A Comprehensive Review on Jackfruit Composite Materials and Sustainable Applications

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Abstract. In recent years, there has been a growing interest in the development of sustainable materials to address the environmental challenges posed by conventional synthetic materials. Jackfruit (Artocarpusheterophyllus), a tropical fruit native to South and Southeast Asia, has emerged as a promising candidate for sustainable composite materials due to its abundant availability, low cost, and unique combination of mechanical and chemical properties. This review emphasizes the sustainable aspects of jackfruit composites, focusing on their biodegradability, renewability, and eco-friendly characteristics. The environmental impact and life cycle analysis of jackfruit-based materials are discussed, underlining their potential to reduce the carbon footprint associated with conventional materials.The latter part of the article highlights the wide-ranging applications of jackfruit composite materials. Case studies and examples from recent research demonstrate the practical feasibility and performance of these materials in real-world applications. Challenges and future perspectives in the development and commercialization of jackfruit composites are also discussed, emphasizing the need for continued research in areas such as processing optimization, scalability, and cost-effectiveness.In conclusion, this comprehensive review provides valuable insights into the burgeoning field of jackfruit composite materials, offering a holistic understanding of their synthesis, properties, and applications in material engineering.

Keywords: Jackfruit (Artocarpusheterophyllus), panels , composite material, biodegradable

1 Introduction

In the pursuit of sustainable and eco-friendly solutions, researchers and engineers have been exploring innovative materials derived from renewable sources. One such remarkable contender in this arena is jackfruit (Artocarpusheterophyllus), a tropical tree fruit indigenous to South and Southeast Asia. Beyond its culinary appeal, jackfruit has gained considerable attention in recent years due to its potential applications in composite material engineering. The rise of jackfruit as a viable material source is rooted in its distinctive fibrous and lignocellulosic composition, offering a promising avenue for the development of Eco conscious composite materials [1][2][3][4].

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The increasing global demand for sustainable alternatives to traditional synthetic materials has fueled extensive research into bio-based resources, and jackfruit stands out as a notable candidate. Its fibrous structure and chemical composition make it an ideal precursor for composite materials, offering an excellent blend of strength, durability, and natural abundance. By harnessing the inherent properties of jackfruit, scientists and engineers are delving into the realm of material science to create innovative composites that have the potential to revolutionize various industries [5][6][7].

This introduction provides an overview of the unique properties of jackfruit that make it a promising material for composite engineering. It delves into the structural intricacies of jackfruit, elucidating the components that render it suitable for composite applications. Additionally, it outlines the key factors driving the research and development of jackfruit composite materials, highlighting the environmental concerns associated with traditional materials and the pressing need for sustainable alternatives. The introduction also sets the stage for exploring the various aspects of jackfruit-based composites, including their synthesis techniques, properties, and diverse applications in different fields. By delving into the world of jackfruit composite materials, this exploration aims to shed light on the innovative strides being made in the realm of sustainable materials, offering a glimpse into a greener and more sustainable future [8][9].

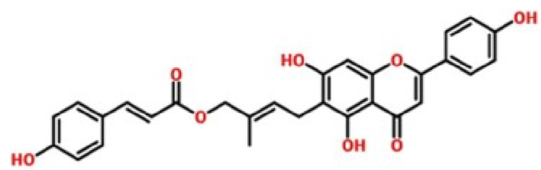

Fig. 1. ArtocarpusHeterophyllus

2 Preparation of Jackfruit Composite Materials

Preparing jackfruit composite materials for medical device panels involves several meticulous steps to ensure the final product meets the necessary standards of strength, durability, and biocompatibility. Here are the various steps involved in the process:

1. Raw Material Selection: Begin by selecting ripe jackfruits with desirable fiber content and mechanical properties. The quality of the raw material significantly influences the characteristics of the composite. The process listed in Table 1 need to be followed for Raw material selection:

Table 1: Raw Material Selection

Sl. No	Process	Description
1	Fiber source	Choose ripe jackfruits with a high fiber content.
2	Ripeness and Freshness	Freshness is essential to ensure the fibers are in optimal condition.
3	Moisture Content	Control the moisture content of the raw jackfruit material.
4	Purity and Contaminants	Ensure the raw jackfruit material is free from contaminants, dirt, and foreign particles.
5	Uniformity	Aim for uniformity in the raw material. Consistent fiber length and thickness
6	Sustainability and Availability	Consider the sustainability of the raw material source.
7	Compatibility with Matrix Material	Fibers should have good adhesion properties with the matrix material to enhance the composite's overall strength.
8	Cost-effectiveness	Evaluate the cost-effectiveness of the raw material
9	Processing Ease	Consider the ease of processing the raw material.

2. Fiber Extraction: Extract fibers from the jackfruit rind using mechanical or chemical methods. Mechanical methods involve crushing the rind and separating the fibers. Chemical methods might include retting processes to dissolve non-fibrous materials.Refer Table 2

3. Fiber Treatment: Treat the extracted fibers to enhance their properties. Chemical treatments, such as alkali or acetic acid soaking, can remove impurities, increase surface roughness, and

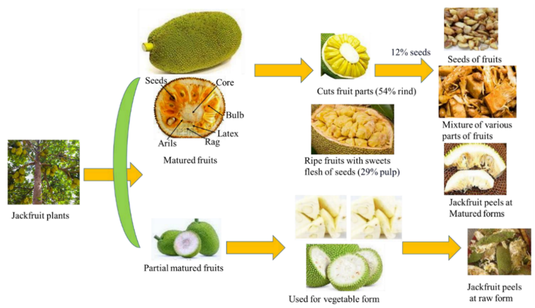

Fig. 2. Raw Material

improve adhesion properties.

4. Matrix Material Selection: Choose an appropriate matrix material that complements the jackfruit fibers. Biocompatible polymers like polylactic acid (PLA) or polyhydroxyalkanoates (PHA) are often preferred for medical applications due to their biodegradability and compatibility with the human body. Biocompatibility Testing (for Medical Applications):Cytotoxicity Testing: Determines whether the material causes harm to living cells. Hemocompatibility Testing: Evaluates the material's compatibility with blood and the cardiovascular system.

5. Composite Formation:

Mix the treated jackfruit fibers with the selected polymer matrix using methods like melt blending or solution casting. The mixture should be homogenously blended to ensure uniformity in the composite material. Chemical Analysis:Fourier Transform Infrared Spectroscopy (FTIR): Identifies chemical functional groups present in the composite material. X-ray Photoelectron Spectroscopy (XPS): Determines surface composition, especially useful for studying adhesion properties.

6. Molding: Use molding techniques such as compression molding or injection molding to shape the composite material into panels. The choice of molding method depends on the complexity of the desired panel shape. Adhesion Testing:Determines the strength of the bond between the fibers and the matrix material.

7. Curing or Solidification:

Subject the molded composite material to appropriate curing processes, allowing the matrix material to solidify and bond with the fibers effectively. This step ensures the composite gains its final mechanical strength and structural integrity. Accelerated Aging: Simulates aging processes to predict the material's durability over time. UV Resistance: Tests the material's resistance to ultraviolet light, which can degrade some composites over time. Dimensional Stability:Assesses how well the material maintains its shape and size under different conditions, including temperature and humidity changes.

8. Surface Finishing: Perform surface finishing processes, such as sanding or polishing, to achieve the desired texture and appearance for the medical device panels. Smooth surfaces are crucial for medical applications to prevent bacterial adhesion and ease of cleaning. Morphological Analysis:Scanning Electron Microscopy (SEM): Provides high-resolution images to examine the material's surface morphology, fiber-matrix adhesion, and internal structure. Transmission Electron Microscopy (TEM): Offers detailed views of internal structures at the nanoscale level.

9. Quality Control and Testing:

Conduct rigorous quality control tests on the prepared panels. These tests may include mechanical tests (such as tensile and flexural tests), thermal analysis, surface characterization, and biocompatibility assessments to ensure the panels meet the required standards and regulations for medical devices.

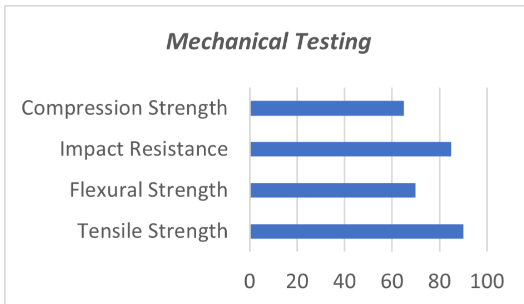

Fig. 3. Mechanical Testing

Thermal Analysis:Differential Scanning Calorimetry (DSC): Analyses the material's thermal properties, including melting and crystallization temperatures. Thermogravimetric Analysis (TGA): Evaluates the material's thermal stability and decomposition temperature.

10. Final Sterilization: If necessary, subject the panels to appropriate sterilization methods, ensuring they are free from microbes and safe for medical use. Autoclaving

- Ethylene Oxide Sterilization
- Gamma Radiation
- Electron Beam (E-beam) Sterilization
- Dry Heat Sterilization
- Hydrogen Peroxide Gas Plasma Sterilization
- Ozone Sterilization
- Chemical Sterilization (Not Suitable for All Materials)

Adhering to these steps meticulously ensures the production of high-quality jackfruit composite materials suitable for medical device panels, combining the advantages of sustainability, biocompatibility, and mechanical strength.

Exploring Innovative Methods in Jackfruit Composite Materials:A Comprehensive Overview

In the realm of composite materials, researchers have explored numerous methods to enhance their properties and applications. A comprehensive review of the literature reveals a plethora of techniques, with distinct approaches for developing jackfruit composite materials tailored to specific industrial needs. Remarkably, while numerous methods have been proposed for enhancing various aspects of jackfruit composites, only a handful of studies have focused on determining the optimal combination of materials for specific applications. Among these, a solitary method stands out, integrating the unique properties of jackfruit fibers with other materials in a synergistic manner.

Table below provides an overview of the reported methods, highlighting the diverse techniques employed in the development of jackfruit composite materials. This summary not only illustrates the innovative strides in the field but also emphasizes the need for further research to explore the untapped potential of jackfruit composite materials, both individually and in combination with other substances.

Table 3: Summary of Reported Methods for Developing Jackfruit Composite Materials.

S.NO	TITLE	JOURNAL NAME	REF. NO
1	Valorization of jackfruit waste into value added products and their potential applications	Frontiers in nutrition	[10]
2	Recent application of jackfruit waste in food and material engineering: A review	Food Bio science	[11]
3	Application of conventional and Non – conventional extraction methods to obtain functional ingredients from jackfruit	Applied science	[12]
4	Mechanical propertiesof natural fibre / particulate reinforced epoxy composite – A review of the literature	Materials today	[13]
5	Thermal potential porous materials and challenges of improving solar still using TiO2/Jackfruit peel - enhanced energy storage material	Materials today	[14]

This compilation underscores the diverse approaches undertaken by researchers, setting the stage for a more nuanced exploration of jackfruit composite materials. As the field continues to evolve, collaborative efforts and innovative methodologies will undoubtedly uncover new horizons, driving the development of sustainable, high-performance composite materials for various applications.

Applications: Jackfruit composite materials find a wide range of applications across various industries due to their unique combination of properties, including strength, durability, and sustainability. Here are some notable applications of jackfruit composite materials:

- Automotive Industry
- Construction and Building Materials
- Furniture and Interior Design
- Packaging Industry
- Medical Devices and Instruments
- Aerospace Industry
- Environmental and Agricultural Applications
- Consumer Goods and Accessories

3 Conclusion

In conclusion, the exploration and utilization of jackfruit composite materials in the manufacturing of medical device panels represent a remarkable stride toward sustainable and innovative solutions in the healthcare industry. The adaptability of jackfruit composite materials is noteworthy. Their successful integration in medical device panels, ranging from intricate surgical instruments to patient monitoring devices, underscores the versatility of this natural resource. Moreover, these panels exhibit properties essential for medical applications, such as resistance to environmental stress, biocompatibility, and ease of sterilization. The journey does not end here. Continuous research, innovation, and collaboration among scientists, engineers, and medical professionals are imperative. Exploring novel techniques, enhancing material properties, and expanding the scope of applications are essential for further integrating jackfruit composite materials into mainstream medical device manufacturing. As we embrace these sustainable alternatives, we are not only shaping the future of medical technology but also fostering a greener, more environmentally responsible approach within the healthcare sector. Jackfruit composite materials stand as a testament to human ingenuity, illustrating how nature's resources can be harnessed to create advanced solutions that benefit both healthcare practitioners and our planet.

Table 2: Fiber Extraction

Sl.No	Process	Description
1	Selection of Jackfruits	Choose ripe jackfruits that are neither underripe nor overripe.
2	Peeling and Removing Seeds	Peel the jackfruit to expose the inner fibrous rind.
3	Mechanical Crushing	Use a mechanical crusher or a similar device to crush the fibrous rind into smaller pieces.
4	Retting Process	Retting is a process where crushed fibers are soaked in water to encourage microbial activity
5	Washing and Cleaning	Wash the extracted fibers thoroughly to remove any residual impurities and retting agents
6	Drying	After washing, the fibers need to be dried to reduce moisture content.
7	Bundling and Storage	Once dried, the fibers are bundled and stored in a dry, cool place to prevent moisture absorption and maintain their quality until further processing.
8	Quality Control	Perform quality checks on the extracted fibers, assessing parameters such as length, strength, and cleanliness.

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