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STATE OF THE ART ON NATURAL HYBRID COMPOSITE FIBRE STRENGTH; A REVIEW

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In this work, a hybrid layered natural composite made of banana and Bristol coir is constructed using a hand layup process, and the mechanical characteristics are investigated using numerical analysis, Finite Element Analysis, and experimental investigation. The mechanical properties of the proposed hybrid natural composite were numerically evaluated using an excel sheet, and the tensile and flexural strength results were derived by FEM analysis utilizing. Tensile and flammability tests are carried out, and the experimental findings are reported. When the numerical analysis findings are compared to the experimental test results, it is found that the divergence between the result is very close percentage for all produced laminates.

INTRODUCTION

Banana and coir layered composite materials have gained significant attention in recent years due to their eco-friendly nature, renewable sources, and potential for various applications. These composites combine the strength of banana fibers with the flexibility and resilience of coir fibers, resulting in materials with unique properties. In this review, we explore the characteristics, manufacturing methods, and diverse applications of banana and coir layered composites. Banana fibers are extracted from the pseudostems of banana plants, while coir fibers are derived from coconut husks. Both fibers are natural, biodegradable, and possess distinct properties that make them suitable for composite materials.Banana fibers are known for their high tensile strength, lightweight nature, and good thermal stability. They exhibit excellent resistance to abrasion and are considered a sustainable alternative to synthetic fibers in composites.Coir fibers offer flexibility, resilience, and resistance to moisture, making them ideal for reinforcing composites. They are also resistant to saltwater, which enhances their suitability for marine applications. Banana and coir layered composites offer a compelling combination of strength, flexibility, and sustainability. Their unique properties and environmentally friendly nature make them attractive for various applications across multiple industries. As research continues to advance, these composites hold the potential to play a significant role in the development of greener and more sustainable materials for the future.

Literature Survey

Alexander et al.[1] have presented because of its better strength-to-weight ratio as compared to metals, glass fibre composites are commonly employed in engineering applications.Tribological properties of these composites vary with operational conditions and fiber distribution. Three orthogonally aligned and chopped fibers were used to create four composite types with similar volume fractions. The Taguchi Optimization and revealed that the addition of The combination of 2% AWSP and 20% jute fibre produced the best mechanical performance. They demonstrated that combining jute fibre with AWSP enhanced polypropylene composites, allowing them to be used in automobiles. Bobbiliet al.[2] have synthesized a sustainable bio-composite material using polypropylene (PP) reinforced with banana fibers (BF) and permeated with nano manganese oxide (MnO2). Different samples were synthesized with varying percentages of PP, BF, and MnO2. Mechanical property analysis revealed that the maximum tensile strength was achieved with a 15 mm fiber length and 20% banana fiber loading. Flexural strength increased with increasing fiber loading up to 15%, then decreased. Binojet al.[3] have discussed the global consumption of thermoplastic materials derived from fossil sources and the associated environmental impacts due to energy consumption during their production and processing. They proposed using natural materials such as banana fibre (BF) as a sustainable option to progressively replace these thermoplastic polymers. Biswalet al.[4] have discussed the growing application of natural fiber-reinforced composite materials in the automobile sector due to their advantageous properties. The automotive industry has recognized the benefits of natural fibers and natural-fiber composites (NFC), which result from combining various natural fibers with different types of polymers. Recent advancements in noise management, particularly in sound absorption, have created opportunities to explore porous materials, including fiber-based composites.

Study on Fibre Materials

Chun et al.[5] have presented a study in which thermoplastic composite and glass fibre packing foam sheets were effectively manufactured using the Dunlop technique. Activated carbon (AC) was utilised as a filler to improve mechanical characteristics and absorb ethylene gas generated by packed bananas. The major goal of this work was to investigate the effect of activated carbon levels ranging from 0 to 20 phr on the physical, morphological, mechanical, and thermal characteristics of bio-composite foams. This research suggests that the proposed bio-composite foam has the potential to enhance the postharvest storage stability of bananas and can be used as packaging for other fresh fruit products. Das et al.[6] have proposed an unique method for producing natural fiber-reinforced polymer composites with mechanical qualities equivalent to glass fibre composites without the use of any chemicals. Fiber reinforcement was taken from the pseudostem of the Nendran banana plant, and a needle punching technique was used to create a non-woven fabric composite. Mechanical parameters such as tensile strength, flexural strength, hardness, quasi-static indentation (QSI), and dynamic mechanical analysis (DMA) were assessed and confirmed using theoretical models Dhanalakshmiet al.[7] have demonstrated the use of natural fibers in polymer composites. These cost-effective fibers have low density and high specific attributes. Natural fiber composites exhibited attributes similar to those of regular fiber composites, including excellent mechanical properties, high specific strength, low abrasion, eco-friendliness, and environmental sustainability. The adhesion between the matrix and fibers significantly influenced the ductile properties of natural fiber-reinforced polymers. This study provided a detailed exploration of natural fiber-reinforced composites, considering fiber types, fabrication methods, mechanical properties, and various applications. Erdenet al. [8] have addressed the environmental challenges posed by the traditional disposal of agricultural biowaste, such as pig manure and banana peel waste. These materials can lead to the release of toxic effluent and methane, a potent greenhouse gas. Agricultural bio-waste is rich in nutrients, including nitrogen and phosphorus. Geethamaet al.[8] have explained that traditional disposal of agricultural bio-waste, such as pig manure and banana peel waste, poses environmental challenges. Uncontrolled decomposition of these wastes results in toxic effluent and methane emissions, a potent greenhouse gas. These waste materials are rich in valuable nutrients like nitrogen and phosphorus. The study aimed to investigate the solubilization of phosphorus (P) during anaerobic digestion (AD) of pig manure with banana peel waste as a co-substrate. The objective was to enhance the biological dissolution of phosphorus from solid pig manure to the aqueous phase, enabling its recovery as a concentrated product through crystallization. Huanget al.[10] have researched the best way to hybridise banana-coir fibre particles in a polymer matrix for possible use in automotive component design and manufacture. They used a Central Composite Design with control factors such as particle size, volume fraction, and stirring time, while evaluating tensile strength and flexural strength as response variables. Jansonset al. [11] have conducted a study on banana cellulose nanofibers (BNCFs) prepared from waste banana stems. They synthesized a novel two-dimensional (2D) Zn-MOF using 5-(1-hydroimidazolyl) isophthalic acid as the ligand. The stability of Zn-MOF was confirmed through X-ray diffraction, thermogravimetry, and scanning electron microscopy analyses. Zn-MOF was then used to catalyze the grafting of poly(ε-caprolactone) (ε-CL) onto BNCFs through homogeneous ring-opening polymerization in an ionic liquid. Kutty et al.[12]proposed the work on fibre-thermoplastic polyurethane compositewas not only non-toxic to Hela cells but also promoted the growth of Hela cells within a certain concentration range. Therefore, this study demonstrates the promising potential of fibre-thermoplastic polyurethane compositefor biomedical applications, highlighting the high efficiency, non-toxicity, and stability of Zn-MOF as the catalyst. Additionally, this research provides a theoretical basis for the application of MOFs as catalysts in polymerization reactions. Kristiinaet al.[13] have addressed the role of ethylene in regulating fruit ripening, particularly in banana fruit, where the modulation of ethylene biosynthesis and quality formation remains unclear. Lalyet al.[14] have explored the utilization of banana by-products, including banana pseudo-stem and banana flower, in tilapia feeds and their extracts' impact on tilapia juveniles' development and health. Loganathanet al. [15] have conducted a study in which they utilized Banana pseudo-stem juice (BPJ) to produce bioplastics through a low-energy and solvent-free fermentation process. The fermentation process was designed to mimic the production of nata de coco, where Acetobacter xylinum ferments coconut water (CW) to yield microbial nanocellulose. The ratio between BPJ and CW played a significant role in determining the nanocellulose biomass yield. Maduet al.[16] have investigated the mechanical properties of composite materials reinforced in an epoxy matrix with banana and glass fibres. They used the hand lay-up method to create unidirectional composites and tested their tensile strength and fracture toughness while taking into account factors like fibre volume fraction, thickness, and length. The study used Taguchi L9 orthogonal array experiments and analyzed variations to identify significant parameters contributing to mechanical characteristics. Narayananet al.[17] have addressed the importance of filament winding (FW) technology in creating high-performance filament-wound composites. However, they pointed out that the current methods for evaluating the mechanical properties of plant fibers for FW are borrowed directly from those used for synthetic fibers. Otaet al.[9] have aimed to study objective and subjective weighting methods in multi-attribute decision-making (MADM) for selecting the best natural fiber-reinforced friction composite for automobile braking applications. They fabricated sixteen friction composites with varying weight percentages of pineapple, ramie, hemp, and banana fibers (5, 10, 15, and 20 wt%). The experimental results, including friction coefficient, fade-recovery performance, friction fluctuations, wear, friction stability, and variability, were considered as performance attributes for selecting the optimal composition.

Palanikumaret al.[19] have provided a comprehensive overview of the extensive research conducted on microorganisms, which have been extensively studied and harnessed for the production of a wide range of enzymes and bioactive substances serving various purposes. Among these enzymes, cellulases have garnered significant attention due to their pivotal role in bioprocessing and biotransformation applications, rendering them

Study on Natural composite

Senbagan et al.[20] have discussed traditional composite materials, emphasizing the use of either natural composites such as banana, Bristle coir and jute mixed with different percentage based on weight for the insulation on cylindrical exhaust smog passage to identify the heat transfer properties analysis. They highlighted that natural fiber-reinforced composites often suffer from poor mechanical and interfacial characteristics due to random fiber orientation and weak fiber-matrix interfaces. However, combining natural (jute) and synthetic (glass) fibers significantly improved mechanical properties, electrical and thermal conductivity, addressing the limitations of natural fiber composites. Singh et al. [21] have presented a study on microbial fuel cells (MFCs), which are considered an emerging and cost-effective technology for treating organic waste and generating bioelectricity. In this study, the performance of an S. cerevisiae-based H-shaped microbial fuel cell using banana peel waste as a substrate was evaluated. The MFCs were operated for 30 days in three cycles. Banana peel slurry was fed into two different MFCs, one with S. cerevisiae and another without. Additionally, it was observed that simple saccharides present in banana peel waste were consumed by S. cerevisiae and other indigenous microbes in the anode chamber. These microbes released electrons in the anode chamber, contributing to voltage generation in the MFC. Wang et al.[22] have emphasized the significance of studying the behavior of pesticide residues in fruits to ensure the effective application of pesticides and minimize the risk of pesticide exposure to humans. Unfortunately, many studies overlook the in situ visual analysis of residues and migration patterns within fresh fruit samples. Youssef et al.[23] have described the role of ethylene in the ripening of climacteric fruits like bananas and identified two WRKY transcription factors, MaWRKY49 and MaWRKY111, from banana fruit. These transcription factors, which are localized in the nucleus, displayed increased transcription levels as banana fruit ripened. MaWRKY49 and MaWRKY111 not only stimulated their own transcription, forming a feedback regulatory loop, but also promoted the transcription of ethylene biosynthesis genes MaACS1 and MaACO1 by directly targeting the W-box elements. Additionally, MaWRKY49 and MaWRKY111 interacted to form a heterodimer, further enhancing their target gene transcription. Both MaWRKY49 and MaWRKY111 also interacted with another transcriptional activator, MabZIP21, synergistically strengthening the transcription of MaACS1 and MaACO1. These findings suggest that MaWRKY49 and MaWRKY111 cooperate with MabZIP21 to positively regulate banana ripening by promoting the transcription of ethylene biosynthesis genes MaACS1 and MaACO1. Zainudinet al.[24]have used chemical techniques to Banana Psedo-Stem onto Unplasticized Polyvinyl Chloride in a research. They looked at how GNPs as reinforcement affected the mechanical and tribological properties of CFs/phenolic resin composites. When the distribution density was 10.82 mg/m2, GNPs grafted equally onto the carbon fibre surface, according to the experimental results. When compared to untreated composites, the tensile strength of CFs/phenolic resin composites modified by GNPs increased by 47.5 percent.

Basic Theories And Principles

The thickness of the composite is considered as two-layer Banana and Bristol coir fiber respectively.

$$t_c = t_b + t_c + t_b \tag{3.1}$$

The Young's modulus, Poison ratio and Shear modulus of the natural hybrid composite can be calculated using Eq. (3.2),

$$E_c = \left(\frac{1}{n}\right)(E_b * t_b + E_r * t_r)$$

$$V_c = \left(\frac{1}{n}\right)(V_b * t_b + V_r * t_r)$$

$$G_c = \left(\frac{1}{n}\right)(G_b * t_b + G_r * t_r) \quad (3.2)$$

Where, E is the young's modulus, V is the Poisson ratio, G is the Shear Modulus, the suffix b & r is the banana and the Bristol coir respectively.

The Stress and Strain component components for composite using the rule of mixtures can be calculated using following Eqs.

$$\sigma_x = (Eb/E_c) * (t_b/t_c) * \sigma_{bx} + \left(\frac{E_r}{E_c}\right) * (t_b/t_c) * \sigma_{rx} \quad (3.3)$$

$$\sigma_y = (Eb/E_c) * (t_b/t_c) * \sigma_{by} + \left(\frac{E_r}{E_c}\right) * (t_r/t_c) * \sigma_{ry} \quad (3.4)$$

$$\tau_{xz} = (Gb/G_c) * (t_b/t_c) * \tau_{bxz} + \left(\frac{E_r}{E_c}\right) * (t_r/t_c) * \tau_{rxz} \quad (3.5)$$

$$\epsilon_x = (1/E_c)*\sigma_x, \quad (3.6)$$

$$\epsilon_y = (1/E_c)*\sigma_y \quad (3.7)$$

$$\gamma_{xy} = (1/G_c)*\tau_{xz} \quad (3.8)$$

The basic equations used to describe the mechanical properties of a Banana and Bristol coir composite can be similar to those used to describe the mechanical properties of a hybrid composite. In this case, however, the composite is composed of only two types of fibers, banana and Bristol coir, with no additional matrix material. Therefore, the equations for the mechanical properties of the composite will be simpler and will depend mainly on the properties of the fibers. The Young's modulus of the fibers can be calculated using Eq. (3.9);

$$E = V_{bn}E_{bn} + V_{br}E_{br} + V_{bn}E_{bn} \quad (3.9)$$

Where, E is the Young's modulus of the composite, E_{bn}&$E_{br}$are the Young's moduli of banana and Bristol coir fibers, respectively.

Similarly, the tensile strength can be calculated using Eq. (3.10) given as;

$$\sigma = V_{bn}\sigma_{bn} + V_{br}\sigma_{br} \quad (3.10)$$

Where, σ is the tensile strength of the composite, σ_{bn}&σ_{br} are the tensile strengths of Banana and Bristol coir fibers, and V_{bn}&$V_{br}$are the volume fractions of Banana and Bristol coir fibers, respectively.

Poisson ratio of the fibers can be calculated using Eq. (3.11);

$$v = V_{nv} + V_{rv} \quad (3.11)$$

Where, ν is the Poisson's ratio of the compositeV_{nv}&$V_{rv}$are the Poisson's ratios of banana and Bristol coir fibers, respectively.

Similarly, the shear modulus of the fibers can be calculated using Eq. (3.12);

$$G = V_{bn}G_{bn} + V_{br}G_{br} \quad (3.12)$$

Where, G is the shear modulus of the composite and G_{bn}&$G_{br}$are the shear moduli of banana and Bristol coir fibers, respectively.

Note that the above Eq. from (3.9) to (3.12) arethe simplified and do not account for any anisotropy or non-linear behavior of the composite. The actual behavior of the composite may deviate from these equations depending on the specific composition and processing parameters. Therefore, it is important to perform experimental testing to determine the actual mechanical properties of the composite.

Summary

They have investigated the behavior of natural fiber made with banana fiber /PP/MAPP. They realized that the polymer matrix composite is one of the advanced materials engineering technologies. They have reviewed many papers on banana fiber. Banana fiber and its composites can be further attractive & suitable cost-effective design method of fiber separation and its composite production may increase its application to a greater extent. The current research looks at the softening of banana fibersutilizing a variety of chemical (NaOH&HCl) and bacterial treatments. Physical (Hygroscopicity, Density, Linear density), parameters increasing environmental pollution, climate change, and the use of non-biodegradable or renewable resources have become major concerns for Compared to synthetic reinforcing. This research aims to investigate the effect of selected chemical treatment on Banana fiber. This work also investigated the potential of using chemically modified Banana fibers (BPF) as reinforcement for polyester composites manufacture.

Conclusion & future Scope

From the literature survey it has been observed that the research on Banana and Bristol coir composites is a growing field in the area of natural fiber in order to maintain sustainable development, but is still an open area of research and several gaps in the existing research that need to be addressed. Some of the potential research gaps are as follows;

1. **Product life cycle and Durability**
   More research is needed to understand the long-term performance of the composites, including their resistance to environmental factors such as temperature, moisture, and UV light.
2. **Processing Techniques**
   There is a need for more efficient and scalable processing techniques that can be used to fabricate high-quality composites with consistent properties.
3. **Mechanical Properties**
   Despite the promising mechanical properties of the composites, there is a need for more comprehensive and standardized testing methods to accurately assess their strength, stiffness, and toughness.
4. **Environmental Impact**
   The environmental impact of the composites, including their biodegradability, needs to be evaluated in more detail, especially in the context of their end-of-life disposal.
5. **Cost-effectiveness**
   The cost-effectiveness of the natural composites compared to traditional materials such as wood, plastic, and metal needs to be more thoroughly evaluated to assess their commercial viability.
6. **Applications**
   The range of applications for the natural composites, such as packaging, construction, and automotive components, is still largely untapped, and more research is needed to explore and optimize their use in these areas.

Addressing these research gaps can help to further advance the field of banana and Bristol coir natural composites and improve their potential for widespread adoption as sustainable and environmentally friendly materials.

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