Journal of Food Technology Research
2022 Vol. 9, No. 2, pp. 120-134.
ISSN(e): 2312-3796
ISSN(p): 2312-6426
DOI: 10.18488/jftr.v9i2.3124

A COMPREHENSIVE REVIEW ON THE RECENT ADVANCES IN THE VALORIZATION OF JACKFRUIT WASTE FOR THE DEVELOPMENT OF VALUE-ADDED PRODUCTS

Rangina Brahma[1+]
Subhajit Ray[2]

[1,2]*Department of Food Engineering & Technology, Central Institute of Technology Kokrajhar, Kokrajhar, BTAD, Assam, India.*
[1]*Email: ph21fet1002@cit.ac.in Tel: +919954071733*
[2]*Email: subhajit@cit.ac.in Tel: +919330054980*

(+ Corresponding author)

Article History
Received: 16 June 2022
Revised: 2 August 2022
Accepted: 19 August 2022
Published: 12 September 2022

Keywords
Artocarpus heterophyllus
Jackfruit latex
Jackfruit peel
Jackfruit seed
Jackfruit waste
Applications
Valorization.

ABSTRACT

The jackfruit (*Artocarpus heterophyllus*), a particular member of the Moraceae family, is abundantly found in Asia's tropical and subtropical regions, and it has been reported to have a range of useful properties that treat ailments. Jackfruit contains both edible fractions e.g. seed and inedible fractions e.g. peel, rags, latex, perianth, core which are generally disposed of into the environment directly as waste and thereby causing an environmental concern as it leads to bio-waste accumulation. The existence of multiple beneficial compounds in the discarded parts of fruit contributes to its usage as a raw material in various food products such as bread, cake, cookies, extruded products, etc and also in various other sectors such as the fuel, cosmetics, pharmaceutical industries etc. This literature analysis was conducted to gain a good comprehension of changing trends in the Jackfruit waste utilization scenario, shaping up into the formation of value added food products. This review paper is designed by considering some latest findings of several researchers in this area.

Contribution/Originality: About 60% and above of the jackfruit is normally discarded as waste, however researchers from all over the world has found out various ways through which the waste can be treated and utilized in order to reduce waste disposal and increase sustainability. This review paper has been designed to compile those findings in order to get a clear picture of the jackfruit waste valorization scenario.

1. INTRODUCTION

In regions where jackfruit is grown and processed, it is underutilized because of its short shelf life and lack of processing facilities. Only 35% of the jackfruit's whole fruit is edible, with 60% consisting of inedible prickly rind, rags, latex, and seeds (Ranasinghe, Maduwanthi, & Marapana, 2019). A highly perishable fruit, jackfruit flesh is often subject to flavour loss, tissue softening, and browning on the cut surface (Mondal et al., 2013). Bruising and mechanical injury are more likely to occur when the fruit is softened (Ramli, 2009). The postharvest handling and inadequate storage facilities in the areas where jackfruit is processed and marketed result in the rapid degradation of large quantities of ripe jackfruit after harvesting (Saxena, Bawa, & Raju, 2011).

The high perishability of jackfruit reduces its cost-effectiveness because it has to be exported as whole fruits than other fruits. Due to the uncertain shape and size of the fruit, the packaging design gets very cumbersome, and the sturdy body and sticky latex make the preparation very difficult (Ramli, 2009). Peeling is very difficult in the case of Jackfruit since it's a large fruit. Inconsistencies in size and shape make packaging very difficult and the rough and thick skin and the latex make preparation difficult. Furthermore, segregating jackfruit edible bulbs from the rind is a manual labor exertion process and requires loads of time, which makes it an impractical option for the metropolitan inhabitants. A great deal of inedible parts is generated in jackfruit processing industries, and they are usually used as animal feed (Akter & Haque, 2019). There have been a few studies devoted to investigating how these wastes could be converted into augmented products. The result is a sizeable load of jackfruit waste being disposed of, which has serious suggestions for waste disposal and the surroundings. For this reason, it is crucial that commercial jackfruit handling employs modern processing automation and a sustainable waste control approach.

It has only been possible to conduct limited studies on Jackfruit waste counterparts. Adan, Ojwang, Muge, Mwanza, and Nyaboga (2020) found out that the peel and fibres of jackfruit have many bioactive compounds. The latex of jackfruit which has a sticky nature and is often looked down upon has also been discovered to have antioxidants and anti-cancer properties (Samrot & Sea, 2022). The Jackfruit seeds though edible are often thrown as waste because of the lack of significant flavor. The Jackfruit rags which surround the bulb of the fruit are rich in various compounds like cellulose, protein, reduced sugar and pectin however they are discarded as waste because of the chewy texture (Dam & Nguyen, 2012).

2. UNUTILIZED PARTS OF THE JACKFRUIT

2.1. Jackfruit Seed

In general, jackfruit seeds are discarded as waste, but they are beneficial in terms of nutrition. Jackfruit seeds represent about 10-15% of the fruit mass (Hossain et al., 2014). Numerous difficulties arise during processing and storage because of its perishable nature and thus large numbers of seeds are disposed per annum. In order to acquire a shelf-stable jackfruit seed product, they are normally roasted and ground into powdered form. In bakery and confectionary industries, jackfruit seed powder is used as a substitute for wheat flour and other types of flour (Hossain et al., 2014). Alternatively, the seeds are boiled or roasted and are also used as a supplement for potatoes. The seeds of jackfruit could serve as an economically feasible protein source for malnourished people (Chowdhury, Bhattacharyya, & Chattopadhyay, 2012). Due to its capability to come up with supplementary physiological advantages alongside basic nutrition, it is a crucial functional ingredient.

2.1.1. Nutritional Profile

Detailed research is yet to be done on the nutritional assets of Jackfruit seeds. Gohain Barua and Boruah (2004) recorded the presence of Iron (Fe), Manganese(Mn) and Magnesium(Mg) through emission and Fourier transform infrared spectra.

Table 1 presents the physicochemical parameters of jackfruit seed powder.

Table 1. Physicochemical parameters of jackfruit seed powder.

Parameter	Amount (% dry matter)
Crude Fat	1.27 ±0.01
Moisture	6.09 ±0.01
Carbohydrate	79.34 ±0.06
pH	5.78 ±0.01
Protein	13.50± 0.06
Titratable Acidity (as lactic acid)	1.12 ±0.03
Fibre	3.19 ±0.01
Energy(Kcal/100g)	382.79 ±1.20
Ash	2.70 ±0.02

Source: Ocloo, Bansa, Boatin, Adom, and Agbemavor (2010).

Table 2 presents the Mineral constitution of jackfruit seed flour.

Table 2. Mineral constitution of jackfruit seed flour.

Minerals	Amount (% dry matter)
Zinc	<0.01
Manganese	1.12± 0.11
Copper	10.45± 0.89
Iron	130.74 ±12.37
Calcium	3087 166
Magnesium	3380 ±388
Sodium	60.66 ±2.01
Potassium	14781± 256

Source: Ocloo et al. (2010).

Table 3 presents Functional parameters of Jackfruit flour.

Table 3. Functional parameters of Jackfruit flour.

Parameters	Amount (% dry matter)
Fat Absorption capacity(%)	17.00 ±1.37
Swelling Power (g/g)	4.77± 0.10
Foaming capacity(%)	25.34 ±0.02
Bulk density(g/cm^3)	0.80 ±0.02
Foam Stability(%)	33.00 ±0.01
Water Absorption Capacity(%)	25.00 ±1.67

Source: Ocloo et al. (2010).

2.1.2. Pre-Processing Methods of Jackfruit Seed

Various methods are involved in the pre-processing of Jackfruit seeds in order to make it suitable for further incorporation into various food products. The seeds after undergoing the processing treatments undergo various changes in their physico-chemical properties. The processed seeds are then milled to flour and are used for further applications. The seeds are mainly pre-processed by techniques such as baking, pan roasting, pressure cooking and microwave roasting. After being subjected to various pre-treatments they exhibit various changes in their physico-chemical properties which are shown in a schematic diagram down below.

Figure 1 illustrates the pre-processing methods of jackfruit seeds and their effects

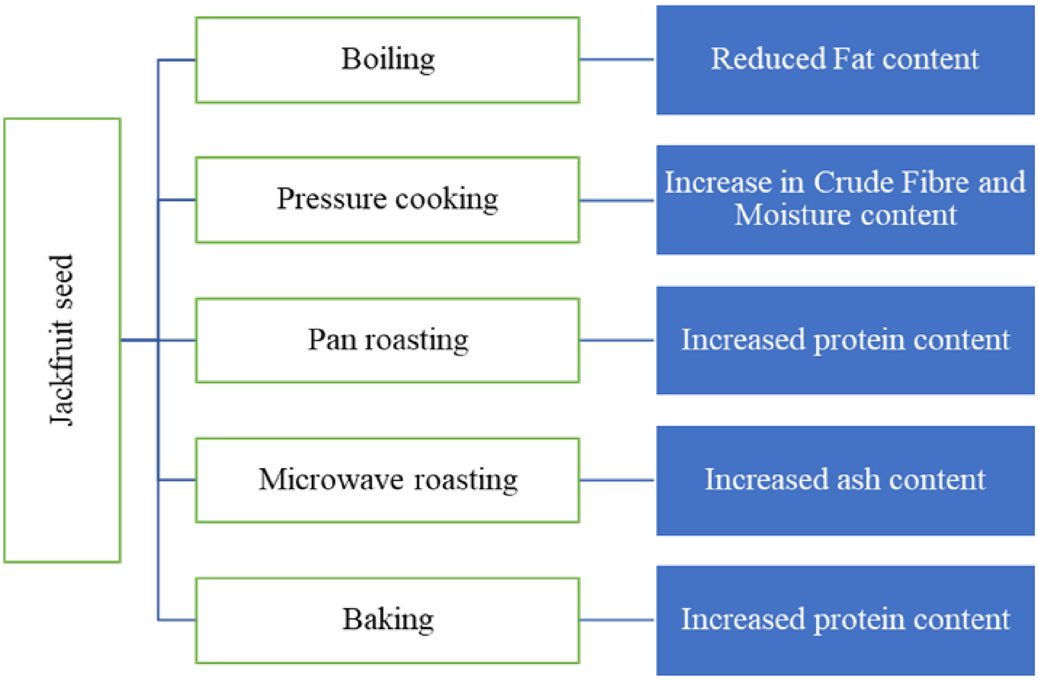

Figure 1. Pre-processing methods of jackfruit seeds and their effects.

2.1.3. Value-Added Food Products

Value addition of a food product refers to the inclusion of a certain component that is not originally present in the product, thereby improving its overall value/utility. Modern food processing technologies can be used to incorporate a new beneficial ingredient or packaging visuals can be improved to target a certain demographic. Examples of value-added products involve juices, bread, extruded products, jam, jellies, breakfast cereals, etc.

Table 4. Value-added products developed by using jackfruit seed.

Products	Observations	References
Bread	Bread containing 25% jackfruit seed flour was nutritionally better than whole wheat bread because of its higher carbohydrates, fat, protein, and crude fiber content.	Hossain et al. (2014)
Chapaties	With the addition of 5% jackfruit seed flour to the chapaties, overall protein content was increased by 11% as well as calorific content.	Sultana, Rahman, Islam, Rahman, and Alim (2014)
Cake	As the jackfruit seed flour content increased, the fat content of the cake decreased.	Khan, Saqib, and Alim (2016)
Cake	Using 16% Jackfruit seed flour and sucrose substitute (polydextrose) the calorie content of the cake was reduced by 34%.	Faridah and Aziah (2012)
Buns	A composite bun with an enhanced nutritional profile was created by adding 10% jackfruit seed flour to wheat flour.	Ngwere and Mongi (2021)
Bread Spread	The bread spread had a nutritional profile of 82 Kcal and also consisted of potassium, phosphorus, calcium and magnesium, niacin and vitamin C.	Supit et al. (2018)
Tortilla	Pumpkin and jackfruit seed flour was incorporated to make Tortillas with increased dietary fibre values.	Ihromi and Dewi (2021)
Cookies	The protein, fat, fiber, and ash content of cookies with Jackfruit seed flour was higher than those with wheat flour. Phytate and oxalate were also found within acceptable limits.	Maskey, Subedi, and Shrestha (2020)
Snacks	The snacks were prepared using jackfruit seed flour and corn flour and it showed protein (11%), fibre (2.45%). The optimum product was formed from 70% seed flour and 30% corn flour and exhibited higher organoleptic properties.	Shehin, Kaur, and Gupta (2019)
Biscuits	Coconut milk residue and jackfruit seed flour was mixed to form baked biscuits at the temperature of 180°c and scored good in sensory evaluation.	Barge and Divekar (2018)
Biscuits	A higher replacement of wheat flour with jack seed flour increased moisture, fat, crude fiber, and ash content. The sensory panelists, however, rejected the jackfruit seed flour if the amount was increased by more than 20% because the colour was black and the texture was rough.	Islam, Begum, Khatun, and Dey (2015)
Tambang cookie	Using Jackfruit seed flour/powder in the cookies showed the presence of calcium and phosphorus.	Hidayati, Soekopitojo, Chisbiyah, and Mareta (2019)
3D printed cookies	The cookies showed a higher storage modulus (elasticity) than the loss modulus (viscosity/viscous behaviour).	Varghese et al. (2020)
Unleavened Flat Bread	The product showed dough springiness, good colour and good overall acceptability. The analysis indicated that the jackfruit seed flour boosts the nutritional profile and shall stay acceptable	Rajput, Rawson, Krishnamoorthy, and Rangarajan (2022)
Pasta	Jackfruit seed flour along with red amaranthus was used to make pasta, it was concluded that the protein, fibre, carotenoid value had increased. It was also seen that the amaranthus contributed to the reduction of cooking losses of the pasta.	Swathi, Lekshmi, and Sajeev (2019)
Pasta	Jackfruit seed and jackfruit bulb flour were used to make pasta with reduced cooking losses and higher water absorption capacity	Lakmali and Arampath (2021)
Extruded product	Jackfruit seed flour(10%) along with maize grits(75%) and tapioca flour(15 %) were utilized to form an extruded product with good texture and physicochemical qualities	Thejas Gowda et al. (2021)
Chips	Jackfruit seed flour based chips showed higher carbohydrate values and good organoleptic properties.	Sofiyanita and Nurhayati (2018)
Noodles	Jackfruit seed flour along with Broccoli was utilized for the purpose of calcium fortification in noodles. An increase in micronutrients were analyzed.	Yulia (2019)
Butter cake	The butter cake's protein and crude fibre contents increased when the amount of jackfruit seed flour was increased. However, the sensory panellists rejected the increased jackfruit seed flour, therefore it was only reduced to 15%.	Abd El-Aziz and Esmail (2016)

Jackfruit seeds have a very good nutritional profile but they are underutilized and mostly go to waste. However, in recent times they are being used as a substitute for wheat flour and other types of flour in the bakery and confectionary industry (Hossain et al., 2014). Chowdhury et al. (2012) found out that the jackfruit seed flour and its blends have exceptional water and oil absorption capabilities, and up to 15% (w/w) blending may be recommended for use in bread development moreover, it can also be used as a protein alternative and functional component for the purpose of improved human nutrition.

Table 4 presents the value-added products developed by using jackfruit seed.

2.1.4. Other Applications

Jackfruit seeds is not only used directly as a food product but can also be used in order to make other products that benefits the food industry. For e.g.: Coating material, prebiotics, nanomaterials, starch etc.

Table 5 presents the various other products that are used in the food industry but are not directly a food product.

Table 5. Various other products that are used in the food industry but are not directly a food product.

Products	Observations	References
Smart seed starch coating as a freshness indicator for fish	The color change in the smart film occurred due to the release of total volatile basic nitrogen during the fish deterioration, altering the pH of the products which reacts with the anthocyanin.	Costa et al. (2020)
Prebiotics	Jackfruit seeds were extracted with 50% ethanol as a solvent. Based on the extraction yield and the quantity of non-reducing sugar, which is thought to contain prebiotics, the extraction efficiency was calculated.	Bhornsmithikun, Chetpattananondh, Yamsaengsung, and Prasertsit (2010)
Pectin from the slimy coating of a jackfruit seed	A modest 35.52% recovery was acquired by utilising oxalic acid in acidic extraction of pectin. In comparison with commercial apple and citrus pectin, the sheath displays the highest levels of antioxidant activity.	Kumar et al. (2021)
Jackfruit seed starch as raw material to make microcapsules holding in vanilla oil	A novel shell material based on the ultrasonic process, jackfruit seed starch, was used to microencapsulate vanilla essential oil. Jackfruit seed starch demonstrated a high encapsulation efficiency despite a poor yield. It outperformed other types of microcapsules in terms of storage stability and potential for gradual release.	Zhu, Zhang, Tian, and Chu (2018)
Jackfruit seed starch	The jackfruit starch has the potential to compete with or supplement other commercially significant starches in some applications due to its advantages over major starches, including less particle size, more amylose and resistant starch content, good water and oil absorption capacities, and thermal stability of paste.	Zhang et al. (2021)
Jackfruit seeds as a replacement to cocoa powder	A 50 or 75 percent substitution of cocoa powder with dry jackfruit seed flour did not alter the sensory acceptability or features of the final product. Dry jackfruit seed flour can be used as an ingredient in cappuccino formulations.	Papa et al. (2018)
Protein Isolate	Jackfruit seed defatted flour was used with an alkaline solution which was then ultrasound treated. The Isolate had glutelins in huge amounts.	Ulloa et al. (2017)
Pigments (Food Colorant)	Due to the substrate's buffering characteristics and the pigments' colour stability over a large variety of initial pH, this pigment can be used in a range of food applications.	Babitha, Soccol, and Pandey (2007)
Silver nanoparticles	By interacting with the bacterial cell wall or plasma membrane, bacterial DNA, and bacterial proteins, the silver nanoparticles demonstrated antibacterial property against a huge assortment of Gram positive and Gram negative bacteria.	Jagtap and Bapat (2013)
Thickener	Jackfruit seed starch was extracted and was utilized as a thickener and stabilizer in chilli sauce and also it scored a high overall acceptability value.	Rengsutthi and Charoenrein (2011)

2.2. Jackfruit Rags

Jackfruit rags are long filaments like structures that are found surrounding the bulb portion of the fruit and is at most times discarded as waste. They comprise approximately 25% of the fruit weight and are rich in cellulose, protein, reduced sugar, pectin (Dam & Nguyen, 2012). The presence of substances like polyphenolics including anthocyanins, coumarins, flavonoids, and substances belonging to the terpenoid, saponin, and cardiac glycoside families were also experimentally discovered, according to phytochemical screening assays (Dhwani et al., 2020).

Table 6 exhibits Value-added products prepared by using jackfruit rags.

Table 6. Value-added products prepared by using jackfruit rags.

Products	Observations	References
Corned milkfish	The raw material is immersed in salt as part of the corning preservation technique to enhance flavour and prolong shelf life. A corned product made from milkfish, which is common in the Philippines, and rags from jackfruit received a 55 percent approval rating overall.	Gipolan and Tabinas (2022)
Fermented Beverage	The mixture made from jackfruit rags was transported into fermentation containers and pectinase was added. 11°Brix, pH 4.35, 1.28 percent total acids, and 5.5% (v/v) ethanol were the end product's parameters.	Dam and Nguyen (2012)
Vinegar	Jackfruit rag comprises 20% carbohydrates, which are enzymatically broken down into reducing sugar and used as a starting point for the creation of vinegar.	Photphisutthiphong and Vatanyoopaisarn (2019)

Table 7 exhibits various products prepared by using jackfruit rags.

Table 7. Other products prepared by using jackfruit rags.

Products	Observations	References
Amylase	The enzyme exhibited functional activity at pH 6-7, making it useful for the food industry's production of dough, the processing of juice and fruit, baking, and the brewing business. Additionally, a lower incubation time and less expensive substrates may enable for the production of amylase at a cheap cost, making the procedure both commercially and economically viable.	Weerasooriya and Piyarathne (2019)
Natural Photo-sensitizer	The natural dye extracted from Jackfruit rags was used in the dye-sensitized solar cells, which demonstrated promising photovoltaic performance and led to the creation of minimal cost photo-sensitizers for energy harvesting functions.	Ashok et al. (2018)
Single-slope solar still	The trials generated a promising yield of 9.3% rate of increase of potable water compared to traditional stills employing Jackfruit rags and Azadirachta indica gum insulation.	Balachandran et al. (2021)
Porous N-doped Carbon (PNC)	Without using any chemical or physical activation, PNC materials were created from rags from jackfruit using a simple calcination procedure in an argon environment. When employed as the anode of sodium-ion batteries, the hierarchical NPC made from jackfruit rags at 800 °C (NPC-800) had the best cycling performance and rate capability.	Zhao, Ding, and Wen (2019)
Jackfruit rags utilized as meat extender and phosphate binder	The resulting meat loaf had a moisture content of 50.91%, a crude fibre content of 7.27%, a crude protein content of 30.56%, and an ash content of 10.69%.	Braga and Galvez (2018)
Glucose syrup	Cellulose from rags were hydrolysed by Hydrochloric acid to produce glucose syrups	Sari (2019)
Acrylonitrile Butadiene Styrene Thermoplastic	The Jackfruit rags are reinforced with ABS (Acrylonitrile Butadiene Styrene) using compression moulding technique to form a natural fibre reinforced polymer. The resulting polymer exhibited commendable tensile and flexural properties.	Arun Sankar et al. (2021)
Antibacterial Component	For a wide range of laboratory and clinical strains of gram-positive and gram-negative bacteria, the rags extracts caused zones of inhibition which were visible in the agar well disc diffusion assay. According to analysis of bacterial cell pictures taken under an electron microscope, rag extracts induce cell death by rupturing the bacterial cell wall and eventually causes intracytoplasmic clumping.	Dhwani et al. (2020)
Biosurfactant	The only media used in this work for the generation of microbial biosurfactants was isolated from jackfruit waste i.e. rags. In in-vitro tests, the final product showed strong antifungal efficacy against Alternaria solani, suppressing fungal growth by up to 83%. The nontoxicity of rhamnolipids generated from jackfruit waste suggests that they have potential for use in cosmetic and medicinal products.	Patowary et al. (2022)

Table 8. Value-added products prepared by using jackfruit latex.

Products	Observations	References
Antioxidants	Antioxidant activity in the aqueous extract of the jackfruit latex have been found	Samrot and Sea (2022)
Anticancer components	Jackfruit latex inhibited breast cancer cell proliferation and migration. Extract killed all cancer cells and inhibited cell proliferation, migration at higher concentration	Prakash and Gupta (2013)
Protease	Artocarpin protease was extracted from Jackfruit latex and it indicated presence of proteolytic activity against casein.	Prasad and Virupaksha (1990)
Protease	Protease was isolated which involves human blood coagulation factors	Siritapetawee, Thumanu, Sojikul, and Thammasirirak (2012)
Mucoadhesive tablet	Jackfruit latex has the potential to act as a natural binder in mucoadhesive solid dosage form (tablet) and can also be used to formulate tablets, according to research in the form of in-vitro dissolution studies, comparative mucoadhesion studies, compatibility studies with the selected formulation, stability studies, etc.	Gohain and Sahu (2017)
Natural rubber	Jackfruit latex increases a tire's wet skid resistance (WSR). Additionally, it enhances carbon black's dispersion in rubber compound. In order to improve the dispersion of carbon black in rubber compounds and to improve WSR for tyres, it can be utilised as a low molecular weight natural resin rather than as a direct replacement for natural rubber. It can also be utilised as vulcanizable low molecular weight natural resin in a variety of vulcanizable elastomeric products, such as rubber rollers, matting, hot water bags, O rings, rail pads, conveyor belts, boats, dock fenders, and tyres. The peculiarity of this substance is that it comes from a natural source, is vulcanizable like natural rubber, enhances filler dispersion, and raises tyre wet skid resistance.	Bhadra, Mohan, Parikh, and Nair (2019)
Natural Rubber/LDPE/Waste Polyethylene Composites	Latex composites improve tensile, swelling properties and gel content.	Sandaruwan, WDM, Edirisinghe, and Sudusingha (2020)
Binder	Jackfruit latex was used as binder for fabric dyes	Kabir, Kim, and Koh (2018)
Bimetallic Silver-Gold nanoparticles	The flavonoids, phenolics, and tannins included in the latex extract secondary metabolites are thought to be surface-active chemicals stabilising the bimetallic nanoparticles. Proteins and tannins may help in the bioreduction of metal ions to produce Ag-Au nanoparticles. The production of bimetallic nanoparticles was demonstrated using spectroscopic and surface morphological approaches.	Krishnan Sundarrajan and Pottail (2021)
Polyisoprenes	The majority of the chemicals in the extracts, including polyisoprenes (89%), were lipophilic compounds, according to the proximate chemical analysis. Polyisoprene extracts have physicochemical and techno-functional characteristics that suggest they could be employed in emulsions or electrohydrodynamic encapsulation procedures.	Ramos-Martínez, González-Cruz, Calderón-Santoyo, and Ragazzo-Sánchez (2022)
Glycoprotein	Jackfruit latex was exposed to heat precipitation and Ion-exchange chromatography in order to obtain a heteromultimeric glycoprotein which had an inhibitory effect on the blood coagulation.	Siritapetawee and Thammasirirak (2011)

2.3. Jackfruit Latex

Jackfruit produces latex from the fruits, stem, bark, leaves. The latex is white in colour and has a sticky nature i.e. it has gum-like properties. It tends to coagulate when in contact with air and has a characteristic fruity smell. The chemical composition of jackfruit is that it is rich in lipid-derived waxy substances, proteins, secondary plant metabolites like flavonoids, alkaloids and tannins (Krishnan Sundarrajan & Pottail, 2021). It grabs very less interest in terms of commerce or market but it has high potential because it has antioxidant properties which is highly beneficial to human health (Samrot & Sea, 2022). According to Swami, Thakor, Haldankar, and Kalse (2012), pharyngitis, snakebites and glandular swellings can also be cured by the jackfruit latex. Not much scientific activities have been found regarding the jackfruit latex and its usage in the food industry but it definitely has an impact in the medicinal or pharmaceutical industry.

2.3.1. Profile of Jackfruit Latex

According to Samrot and Sean (2021) latex extract exhibited the presence of 1,2-benzoldicarbonsaeure, nonpolar compounds and antioxidant activities.

Table 8 presents the value-added products prepared by using jackfruit latex.

2.4. Jackfruit Peel

Jackfruit peels consists of various beneficial compounds such phenols and flavonols (Zhang et al., 2017). They also contain various other compounds such as ascorbic acid, polyphenols (catechins and chlorogenic acid) and β-carotene (Sharma, Gupta, & Verma, 2015).

They are also a rich source of pectin; consists about 8-15% of pectin in dry matter (Xu et al., 2018). Cellulose is also predominantly present in a range of 20-30% in the peel. Adan et al. (2020) found out that jackfruit peel had abundant minerals, such as potassium, magnesium, zinc, manganese, sodium, copper, calcium through Atomic Absorption spectrometry (AAS).

Table 9 exhibits the value-added products prepared by using jackfruit peel.

Table 9. Value-added products prepared by using jackfruit peel.

Products	Observations	References
Healthy meat analogue	Jackfruit peel powder was mixed in a wheat gluten ratio to produce a meat analogue	Hamid et al. (2020)
Bread	When combined with other ingredients to make bread, peel powder (5%) increased the amount of fibre, the ability to hold oil and water, and the pasting capabilities.	Felli, Yang, Abdullah, and Zzaman (2018)
Cookies	Cookies obtained after utilization of rind powder had high carbohydrates and fibre content and also had high overall acceptance	Ramya, Anitha, and Ashwini (2020)
Wine	Wine from Jackfruit peel has a TSS (Total Soluble Solids) of 5 and a good overall acceptance	Cagasan et al. (2021)
Vinegar	Vinegar was prepared from Jackfruit peel and had a protein content of 2.45%	Constance et al. (2021)

Table 10 presents the value-added products prepared by using jackfruit peel.

Table 10. Value-added products prepared by using jackfruit peel.

Products	Observations	References
Antimicrobial packaging films	Tapioca starch and thymol were used to prepare jackfruit peel-based films as a filler and antimicrobial substance, respectively.	Shukor, Nordin, Tawakkal, Talib, and Othman (2021)
Potassium, sodium, calcium, Magnesium, Zinc, Copper, Manganese	Analyzed by Atomic absorption flame emission spectrometry	Adan et al. (2020)
Pectin	Jackfruit peel was subjected to Radio frequency- assisted extraction to obtain pectin	Naik, Rawson, and Rangarajan (2020)
Cellulose and spherical cellulose nanocrystals (CSCN)	By sulphuric acid hydrolysis, Jackfruit peel derived Cellulose and spherical cellulose nanocrystals were isolated	Trilokesh and Uppuluri (2019)
Steroids, Triterpenoids, saponins, alkaloids, glycosides, tannins and polyphenols, flavonoids, proteins, carbohydrates	Jackfruit peels was treated with ethanol and methanol as extraction solvents	Sundarraj and Ranganathan (2018)
Dye Remover	Jackfruit peel was used for activated carbon preparation and utilized for Red 2BN dye removal	Ramasamy and Miranda (2022)
Biodegradable plastics	Pure nanocellulose was extracted from the peel through acid hydrolysis. Thin films were formed using nanocellulose as prime consitituent.	Reshmy et al. (2021)
Binder in pharmaceutical tablets	Jackfruit peels were treated in order to extract pectin which was used as a binder	Khedmat, Izadi, Mofid, and Mojtahedi (2020)
Water purifying agent	Jackfruit peel derived biochar was used for copper metal ions elimination from water.	Abid, Ibrahim, and Zulkifli (2019)
Bioethanol	Fermentation was carried by using filtrates of treated Jackfruit peel extract with *Sachharomyces cerevisiae*	Soumya, Gupta, Vikas, and Pradeep (2019)
Bio-insecticide	The maceration of jackfruit peels in 70% ethanol and their use as a pesticide enabled rice weevils to die after 20 minutes	Acero (2019)
Bionanoparticles	Jackfruit peel was used in the fabrication of the P/HA bionanoparticles which possesses bone healing properties	Govindaraj, Rajan, Hatamleh, and Munusamy (2018)
Bio-oil	Jackfruit peel was used as the raw material in pyrolysis to obtain bio-fuel	Soetardji, Widjaja, Djojorahardjo, Soetaredjo, and Ismadji (2014)

3. CONCLUSIONS AND FUTURE PERSPECTIVES

This literature study revealed that there are various potential applications of jackfruit waste and there are numerous benefits of each waste part of this seasonal fruit. Thus, using it as a raw material can serve as a major step toward environmental waste remediation. The various waste parts of jackfruit have nutrients that can serve as a good source for industrial applications. Jackfruit seeds mostly have been the most researched upon, out of all the waste parts, being rich in carbohydrates and phenolic compounds it can serve as an excellent food source. Jackfruit peel has also been found to be rich in carbohydrates, fibres and pectin. The pectin derived from the jackfruit peel has been found to have properties which can compete with the commercial grade pectin found in the market (Begum, Aziz, Yusof, Saifullah, & Uddin, 2021). Jackfruit rags possess cellulose, protein and reduced sugar (Dam & Nguyen, 2012). Lastly, jackfruit latex has antioxidant properties (Samrot & Sea, 2022). Investigations also led to finding that the rags can serve as a binder for formulating tablets (Gohain & Sahu, 2017). Putting all the above points together we can come to a conclusion that although Jackfruit comprises of 60% inedible parts, all those waste parts have their own benefits and are rich in physico-chemical composition.

However, Jackfruit being a perishable product attracts less interest from the industrial eye and because most of the fruit parts are considered inedible they are almost neglected despite having various nutritional properties and benefits. Thus, more attention and studies are required to develop appropriate post-harvest and processing methods, reduce post-harvest and production losses, and turn jackfruit waste into value-added products so that jackfruit cultivation, consumption, and waste management in jackfruit processing industries can become more widespread.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Both authors contributed equally to the conception and design of the study.

REFERENCES

Abd El-Aziz, A. A., & Esmail, R. M. (2016). Evaluation of physico-chemical properties, functional, organoleptic characteristics and sensory evaluation of butter cake supplemented with different levels of jackfruit (Artocarpus Heterophyllus Lam.) Seeds Flour. *Journal of Home Economics*, *26*(3), 139-153.

Abid, M. K., Ibrahim, H. B., & Zulkifli, S. Z. (2019). Synthesis and characterization of biochar from peel and seed of jackfruit plant waste for the adsorption of copper metal ion from water. *Research Journal of Pharmacy and Technology*, *12*(9), 4182-4188.Available at: https://doi.org/10.5958/0974-360x.2019.00720.0.

Acero, L. H. (2019). Insecticidal property of jackfruit (Artocarpus heterophyllus) peel ethanol extract against rice weevils (Sitophilus oryzae). *International Journal of Bioscience, Biochemistry and Bioinformatics*, *158*(9), 158-165.

Adan, A., Ojwang, R., Muge, E., Mwanza, B., & Nyaboga, E. (2020). Phytochemical composition and essential mineral profile, antioxidant and antimicrobial potential of unutilized parts of jackfruit. *Food Reserch*, *4*(4), 1125-1134.Available at: https://doi.org/10.26656/fr.2017.4(4).326.

Akter, F., & Haque, M. (2019). Jackfruit waste: A promising source of food and feed. *Annals of Bangladesh Agriculture*, *23*(1), 91-102.Available at: https://doi.org/10.3329/aba.v23i1.51477.

Arun Sankar, V., Suresh, P., Manu Lal, J., Ajith, N., Dinesh Kumar, C., & Senthil Kumar, G. (2021). Analysis of mechanical properties on ABS thermoplastic infused with Jack Fruit Rags. *Annals of the Romanian Society for Cell Biology*, *25*(6), 12663-12670.

Ashok, A., Mathew, S. E., Shivaram, S. B., Shankarappa, S. A., Nair, S. V., & Shanmugam, M. (2018). Cost effective natural photo-sensitizer from upcycled jackfruit rags for dye sensitized solar cells. *Journal of Science: Advanced Materials and Devices*, *3*(2), 213-220.Available at: https://doi.org/10.1016/j.jsamd.2018.04.006.

Babitha, S., Soccol, C. R., & Pandey, A. (2007). Solid-state fermentation for the production of Monascus pigments from jackfruit seed. *Bioresource Technology*, *98*(8), 1554-1560.Available at: https://doi.org/10.1016/j.biortech.2006.06.005.

Balachandran, G. B., David, P. W., Radhakrishnan, V., Ali, M. N. A., Baskaran, V. K., Virumandi, D., . . . Sathyamurthy, R. (2021). Investigation on the performance enhancement of single-slope solar still using green fibre insulation derived from Artocarpus heterophyllus rags reinforced with Azadirachta indica gum. *Environmental Science and Pollution Research*, *28*(25), 32879-32890.Available at: https://doi.org/10.1007/s11356-021-13062-x.

Barge, K., & Divekar, S. (2018). Development of coconut milk residue and jackfruit seed enriched biscuit. *International Journal of Agricultural Engineering*, *11*(2), 373-378.Available at: https://doi.org/10.15740/has/ijae/11.2/373-378.

Begum, R., Aziz, M. G., Yusof, Y. A., Saifullah, M., & Uddin, M. B. (2021). Evaluation of gelation properties of jackfruit (Artocarpus heterophyllus) waste pectin. *Carbohydrate Polymer Technologies and Applications*, *2*, 100160.Available at: https://doi.org/10.1016/j.carpta.2021.100160.

Bhadra, S., Mohan, N., Parikh, G., & Nair, S. (2019). Possibility of artocarpus heterophyllus latex as an alternative source for natural rubber. *Polymer Testing*, *79*, 106066.Available at: https://doi.org/10.1016/j.polymertesting.2019.106066.

Bhornsmithikun, V., Chetpattananondh, P., Yamsaengsung, R., & Prasertsit, K. (2010). Continuous extraction of prebiotics from jackfruit seeds. *Songklanakarin Journal of Science and Technology*, *32*(6), 635-642.

Braga, J., & Galvez, L. (2018). *Formulation optimization of meat loaf with different levels of powdered jackfruit (Artocarpus heterophyllus Lam) rags as meat extender and phosphate binder*. Paper presented at the International Conference on Nutrition-Sensitive Agriculture and Food Systems: Strategic Approaches to Nutrition-Sensitive Agriculture and Food Systems in Southeast Asia,, Tagaytay City (Philippines), 7-10 Nov 2018, Interdisciplinary Studies Center for Food and Nutrition Security.

Cagasan, C. U., Lingatong, C. A. V., Pore, K. M. T., Raymond, V., Restor, C. D. D., & Lauzon, R. D. (2021). Production and quality evaluation of wine from jackfruit co-products. *International Journal of Life Sciences and Biotechnology*, *4*(3), 340-352.

Chowdhury, A. R., Bhattacharyya, A. K., & Chattopadhyay, P. (2012). Study on functional properties of raw and blended jackfruit seed flour (a non-conventional source) for food application. *Indian Journal of Natural Products and Resources*, *3*(3), 347-353.

Constance, E. C., Ifunanya, W. U., Amarachi, M. C. E., Idera, E. E. C., Ikechukwu, N., Ogechi, P. C., & Perpetua, O. C. (2021). Evaluation of vinegar production properties of Garcina kola and Artocarpus heterophyllus. *Journal of Applied Chemical Science International*, *12*(2), 48-60.

Costa, L. A. D., Diogenes, I. C. N., Oliveira, M. d. A., Ribeiro, S. F., Furtado, R. F., BASTOS, M. d. S. R., . . . Benevides, S. D. (2020). Smart film of jackfruit seed starch as a potential indicator of fish freshness. *Food Science and Technology*, *41*, 489-496.Available at: https://doi.org/10.1590/fst.06420.

Dam, S., & Nguyen, N. (2012). *Production of fermented beverage from fruit rags of jackfruit (Artocarpus heterophyllus)*. Paper presented at the Southeast Asia Symposium on Quality Management in Postharvest Systems and Asia Pacific Symposium on Postharvest Quality 989.

Dam, S. M., & Nguyen, N. T. (2012). *Production of fermented beverage from fruit rags of jackfruit (Artocarpus heterophyllus)*. Paper presented at the Southeast Asia Symposium on Quality Management in Postharvest Systems and Asia Pacific Symposium on Postharvest Quality 989.

Dhwani, N., Raju, G., Mathew, S. E., Baranwal, G., Shivaram, S. B., Katiyar, N., . . . Nagegowda, D. A. (2020). Antibacterial efficacy of Jackfruit rag extract against clinically important pathogens and validation of its antimicrobial activity in Shigella dysenteriae infected Drosophila melanogaster infection model. *BioRxiv*.Available at: https://doi.org/10.1101/2020.03.09.983015.

Faridah, S., & Aziah, A. (2012). Development of reduced calorie chocolate cake with jackfruit seed (Artocarpus heterophyllus Lam.) flour and polydextrose using response surface methodology (RSM). *International Food Research Journal*, *19*(2), 515-519.

Felli, R., Yang, T. A., Abdullah, W. N. W., & Zzaman, W. (2018). Effects of incorporation of jackfruit rind powder on chemical and functional properties of bread. *Tropical Life Sciences Research*, *29*(1), 113-126.Available at: https://doi.org/10.21315%2Ftlsr2018.29.1.8.

Gipolan, I. G., & Tabinas, R. J. (2022). *Optimization of Jackfruit (Artocarpus heterophyllus Lam) rags and salt levels in the development of corned milkfish (Chanos chanos)*. Paper presented at the In IOP Conference Series: Earth and Environmental Science. IOP Publishing.

Gohain Barua, A., & Boruah, B. R. (2004). Minerals and functional groups present in the jackfruit seed: A spectroscopic investigation. *International Journal of Food Sciences and Nutrition*, *55*(6), 479-483.

Gohain, H. C., & Sahu, B. P. (2017). Formulation and evaluation of mucoadhesive tablet of metformin HCl using Jack Fruit Latex (Artocarpus heterophyllus). *Research Journal of Pharmacy and Technology*, *10*(2), 371-377.Available at: https://doi.org/10.5958/0974-360X.2017.00075.0.

Govindaraj, D., Rajan, M., Hatamleh, A. A., & Munusamy, M. A. (2018). From waste to high-value product: Jackfruit peel derived pectin/apatite bionanocomposites for bone healing applications. *International Journal of Biological Macromolecules*, *106*, 293-301.Available at: https://doi.org/10.1016/j.ijbiomac.2017.08.017.

Hamid, M. A., Tsia, F. L. C., Okit, A. A. B., Xin, C. W., Cien, H. H., Harn, L. S., & Yee, C. F. (2020). *The application of Jackfruit by-product on the development of healthy meat analogue*. Paper presented at the In IOP Conference Series: Earth and Environmental Science. IOP Publishing.

Hidayati, L., Soekopitojo, S., Chisbiyah, L. A., & Mareta, V. (2019). *Effect of Jackfruit seed flour substitution on tambang cookies' calsium, phosphor and hedonic rating*. Paper presented at the In 2nd International Conference on Vocational Education and Training (ICOVET 2018). Atlantis Press.

Hossain, M. T., Hossain, M. M., Sarker, M., Shuvo, A. N., Alam, M. M., & Rahman, M. S. (2014). Development and quality evaluation of bread supplemented with jackfruit seed flour. *International Journal of Nutrition and Food Sciences, 3*(5), 484-487.Available at: https://doi.org/10.11648/j.ijnfs.20140305.28.

Ihromi, S., & Dewi, E. S. (2021). *The combination of pumpkin and jackfruit seeds for making tortilla*. Paper presented at the In IOP Conference Series: Earth and Environmental Science. IOP Publishing.

Islam, M. S., Begum, R., Khatun, M., & Dey, K. C. (2015). A study on nutritional and functional properties analysis of jackfruit seed flour and value addition to biscuits. *IJERT, International Journal of Engineering Research and Technology, 4*(12), 139-147.

Jagtap, U. B., & Bapat, V. A. (2013). Green synthesis of silver nanoparticles using Artocarpus heterophyllus Lam. seed extract and its antibacterial activity. *Industrial Crops and Products, 46*, 132-137.Available at: https://doi.org/10.1016/j.indcrop.2013.01.019.

Kabir, S. M., Kim, S. D., & Koh, J. (2018). Application of jackfruit latex gum as an eco-friendly binder to pigment printing. *Fibers and Polymers, 19*(11), 2365-2371.Available at: https://doi.org/10.1007/s12221-018-8060-z.

Khan, S., Saqib, M., & Alim, M. (2016). Evaluation of quality characteristics of composite cake prepared from mixed jackfruit seed flour and wheat flour. *Journal of the Bangladesh Agricultural University, 14*(2), 219-227.Available at: https://doi.org/10.3329/jbau.v14i2.32697.

Khedmat, L., Izadi, A., Mofid, V., & Mojtahedi, S. Y. (2020). Recent advances in extracting pectin by single and combined ultrasound techniques: A review of techno-functional and bioactive health-promoting aspects. *Carbohydrate Polymers, 229*, 115474.Available at: https://doi.org/10.1016/j.carbpol.2019.115474.

Krishnan Sundarrajan, S., & Pottail, L. (2021). Green synthesis of bimetallic Ag@ Au nanoparticles with aqueous fruit latex extract of Artocarpus heterophyllus and their synergistic medicinal efficacies. *Applied Nanoscience, 11*(3), 971-981.Available at: https://doi.org/10.1007/s13204-020-01657-8.

Kumar, M., Potkule, J., Tomar, M., Punia, S., Singh, S., Patil, S., . . . Kennedy, J. F. (2021). Jackfruit seed slimy sheath, a novel source of pectin: Studies on antioxidant activity, functional group, and structural morphology. *Carbohydrate Polymer Technologies and Applications, 2*, 100054.Available at: https://doi.org/10.1016/j.carpta.2021.100054.

Lakmali, H., & Arampath, P. (2021). Development of jackfruit (Artocarpus heterophyllus) bulb and seed flour-based pasta. *Journal of Dry Zone Agriculture, 7*(2), 97-113.Available at: https://doi.org/10.4038/jdza.v7i2.30.

Maskey, B., Subedi, S., & Shrestha, N. K. (2020). Effect of incorporation of jackfruit (Artocarpus heterophyllus) seed flour on the quality of cookies. *Dristikon: A Multidisciplinary Journal, 10*(1), 60-72.Available at: https://doi.org/10.3126/dristikon.v10i1.34541.

Mondal, C., Remme, R. N., Mamun, A. A., Sultana, S., Ali, M. H., & Mannan, M. A. (2013). Product development from jackfruit (Artocarpus heterophyllus) and analysis of nutritional quality of the processed products. *Journal of Agriculture and Veterinary Science, 4*(1), 76-84.Available at: https://doi.org/10.9790/2380-0417684.

Naik, M., Rawson, A., & Rangarajan, J. M. (2020). Radio frequency-assisted extraction of pectin from jackfruit (Artocarpus heterophyllus) peel and its characterization. *Journal of Food Process Engineering, 43*(6), e13389.Available at: https://doi.org/10.1111/jfpe.13389.

Ngwere, S. S., & Mongi, R. J. (2021). Nutritional composition, sensory profile and consumer acceptability of wheat-jackfruit seed composite buns. *Tanzania Journal of Science, 47*(3), 1154-1164.Available at: https://doi.org/10.4314/tjs.v47i3.24.

Ocloo, F., Bansa, D., Boatin, R., Adom, T., & Agbemavor, W. (2010). Physico-chemical, functional and pasting characteristics of flour produced from Jackfruits (Artocarpus heterophyllus) seeds. *Agriculture and Biology Journal of North America, 1*(5), 903-908.Available at: https://doi.org/10.5251/abjna.2010.1.5.903.908.

Papa, S. F., da Silva, P. P. M., Mandro, G. F., Margiotta, G. B., Spoto, M. H. F., & Canniatti-Brazaca, S. G. (2018). Physicochemical characteristics and high sensory acceptability in cappuccinos made with jackfruit seeds replacing cocoa powder. *PloS one, 13*(8), e0197654.Available at: https://doi.org/10.1371/journal.pone.0197654.

Patowary, R., Patowary, K., Kalita, M. C., Deka, S., Lam, S. S., & Sarma, H. (2022). Green production of noncytotoxic rhamnolipids from jackfruit waste: Process and prospects. *Biomass Conversion and Biorefinery*, 1-14.Available at: https://doi.org/10.1007/s13399-022-02427-y.

Photphisutthiphong, Y., & Vatanyoopaisarn, S. (2019). Production of vinegar from jackfruit rags and jackfruit seeds. *The Journal of Applied Science, 18*(1), 75-93.Available at: https://doi.org/10.14416/j.appsci.2019.03.002.

Prakash, E., & Gupta, D. K. (2013). Jackfruit (Artocarpus Integrifolia) latex extract has anti-cancer property as checked on MCF-7 human breast cancer cell line. *International Journal of Agriculture and Food Science Technology, 4*(1), 77-82.

Prasad, K. R., & Virupaksha, T. K. (1990). Purification and characterization of a protease from jackfruit latex. *Phytochemistry, 29*(6), 1763-1766.Available at: https://doi.org/10.1016/0031-9422(90)85011-4.

Rajput, E., Rawson, A., Krishnamoorthy, S., & Rangarajan, J. (2022). Jackfruit byproducts: Functional properties and scope of utilization as unleavened flat bread. *Journal of Culinary Science & Technology*, 1-23.Available at: https://doi.org/10.1080/15428052.2022.2027307.

Ramasamy, L., & Miranda, L. R. (2022). Surface-modified adsorbent from artocarpus heterophyllus lam biomass to confine reactive red 194 in real and synthetic effluents: Kinetics and equilibrium stud. *Adsorption Science & Technology, 2022*, 1-23.Available at: https://doi.org/10.1155/2022/4129833.

Ramli, R. A. B. (2009). *Physicochemical characteristics of calcium-treated Jackfruit (Artocarpus Heterophyllus) Fleshs during chilled storage*. [Thesis of Degree of Doctor of Philosophy], University Sains Malaysia.

Ramos-Martínez, O., González-Cruz, E. M., Calderón-Santoyo, M., & Ragazzo-Sánchez, J. A. (2022). Polyisoprenes obtained from jackfruit latex (Artocarpus heterophyllus L.): Extraction and characterization. *Journal of Applied Polymer Science, 139*(25), e52392.Available at: https://doi.org/10.1002/app.52392.

Ramya, H., Anitha, S., & Ashwini, A. (2020). Nutritional and sensory evaluation of jackfruit rind powder incorporated with cookies. *International Journal of Current Microbiology and Applied Sciences, 9*(11), 3305-3312.Available at: https://doi.org/10.20546/ijcmas.2020.911.395.

Ranasinghe, R. A. S. N., Maduwanthi, S. D. T., & Marapana, R. A. U. J. (2019). Nutritional and health benefits of jackfruit (Artocarpus heterophyllus Lam.): A review. *International Journal of Food Science, 2019*, 1-12.Available at: https://doi.org/10.1155/2019/4327183.

Rengsutthi, K., & Charoenrein, S. (2011). Physico-chemical properties of jackfruit seed starch (Artocarpus heterophyllus) and its application as a thickener and stabilizer in chilli sauce. *LWT-Food Science and Technology, 44*(5), 1309-1313.Available at: https://doi.org/10.1016/j.lwt.2010.12.019.

Reshmy, R., Philip, E., Vaisakh, P., Raj, S., Paul, S. A., Madhavan, A., . . . Pugazhendhi, A. (2021). Development of an eco-friendly biodegradable plastic from jack fruit peel cellulose with different plasticizers and Boswellia serrata as filler. *Science of the Total Environment, 767*, 144285.Available at: https://doi.org/10.1016/j.scitotenv.2020.144285.

Samrot, A. V., & Sea, T. C. (2022). Investigating the Antioxidant and Antimicrobial Activity of Artocarpus heterophyllus Lam.(Jackfruit) Latex. *Biointerface Research in Applied Chemistry, 12*, 3019-3033.

Samrot, A. V., & Sean, T. C. (2021). Investigating the antioxidant and antimicrobial activity of artocarpus heterophyllus lam.(Jackfruit) Latex. *Biointerface Research in Applied Chemistry, 12*(3), 3019-3033.Available at: https://doi.org/10.33263/briac123.30193033.

Sandaruwan, P. D., WDM, S., Edirisinghe, D. G., & Sudusingha, Y. C. Y. (2020). Effect of artocarpus heterophyllus latex on properties of calcium carbonate filled natural rubber/low density polyethylene/waste polyethylene composites. *Physical Science & Biophysics Journal*, *4*(1).Available at: https://doi.org/10.23880/psbj-16000140.

Sari, N. (2019). The use of glucose syrup as product of selulosa hidrolyze from the jackfruit rags (Artocarpus heterophylus Lamk) as sweetner on candies production from the coconut plam (Cocos nucifera L). *Journal of Pharmaceutical and Sciences*, *2*(1), 17-23.Available at: https://doi.org/10.36490/journal-jps.com.v2i1.12.

Saxena, A., Bawa, A. S., & Raju, P. S. (2011). Jackfruit (Artocarpus heterophyllus Lam.). In Postharvest biology and technology of tropical and subtropical fruits (pp. 275-299e): Woodhead Publishing.

Sharma, A., Gupta, P., & Verma, A. K. (2015). Preliminary nutritional and biological potential of Artocarpus heterophyllus L. shell powder. *Journal of Food Science and Technology*, *52*(3), 1339-1349.Available at: https://doi.org/10.1007/s13197-013-1130-8.

Shehin, V., Kaur, J., & Gupta, P. (2019). Product development: Snacks prepared from jackfruit seed flour and corn flour. *Think India Journal*, *22*(34), 728-738.

Shukor, U. A. A., Nordin, N., Tawakkal, I. S. M. A., Talib, R. A., & Othman, S. H. (2021). Utilization of jackfruit peel waste for the production of biodegradable and active antimicrobial packaging films. In Biopolymers and Biocomposites from Agro-Waste for Packaging Applications (pp. 171-192): Woodhead Publishing.

Siritapetawee, J., & Thammasirirak, S. (2011). Purification and characterization of a heteromultimeric glycoprotein from Artocarpus heterophyllus latex with an inhibitory effect on human blood coagulation. *Acta Biochimica Polonica*, *58*(4), 521-528.Available at: https://doi.org/10.18388/abp.2011_2219.

Siritapetawee, J., Thumanu, K., Sojikul, P., & Thammasirirak, S. (2012). A novel serine protease with human fibrino (geno) lytic activities from Artocarpus heterophyllus latex. *Biochimica et Biophysica Acta (BBA)-Proteins and Proteomics*, *1824*(7), 907-912.Available at: https://doi.org/10.1016/j.bbapap.2012.05.002.

Soetardji, J. P., Widjaja, C., Djojorahardjo, Y., Soetaredjo, F. E., & Ismadji, S. (2014). Bio-oil from jackfruit peel waste. *Procedia Chemistry*, *9*, 158-164.Available at: https://doi.org/10.1016/j.proche.2014.05.019.

Sofiyanita, S., & Nurhayati, S. (2018). Determining the content of nutrition and organoleptic test of chips from jackfruit seed and durian seed. *Indonesian Journal of Chemical Science and Technology*, *1*(1), 43-49.

Soumya, B., Gupta, P., Vikas, R., & Pradeep, K. (2019). Chemoenzymatic saccharification of Artocarpus heterophyllus Lam.(jackfruit) peel waste and its utilization for bioethanol production. *Indian Forester*, *145*(12), 1204-1209.

Sultana, A., Rahman, M. R. T., Islam, M., Rahman, M., & Alim, M. A. (2014). Evaluation of quality of chapaties enriched with jackfruit seed flour and bengal gram flour. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *8*(5), 73-78.Available at: https://doi.org/10.9790/2402-08537378.

Sundarraj, A. A., & Ranganathan, T. V. (2018). Extraction and functional properties of cellulose from jackfruit (Artocarpus integer) Waste. *International Journal of Pharmaceutical Sciences Research 2018c*, *9*, 1000-1008.

Supit, E. G., Caparida, M. C. H., Retutar, W. G., Balagtas, M., Taclan, L., Laborde, G., . . . Estrada, M. R. (2018). *Utilization of Jackfruit (Artocarpus heterophyllus) Seed as a Bread Spread*. Paper presented at the Abstract Proceedings International Scholars Conference.

Swami, S. B., Thakor, N., Haldankar, P., & Kalse, S. (2012). Jackfruit and its many functional components as related to human health: A review. *Comprehensive Reviews in Food Science and Food Safety*, *11*(6), 565-576.Available at: https://doi.org/10.1111/j.1541-4337.2012.00210.x.

Swathi, B., Lekshmi, G., & Sajeev, M. (2019). Cooking quality, nutritional composition and consumer acceptance of functional jackfruit pasta enriched with red amaranthus. *Environment Conservation Journal*, *20*(3), 89-97.Available at: https://doi.org/10.36953/ecj.2019.20313.

Thejas Gowda, K. S., Sadananda, G. K., Kirankumar Gorabal, D., Laxman Kukanoor, D. K., Nagajjanavar, K., & Koulagi, S. (2021). Evaluation of organoleptic quality of tomato and methi leaves powder fortified extruded product. *The Pharma Innovation Journal*, *10*(5), 346-349.

Trilokesh, C., & Uppuluri, K. B. (2019). Isolation and characterization of cellulose nanocrystals from jackfruit peel. *Scientific Reports, 9*(1), 1-8.Available at: https://doi.org/10.1038/s41598-019-53412-x.

Ulloa, J. A., Villalobos Barbosa, M. C., Resendiz Vazquez, J. A., Rosas Ulloa, P., Ramírez Ramírez, J. C., Silva Carrillo, Y., & González Torres, L. (2017). Production, physico-chemical and functional characterization of a protein isolate from jackfruit (Artocarpus heterophyllus) seeds. *CyTA-Journal of Food, 15*(4), 497-507.Available at: https://doi.org/10.1080/19476337.2017.1301554.

Varghese, C., Wolodko, J., Chen, L., Doschak, M., Srivastav, P. P., & Roopesh, M. (2020). Influence of selected product and process parameters on microstructure, rheological, and textural properties of 3D printed cookies. *Foods, 9*(7), 907.Available at: https://doi.org/10.3390/foods9070907.

Weerasooriya, M., & Piyarathne, S. (2019). Production of extracellular amylase by Aspergillus niger under submerged fermentation using jack fruit rag as the carbon source. *Indian Journal of Traditional Knowledge, 19*(1), 158-163.

Xu, S. Y., Liu, J. P., Huang, X., Du, L. P., Shi, F. L., Dong, R., & Cheong, K. L. (2018). Ultrasonic-microwave assisted extraction, characterization and biological activity of pectin from jackfruit peel. *Lwt, 90*, 577-582.Available at: https://doi.org/10.1016/j.lwt.2018.01.007.

Yulia, R. (2019). Calcium fortification of dried noodle substituted by jackfruit seed (Artocarpusheterophyllus) flour with broccoly (Brassica oleracea var.) Pasta. *Journal of Physics: Conference Series IOP Publishing, 1232*(1), 012048.Available at: https://doi.org/10.1088/1742-6596/1232/1/012048.

Zhang, L., Tu, Z. C., Xie, X., Wang, H., Wang, H., Wang, Z. X., & Lu, Y. (2017). Jackfruit (Artocarpus heterophyllus Lam.) peel: A better source of antioxidants and a-glucosidase inhibitors than pulp, flake and seed, and phytochemical profile by HPLC-QTOF-MS/MS. *Food Chemistry, 234*, 303-313.Available at: https://doi.org/10.1016/j.foodchem.2017.05.003.

Zhang, Y., Li, B., Xu, F., He, S., Zhang, Y., Sun, L., & Tan, L. (2021). Jackfruit starch: Composition, structure, functional properties, modifications and applications. *Trends in Food Science & Technology, 107*, 268-283.Available at: https://doi.org/10.1016/j.tifs.2020.10.041.

Zhao, B., Ding, Y., & Wen, Z. (2019). From jackfruit rags to hierarchical porous N-doped carbon: A high-performance anode material for sodium-ion batteries. *Transactions of Tianjin University, 25*(5), 429-436.Available at: https://doi.org/10.1007/s12209-019-00209-8.

Zhu, H., Zhang, Y., Tian, J., & Chu, Z. (2018). Effect of a new shell material—Jackfruit seed starch on novel flavor microcapsules containing vanilla oil. *Industrial Crops and Products, 112*, 47-52.Available at: https://doi.org/10.1016/j.indcrop.2017.10.060.