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Examining underutilized jackfruit (*Artocarpus heterophyllus*) seeds as a potential source of human subsistence in the Byse community, India

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Introduction: The seeds of jackfruit are often overlooked and discarded globally, leading to the underutilization of this valuable resource. This study explored the potential of utilizing underutilized jackfruit seeds as an alternative source of human subsistence by investigating the availability of jackfruit, the utilization and underutilization of seeds at the household level, and the types of subsistence activities in the community.

Methods: We used a case study of Byse village in Karnataka, India, to understand this topic. A mixed research approach was used. First, a descriptive research design was employed to collect and describe the data, while a correlation design was used to examine the relationships among variables related to jackfruit seed utilization. Second, a bibliometric analysis was conducted to explore global trends in jackfruit seed utilization.

Results and Discussion: The findings indicated that agriculture, particularly arecanut farming followed by paddy rice cultivation, was the primary means of subsistence in the community. While human consumption of jackfruit seeds is statistically significant, it has a detrimental effect on seed utilization in the community ($r = -0.295$, $p = 0.008$). The study also revealed that consuming jackfruit seeds in a semidry form had a positive and significant influence ($r = 0.345$, $p = 0.002$) compared to eating them in a fresh form. Consequently, more focus could be placed on encouraging the consumption of semidry jackfruit seeds as a preferred option among residents. Despite the abundance of jackfruits, their seeds are rarely used, with a mean utilization score of 1.77. Since jackfruit seeds are limited in their application and are readily available, they could be utilized as an alternative source for sustainable human subsistence.

KEYWORDS

sustainable human subsistence, jackfruit seeds, community development, agro-diversity, SDGs 1 and 2

1 Introduction

Jackfruit seeds, often overlooked, possess immense potential for both household consumption and industrial applications, as evidenced by various global culinary traditions and recent research findings (Waghmare et al., 2019). The global significance of jackfruit seeds has been recognized through diverse applications, notably, sustainable microbial fermentation

and environmentally friendly green extraction methods, yielding biochemicals, and renewable energy sources (Brahma and Ray, 2023). The multifaceted utilization of jackfruit seeds not only underscores their economic value but also contributes to the burgeoning opportunities within the sustainability discourse, especially in the energy sector. The nomenclature “jackfruit” finds its origins in the Portuguese term “*Jaca*” (Bakewell-Stone, 2023). Jackfruit (*Artocarpus heterophyllus*), a prominent fruit plant indigenous to Asian nations (Waghmare et al., 2019), represents a sizable, tree-borne tropical fruit within the *Moraceae* family, and both the primary and secondary branches of the jackfruit tree exhibit prolific fruit-bearing capacity. Burgeoning research has revealed that the jackfruit tree demonstrates commendable productivity, yielding an average of approximately 25.71 tons per hectare, with mature trees yielding approximately 10 to 200 fruits each, and this could be harnessed for socioeconomic livelihood welfare (Ranasinghe et al., 2019). While the typical weight of a fully matured jackfruit ranges from 10 to 25 kg, certain cultivars may yield giant fruits weighing up to 50 kg, and an individual ripe jackfruit typically contains between 100 and 500 seeds (Suzihaque et al., 2022).

In most research, *Artocarpus heterophyllus* species are believed to originate from the Western Ghats of India, a region known as the foremost producer (Mandave et al., 2018), and cultivation outreach has now stretched to several tropical regions and countries, such as Bangladesh, Burma, Malaysia, Indonesia, Uganda, Thailand, Brazil, and Australia (Fine, 2021; Rao, 2023). In regions such as Bangladesh, jackfruit seeds are integral to traditional cuisines, offering unique flavors to dishes and serving as a base for stews and curries, prompting explorations into value addition and export potential (Akter and Haque, 2018). Similarly, Brazilian researchers have identified innovative uses such as fermenting, roasting, and grinding seeds into flour, offering an alternative to cocoa with economic benefits for farmers (Suzihaque et al., 2022). Studies have reported the use of jackfruit seeds as a protein source in Nigeria, where they are commonly roasted, cooked, or ground into flour for inclusion in stews and soups (Eburuaja et al., 2020; Chandran et al., 2022). Furthermore, these seeds find application in the production of animal feed, thereby creating new revenue streams in agricultural economies (Eburuaja et al., 2020; Chandran et al., 2022). Jackfruit seeds have gained traction in the United States as a viable meat substitute, aligning with the increasing adoption of vegetarian diets among consumers (Hamid et al., 2020). Consequently, consumers now have the opportunity to choose products that align with their values without compromising taste or convenience (Hamid et al., 2020). This trend reflects a broader shift toward meeting diverse dietary needs through ethically and sustainably produced alternatives, including those derived from jackfruit seeds and the possibility of using jackfruit and its seeds for several purposes (Hamid et al., 2020).

In this context, given the widespread prevalence of jackfruit, especially in India, there is potential for its seeds to be utilized or serve myriad purposes, such as a source of starch (Kumoro et al., 2020). This is evidenced in several regions where jackfruit seeds are roasted with salt and spices and eaten as tasty wholesome snacks after being boiled or steamed. Similarly, Indian curries and gravies are traditionally made with jackfruit seeds to give the meal a distinctive texture and flavor, presenting a novel narrative for making curries with jackfruit seeds in several states. The continuous realization of this potential has attracted innumerable Indian business people to turn even more

jackfruit seeds into flour. They have also explored the use of seeds as a thickener in various recipes or as an alternative to gluten in baking (Hidayati et al., 2019). This partly explains the use of ground jackfruit seeds in paste and as a batter to make thin pancakes (also known as steamed rice cakes), called *dosas* and *idlis* (Hidayati et al., 2019; Waghmare et al., 2019). This enhances their flavor as well as their nutritional value. Jackfruit seeds, especially boiled or roasted seeds, are good sources of protein, making them crucial in vegetarian dishes, and are preserved with pickling, which is an additional conventional technique that commonly serves as a tangy and spicy side dish that enhances the taste of rice dishes (Hidayati et al., 2019; Waghmare et al., 2019). The astounding availability in most of India's states and the use of jackfruit and its seeds are well reported in the National Horticulture Board's statistics. Accordingly, the top ten Indian states in terms of jackfruit production in 2018–2019 included Kerala, West Bengal, Assam, Orissa, Jharkhand, Chhattisgarh, Madhya Pradesh, Tamil Nadu, Tripura, and Karnataka (Table 1), with 18,57,000 MT grown on 1,87,000 hectares of land (Antony and Thottiam, 2018; The Indian Blog, 2020; Ibrahim et al., 2022). According to Table 1, Karnataka (the study area) is the fifth most abundant state in India, with 196.47 metric tons.

Unfortunately, even though Karnataka ranks among the top 10 producers of jackfruit in India, the potential of jackfruit seeds has not been fully exploited. Multiple studies have revealed that approximately 2,000 crore Indian rupees worth jackfruit are wasted in Karnataka alone (Karelia, 2019). Related studies, notably by Hossain (2014), noted that approximately 15% of jackfruit seeds are discarded and considered waste, irrespective of the state in India. This perspective and insight are well nested in the Byse community in Karnataka state, where although jackfruits are abundant, the seeds are less utilized and dumped as waste (Saibhavana et al., 2023). Additionally, excessively ripe jackfruits are mostly left to decay and litter into the environment in many places of the community, posing sanitary and health risks that could emanate from pathogenic microorganisms (Ubisi et al., 2017). Increased loss of jackfruit and seeds is not only a threat to sustainability but also limits the ability to tap the benefits of jackfruit, especially from the nutritional components that could aid the socioeconomic welfare of vulnerable and poor communities, as reported in several studies on the potential use of underutilized jackfruit seeds for both industrial and household purposes (Waghmare et al., 2019). However,

TABLE 1 The top ten jackfruit-producing states in India.

No	Name of state	Production (Metric tons)	Production (%)
1	Tripura	291.59	16.84
2	Orissa	232.79	13.44
3	Assam	197.20	11.39
4	West Bengal	196.76	11.36
5	Karnataka	196.47	11.17
6	Kerala	190.14	10.98
7	Chhattisgarh	183.23	10.58
8	Jharkhand	117.46	6.78
9	Madhya Pradesh	53.09	3.07
10	Tamil Nadu	49.73	2.87

Source: The Indian Blog (2020).

limited research has been conducted on the utilization of jackfruit seeds, especially among poor communities in India, which contributes to human subsistence diversity, livelihoods, and environmental sustainability (Aryal et al., 2009). Thus, the primary objective of this study was to assess whether underutilized jackfruit seeds in the Byse community in the state of Karnataka, India, could be used as an alternative source of human sustenance and improve livelihood welfare. To further explore this topic, our study explored the status of jackfruit availability and seed utilization and identified instances of underutilization of seeds at the household level. To critically explore the systemic causation of low jackfruit usage and utilization, we also delve deeper into alternative subsistence activities to chart transformative narratives for sustainable utilization of both jackfruit seeds and other agronomic byproducts.

2 Study area

The study was conducted in Byse, a small village in Hosanagara Taluk in the Shimoga district of Karnataka state in India (Figure 1). Byse is situated 15 km south of the southwest of the town of Hosanagara (13° 49' 45" N to 75° 00' 43" E), 96 km away from Shimoga district headquarters in the state of Karnataka (Menon, 2012). According to the Indian village directory, the total geographical area of Byse village is 1266.61 hectares. According to the 2011 Government of India census report, Byse has 208 houses and approximately 961 people, with an estimated population of 1,057 in 2021. Records show that in 2022, the population was 1,076, and it is estimated to be 1,172 in 2023. The local population explosion dynamics in Byse are synonymous with global population trends and, if unmanaged, might create local development conundrums, especially related to community shrinkage, sustainability, regeneration strategies, and the social dynamics of demographic change. Thus, transitioning

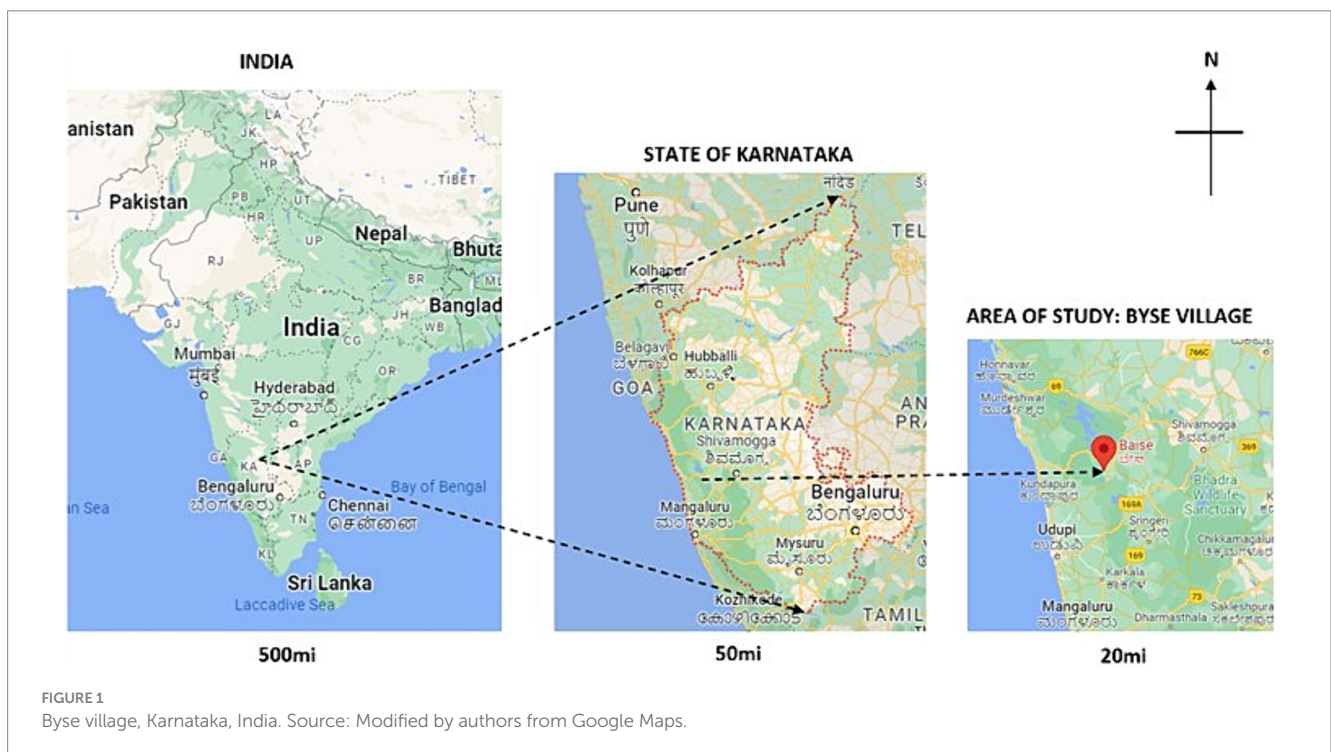
to sustainable practices could be a conduit for fair development and livelihood welfare sustainability, and this crucially aligns with the Government of India's development agenda, which seeks to align local perspectives with the need for local governments to take action for sustainable development, emphasizing inclusivity and economic diversification.

3 Methodology

A mixed research paradigm was adopted in this study (Shah, 2021). First, a descriptive research design (Helen, 2015) was chosen to obtain and describe information regarding jackfruit availability, human subsistence activities, seed utilization in producing final products and how these products could be transformed toward achieving sustainable human subsistence. This was supplemented with a correlational design to facilitate an examination of the relationships among variables related to jackfruit seed utilization and to determine its consumption and economic benefits for the rural community in the Byse.

3.1 Search strategy for bibliometric analysis

The growing interest in this subject is demonstrated by first conducting a bibliometric analysis of jackfruit seed utilization to understand global trends. Bibliometric analysis is a scientific computer-assisted review methodology used to identify core research or authors, as well as their relationships, by covering all publications related to a given topic or field (Han et al., 2020). In this study, 39 findings from 34 diverse sources were compiled, all obtained through an online search using the phrase “jackfruit AND seeds AND utilization” in the Scopus database. The analysis was carried out using



a bibliometric cloud platform called “biblioshiny.” Notably, no limitations were imposed on the type of documents or the years of publication, although the search was confined to English-language publications. [Link to CSV file – <https://t.ly/GimwQ>].

3.2 Sampling methodology

To improve our understanding of the key research objective and contextual problems resulting from the underutilization of jackfruit seeds, we employed two primary data methods (Interviews and Focus Group Discussions (FGDs)). First, interviews were conducted with an average of four individuals per household, and we interacted with a total of 27 households. To do this, purposive and simple random sampling were employed for interview participants (Rai and Thapa, 2019); 80 local participants in Byse were considered FGDs who had experience with the use of jackfruit. The purposeful selection of participants sought to gather a range of viewpoints and experiences regarding the availability of jackfruit and its seeds as a source of human subsistence in Byse village. The sample size was determined by using the Slovin (1960) formula as shown below:

$$n = \frac{N}{1 + N(e)^2}$$

where,

N is the population size (that is, the total number of the selected population).

n is the required sample size, and

e is the sampling error (which is 5%).

$N = 108$.

$e = 5\%$

$$n = \frac{108}{1 + 108(0.05)^2}$$

$n = 80$.

3.3 Data collection

This study used Focus Group Discussions (FGDs) and a Household survey as the main methods for collecting data using both structured and unstructured questionnaires. This was done to thoroughly examine aspects linked to knowledge on jackfruit, its utilization and underutilization. We also used participant observation to identify instances of underutilization and human subsistence activities in the Byse community.

3.4 Data analysis

Descriptive statistical analysis was performed on the quantitative data obtained from the study participants in Byse. To comprehensively validate and synthesize the findings, we quantified the findings, especially on jackfruit availability and consumption patterns.

Simultaneously, we calculated and visualized data on aspects related to the underutilization of seeds and the distribution of human subsistence activities. These quantitative results offered a quantifiable baseline for evaluating human subsistence activities and the frequency and kind of jackfruit-related practices in the households.

Thematic analysis was used to examine the qualitative data gathered from the FGDs. To do this, recurrent themes and patterns in the participants’ narratives were identified, coded, and categorized. The aim was to gain an in-depth understanding of the human subsistence activities that are carried out in the Byse community and to uncover complex viewpoints on the use and importance of jackfruit. This technique allowed for the extraction of themes that addressed the economic and social aspects of jackfruit-related activities, which helped to provide a thorough understanding of the value of jackfruits and local perspectives on their utilization. The combination of both quantitative and qualitative findings enabled a comprehensive analysis of the data, enhancing the general conclusions reached from the study.

4 Results and discussions

4.1 Jackfruit seed utilization trends from bibliometric analysis

The application of jackfruit seeds has gained traction in research since it is believed that they are a frequently disregarded and undervalued part of jackfruit. Research reveals that jackfruit seeds are rich in compounds such as proteins, lignins, saponins, flavonoids, and phenolics (Thiruseelvi and Durairaj, 2018). Numerous physiological advantages, including anticancer, antihypertensive, antiaging, antioxidant, and antiulcer capabilities, have been linked to metabolites, especially in jackfruit seeds (Cheok et al., 2018; Chakraborty et al., 2022). The seeds of jackfruit fruit are also a rich source of vital minerals, especially potassium, followed by sodium, magnesium, and calcium (Ulloa et al., 2017). The recognition of these benefits has partly led to the proliferation of research in this field in recent years, with the highest spike of annual scientific article publications occurring in 2021 (Figure 2).

Unfortunately, booming research in jackfruit has hardly translated into increased citation interest. For instance, the highest number of average citations was recorded in 2019, and there has been a consistent decline in the number of citations related to jackfruit utilization since 2021. The lowest number of citations occurred between 1998 and 2003 (Figure 3).

In terms of country contributions to research in this field, a plethora of countries, especially in the tropics, have contributed articles on jackfruit utilization. A comprehensive survey on Scopus revealed that India, China, Brazil, Indonesia, and Malaysia have emerged as the primary contributors in this domain, with India taking the lead by a significant margin by the year 2023 (Figure 4). It is also noteworthy that 20.51% of the total production comprises documents coauthored internationally.

In the context of India, however, author leadership has shifted to authors in other countries over time. To put this into a clear perspective, while India has been actively publishing articles since 1993, the other countries began their contributions approximately 2015. Zhang, a Chinese national author, is the leading author of 29 articles about the utilization of jackfruit seeds (Figure 5).

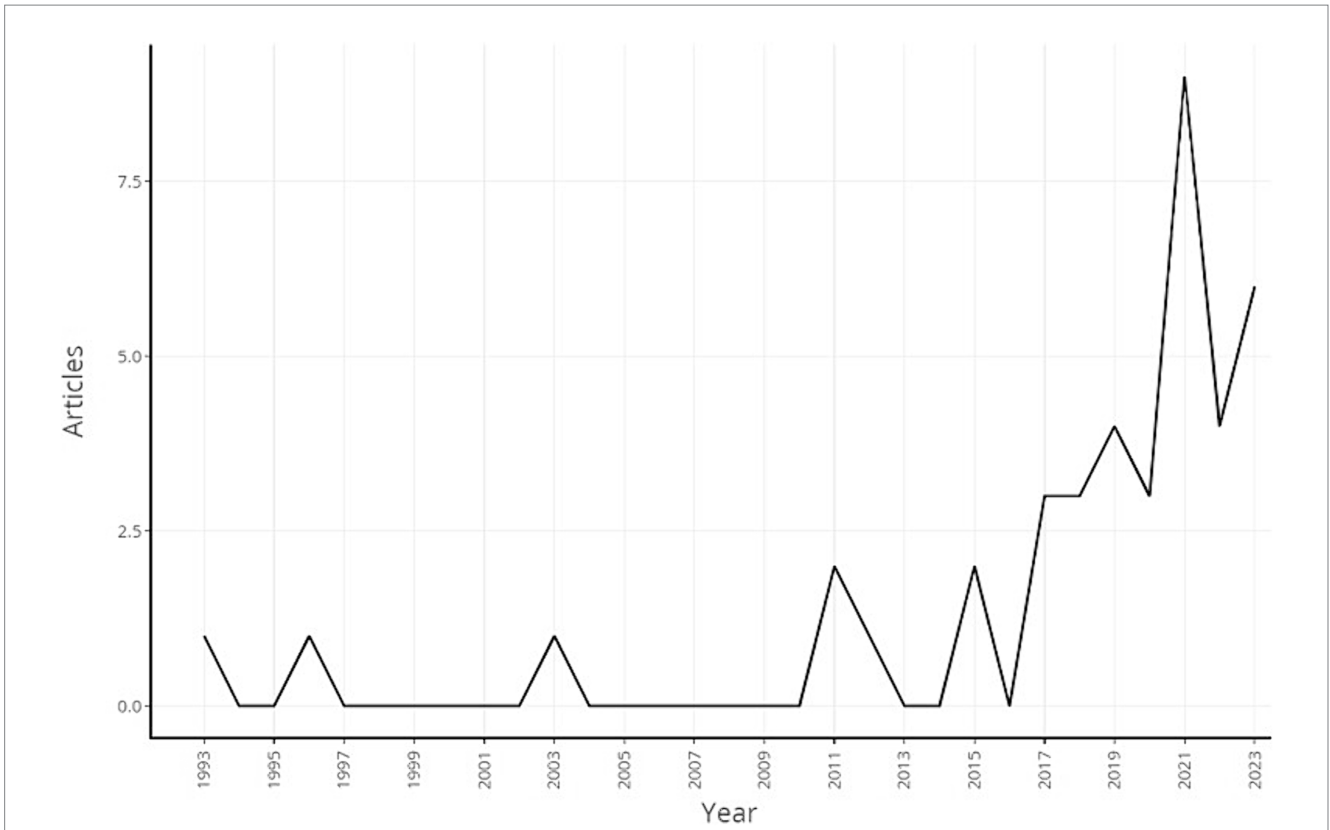


FIGURE 2 Annual scientific production of publications (1993–2023). Source: Authors.

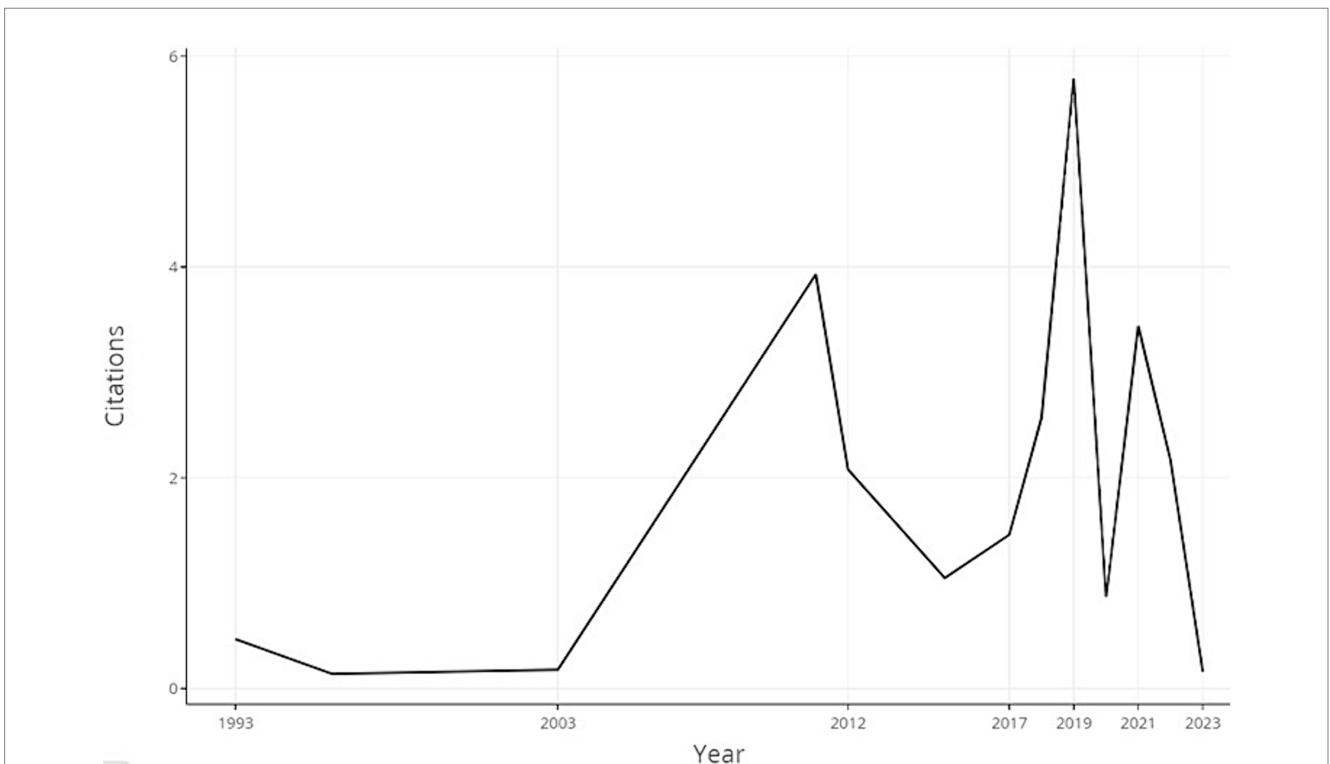
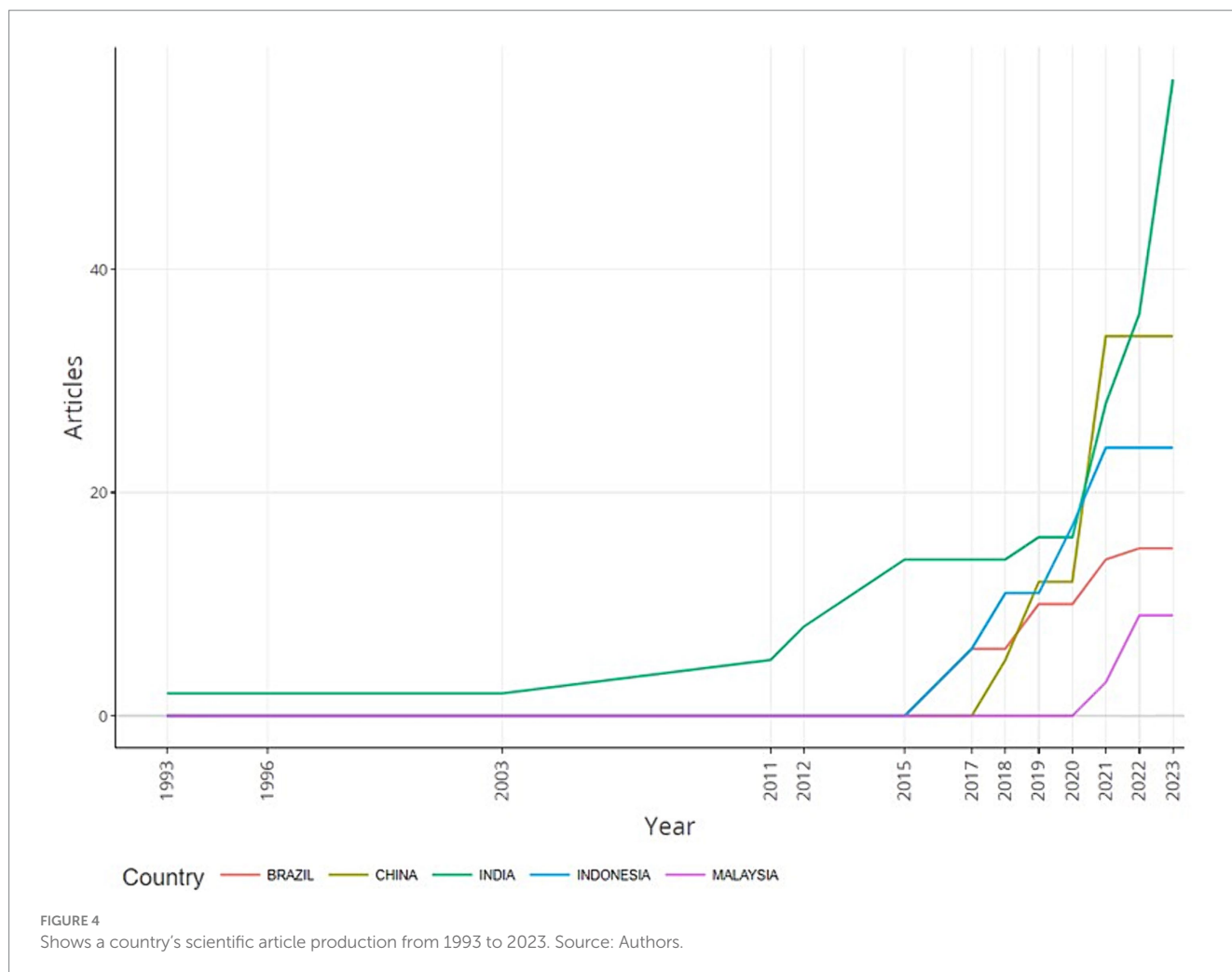


FIGURE 3 Shows the average number of citations per year (1993–2023). Source: Authors.



Nevertheless, the examination of the correlation between articles, as reflected in their titles and keywords, reveals that India stands among the top ten countries, with a significant focus on research related to jackfruit seeds (Figure 6). This could allow for more impactful and insightful research into which India would be more productive in contributing to specific themes related to jackfruit seed utilization. This could be achieved through prioritizing collaboration with countries with lower scientific productivity but with significant contributions in specific document titles or keywords such as the United Kingdom, Thailand, and Sri Lanka. This is partly because research has proven that jackfruit seed-associated keywords are consistent for India, which confirms the trend of the jackfruit seed theme in the literature.

Other insights for India include geographical patterns showing emphasis on particular topics. Additionally, India's authorship, which has a great impact on this kind of research, offers opportunities for the global distribution of expertise. Prominently, document titles indicate a concentration in specific aspects such as nutrition, agriculture, or health benefits of jackfruit utilization. The most recurring terms in the document titles include jackfruit, heterophyllous, seed, *Artocarpus*, and starch, with dominant keywords comprising jackfruit, functional properties, jackfruit seed starch, *Artocarpus heterophyllus*, waste utilization, jackfruit seed, starch, and jackfruit seed flour.

The survey also showed that the word '*Artocarpus heterophyllus*', a species of jackfruit, is the most trending topic among all other dominating words. It had the highest frequency under investigation in these studies, followed by starch, as depicted in Figure 7.

The co-occurrence network analysis (Figure 8) revealed distinct clusters in the study of jackfruit seeds. The Red and Green Clusters focus on general characteristics, composition, and potential uses. They address functional features, chemical composition, and extraction methods. In these clusters, "*Artocarpus heterophyllus*" and "starch" were central, indicating high levels of significance. The blue cluster centers on jackfruit seed properties, especially functional and physicochemical aspects, suggesting applications in the bakery industry. The purple cluster highlights broader applications and characteristics of *Artocarpus*. It incorporates waste utilization, chemical, and aroma compounds. Researchers and policymakers are encouraged to explore the potential applications and significance of jackfruit seed starch depicted in the Red and Green Clusters. Additionally, the Blue Cluster offers insights for those interested in functional and physicochemical properties, guiding further research and applications in the Byse community for human subsistence.

The relationship between *Artocarpus heterophyllus* and starch (Figure 8) emphasizes the value of jackfruit seeds as a possible source of starch for several useful applications, such as cosmetic formulations,

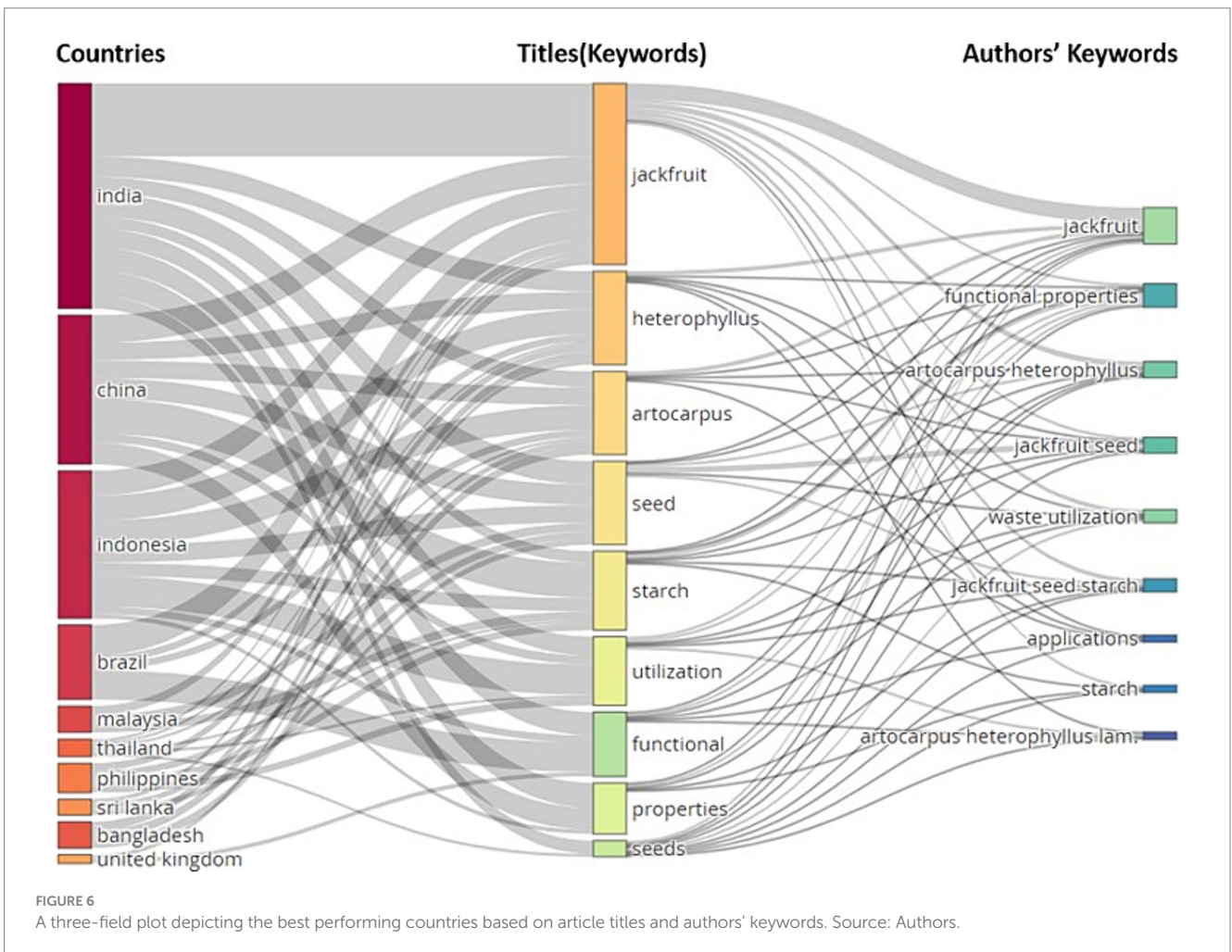
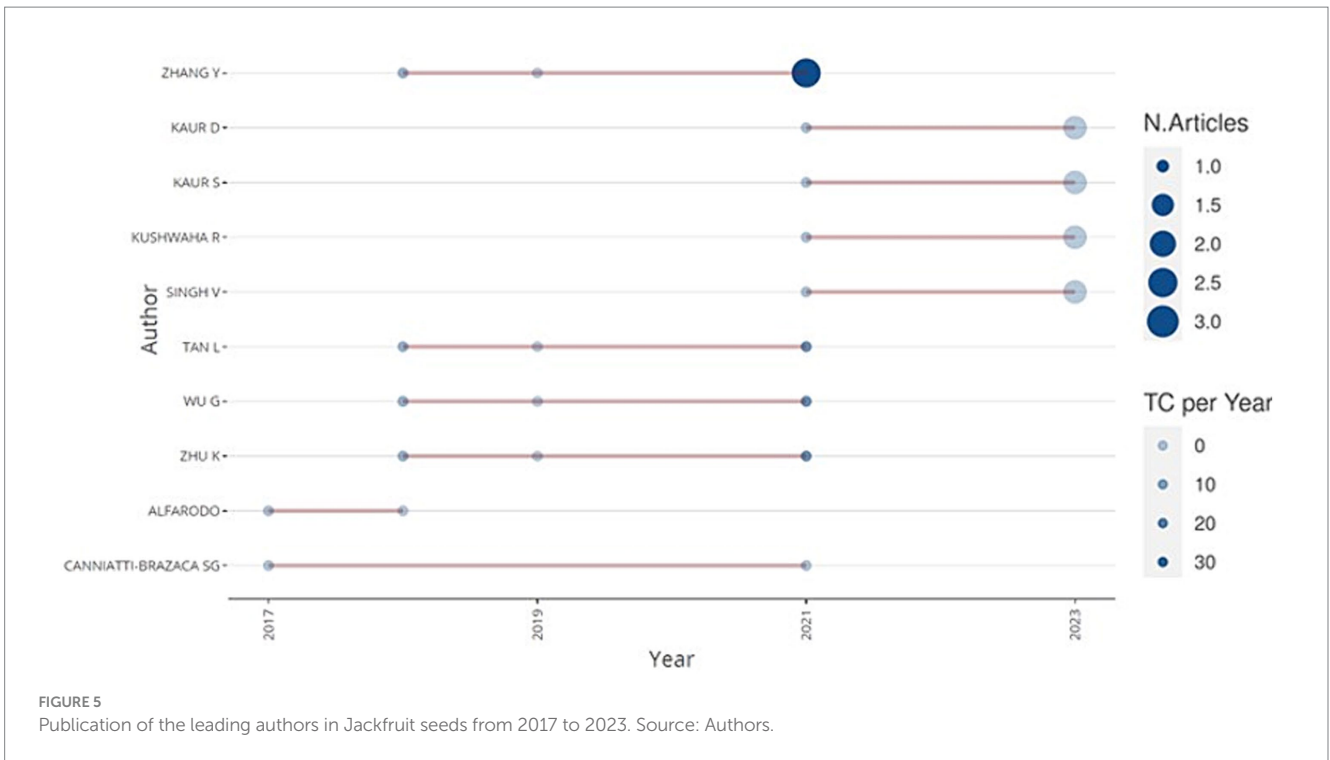


TABLE 2 Demographics of the respondents from the 27 households in Byse village.

Variable (n = 80)		Frequency	Percentage (%)
Gender	Male	24	30
	Female	56	70
Age	<30	12	15
	30–40	16	20
	40–50	38	47
	50–60	11	13
	60–70	0	0
	>70	3	3.8

(Source: Authors).

6 Human subsistence in Byse village

According to [Chimhowu and Hulme \(2006\)](#) and [Chambers and Conway \(1992\)](#), human subsistence comprises people, their capacities, and their means of subsistence, such as their access to food, money, and property. In simpler form, it's a way to make a living.

6.1 Insights from participant interactions related to jackfruit seeds

Field findings revealed that people in the Byse community mainly depend on agriculture for their human subsistence ([Table 3](#)). Studies have shown that in many cases, men are the majority involved in agricultural practices ([John, 1998; Bradstock, 2005](#)) and, as such, give them the power to control finances, leaving women vulnerable ([Coley et al., 2023; Kanyagui et al., 2023](#)). A study by ([Ellis and Allison, 2004](#)) noted that most of the time, women are left behind on farms. However, they have limited real control to direct the use of agricultural resources, yet their ability to generate income on their own is limited.

Therefore, it is imperative to examine the potential of underutilized jackfruit seeds as an alternative source of subsistence. This could enhance smallholder farmers' income generation in the Byse rural community and reverse the gender inequality issues that affect most communities, especially in the developing world ([Waghmare et al., 2019; Weintraub et al., 2022](#)).

6.2 Main agricultural activities for human subsistence

The principal agrarian pursuits constituting the primary means of sustenance within the Byse community were elucidated during the focus group discussion (FGD). These activities predominantly entail the cultivation of areca nuts and paddy rice, with areca nut cultivation being particularly prevalent. As evidenced by one farmer's testimony during the FGD, "... *Areca nuts have gained popularity in the past five years due to their profitability. However, before then, paddy rice cultivation was the most popular.*" Additionally, there are instances of ownership of cashew nut and coconut plantations among community members. A member of the women's self-help group (SHG) highlighted that "... *It is also a common practice in the Byse*

community for people with unstable incomes to work on either areca nut farms or paddy farms or sell milk if they own milk cows." [Figure 9](#) delineates the prevalent means of subsistence within the Byse community.

6.3 Distribution of human subsistence activity

The findings from the household survey revealed that, depending on the level of economic stability/security, a household would be either a farm owner or a farm worker. [Figure 10](#) illustrates the human subsistence activity distribution.

With respect to the human subsistence activity distributions that were revealed in the Byse community, households mainly depend on agriculture in a variety of ways to support livelihood welfare. One of the main agricultural practices carried out in this community is the growth of areca nuts. Approximately 28% of the respondents were arecanut farm owners who rely on arecanut cultivation for income generation, while 6% of the participants utilized arecanut for home use. It is a common practice in the Byse community for less privileged people to work in farmlands for income. Approximately 6% of the participants earn a living by working in arecanut fields. They maintain their human subsistence while supporting a collaborative effort that sustains the village's agricultural foundation. Paddy rice is another important source of income and a staple food. A significant 18% of people are paddy rice farm owners who make their living from cultivating and selling the product. While 6% cultivated paddy rice for their home consumption, approximately 8% of the participants were employed as paddy rice farm workers. This dual representation shows the value of paddy rice as a staple food and as a source of income. The cultivation of black pepper and cashew nut also plays a role in income generation. It accounted for approximately 2 and 4% of the participants, respectively. The Byse community significantly practices dairy cattle rearing, of which 4% of the participants make their living by selling cow milk and 2% of people use cow milk only for home consumption. Additionally, coconut cultivation provided 8% of the participants with a significant additional source of income, and only 2% cultivated coconut for home consumption. Despite income-focused activities ([Ganesh et al., 2020](#)), it is interesting to note that there is a heavy emphasis on self-consumption as well. For example, 6% of the population consumes more cashew nuts to satisfy their demands, which also provides income for approximately 4% of the participants. In contrast to agricultural operations, approximately 8% of the population does not participate in any plantation activity. These complex human subsistence patterns demonstrate the community's reliance on agriculture for sustenance and income while also demonstrating a balance between income generation and local consumption. To further diversify their livelihoods, some local households are venturing into jackfruit cultivation, which is complemented by the harvesting of wild jackfruit. This is because local people anticipate that this could increase their household revenue streams, promote resilience in the face of shifting agricultural dynamics, alleviate risks emanating from the declining revenue associated with low crop yields, and mitigate fluctuations in markets as well as climatic uncertainties. These perspectives on the need for diversification and alternative sources for human subsistence are supported by several studies ([Baird and Gray, 2014](#)).

TABLE 3 Byse village's gender-based work status.

Work status	Total number	Men	Women
Workers (employment or earning more than 6 months)	445	294	151
Agricultural cultivators dependent on agricultural farming	189	181	8
Agricultural laborers	125	86	39

Source: <https://www.census2011.co.in/data/village/608027-byse-karnataka.html>.
(Source: Authors).

6.4 Challenges facing human subsistence in the Byse community

A duopoly of human and environmental risks is prevalent in Byse. Prominently, climate change poses a significant challenge to the Byse community, impacting essential economic sectors, with agriculture emerging as the most vulnerable. Alterations in temperature, rainfall, and other life-threatening events stemming from climate variations have far-reaching consequences for community well-being. Furthermore, the community has experienced the consequences of climate change in the form of drought and flash rains, thus leading to soil degradation. The topsoil of the land surface is eroded by runoff water from heavy rains, resulting in diminished harvests of main crops and drying of jackfruit trees. This agricultural setback has compelled residents to travel to Nagara Market, which is situated 10 kilometers away from the village, to meet their daily basic (foodstuff) needs.

This is compounded by multitude human challenges, especially knowledge gaps related to the viability of jackfruit as a commercial product and the limited knowledge about commercially producing value-added products from jackfruit. Bridging these gaps could enhance their survival and improve their welfare, and alternative options based on jackfruit utilization could be developed, which could be completed with the continuous diversification of local businesses and assets (human subsistence diversification activities).

7 Jackfruits in Byse village

Byse village is blessed with natural resources such as jackfruit. Jackfruit is commonly called *Halasa* in the *Kanada* local language. In this village, jackfruit is utilized for consumption, but its seed is less used despite its many benefits. The jackfruit trees normally grow wildly or are planted and spread unevenly in the community, growing in different locations spanning many hectares or acres of land. Most of the jackfruit trees are also preserved within the arecanut fields, and some have been planted within local community households as part of a local sociocultural system construct.

7.1 Planted versus naturally grown jackfruit trees per household

At least 15 households among those recorded in the survey had the most naturally growing jackfruit trees (Figure 11). These homes had trees that had grown because of natural processes, which may be an indication of a longer-standing presence of jackfruit trees in the

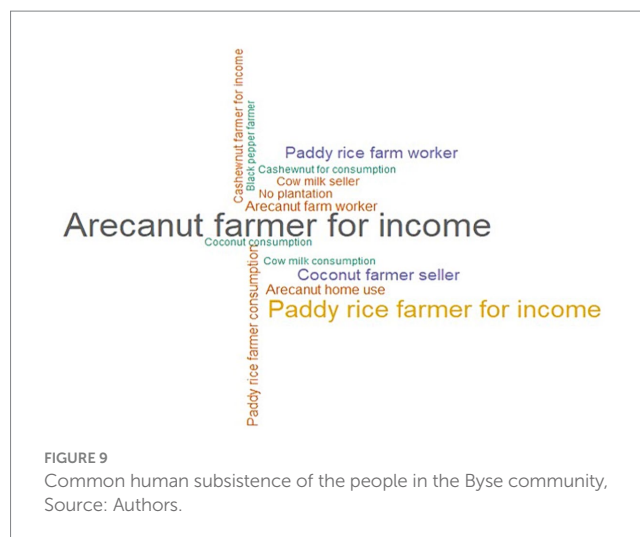


FIGURE 9
Common human subsistence of the people in the Byse community.
Source: Authors.

Byse community. Approximately nine houses had mainly planted jackfruit trees. These households intentionally cultivated jackfruit trees. Interestingly, 22 houses had both naturally growing trees and a significant number of planted trees, demonstrating a variety of cultivation techniques. In some locations, households 18 and 20 stood apart because they also had a mixture of trees that were both planted and naturally grown, while household 26 appeared to be making minimum attempts with just a few planted trees. This variety of cultivation techniques illustrates the numerous methods households utilize to manage their jackfruit tree resources, including encouraging natural development and active planting techniques.

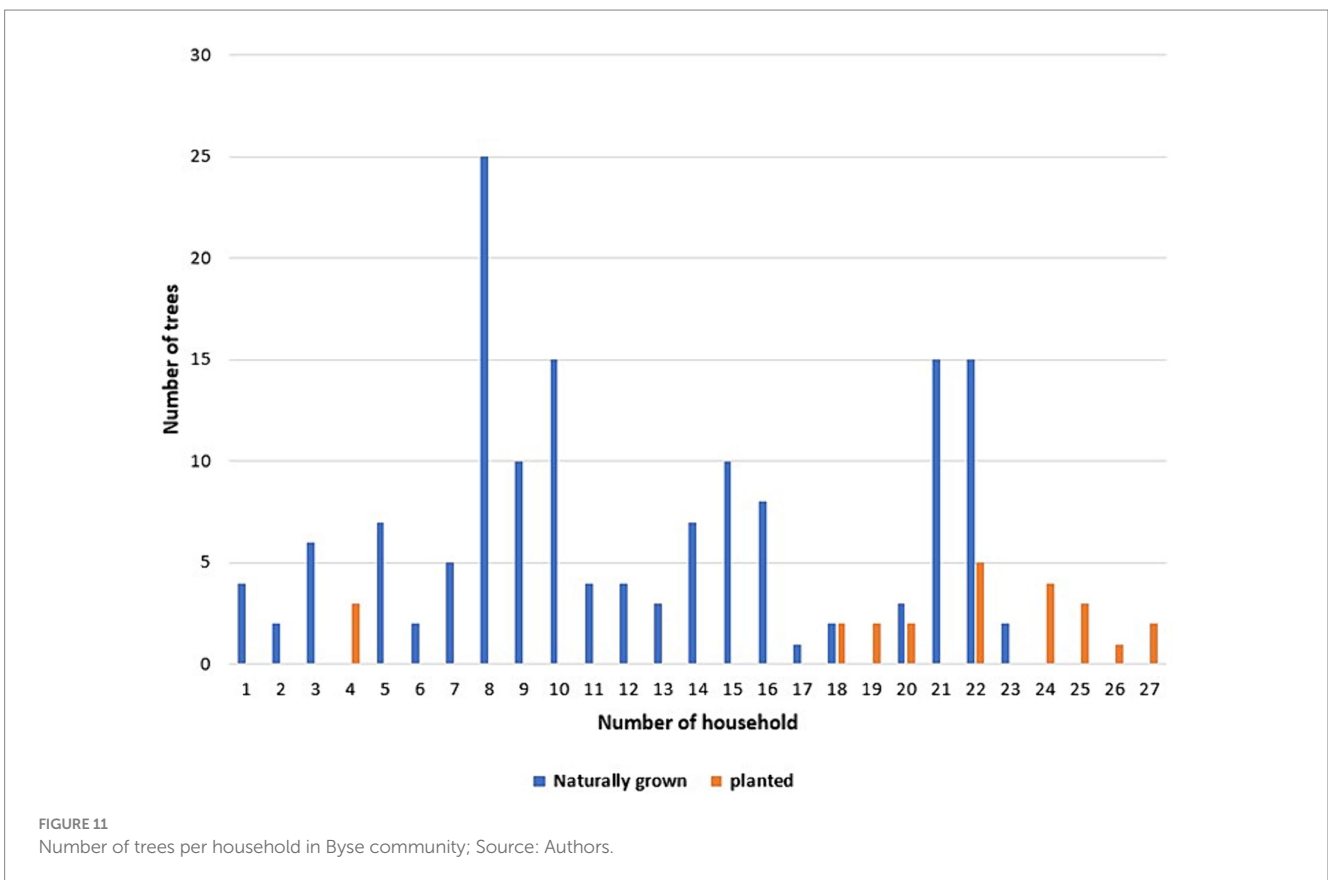
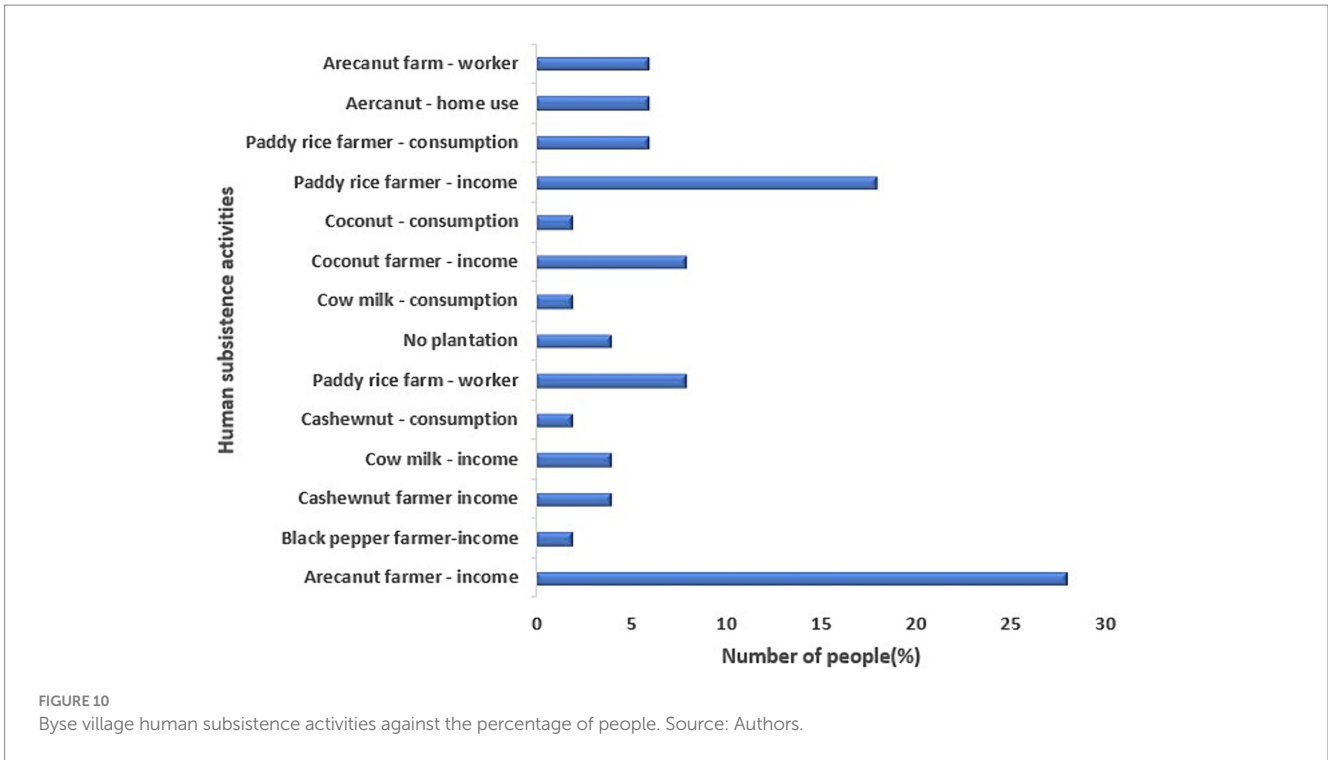
7.2 Seasonality and harvesting of jackfruit

The jackfruit tree life cycle in the Byse community has a varied annual seasonal pattern (Table 4). The trees produce flowers during the months from November to December, and they start to bear fruit during this period. The growing season begins at the start of the new year and lasts through March.

In preparation for the next harvest, the immature jackfruit grows over these months. The ripe jackfruits are ready for harvest around April. The months during which the fruits are harvested from the trees when they have reached full maturity are May, June, July, and August. During September and October, fallowing is performed for the jackfruit trees, during which they are unable to bear fruit as they recover from the production cycle. The Byse community's annual jackfruit cultivation pattern is defined by this cycle of flowering, fruiting, growth, and rest, which also influences the community's agricultural practices and means of human subsistence.

7.3 Jackfruit plant ownership

The distribution of jackfruit tree ownership across the 27 households that were surveyed revealed a wide variety of tree counts. For instance, eight households had considerable ownership of 25-five jackfruit trees, while ten and 22 households had significant ownership of 15 and 20 trees, respectively. With tree counts ranging from two to seven, most homes maintained more moderate ownership. The fewest



trees, however, were found in households 16 and 26, each of which had only one jackfruit tree. The heterogeneity of tree ownership within the community is highlighted by this distribution, which is likely driven by elements such as accessible land, agricultural endeavors, and

individual preferences. These differences in ownership in the findings depict the varied levels of jackfruit cultivation engagement, showing the predominance of this practice in certain households and its comparatively little interest in others.

7.4 Jackfruit utilization in Byse village

The analysis of jackfruit seed utilization in the Byse community is crucial due to its implications for community well-being and resource optimization. This section highlights the potential for enhancing the nutritional and economic benefits derived from jackfruit seeds, thereby advocating for their alternative uses to benefit villagers and the community at large. The consumption of jackfruit seeds by humans had a statistically significant but negative effect on the utilization of jackfruit seeds in the Byse community ($r = -0.295, p = 0.008$) (Table 4). This is an indication that jackfruit seeds are underutilized and must therefore be put to other uses to benefit the community at large. In confirmation of the above findings, the study results indicate that human consumption of jackfruit seeds had a positive and significant effect on consumption in the semidry form rather than in the fresh form ($r = 0.345, p = 0.002$) (Table 5). For this reason, more emphasis must be placed on the consumption of jackfruit in semidry form as a preference by the people of Byse village.

As shown in Table 6, the mean for rare utilization of seeds (1.77) was greater than that for the other means of utilization. This means that generally, there is less use of jackfruit seeds.

It was also found that among jackfruit seed users, there was more seed utilization by women than by men, which presupposes that some women eat fruit pulp and use semidried seeds in samba. As shown in

TABLE 4 Byse community jackfruit seasonal calendar.

Jackfruit seasonal calendar	
Flowering/Fruiting months	November – December
Glowing season	January – February – March
Harvesting months	April – May – June – July – August
None fruiting months	September – October

TABLE 5 Correlations with statistical significance of variables related to jackfruit seed utilization.

	Consumed by humans	Seed utilization	Consumed by animals	Discarded	Utilization	Semidry form	Fresh form
Consumed by humans	1	-0.295**	0.011	-0.078	0.075	0.345**	0.2
Sig		0.008	0.922	0.489	0.511	0.002	0.075
Seed utilization	-0.295**	1	-0.159	0.032	-0.554**	-0.113	-0.246*
Sig	0.008		0.16	0.779	0	0.318	0.028
Consumed by animals	0.011	-0.159	1	0.091	0.063	-0.098	0.06
Sig	0.922	0.16		0.424	0.576	0.388	0.599
Discarded	-0.078	0.032	0.091	1	0.104	0.06	-0.137
Sig	0.489	0.779	0.424		0.359	0.597	0.224
Utilization	0.075	-0.554**	0.063	0.104	1	0	0.049
Sig	0.511	0	0.576	0.359		1	0.665
Semidry form	0.345**	-0.113	-0.098	0.06	0	1	0.131
Sig	0.002	0.318	0.388	0.597	1		0.249
Fresh form	0.2	-0.246*	0.06	-0.137	0.049	0.131	1
	0.075	0.028	0.599	0.224	0.665	0.249	

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed). (Source: Authors).

Table 7, the mean seed utilization of women was greater than the mean seed utilization for men.

This is indicative of the gender domains in jackfruit use, as field findings revealed that more women use jackfruit seeds but on rare occasions than men do. This is well illustrated in Table 8, which shows that women make use of jackfruit seeds in the semidry form more than men do in Byse village.

From Table 9, approximately 77.5% of users claim that using jackfruit seeds has benefits, while another 22.5% believe that using jackfruit seeds has no benefits.

TABLE 6 Statistical summary of means and frequencies for jackfruit seed utilization.

Seed utilization	Mean	N	Std. deviation
Once a month	1.60	10	0.516
Twice a month	1.64	14	0.497
Rarely	1.77	39	0.427
Four times a month	1.33	3	0.577
Once in a year	1.75	4	0.500
Never	1.70	10	0.483
Total	1.70	80	0.461

(Source: Authors).

TABLE 7 Statistical summary of means for jackfruit seed utilization with respect to sex.

	Gender	N	Mean	Std. deviation	Std. error mean
Seed utilization	M	24	3	1.532	0.313
	F	56	3.13	1.402	0.187

(Source: Authors).

TABLE 8 Frequency of jackfruit seed utilization with respect to sex.

		Seed utilization						Total
		Once a month	Twice a month	Rarely	Four times a month	Once in a year	Never	
Gender	M	4	5	9	2	1	3	24
	F	6	9	30	1	3	7	56
Total		10	14	39	3	4	10	80

(Source: Authors).

TABLE 9 Number of responses with regard to gender on the benefits of jackfruit seeds to humans.

		Gender		Total
		M	F	
Jackfruit seeds have some benefits for humans	Yes	19	43	62
	No	5	13	18
	Total	24	56	80

(Source: Authors).

TABLE 10 Number of responses with regard to gender on the types of benefits of jackfruit seeds to humans.

		Gender		Total
		M	F	
Types of benefits	Snacks	11	17	28
	Food flour	6	21	27
	Preparation of samba	7	18	25
Total		24	56	80

(Source: Authors).

From Table 10, it is clear that most local people have great knowledge of the benefits of jackfruit seeds. Approximately 21 women agreed that the seeds can be turned into powder and used in food preparation. These benefits corroborate several findings in research that unearth several potential benefits of jackfruit, irrespective of the fact that in most communities, products such as jackfruit seeds are less utilized. When it is tapped into valuable products, it will help augment the income of the community.

Field findings from the Byse community have revealed significant insights related to jackfruit seeds and their (under)utilization, which could be well described in the literature. First, most local communities acknowledge the value of jackfruit, especially as a panacea for its nutritional requirements, alternative livelihood and sustainable economic stability (Ulloa et al., 2017). However, in most cases, harnessing the potential of jackfruit products, especially jackfruit seeds, largely remains untapped, and local knowledge on the benefits of these seeds is largely lacking. With this insight, increasing the amount of research and localizing initiatives in this discourse could be a feasible conduit for leveraging the untapped benefits of jackfruits, including seeds. This could occur through the turning of jackfruit seeds into flour and its use as an ingredient in food products with added value, which could crucially benefit local communities, especially women.

8 Conclusion

Our study focused on examining the potential of underutilized jackfruit (*Artocarpus heterophyllus*) seeds as a source of human subsistence (encompassing livelihood welfare) and sustainability at the microscale using the Byse community in Karnataka, India, as a case study. We used a multifaceted approach, first involving the critical synthesis of literature jackfruit seeds that was analyzed using bibliometrics and, second, an evidence-based interaction with local participants. Byse, our study revealed key insights into the discourse

of underutilized jackfruit seeds that could be well-factored into sustainability studies and research, and this could be key in unlocking systemic challenges that have riddled several jackfruit-producing zones with regard to harnessing the value of jackfruit seeds. From the study findings, it is clear that jackfruit is predominant in several tropical regions, especially in the rural communities of India, and in most cases, it has abundant seeds. However, despite this abundance, underutilization of jackfruit seeds was observed and still prevalent, with most jackfruit harnessed for consumption and byproducts such as discarded seeds. This signifies a missed opportunity, especially in the tapping of alternative beneficial uses of seeds for the community. In recent studies, it has been well documented that the inclusion of jackfruit seeds as an alternative source of human subsistence not only aligns with sustainable development goals (SDGs), such as poverty eradication and hunger alleviation, but could also be a panacea for alleviating health and nutritional concerns among poor communities, and this could further be scaled up in novel research domains, especially in phytochemical research. Even though our study used a small case study of Byse village, which limits the generalizability of the findings to other places with unique socioeconomic, cultural, and environmental contexts, key insights were generated; in particular, underutilization could be factored into transdisciplinary research domains to use local resources for social, economic, and environmental benefits/sustainability. Thus, future studies could focus on multidisciplinary research to address diverse geographical locations. This is because diverse community participation and cross-cultural investigations are essential for the advancement of jackfruit seed utilization; notably, fostering economic and nutritional benefits would promote the enhancement of local food systems and reduce dependency on external sources. In local contexts, a multidimensional approach, advocating for educational programs, promoting awareness of jackfruit seed benefits, establishing local processing units, addressing gender-based disparities, integrating

jackfruit cultivation into local policies, and encouraging research and development could further be used to advance this.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AM: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. CE: Formal analysis, Methodology, Software, Writing – review & editing. IL: Methodology, Writing – original draft, Writing – review and editing, Software, Visualizations, Validation. CB: Supervision, Writing – review & editing. SS: Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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