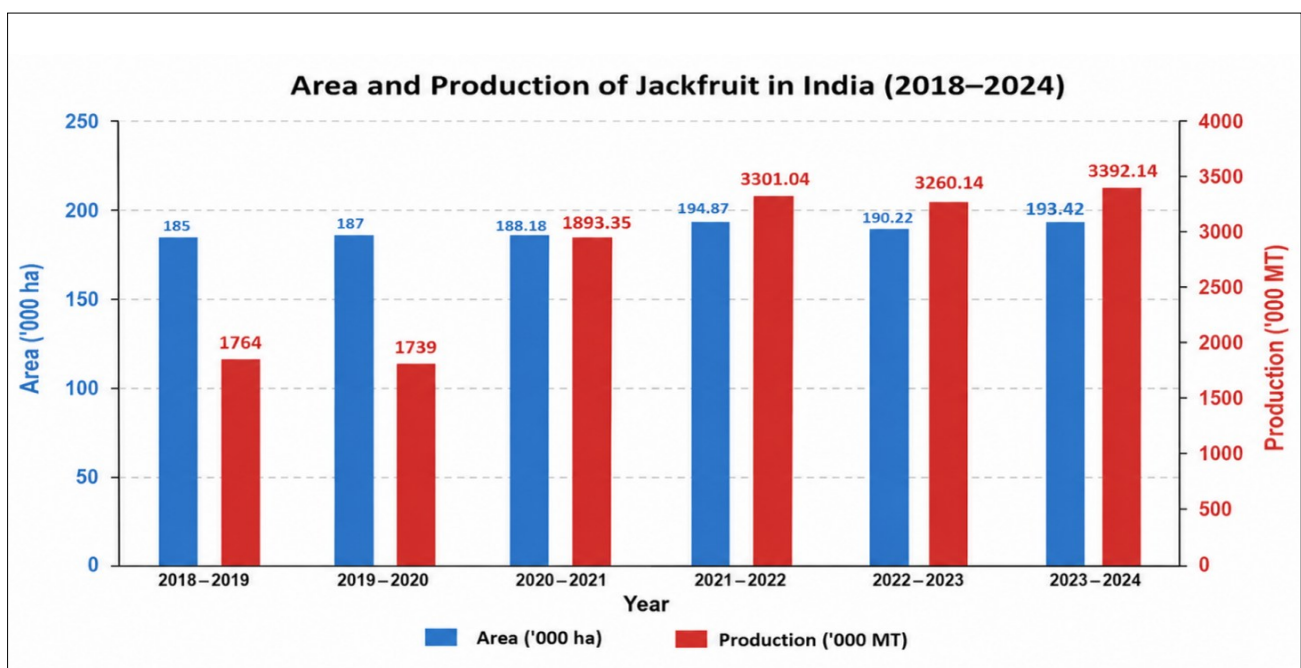


Fig. 1. Area and production of jackfruit in India (2018–2024).

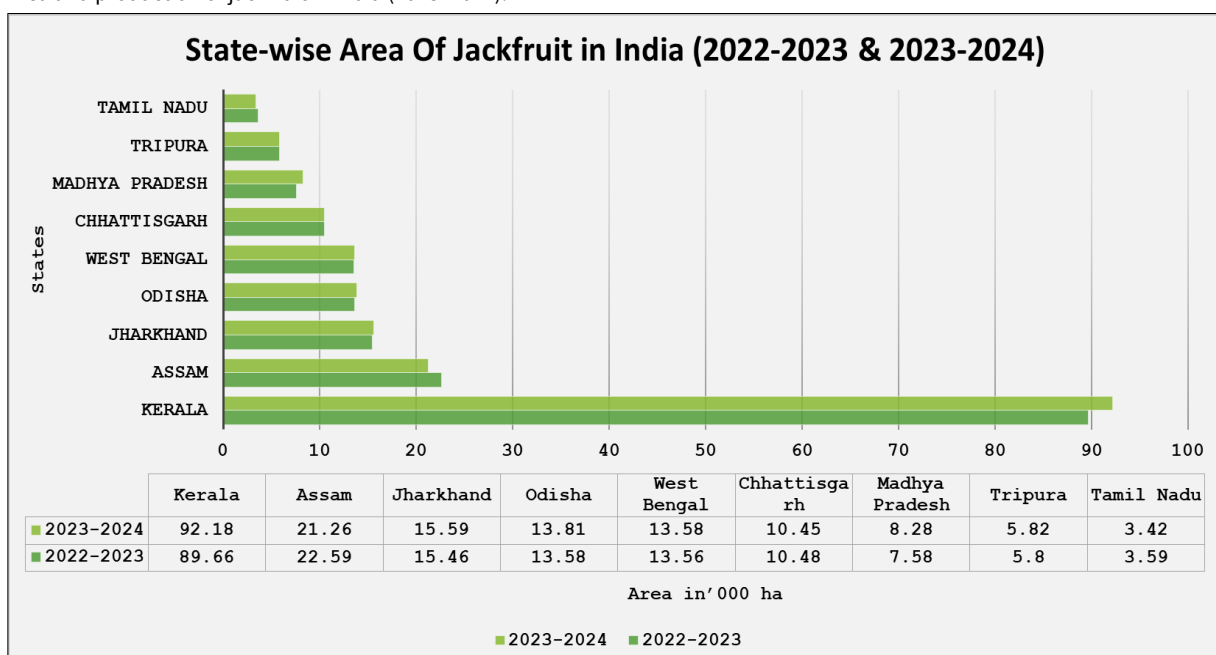


Fig. 2. State-wise area of jackfruit in India (2022–23 and 2023–24).

certain regions, like Cuddalore in Tamil Nadu (12).

Considering all these factors, it may be concluded that, according to the data, the states that are engaged in the production of jackfruit are limited to Kerala and Assam. The need to address the region-specific requirements to boost the growth of jackfruit farming can be gauged from the fact that while there are states that are experiencing a slight increase, there are states that are experiencing a slight decline or stability.

The recent state-wise output of jackfruit in India is presented in Fig. 3. Because of differences in agro-climatic suitability, cultivation practices adopted and land availability under cultivation, it can be seen from the figures that there is a very unequal distribution of productivity among states (14).

Out of all the states in India, Kerala cultivates the maximum quantity of jackfruit. The large area of land in Kerala under jackfruit cultivation, traditional practices in growing the crop and the favourable climatic conditions all add up to the much larger quantity produced in Kerala when compared to other states. This confirms that Kerala leads jackfruit production in India (14).

Although it is producing much less in comparison to Kerala, Assam is the second-highest producer in the country. Due to the favourable environmental conditions, the state continues to contribute to the total production scenario in terms of jackfruit cultivation. West Bengal, Jharkhand and Odisha are the next in the list, contributing moderate levels of production with relatively stable trends over time (14).

The states that have almost low output levels are Madhya Pradesh, Tripura and Chhattisgarh. However, some of these states are showing slow development, which indicates that there is scope for development with proper management of resources.

Although Tamil Nadu is famous for growing excellent quality jackfruit varieties, its contribution to the total jackfruit production in the country is relatively low. The low cultivated area in Tamil Nadu, which is mainly in certain regions like Cuddalore District, is the major reason for this. However, Tamil Nadu possesses huge potential to enhance its production with better supply chain management and

value addition (14).

Tamil Nadu scenario of jackfruit

Due to its favourable agro-climatic conditions, Tamil Nadu is a major jackfruit-producing state in India. The cultivation of jackfruit in Tamil Nadu covers an area of 3445 ha as of 2025. This indicates the importance of jackfruit in horticulture in the region. Tamil Nadu has a long history of jackfruit cultivation and holds significant economic and cultural importance. The fact that jackfruit has been recognised as the state fruit underscores its socio-economic importance in the region (14).

Panruti in Cuddalore District serves as the primary hub for jackfruit cultivation in the state. The region is said to be the "jackfruit paradise" due to its good yield and favourable climatic conditions. Panruti has more than 800 ha of jackfruit cultivation, which makes it the largest jackfruit-growing region in the state (15).

The special flavour, texture and pulp of jackfruit grown in Panruti can be attributed to its special soil characteristics and climate. In April 2025, jackfruit grown in Panruti was awarded the geographical indication (GI) badge in appreciation of its special qualities. It is believed that this certification would fetch jackfruit a higher market value and provide farmers more marketing opportunities (15).

However, jackfruit cultivation in Tamil Nadu is not practiced in all parts of the state but is confined to a few areas. The small land utilised in comparison to other top states like Kerala implies that there is growth potential which remains to be exploited. The economic benefits of jackfruit cultivation in Tamil Nadu can be enhanced in a major way by improving cultivation practices and strengthening market links.

The trends in area, production and productivity of jackfruit in Tamil Nadu from 2017–18 to 2023–24 are presented in Fig. 4, showing both fluctuations and an overall increasing trend.

In the year 2017–18, the agricultural land under cultivation was 3134 ha, which increased to 3285 ha in the year 2023–24. This

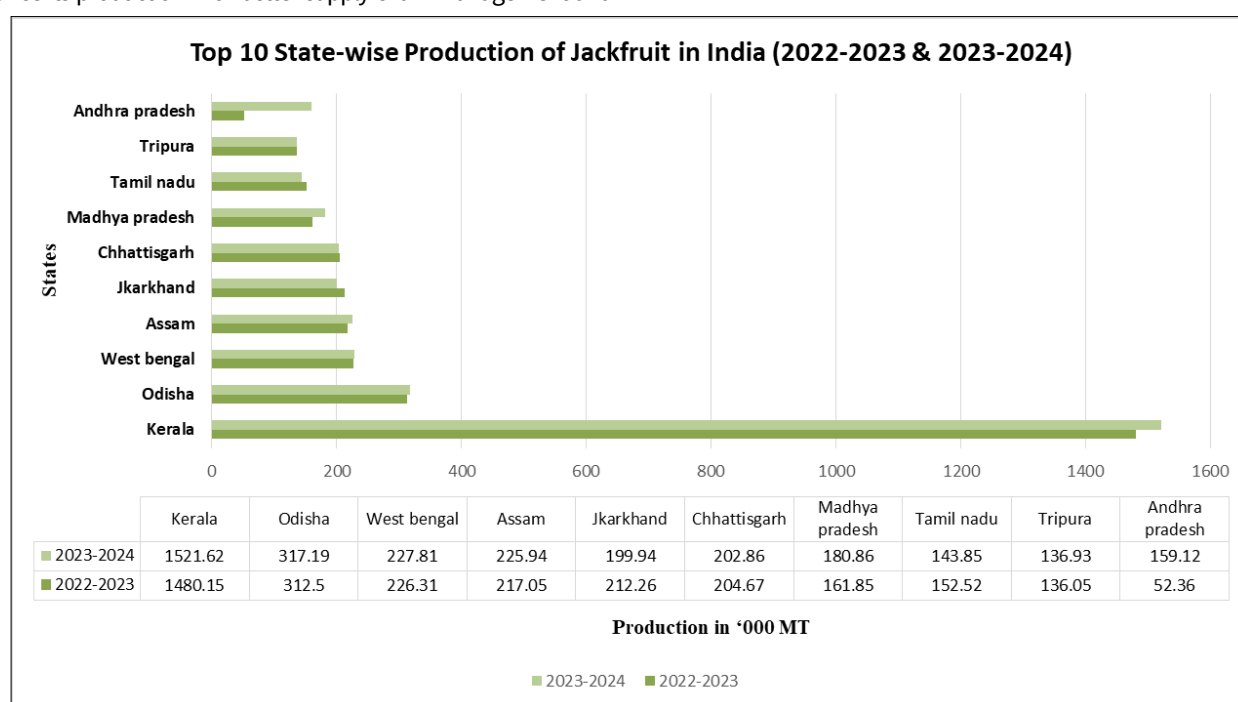


Fig. 3. Top 10 state-wise production of jackfruit in India (2022–23 and 2023–24).

shows a gradual increase in the land under cultivation, which might be due to the constraint in agricultural land development because of contrasting land use patterns and land restrictions. The same trend can be observed in a district like Cuddalore, which has limited potential for land development as most of the land is already under cultivation.

The production rose from 43562 tons in 2017–18 to 87911 tons in 2023–24. This shows an increasing trend. The production rises significantly after 2020–21, even though it declined to 50056 tons in 2019–20, possibly due to climate factors such as rainfall. This shows the resilience of the agriculture sector as well as the efficiency of improved farming practices and irrigation support.

Furthermore, productivity (kg/ha) has also shown considerable growth from 13900 kg/ha in 2017–18 to 26761 kg/ha in 2023–24. In 2019–20, a slight dip can be noticed, but in the years that follow, growth can be seen. This can be attributed to the introduction of high-yielding varieties, better cultivation practices and technology advancements. The yields are increased manifold in regions like Cuddalore due to factors like different kinds of soils and irrigation systems (16).

Despite its economic importance, limited empirical studies have comprehensively examined the integration of production dynamics, post-harvest management and value addition in region-specific jackfruit systems such as Panruti. Therefore, this study aims to bridge this gap by analysing production trends, constraints and value addition opportunities to enhance the efficiency of the jackfruit value chain.

The present study aims to analyse the current status of jackfruit production in Cuddalore district, while also assessing the socio-economic profile of farmers and identifying the key constraints associated with the harvesting, handling and processing of jackfruit. In addition, the study explores potential value addition opportunities to enhance the shelf life and market value of jackfruit.

Materials and Methods

Area of study

The major jackfruit-growing region in Panruti, located in Tamil Nadu, was selected as the study area. This region, situated in the Cuddalore

District, is widely recognised for its superior jackfruit production and regional specialisation. In recent years, it has gained further prominence due to its GI status granted in 2019 by the Geographical Indications Registry, Government of India (Panruti Jackfruit GI Registry, 2019). The distinct quality of jackfruit from this region is attributed to its favourable agro-climatic conditions, including red loamy to alluvial soils, a tropical humid climate, moderate and well-distributed rainfall and warm temperature conditions typical of the coastal belt. These environmental factors collectively contribute to the fruit's unique flavour, aroma and overall quality. The selection of this region is justified by its significant contribution to jackfruit cultivation and its strong potential for production and value addition.

Sample size and method

The respondents in the given study have been chosen by employing a technique of convenience sampling. The choice of convenience sampling was based on the accessibility of growers. To ensure proper representation of farmers engaged in the production, post-harvest processing and marketing of jackfruit, the sample size was fixed at 120 farmers.

Data collection

The study utilised both primary and secondary data sources. Primary data were collected using a structured and systematically designed interview schedule administered to the respondents. The schedule was developed to capture information on marketing channels, value addition activities, post-harvest handling practices, production techniques and socio-economic characteristics. Prior to the main survey, the interview schedule was pre-tested with a small group of respondents to ensure clarity, relevance and consistency of the questions and necessary modifications were made accordingly. This process helped to improve the reliability and validity of the instrument. Secondary data on *A. heterophyllum* data were collected from reliable sources such as FAOSTAT, government publications and Indiastat, which facilitated both national and regional-level analysis of production patterns, geographical distribution and market trends.

Analytical tools and techniques

The collected data were analysed using a combination of descriptive and exploratory statistical methods. Initially, exploratory data analysis (EDA) was carried out to understand the basic structure and

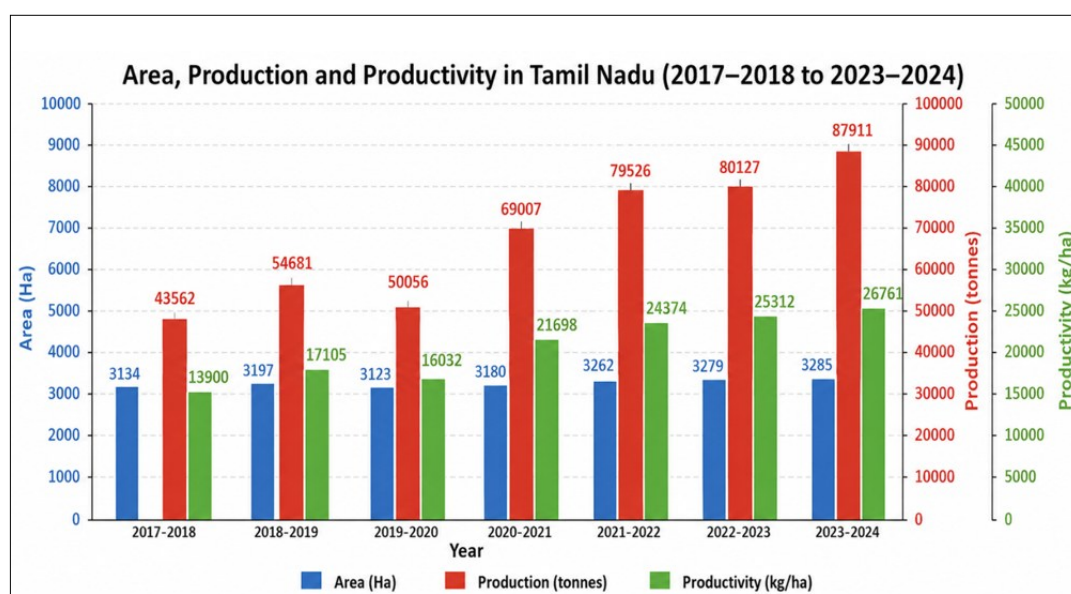


Fig. 4. Area, production and productivity in Tamil Nadu.

distribution of the data. Descriptive statistical tools such as frequency distribution, percentages and mean values were then applied to summarise and interpret the data. While these methods provide a clear overview of the study context, the analysis does not include inferential statistical techniques such as regression or correlation due to data limitations. This is recognised as a limitation of the study and future research may incorporate advanced statistical methods to enhance the robustness and generalisability of the findings.

Garrett ranking technique was employed to identify and prioritise the key limitations faced by farmers in jackfruit production, processing and value addition. This technique enables the systematic ranking of constraints by converting the ranks assigned by respondents into percentage scores, allowing accurate prioritisation based on severity. The Garrett ranking method is widely used in agricultural and social science research for prioritising constraints in a reliable and objective manner (17). Through this approach, the most critical limitations were identified based on their weighted scores.

Study period

The study was conducted between 2025 and 2026. To ensure that the results obtained would accurately reflect the status of jackfruit production, post-harvesting practices and value-adding possibilities in the study area, the study was conducted over this period.

Results and Discussion

Trend in area, production and productivity of jackfruit in Cuddalore District

As shown in Table 2, there are trends in jackfruit output, productivity and area over time in Cuddalore District from 2015–16 to 2023–24. According to the statistics, variations were observed in output, productivity and area under cultivation across the study period. However, these differences were not tested for statistical significance in the present analysis. The observed changes may be influenced by factors such as market forces, adoption of improved agricultural practices and prevailing meteorological conditions (18).

The jackfruit area under cultivation in Cuddalore District has been steadily growing over time, reaching a maximum of 1000 ha in 2022–23. However, there was a decline to 637 ha in 2023–24. The reasons for this decline were not statistically examined in the present study; therefore, no causal interpretation is made. Further investigation

is required to understand the factors influencing this variation.

Throughout the investigation period, production trends showed measurable variation. Production increased gradually throughout the period until 2019–20, when it peaked at 28641 kg. However, it then dropped drastically to 8279 kg in 2023–24. This can be attributed to fluctuations in production, which can be caused by an infestation of insects or environmental stress, among other factors. In addition, productivity also increased throughout the period with 2020–21 peaking at 36276 kg/ha. However, it then dropped drastically to 12996 kg/ha in 2023–24. The decline in production can be attributed to inefficiency in farming practices.

Block-wise area under jackfruit cultivation in Cuddalore District

The block-wise distribution of area under jackfruit cultivation in Cuddalore District for the years 2022–23 to 2024–25 is shown in Table 3. The figures indicate that there is a highly skewed distribution of jackfruit cultivation across different blocks of the district.

The figures clearly indicate that the Panruti block of the district, with a much larger area of land than the other blocks of the district, is the main hub of jackfruit cultivation in the Cuddalore District. Though there is a decline in the area under jackfruit cultivation from 837.34 ha in 2022–23 to 510.44 ha in 2023–24, the area under jackfruit cultivation in the Panruti block of the district again increased to 614.97 ha in 2024–25.

The next notable agricultural regions are the Kammapuram block and Cuddalore block. The area under agriculture in Kammapuram has been steadily growing over time. The area under jackfruit cultivation has been growing steadily from 37.42 ha during 2022–23 to 46.69 ha during 2024–25. This indicates that jackfruit agriculture is gaining popularity. Similar to this, the area under agriculture in Cuddalore block has been growing steadily over time.

The area under agriculture in Kurinjipadi block has been declining over time. The area under agriculture has been declining steadily from 42.71 ha during 2022–23 to 34.27 ha during 2024–25. This could be due to changes in cropping patterns. The Parangipettai block and Annagramam block have been steadily growing over time.

The lowest area under jackfruit cultivation was recorded in Virudhachalam. In recent years, a decline in jackfruit cultivation was noticed in this block. This implies that jackfruit cultivation is not popular in this block (18).

Village-wise area under jackfruit cultivation in Cuddalore district

Table 2. Area, production and productivity of jackfruit in Cuddalore District

Year	Area (ha)	Production (tonnes)	Productivity (kg/ha)
2015–16	669	11432	17092
2016–17	689	24012	35023
2017–18	690	25431	32870
2018–19	702	20540	26251
2019–20	715	28641	32892
2020–21	718	26034	36276
2021–22	729	16184	22168
2022–23	1000	18399	18399
2023–24	637	8279	12996

Table 3. Block-wise area under jackfruit cultivation in Cuddalore District (ha)

Block	2024–25	2023–24	2022–23
Virudhachalam	6.13	17.45	15.45
Kammapuram	46.69	39.41	37.42
Cuddalore	37.87	38.42	35.27
Kurinjipadi	34.27	40.57	42.71
Parangipettai	12.21	12.21	13.10
Annagramam	16.57	16.52	16.88
Panruti	614.97	510.44	837.34

(2024–25)

The distribution of the area under jackfruit cultivation at the village level in Cuddalore district for the year 2024–25 is shown in Table 4. From the information provided in the table, The findings suggest that there is a significant difference in the areas under jackfruit cultivation at the village level. This is due to the difference in the availability of resources, farmers' preferences and the suitability of the environment for jackfruit cultivation (18).

The findings indicate variation in the distribution of jackfruit cultivation across the study revealed. Among all the villages, the maximum area under jackfruit cultivation is recorded in Keezhmambattu village, which is 113 ha.

Kedampuliyur (46 ha), Maligampattu (44 ha) and Panikankuppam (43 ha) are some other villages that have shown relatively higher rates of jackfruit cultivation. The results indicate that these villages are important as secondary jackfruit cultivation centres. Villages such as Meliruppu (31 ha), Keelkangeyankuppam (30 ha) and Veerasingankuppam (29 ha) have shown moderate rates of jackfruit cultivation.

On the other hand, villages such as Sorathur (1 ha), Purangani (4 ha) and Azhagappasamudram (5 ha) have shown very low rates of jackfruit cultivation. This could be because of various reasons such as lack of awareness.

Jackfruit cultivation practices in the study area

The cultivation of jackfruit in the study area is mainly influenced by climatic and soil factors along with traditional knowledge and farmers' experience. Jackfruit is well adapted to tropical climatic conditions with a temperature range of 25–35 °C and annual rainfall between 1000 and 2400 mm. Most of the soils that are considered suitable for the growth of jackfruit have a pH ranging from 5.5 to 7.5. They are also considered to be loamy to sandy loams. Waterlogging is harmful to the development of plants; hence farmers usually look for sunny areas to farm the fruit. Deep plowing up to a depth of about 30–40 cm is employed for the preparation of the field. The standard-sized pits, measuring 90 x 90 x 90 cm, are dug and a mixture of compost, neem cake, farmyard manure (10–15 kg) and topsoil is filled in. This practice increases the fertility of the soil and provides essential nutrients for the initial development of the plants.

Table 4. Village-wise area under jackfruit cultivation in Cuddalore district (2024–25)

Village	Area (ha)
Thazhambattu	22
Maligampattu	44
Semmedu	11
Kedampuliyur	46
Keezhiruppu	20
Meliruppu	31
Visur	19
Karukkai	11
Veerasingankuppam	29
Kattugudalur	12
Keelkangeyankuppam	30
Melkangeyankuppam	21
Vallam	24
Nadukuppam	14
Perperiyankuppam	6
Sorathur	1
Purangani	4
Azhagappasamudram	5
Panikankuppam	43
Keezhmambattu	113

To create space for multicultural practices and provide enough space for the canopy to develop, spacing is done at either 8 x 8 m or 10 x 10 m. Under normal circumstances, it can support as many as 156 plants per hectare.

The cropping pattern of jackfruit follows distinct seasonal phases. The regular cropping season occurs between January and February, while the peak harvesting period extends from March to June, coinciding with maximum market arrivals. The period from July to December is considered the off-season, providing opportunities for storage and value addition.

Nutrient management practices in the study area depend on the age of the trees. The young plants require relatively lower quantities of fertilisers, whereas the older trees require higher quantities of farmyard manure (FYM) and other essential nutrients, including nitrogen, phosphorus and potassium. For example, one-year-old plants require only 10 kg of FYM along with smaller quantities of chemical fertilisers, whereas trees older than 5 years require 50 kg of FYM along with higher quantities of fertilisers. Nutrient management practices are critical in enhancing the yields and quality of fruits.

The plant's development stage is a factor in the selection of irrigation techniques. To support their establishment, young plants require irrigation at intervals of 7–10 days. Mature trees, on the other hand, require watering mainly at critical stages, e.g., when the fruit is growing and when the flowers are forming. The enhancement of fruit setting, size and quality at critical stages depends on the availability of water.

Pest and disease management is another vital aspect in the cultivation of jackfruit. The main pests attacking the crop are shoot and fruit borers, as well as mealy bugs. The main diseases identified in the study area are root rot and dieback. The farmers use integrated pest management (IPM) techniques, which include the use of neem oil spray at a 3 % concentration. The farmers also practice good field sanitation. Proper drainage is also important to avoid root rot and other soil-borne diseases.

The cultivation of jackfruit in the study area is mainly influenced by climatic and soil factors along with traditional knowledge and experience. The jackfruit plant is best adapted to tropical climatic conditions with a temperature range of 25–35 °C. The rainfall for jackfruit cultivation varies from 1000 to 2400 mm annually. The soils for jackfruit cultivation are mainly loamy to sandy loamy in texture with a pH range of 5.5 to 7.5. The farmers mainly prefer well-drained areas for jackfruit cultivation because jackfruit plants cannot tolerate waterlogging conditions; such conditions are harmful to the growth of the plants.

In the field preparation, deep plowing up to a depth of 30–40 cm is done, which aids in aeration and root penetration. Pits of standard size, i.e., 90 x 90 x 90 cm, are dug and filled with a mixture of topsoil, FYM (10–15 kg), compost and neem cake. This also aids in the fertility of the soil, providing the necessary nutrients required in the initial stages of plant development. The spacing is maintained at 8 x 8 m or 10 x 10 m, providing enough space for the canopy, which aids in interculture, with a total of 156 plants per hectare.

The cropping season of jackfruit is marked by specific periods. The regular cropping season is between January and February. The peak season is between March and June; that is when maximum market arrivals are recorded. July to December is considered an off-season when there is no availability of the crop.

This is considered an opportunity to carry out value addition and storage.

The harvesting process of jackfruit begins when trees start producing fruits in 3–4 years in the case of grafted trees. The fruits take 3–5 months to mature after they flower. The major harvesting period occurs between March and July. However, it can vary slightly depending on regional climatic conditions. The harvesting process should be done at an appropriate stage to ensure quality and reduce losses.

The yields obtained from jackfruit trees depend on several factors, including age, management and environmental conditions. A mature jackfruit tree has the potential to bear between 50 and 250 fruits per annum. The average yields obtained per hectare of land are estimated at between 10 and 20 tonnes. The average weight of a single fruit varies between 10 and 15 kg, thus qualifying it as the largest fruit borne on a tree. The characteristics of jackfruit yields indicate its potential in terms of high yields and income generation.

Nutrient management practices in the specific area differ based on the age of the plants. Young plants are given less quantity of fertilisers compared to mature plants. Mature plants are given a large quantity of FYM along with essential nutrients such as nitrogen, phosphorous and potassium. For example, one-year-old plants are given 10 kg of FYM along with small quantities of fertilisers. Similarly, plants that are 5 years and above in age are given 50 kg of FYM along with large quantities of fertilisers. Nutrient management is very important in enhancing yield.

The methods of irrigation are based on the growth stage of the plants. Young plants are irrigated at intervals of 7 to 10 days to support their establishment. Mature trees are irrigated only during critical stages such as flowering and fruit development. Adequate water availability during these stages is critical to enhancing fruit development, size and quality.

Pest and disease management is another critical activity in jackfruit cultivation. The major pest problems that have been identified as affecting this crop are shoot borers, fruit borers and mealy bugs. On the other hand, the diseases that have been

identified as affecting this crop are root rot and dieback. Farmers have been using IPM techniques such as neem oil spray at 3 % concentration.

Cost of cultivation and economic analysis of jackfruit (per acre)

The results obtained from Table 5 reveal that jackfruit cultivation involves a relatively higher amount of investment, especially during the establishment phase. The total investment cost incurred during the first year of jackfruit cultivation varies between ₹100000 to ₹160000 per acre. Among all the components, the cost incurred on the installation of drip irrigation systems forms a major portion of the total investment cost, thereby emphasising the need to manage water efficiently for jackfruit cultivation.

Expenditure incurred on input resources like FYM and chemical fertilisers also forms a major share of the total cost, which indicates the importance of proper management of nutrients for better yields. The cost of labour employed for planting, intercultural operations and harvesting also forms a major share of the total cost, which indicates that the labour required for growing jackfruit is moderate.

After the establishment phase, the cost of maintaining the orchard on an annual basis is relatively low, ranging from ₹30000 to ₹45000 per acre. The results indicate that after the establishment of the orchard, the cost of maintaining the orchard is relatively low, making this enterprise economically viable.

Regarding economic returns, the income potential in growing jackfruit is significant. The average yield is between 18–22 tonnes per acre. The cost of jackfruit varies from ₹10–30 per kg depending on the market conditions. Based on this, the gross earnings would vary from ₹1.8 lakh to ₹3 lakh per acre.

The net profit earned by the farmers varies between ₹1 lakh to ₹2 lakh per acre, which shows that the cultivation of jackfruit is a profitable business. However, profitability depends on price fluctuations, availability and value addition. Most farmers sell the fresh product without any value addition, which affects the earning capacity.

Major jackfruit varieties in India and Tamil Nadu

In India, a variety of jackfruit cultivars is grown across the country. These vary in their yield potential, size of the fruits and time of

Table 5. Cost of cultivation and returns of jackfruit (per acre)

Particulars	Cost (₹/acre)
Land preparation (ploughing and leveling)	6000–10000
Pit digging and filling	5000–8000
Grafted seedlings (80–100 plants)	4000–8000
Transport of seedlings	1000–2000
Farmyard manure (FYM)	10000–15000
Chemical fertilisers	5000–8000
Planting labour	4000–6000
Irrigation setup (drip)	35000–40000
Intercultural operations	6000–10000
Plant protection	5000–7000
Pruning and training	2000–4000
Mulching materials	3000–5000
Harvesting labour	5000–8000
Packing and transportation	5000–10000
Miscellaneous expenses	3000–5000
Total establishment cost (1st year)	₹100000–₹160000
Annual maintenance cost	₹30000–₹45000
Number of trees per acre	80–100
Bearing age	3–4 years
Average yield	18–22 tonnes
Market price	₹10–₹30/kg
Gross income	₹1.8–₹3 lakh
Net profit	₹1–₹2 lakh

availability. In Karnataka, popular cultivars include Siddu, Shankara and Swarna. Siddu yields 450 fruits per tree (1098 kg/tree) and Swarna is distinguished by the size of the fruits, which range from 6 to 8 kg. In Maharashtra, Konkan Prolific is the popular cultivar, yielding 420–550 kg/tree. Gumless variety developed by IIHR in Bangalore is also popular in Maharashtra due to low latex content. In Tamil Nadu state, improved varieties like PLR 1, PPI 1 and PLR (J) 2 are cultivated. Among these, PPI 1 is a high-yielding variety with an average yield of 1819 kg/tree with fruit weights ranging from 17 kg/tree. Another variety, PLR (J) 2, extends its harvesting period from June to December. In addition to this, another variety called Panruti local is cultivated in Cuddalore District and is popular due to its quality, flavour and acceptability. Overall, different varieties are cultivated in different states and regions, which helps farmers to select suitable varieties based on productivity and income potential.

Marketing of jackfruit: Panruti Mandi

One of the major marketing centres for jackfruit in Tamil Nadu, Panruti Mandi in Cuddalore district is an important component in the regional value chain. There is a clear seasonal pattern in the supply of jackfruit in this mandi, which ranges from January to September. A considerable volume is handled by approximately 25 stores that are actively engaged in the business. It is estimated that approximately 937.5 tonnes are handled daily in the mandi, with about 37.5 tonnes being dealt with by each business. The size, quality and seasonality of the fruit also influence the price in the market, which is about ₹30 per kilogram. Due to the special characteristics of the soil in this region, the jackfruit cultivated in Panruti is highly preferred for its sweetness.

There is a substantial change in the pattern of arrival and pricing. During the mild season (January to February), there is a daily arrival of 10–15 tons. This leads to a medium level of availability at a moderate price of ₹30–40 per kilogram. During the peak season (March to June), the daily arrival of fruit drastically increases to 20–38 tons. This causes the price to fall to ₹20–30 per kilogram due to

increased availability. During the lean season (July to September), the daily arrival drastically decreases to 2–5 tons. This causes the price to rise to ₹40–55 per kilogram.

The study revealed that there are various marketing channels through which the movement of jackfruit takes place from the producer to the consumer. The most common marketing channel involves farmers who sell their products to the mandi, followed by wholesalers, retailers and eventually the consumers. This channel can be represented as follows: Farmer → Mandi → Wholesaler → Retailer → Consumer. Another channel that was found involves the following marketing agents: Farmer → Mandi → Wholesaler → Consumer. This channel does not involve retailers, resulting in faster movement of the products. Yet another marketing channel involves farmers who sell their products to roadside vendors, who eventually sell to the consumers. This channel involves the following agents: Farmer → Roadside vendor → Consumer of these, the longer marketing channels tend to result in a reduced proportion of farmers in the final consumer prices, while the shorter channels result in better realisation but in limited scale (Fig. 5).

Socio-economic profile of jackfruit farmers

The socio-economic characteristics of the farmers who cultivate jackfruit show that most of the farmers are either middle-aged or elderly. Out of the total of 120 farmers, 61 (50.83 %), fall within the age group of 51–60 years, while 36 farmers fall within the age group of 41–50 years. Only 10 farmers fall within the younger age group of 31–40 years. This finding shows that there is less involvement of the youth in the cultivation of jackfruit. When considering the gender of the farmers, it can be concluded that the sector is dominated by men, as out of the total of 120 farmers, 103 are male farmers, while only 17 are female.

The educational status of the respondents reveals that most farmers have a minimum level of formal education. About 71 farmers (59.17 %) have completed their primary education, whereas

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Fig. 5. Marketing channel of Panruti.

farmers (34.17 %) have attained secondary-level education and only 8 farmers (6.66 %) are graduates. The trend suggests that limited higher education levels may influence the adoption of advanced cultivation technologies. Regarding their occupation, it has been observed that most farmers rely on agricultural activities, as 90 farmers (75 %) are involved in farming, whereas 28 farmers (23.33 %) are involved in business activities. Only a small number of farmers work in the private and government sectors.

The pattern of the size of the landholdings of the farmers indicates that most of the farmers are small and marginal farmers. Nearly 49 farmers (40.83 %) own less than one acre of land, while 40 farmers (33.33 %) own between 1–2 acres of land. Around 30 farmers own between 2–5 acres of land, while only 1 farmer owns more than 5 acres of land. This pattern of ownership of landholdings by the farmers of the study area is similar to the number of jackfruit trees cultivated by the farmers. Among the farmers, 50 own fewer than 50 trees, while 35 own between 51–100 trees. Further, 25 farmers own between 101–200 trees, while only 10 own more than 200 trees.

In terms of the variety grown, most farmers (62.5 %) grew local varieties owing to their suitability and market preference. Among the improved varieties, 19.17 % farmers grew PLR 1, followed by PLR (J) 2 and PPI 1 at 12.5 % and 5.83 % respectively. This low adoption of improved varieties may also be attributed to low levels of awareness and risk perception.

Constraints faced by farmers from harvesting to marketing of jackfruit

As indicated in the results presented in Table 6, various challenges are faced by jackfruit farmers in the processes of harvesting, handling after harvesting and selling. Based on the highest mean value of 75.51, the challenge of mechanical and physical damage sustained during harvesting and handling was the worst challenge. This is an indication of the loss caused by improper handling techniques.

The high perishability and rate of ripening of jackfruit, which has a mean score of 70.60, is determined to be the second major limitation. Due to the short shelf life of the product, farmers must sell their food item once at the time of harvesting. This sometimes leads to the selling of the item at a low price. The third major limitation faced by farmers is the absence of cold storage and the high cost of storage, which has a mean score of 68.85.

Physical difficulty and risk in harvesting from tall and unmanaged trees are ranked fourth, with a mean score of 63.83. This calls for better orchard management techniques to be employed. The non-availability of specialised harvesting equipment and labour is ranked fifth, with a mean score of 60.38.

Transportation-related problems such as higher costs and market connectivity are ranked at number six (mean score 57.75), impacting timely marketing and profitability. Lastly, the absence of value addition units and price volatility is ranked at number seven

Table 6. Constraints faced by farmers (Garrett ranking analysis)

Constraint	Mean score	Rank
Mechanical and physical damage during harvesting and transit	75.51	I
High perishability and rapid ripening leading to short shelf-life	70.60	II
Inadequate cold storage infrastructure and high storage costs	68.85	III
Physical risk and difficulty in harvesting from tall/unmanaged trees	63.83	IV
Non-availability of specialised harvesting tools and skilled labor	60.38	V
High transportation costs and poor connectivity to markets	57.75	VI
Lack of value addition units and high price volatility	53.93	VII

(mean score 53.93), indicating limited opportunities for farmers to enhance income through processing and value addition. The Garrett ranking technique was applied to prioritise constraints based on responses collected from 120 farmers. While the method effectively ranks constraints, it does not provide statistical significance between ranks or variability measures such as standard deviation. Therefore, the results should be interpreted as indicative. Future studies may incorporate statistical tests such as the Friedman test and present disaggregated analysis across farm sizes for improved robustness.

Value addition opportunities in jackfruit

Value addition plays a vital role in enhancing the shelf life, minimising losses and increasing the market value of jackfruit. Due to the perishable nature of jackfruit, which is available only during a particular season, value addition to jackfruit has created immense opportunities. Among various value-added products, jackfruit noodles have shown promise as a profitable venture.

Preparation of jackfruit wheat noodles

Preparation process: The preparation process starts with the selection of mature jackfruit bulbs and seeds, which are ground into flour. A composite flour is obtained by blending jackfruit bulb flour, jackfruit seed flour and refined wheat flour. The mixture is kneaded into dough, which is sheeted into thin strands, about 2 mm thick. The dough is allowed to rest at room temperature for 20 to 30 min, after which it is conditioned by the addition of water. The sheet is slit and cut into noodle strands, which are dried in a cabinet dryer at 60 °C. The dried noodles are packed and stored.

The economic results indicated that producing jackfruit wheat noodles is a profitable and practical value addition activity. The total monthly operational cost is estimated at ₹103100, while the gross return reaches ₹270000. After deducting the cost, the net return comes to ₹166900. The cost-benefit ratio of 2.62 suggests that returns are more than double the investment, reflecting the financial viability of this enterprise (Tables 7 and 8). However, standard financial metrics such as net present value (NPV), internal rate of return (IRR) and break-even analysis were not computed due to limitations in long-term data availability and the short study period. This is acknowledged as a limitation of the study and future research may incorporate these advanced financial indicators for a more comprehensive economic evaluation.

One of the key reasons for this profitability is the value addition. Instead of selling raw jackfruit, which often faces price drops during peak seasons, converting it into a processed product like noodles helps in securing a better and more stable price. It also reduces the problem of quick spoilage, as processed products have a longer shelf life and can be stored and sold over time.

Another important advantage is the efficient use of resources. Both jackfruit bulbs and seeds are utilised in the production process, which minimises waste and improves overall returns. At the same time, the growing demand for convenient and

Table 7. Cost of production of jackfruit wheat noodles

Particulars	Cost (₹)
A. Fixed cost	
Machinery and equipment	300000
Depreciation	100000
Rental value of land	100000
Total fixed cost	400000
B. Operational cost (per month)	
Particulars	Cost (₹)
Raw materials	11100
Electricity	10000
Maintenance	10000
Packaging	7000
Labour	50000
Marketing	15000
Total operational cost	103100

Table 8. Economic analysis of jackfruit wheat noodles

Particulars	Value
Total operational cost	₹103100
Production yield	450 kg
Selling price	₹600/kg
Gross return	₹270000
Net return	₹166900
Cost-benefit ratio	2.62

nutritious food products supports the market potential of jackfruit-based noodles.

Preparation of freeze-dried jackfruit chips

The process of producing jackfruit chips involved selecting fresh and ripe jackfruit, followed by cleaning and peeling. The pre-treatment included freezing the jackfruit prior to processing. The frozen samples were then subjected to vacuum frying at 100 °C for 20 min. After frying, de-oiling was carried out using a centrifugation process at 1000 rpm for 5 min. Finally, the product was evaluated for quality attributes to ensure that it met the required standards.

The economic analysis of freeze-dried jackfruit chips indicates that the enterprise is feasible but offers relatively lower profit margins compared to other value-added products. The total monthly operational cost is estimated at ₹315000, while the gross return is ₹360000, resulting in a net return of ₹45000. The cost-benefit ratio of 1.14 shows that the returns are only slightly higher than the investment, indicating moderate profitability (Tables 9 and

10).

The relatively lower profit margin is mainly due to the high cost of raw materials and the expensive freeze-drying technology, which requires significant capital investment and energy consumption. Although freeze-drying helps in preserving the nutritional quality, texture and shelf life of jackfruit, it increases the overall production cost.

However, freeze-dried jackfruit chips have strong potential in premium and niche markets, especially among health-conscious consumers and export markets, where higher prices can be realised. The product also benefits from extended shelf life and better-quality retention, which reduces spoilage and allows for long-distance marketing. Overall, while freeze-dried jackfruit chips may not yield very high profits under normal market conditions, they offer good opportunities when targeted towards high-value markets. With improved market linkages, branding and scaling of production, the profitability of this enterprise can be enhanced.

Preparation of jackfruit leather (honey jackfruit bites)

The processing of jackfruit leather starts with washing the jackfruit, followed by the removal of the jackfruit's rind and the central core. The bulbs are separated from the jackfruit pulp. The jackfruit pulp is mixed with 20 % sugar and 0.1 % potassium metabisulfite (KMS) to enhance preservation during storage. The jackfruit pulp is subjected to heat at 90 °C with adequate mixing to concentrate the pulp. The pulp is applied to stainless steel trays that have been greased with ghee. The pulp is dried using a cabinet dryer at 60 °C for 6–10 hr. The jackfruit leather is cut into desired sizes for marketing.

The economic analysis of jackfruit leather production clearly indicates that it is a highly profitable value-added product with strong market potential. The total operational cost incurred per month is estimated at ₹206000, while the gross return generated from the sale of 200 kg of jackfruit leather at ₹2200 per kg amounts to ₹440000. This results in a substantial net return of ₹234000 highlighting the economic viability of this enterprise (Tables 11 and 12).

The cost-benefit ratio of 2.14 further confirms that the returns are more than double the investment made in operational expenses. Although the initial fixed investment required for machinery and

Table 9. Cost of production of freeze-dried jackfruit chips

A. Fixed cost		
Sl. No.	Particulars	Amount (₹)
1	Capital investment and machinery (Freeze dryer 10–15 kg/batch, cutting/pulping tools)	200000
2	Depreciation on fixed assets	100000
3	Rental value of land	100000
	Total fixed capital	220000
B. Operational cost (per month)		
1	Cost of raw material (1000 kg raw jackfruit at ₹20/kg)	200000
2	Electricity	15000
3	Maintenance and utility cost	15000
4	Packaging cost	20000
5	Labour cost (3 workers: 2 skilled + 1 helper)	50000
6	Marketing cost	15000
	Total operational cost	315000

Table 10. Economic analysis of freeze-dried jackfruit chips

Sl. No.	Particulars	Value
1	Total operational cost (₹)	315000
2	Production yield (Recovery after freeze-drying: 20 %)	200 kg chips
3	Selling price	₹450 per 250 g (₹1800/kg)
4	Gross return (GR) (₹)	360000
5	Net return (NR) = GR – Total operational cost (₹)	45000
6	Cost-benefit ratio (CBR) = GR / Total operational cost	1.14

Table 11. Cost of production of jackfruit leather

Sl. No.	Particulars	Amount (₹)
A. Fixed cost		
1	Capital investment and machinery (pulp extractor, tray dryer, packing machine, cutter)	250000
2	Depreciation on fixed assets	100000
3	Rental value of land	100000
	Total fixed capital	350000
B. Operational cost (per month)		
1	Cost of raw material (800 kg raw jackfruit/pulp at ₹50/kg)	40000
2	Electricity	20000
3	Maintenance and utility cost	20000
4	Packaging cost	16000
5	Labour cost (2 workers: 1 operator + 1 helper)	80000
6	Marketing cost	30000
	Total operational cost	206000

Table 12. Economic analysis of jackfruit leather

Sl. No.	Particulars	Value
1	Total operational cost (₹)	206000
2	Production yield (Recovery: 25 %)	200 kg leather
3	Selling price	₹550 per 250 g (₹ 2200/kg)
4	Gross return (GR) (₹)	440000
5	Net return (NR) = GR – Total operational cost (₹)	334000
6	Cost-benefit ratio (CBR) = GR / Total operational cost	2.14

equipment is moderate, the profitability achieved through efficient processing and premium pricing justifies the investment.

The higher price realisation of jackfruit leather compared to other value-added products can be attributed to its longer shelf life, convenience and increasing consumer preference for natural and minimally processed fruit products. Additionally, the relatively simple processing method and moderate labour requirement make it suitable for small-scale entrepreneurs and rural enterprises. Overall, jackfruit leather production offers a promising opportunity for enhancing farmers' income, reducing post-harvest losses and promoting sustainable utilisation of jackfruit. It can play a significant role in strengthening the value chain by converting surplus and perishable raw jackfruit into a high-value, marketable product.

Conclusion

This study demonstrates that jackfruit cultivation in the Panruti region holds significant economic potential for small and marginal farmers. Although area and production have increased over time, fluctuations due to climatic variability, pest incidence and management practices continue to affect productivity. Panruti remains a key cultivation hub due to its favourable agro-climatic conditions and recognised fruit quality.

The findings indicate that farmers face major constraints such as mechanical damage during harvesting, high perishability, lack of storage infrastructure and price fluctuations, which reduce their income. The socio-economic analysis shows low adoption of improved technologies and limited participation of younger farmers.

Value addition emerged as a key strategy to enhance profitability and reduce post-harvest losses. Products such as jackfruit leather and noodles demonstrated high economic viability, while freeze-dried products showed potential in niche markets.

The study suggests that improving post-harvest infrastructure, promoting value addition, strengthening market linkages and providing technical support can significantly enhance

farmer income. Therefore, jackfruit-based value chain development can contribute to rural livelihood improvement, employment generation and sustainable agricultural development. Future research may focus on advanced processing technologies and supply chain optimisation for sustainable development of the jackfruit sector.

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Authors' contributions

SB carried out article collection, analysis and interpretation. NVP contributed to idea development, validation and manuscript review. VMI was involved in drafting the manuscript. MK performed the review process. RV and SB contributed to validation of the study. All authors have read and approved the final manuscript.

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