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An Overview of Natural Fibers and Fillers Reinforced Polymer Composite Materials

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Abstract

Polymer composite materials reinforced with natural fibers and fillers are drawing wide spread attention due to their sustainability, eco-friendliness, and a replacement of conventional synthetic composites. Such materials combine strength and stiffness of natural fibers like jute, hemp, flax, and sisal with flexibility and durability of polymer matrices, including thermoplastics, and thermosets. The paper reviews some developments, properties, and applications of natural fiber-reinforced polymer composites (NFRPCs), focusing on their merits, constraints, and emerging trends. Some main advantages of natural fibers are biodegradability, renewability, and regularity of density and cost-saving. The use of natural fibers in polymer matrices increases mechanical properties such as tension, impact resistance, and thermal stability, yet sparingly impacts the environment. Substituent materials like rice husk, wood flour, or other agricultural residues serve as functional reinforcements in improving composite performance. Nevertheless, challenges such as moisture absorption, poor interfacial bonding, and droplet content could need to be better understood to compete fully. The role of surface treatments, hybridization with synthetic fibers, and advanced fabrication techniques is examined in this paper with respect to their limitations. Progress in bio-based polymers and green processing is further solidifying the justification for using NFRPCs as a convenient solution for automotive, construction, packaging, and consumer product applications.

Keywords: Fibres, filler, thermosetting polymer composite, mechanical, physical properties, applications

INTRODUCTION

Natural fiber filler composite materials for thermoset polymers involves involves extensive research and development. These materials are gaining prominence due to their eco-friendliness, cost-effectiveness, and potential for various applications, including automotive, construction and packaging industries. Research are focus on optimizing the mechanical properties of these composites to meet the growing demand for sustainable materials [1], [2], [3], [4], [5], [6]. Natural fiber filler composites materials with epoxy resin are finding diverse applications across industries [7]–[10]. Natural fiber filler composites incorporate renewable and biodegradable fibers, such as hemp, flax, or jute, as reinforcing agents within a resin matrix. These composites are lightweight, possess good strength-to-weight ratios, and exhibit low energy consumption during production [11]. They're frequently used in applications including automotive components. uses for natural fiber-reinforced polymer composites, including automotive environmental issues and bioengineering applications. qualities that are mechanical and tribological of these composites and their potential to replace conventional substances like glass fibers [12]–[14]. Natural FRP composites have grown in popularity recently as a result of their many appealing qualities [15].

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Review of various studies on natural fiber- composites made of reinforced polymers, including their mechanical, thermal, and tribological properties, and explores recent developments and future trends when it comes to natural fiber composite materials [16], [17], [18]. Fiber composites, including their use in automotive applications, building materials, and biomedical applications [19].Investigate the automated characteristics of epoxy combination composites supplemented with natural fiber/filler garbage for automotive applications [20], [21], [22].Thermal stability, compatibility difficulties, moderate interfacial contact, and other factors are the primary barriers to employing natural fibers [23], [24], [25], [26]. For the right use in creating composites, fibers provide a substantial problem [27], [28]. Natural fibers are affordable, inexpensive, sparsely populated, and possess less machine wear. They also require modest investment [29], [30], [31], [32], [33], [34], [35].The development of more suitable and environmentally friendly materials for various engineering applications , with a specific focus on flax fiber as the reinforcement materials [36]. Composites reinforced with SiC (Silicon Carbide) nano-fillers exhibit better tensile performance compared to those reinforced with banana fiber nano-fillers. This suggests that SiC nano-fillers have a more significant impact on enhancing the tensile properties of the composites in this specific study [37]. This research explores the performance of composites materials containing nano jute fibers the study considers two types of composites: one with jute fiber as an interlayer in glass fiber epoxy matrix , and the other with jute fibers integrated into the epoxy matrix. Through experimentation it is determind that the self- healing nano jute fiber composite exhib its superor tensile and compressive strengths compared to the epoxy resin nano jute glass fiber composite [38], [39]. This study examines the effects of adding silics as a filler to jute fiber-reinforced epoxy composites. The research shows that adding silica to composites enhance their tensile characteristics, modal responsiveness, and fracture toughness. This research advances our understanding of how jute and epoxy composites might be improved for a variety of uses, possibly in sectors that demand materials that are lightweight, renewable, and mechanically tough [40]. This work highlights the successful development of epoxy resin composites reinforced with honecomb natural fibers. The study demonstrates that the addition of honeycomb fibers at specific concentrations can enhance the mechanical properties of the composites, making them competitive with synthetic fiber-reinforced composites. This research contributes to the exploration of sustainable and natural fiber-based materials in various industries [41]. This paper focuses on the development of polymer composites using natural fillers, particularly sugarcane powder obtained from bagbass which is the fibrous residue left after sugarcrane is crushed in mills, bagasse is abundant in india and has various applications, including biofuel production. In this study, sugarcrane powder was used as reinforcement material in combinations with randomly oriented short glass fiber in an epoxy matrix [42]. This research explores the potential of incorporating carbon nanotube fillers into natural fiber composites, specifically jute fiber-based epoxy composites. The finding indicates the addition CNT fillers can enhance various mechanical properties, including tensile, flexural and impact strength up to a certain filler content. Nanofillers can be improve the mechanical performance of natural fiber composites for various engineering applications [43], [44]. This research investigates the impact of natural fillers, such as pineapple leaf (PALF) napier and hemp fibers, on the scratch resistance of epoxy composites. The study finds that napier fiber-filled epoxy composites exhibit the highest peak load, coefficient of friction, and fracture toughness, resulting in superior scratch resistance compared to PALF and hemp fiber-filled composites [45]. The paper also highlights the importance of modelling techniques in designing composites, along with references existing literature to support the finding. Overall, it underscores the potential of natural fibers and fillers in improving the performance of polymer composites across different applications [46], [47]. Comprehensive review of recent research on the mechanical and wear behaviour of thermoset polymers and their composites [48]. It investigates the mechanical properties of these composites, including tensile strength, hardness, and flexural strength, and compares them to synthetic counterparts, aiming to assess their suitability for various applications [49]. This study highlights the significance of composite material, especially natural fiber-reinforced polymer composites, due to their exceptional like lightweight, water resistance and environmental friendliness. it covers the the types of natural fibers used production methods, mechanical and tribological properties and various applications in industries, emphasizing the growing importance of these materials [50]. Abaca exhibits superior mechanical properties among natural composites jute is knwon for its excellent flexural properties while sisal is valued for its hardness characteristics[51]

Figure 1. Natural fibers [4], [24], [28], [37] (a) Banana (b) Sisal (c) Kenaf(d) Sugar palm (e) Kenaf leave

Natural Fiber and Filler Materials

Natural fiber are derived from plants animals, or minerals. They can be used as reinforcement in composites or in textiles, ropes, and other applications. Natural fillers as shown in Fig. 1 are often particulate materials derived from natural sources, used to modify the properties of polymers or to reduce the cost of composites. They are not typically as strong or elongation as fibers. Natural fiber-reinforced composites have gained traction due to their lightweight properties , cost-effectiveness in terms of raw materials, and ease of machining , which make them competitive in the market[52], [53]

Fibers

The properties and manufacturing processes of NFRPCs, their mechanical properties, and their potential applicability across industries , including infrastructure, sporting items, furniture, home appliances, consumer goods, and automobiles. The review covers a range of natural fibers, including flax, coconut, date palm, and pinecone, and discusses various treatments and modifications that can improve their compatibility with polymer matrices [8], [46]. natural fibers as reinforcement materials with relation to fused deposition modeling (FDM) in 3D printing technology [9]. Natural fiber replacement of synthetic fibers in composites ballistic protection applications. natural fibers as reinforcements for polymer composites in various industries and various failure criteria and models for composite materials under different stress states [10], [17]. For the right use in creating composites, fibers provide a substantial problem [28], [30],[54]

Kenaf

A kenaf sapling with the scientific name Hibiscus cannabinus belongs to the Malvaceae family. The work focuses on the utilization of kenaf fiber in various applications. The morphologies of natural fibers, including kenaf fiber, and highlight its characteristics such as flexural and tensile strength. They also mention the chemical configuration of different types of kenaf fibers, such as kenaf core and kenaf bast. The paper further explores the treatment of kenaf fibers with sodium hydroxide to enhance their tensile properties in composite materials. Additionally, the potential applications of kenaf fiber across sectors including construction, aircraft, and the automobile industry [1], [12], [28], [29].

Jute

This fiber produced from In this paper, the authors investigated the mechanical features and performance using fiber made from jute. The jute fiber used in the research was obtained from Easy

Composites, England, and the Bangladesh Jute Research Institute (BJRI), Bangladesh. Jute woven cloth (1*1 plain weave) from the Bangladeshi local market was utilized as reinforcement [5]. The jute fiber had a thickness of 0.4 mm and a density of 1.8 g/cm3 . benefits including cheap cost, low density, and good mechanical properties. The most efficient impact force absorption occurs when jute fibers are aligned in a single path perpendicular to the impact force [2]. Jute seeds were subjected to soil retting to produce the jute fiber that was employed in this investigation, use of jute fiber in composite materials and discusses potential applications for jute composites in the automotive industry [3], [16], [25], [29], [44], [47].

Carbon

Carbon fibers produced from organic polymers. mechanical and moisture-absorbing qualities of carbon hybrid composites based on unconventional fiber orientations and stacking sequences, and to evaluate their potential for use in streamlined load-bearing construction. abrication, testing procedures, and the outcome of stacking sequence and fiber orientation on the characteristics of various types of composites. The motor vehicle, aviation, shipbuilding, building, sporting goods, marine, and offshore industries applications [2], [27].

Sugar palm

Possibilites of the sugar-palm fibers as a new on the attributes of fibres in composites. It covers the properties, treatments, and potential the uses for sugar palm fibers, as well as their advantages over synthetic fibers. The paper also gives a summary of natural fibers and their classification, as well as the availability the sugar palm's morphological characteristics. Applications of sugar palm fiber in composites, including automotive, packaging, and boat making [4].

Banana

Banana fibre utilized to fabricate the composite, testing the composites' mechanical properties using tensile, flexural, and impact tests [6]. 30% banana fiber has potential for substituting conventional materials in automotive lightweight constructions [21], [24], [30], [37], [47].

Timoho fiber

Timoho fiber as the base materials for the composite, improve their properties and characterizes Timoho fiber as a reinforcement in green composites [7].

Sisal

Mechanical and wear properties the effect of layer formation on these properties. Composites were investigated through testing for strength under tensile, flexural, and impact as well as wear rate tests and SEM analysis [12], [24], [27].

Bamboo

To elevate the composites' physical and mechanical characteristics for use in structural in nature and semi-structural applications. Evaluates the impact toughness, thickness swelling, water absorption, density, tensile properties, flexural properties, and low-velocity impact testing of the composites [13].

Palm

Palm fiber can be used as a possible reinforcement in lightweight composites for various applications while minimizing agro-residue waste and deposition [13].

Pineapple leaf

The composite was created using the method of hot press molding, and flexural, impact, and dynamic mechanical analysis properties were evaluated [14], [45].

E-glass

Tensile strength was made to increase using e-glass fiber and it can be used in automotive and aerospace applications [18].

Coconut

Coconut coir had superior mechanical properties, including impact, flexural, compressive, and tensile strength, as well as hardness ,used in automotive and aerospace applications [18].

Sugarcane

Investigate the flexural and compressive properties sugarcane fiber particles into the greatly improved certain flexural and compressive performances [20]. Tensile, flexural, and impact strength were best demonstrated by sugarcane bagasse reinforcement could be useful for automobile applications such as dashboards, door panels, and bumpers [22], [42].

Flax

High ductility breed by flax fibre mechanical properties of flax fibers, such as their flexibility, tensile stiffness, and shear behavior, play a significant role in their machinability and their suitability for various applications in industries that require sustainable materials [25]. Flax fiber woven mats are chosen as the reinforcement material , and the epoxy matrix is composed of epofine 556 with finehard 1972 hardener. The fabrication process employed is hand lay up [36]. Table 1 represents the important properties of the natural fibers.

Filler

Fiber-reinforced polymer composites' improved mechanical, thermal, and tribological characteristics as a result of fillers [17]. The wet layup method using synthetic textiles (carbon, Kevlar, basalt, and Innegra) and bio fillers (coir, sisal, and hemp), as well as TiC nanoparticles[27].

Walnut shell

Walnut shell particulate as composites for automobile applications and to evaluate the mechanical, wear, and flow properties of the composites. Walnut shell particulate improves the hardness, impact, compressive, flexural, tensile, impact, and strength of the composites, while reducing wear loss and melt flow [3].

Wood charcoal

The use of wood charcoal as a filler, to evaluate the effect of different filler concentrations on the mechanical and physicochemical properties, increased thermal stability of the composites as a bio-filler, wood charcoal powder [5].

Table 1. Summarizing The Physical, Mechanical, and Chemical Properties of Fibers Used In Automotive Industry.

Natural fiber	Tensile strength (MPa)	Young's modulus (GPa)	Elongation At break %	Density (g/cm^3)	Moisture absorption (%)	Chemical resistance	Reference
Banana	300-700	2-5	2-5	1.2-1.4	5-10	Good	
Coconut	200-400	2-5	2-5	1.0-1.2	10-12	Good	[18]
Flax	500-1000	30-60	1.5-3.5	1.4-1.5	10-12	Good	[25], [36]
Jute	300-700	10-35	1.5-2.5	1.3-1.5	12-14	Good	[2], [3], [16], [25], [29], [40], [44], [55]
Kenaf	200-500	4-10	2-5	1.3-1.5	5-10	Good	[1], [12], [28], [29]
Palm	250-600	8-30	1-3	0.4-0.9	5-10	Good	[13]
PineappleLeaf	300-700	3-7	2-5	1.1-1.3	10-12	Good	[14]
Sugarpalm	300-600	8-12	2-4	0.8-1.2	6-8	Good	[4]
Sugarcrane	200-400	2-5	2-5	1.0-1.2	10-12	Good	[20], [22]

Timoho	300-600	3-7	2-5	0.9-1.2	5-10	Good	[7]

CD

The potential of using waste CDs as a greener substitute for traditional raw materials in composite manufacturing. waste CD powder didn’t significantly the mechanical characteristics of the composites. Waste CDs can be reused in mechanical engineering application ns, reducing environmental hazards adding 10% of CD filler gave the best results [6].

Iron powder

Iron powder filler on the mechanical, thermal, and flammability properties. iron powder filler and analyzes its flame, thermal, mechanical, and morphological characteristics. The results show that the addition of iron powder filler improves the mechanical provided the composite's thermal characteristics, but decreases its elongation [13].

Olive tree leaves

Improved surface bonding and consistent filler dispersion properties, and exhibited improved impact resistance and thermal stability compared to parent composites[14].

Titanium

Titanium oxide filler effect of filler materials on composites' mechanical characteristics. its potential applications in automotive and construction industries. Titanium oxide filler enhances the composites' tensile strength, with the 5% filler material showing the best results. The use of filler materials in composites can significantly increase their mechanical properties and cost-effectiveness [16].

Aluminium

Evaluate the effect of the addition of fiber on the mechanical properties of the composite. Aluminium under constant load, 4.0 wt% and 82.0 wt% of the powder,on siderable the enhancements were achieved to the material's flexural, compressive, tensile, and impact properties (97.2 J/m2, 144 MPa, 101 MPa, and 94 MPa) [18].

Tamarind

Tamarind seed powder particles greatly improved certain flexural and compressive performances. For 35 weight percent SCF/15 weight percent TSP composites, the highest flexural strength, flexural modulus, and compressive strength were attained. composites showed potential for use in light and medium-duty applications [20].

Rice husk

In comparison to other compositions, 10% rice husk displayed improved mechanical characteristics. Revealed good adhesion, but poor bonding with increased filler weight ratio [21].

Neem wood

Neem wood powder improved bonding and resulted in maximum impact strength. The study concludes that the composite's properties are significantly influenced by the weight percentage of reinforcements within [22]. Table 2 represents the important properties of the fillers.

COMPOSITE MATERIAL

Composite substances are materials composed of at least two distinct components with different physical and combination chemical properties to create a material with enhanced properties. These components can be fibers, particles, or flakes embedded in a matrix material. The reinforcement material is held together by the matrix material, which also transmits applied loads to the reinforcement. reinforcement material due to their durability and small weight, in polymer composites [2], [4], [22], [41]. Polyester, vinyl ester, and epoxy resin are the thermoset matrices used in FRP composites the most frequently [25], [27][56]. Table 3 represents the important properties of the composite materials used in the automotive industry.

Table 2. Summarizing The Mechanical, Physical and Chemical Properties of Materials That Can Be Used as Fillers in the Automotive Industry

Filler Material	Tensile strength (MPa)	Young's modulus (GPa)	Elongation At break %	Density (g/cm^3)	Moisture absorption (%)	Chemical resistance	Reference
Aluminium	200-500	68-83	8-16	2.6-2.8	Negligible	Good	[18]
CD	-	-	-	0.2-0.5	Negligible	Varies	[6]
Iron powder	-	-	-	6.9-7.8	Negligible	Moderate to poor	[13]
Olive tree leave	-	-	-	0.3-0.4	Negligible	Good	[14]
Neem wood	-	-	-	0.8-0.9	Negligible	Good	[22]
Rice Husk	-	-	-	0.2-0.3	High(10-15)	Good	[21]
Tamarind	-	-	-	0.5-0.7	Negligible	Good	[20]
Titanium	1100-1400	100-116	14-21	4.5-4.7	Negligible	Excellent	[16]
Wood charcoal	-	-	-	0.2-0.5	Negligible	Good	[5]
Walnut shell	-	-	-	0.7-0.8	Negligible	Good	[3]

Table 3. Summarizing The Mechanical, Physical and Chemical Properties of Composite Material Commonly Used In The Automotive Industry.

Composite material	Tensile strength (MPa)	Young's modulus (GPa)	Elongation At break %	Density (g/cm^3)	Moisture absorption (%)	Chemical resistance	Reference
Aluminium matrix	200-400	60-80	1-3	2.6-2.9	Negligible	Good	[18]
Aramid fiber	3000-4000	60-130	2-3	1.4-1.5	Negligible	Good	
Carbon fiber	3000-7000	200-700	1.5-2.5	1.5-2.0	Negligible	Excellent	[31], [44]
Glass fiber	1000-4000	20-80	2-5	2.2-2.6	Negligible	Good	[31], [38]
Magnesium matrix	150-300	45-70	2-5	1.8-1.9	Negligible	Good	
Natural fiber	100-1500	2-70	1-15	1.0-1.6	Varies	Varies	[31], [32], [33], [45], [47]
Polymer matrix	50-100	1-5	50-100	1.0-1.5	High (10-15)%	Varies	[34], [46]

Resin matrix

Resin matrix used in these composites plays a crucial role in providing structural integrity and bonding the fibers together. Environmentally friendly resin matrices, such as bio-based resins derived from renewable sources, due to there reduced carbon footprint and recycling [1]. Although epoxy meets the general requirements of the aviation industry, the considerable cross-linking renders the essential fracture toughness characteristic unsatisfactory [34], [48].

Epoxy

Composite materials offer a versatile and customizable solution for various industries, including automotive, aerospace, construction, and sports equipment. Epoxy resins have several physical properties, qualities that make them appealing for a variety of applications. Several of these attributes include: High strength and fantastic adherence. Chemical resistance, little shrinking. Good electrical insulation, Thermal stability and Excellent moisture resistance [2], [6], [46], [47]. Hybrid laminated bio composites made of aramid and epoxy. The study investigates the results of chemical procedures and layering sequence on the mechanical properties of these hybrid bio composites for ballistic applications. epoxy thermosets and the development of transparent, flame-retardant, smoke-suppressive, robust, and tough epoxy resins [1], [6], [7]. Mechanical and wear properties of epoxy hybrid composites filled with fibers, and to study the effect of layer formation on these properties [12]. Influenced by factors such as fiber loading, matrix viscosity, and fiber/matrix interfacial bonding [13]. Reinforced composites and their potential for various applications.[14] Epoxy composite exhibits better tensile properties and can be used in automotive applications [16], [18]–[21]. The hybrid bio/synthetic epoxy's physical, mechanical, and thermal properties [26], [27], [28], [31], [34], [35], [38], [48], [55]. The worjk involving epoxy resin as a matrix material, combined with untreated dupion silk fibers and silicon carbide fillers, demonstrates the successful development of a bio-composite with improved mechanical properties suitable for potential use in orthopaedic implants.[39] The study successfully developed composites using epoxy resin as the matrix and honeycomb natural fibers as the reinforcement material [41], [43].

Polypropylene

Polypropylene composites for automobile applications. polypropylene-based composites reinforced with fiber and filler particulate and evaluate their flow, wear, and mechanical characteristics. Newly developed polypropylene composites that can be used in automotive applications.[3] Polypropylene and fiber are combined 10:90 (wt%). According to ASTM standards, mechanical characteristics including tensile strength and hardness have been established [24].

Polyester

The composites were prepared using reinforcement, unsaturated polyester resin as matrix material, composites were tested for mechanical and physicochemical properties, and it was found that a 4 wt% filler modification improved tensile properties, increased thermal stability compared to the reference composite. reinforced polymer composites and provides insights into the different filler concentrations on the properties of the composites [5], [7], [25], [26].

Vinylester

The failure mode was notably different from the others and most comparable to vinylester in the wet instance, and the reduction in strength was minimal [26], [32]. Important properties of thermoset resins are shown in Table 4.

Table 4. Summarizing The Mechanical, Physical, and Chemical Properties of Epoxy, Polyester, Polypropylene, And Vinyl Ester Resins Used in Automotive Sector.

Resin type	**Tensile strength (MPa)**	**Young's modulus (GPa)**	**Elongation at break (%)**	**Density (g/cm^3)**	**Glass transition temperature (degree celcius)**	**Chemical resistance**	**Reference**
Epoxy	50-100	2-4	2-5	1.1-1.3	50-100	Excellent	[1], [2], [6], [7], [12], [13], [14], [16], [18], [19], [20], [21], [26], [27], [28], [34], [35], [38], [39], [40], [41], [43]
Polyester	50-100	2-4	2-5	1.1-1.4	40-80	Moderate to good	[5], [7], [25], [26]
Polypropylene	25-40	0.8-1.5	10-500	0.9-0.91	-	Excellent	[3], [24]

Vinyle ester	50-100	2-4	2-5	1.1-1.3	60-120	Excellent	[26]

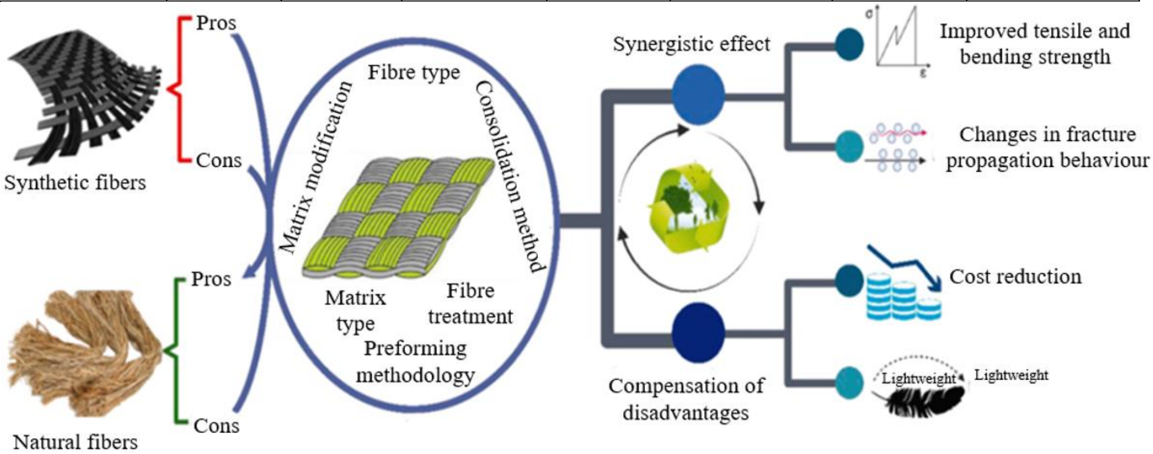

Figure 2. Natural fiber reinforcement polymer basic concepts [15].

Table 5. Summarizing The Mechanical and Physical Properties of Hybrid Composites, Composites That Incorporate Multiple Types of Reinforcing Fibers.

Hybrid composite	Tensile strength (MPa)	Young's modulus (GPa)	Elongation At break %	Flexural strength (MPa)	Density (g/cm^3)	References
Carbon /glass	800-2000	50-100	1-3	60-120	1.4 – 1.8	[18]
Carbon Kevlar	1000-3000	70-150	1-3	80-150	1.4-1.8	
Glass/Kevlar	500-1500	30-80	1-5	50-100	1.4-1.7	
carbon/natural	400-1200	20-70	1-10	40-80	1.3-1.6	
Glass /natural	200-800	10-50	2-15	30-70	1.3-1.6	
Carbon/glass/natural	600-1800	40-90	1-5	50-100	1.4-1.7	[4], [18]
Carbon/aramid	1000-3000	80-150	1-3	80-150	1.4-1.8	
Glass/aramid	500-1500	40-100	1-5	50-100	1.4-1.7	[18]

HYBRID COMPOSITES

High strength degradable polymeric hybrid composites fibers instead of synthetic fibers, the need for new recycling and reuse strategies for non-degradable hybrid fibers, and the need for Comparing these composites to traditional composites that incorporate important mechanical and thermal qualities, LCA provides a clearer knowledge of the end-of-life alternatives for these materials [15]. Hybrid composites and to determine the optimal combination of materials tested for tensile strength and hardness. Composites they were evaluated for tensile, flexural, and impact loading while being assembled by hand [18], [21], [43]. Pros and Cons of natural as well as synthetic fibres are represented in Figure 2. Mechanical and physical properties of hybrid composites are shown in Table 5.

HAND LAY UP PROCESS

The composites are prepared using the HAND LAY UP PROCESS an hat would result in the best mechanical properties for potential use in the automotive industry [22]. Making is the technique used to manufacture laminates in which the air gap is suitably decreased, strengthening the matrices' strong bonding [2].

DISCUSSION

Mechanical Properties of Natural Composites

In this paper work on banana fiber fabric is one of the primary materials used in the composite along with epoxy and waste CD powder. The banana fiber fabric acts as the primary reinforcement material in the epoxy matrix.The composites mechanical properties are evaluated through standard tests , specifically focusing on tensile strength , flexural strength and impact strength. Mechanical properties of this work composite lower than the glass epoxy. It might reused CD fillers [6]. Data as mentioned in Table 1. In this paper study on flax and polypropylene composite reinforcement the thermal effect of machine and mechanical properties result was good in this work. Flax reinforced polypropylene composites offer a balance between strength, stiffness and sustainability. However the actual mechanical properties will depends on various factors like fiber treatment , matrix quality , processing conditions and fiber content and orientation [25]. Data as given table 1. The hybrid composites , which combine both natural (jute) and synthetic (carbon) fibers , show great potential for lightweight, load – bearing structural applications due to their impressive mechanical properties [2]. Data as given in table 1. The paper provide an overview of developing kenaf based composites, considered several factors stacking sequence of the fibers , volume ratio between fibers and the matrix , angular orientation of the fibers , chemical modification of the fiber surface to improve its adhesion to the matrix. the work is centered around the importance and development of kenaf-based hybrid composites, emphasizing their improved mechanical properties, making them viable for high-end applications like aerospace and automotive industries [1]. Data as given table 1. Investigation of mechanical properties of date palm fiber reinforced epoxy composites and a hybrid of date palm / bamboo. Fabrication using hand lay up combined with compression moulding. Mechanical test tensile , flexural and impact assessment of water absorption behavior and its effects. The mechanical benefits of hybridizing date palm fiber [45]. with bamboo in composite fabrication indicating improved performance in both mechanical properties and durability [13]. Data as given table 1. Investigate olive tree leaf powder and pineapple leaf fibre reinforcement together with epoxy composite the hybrid materials demonstrated improved impact strength and dynamic mechanical properties, though their flexural characteristics were not as strong as those of the parent composites [14], [43]. Data as given in table 1. Fibers derived from the sugar palm tree are integrated into composites. the focus is on the potential and challenges of using sugar palm fibers in composite materials, given their eco-friendly nature and promising properties, against the backdrop of a global shift towards greener materials [4]. Mechanical values given a table 1. The inclusion of sugarcane fibers and tamarind seed powder particles in the epoxy matrix enhanced certain mechanical properties, with variations in properties depending on the specific weight percentages of the reinforcements used. Hybrid bio-composites were developed by combining sugarcane fibers and tamarind seed powder particles with an epoxy resin matrix. The aim was to investigate the effect of these natural reinforcements on the flexural and compressive properties of the epoxy composite. Various compositions of these materials were made, and samples were manufactured using a hot injection moulding machine. The resulting boards were then cut into test specimens using water jet machining [20]. The study conducted mechanical testing on these composites, specifically focusing on three important properties: tensile strength, flexural strength, and impact strength. These tests were performed in accordance with ASTM standards [42] Data as given in table 1. excitation functions of evaporation residues in the 18O + 144Sm system at the specified beam energy range, and comparing experimental results with PACE-4 predictions, the current research seeks to enhance the understanding of fusion-evaporation reactions. This will contribute to refining theoretical models and provide better insight into nuclear reaction mechanisms at low-to-medium energies.

FIBERS, FILLER AND COMPOSITE MATERIAL SOME APPLICATIONS

Automotive industry: Jute and epoxy composites can be used in the manufacturing of automotive components such as interior panels, door trims, and seat backs as shown in Fig.3. Summary of some applications in automobile is shown in Table 6. Construction industry: Jute and epoxy composites can be used in the construction of lightweight and durable structures, such as roofing sheets, wall panels, and flooring materials [1], [43]. Aerospace industry: Jute and epoxy composites can be used in the aerospace industry for the manufacturing of aircraft interior components, such as cabin panels and overhead bins [1]. Packaging industry: Jute and epoxy composites can be used in the packaging industry for the production of eco-friendly packaging materials, such as boxes and trays [1]. Sports equipment: Jute and epoxy composites can be utilized in the production of sporting goods including hockey sticks, bicycle frames, and tennis rackets [1], [43], [51]. Marine industry: Jute and epoxy composites can be used in the marine industry for the construction of boat hulls, decks, and other marine structures[1]. The automotive industry the use of these materials is influenced by factors such as mechanical performance, cost-effectiveness, weight reduction goals and sustainability. automotive manufacturers to meet sustainability goals, improve performance, and enhance the overall driving experience while considering environmental impact and cost – effectiveness [1], [2], [28], [29]. These composites are being used in automotive components, construction materials, aerospace components, consumer goods and more they advantages such as lightweight, good strength-to-ratio, eco friendliness and cost-effectiveness making them popular choice for sustainable high-performance applications. Researchers and industries are continuously exploring ways to optimize these materials for various engineering needs while reducing environmental impact [56].

Figure 3. Applications in automotive industry [23].

Table 6. Summarize some applications.

Manufacturer & model	fiber, composite material	Applications	References
Saturn L300	Natural fiber , epoxy	Door panels and package trays	[2]
Trucks	Natural fiber	Insulation for the engine, the interior, the bumper, the internal engine cover, the sun visor,	[1]
Peugeot 406	Natural fiber	Front back door panels, a parcel shelf, the backs	[2]
Citroen C3 Picasso, C5		Spare wheel covers, side mirrors and body panels.	
Opel Astra, Zafira, Vectra	Natural fiber	Engine covers, floor mats and carpets inside vehicles.	[2]
Volkswagen Passat Variant, Golf, A4, Bora	Natural fiber	Interior trim components, spare wheels	[2]
Audi A2, Roadstar, Coupe	Natural fiber	Trunk liners and spare wheel covers, dashboards, center consoles,	[2]
EvoBus (exterior)	Natural fiber	Body panels, bumpers, roof panels,	[2]
BMW 7 other models	Natural fiber	Door panels, dashboards, seat padding, covers, and consoles	[2]
Mercedes Benz C, S, and A classes	Natural fiber	Upholstery of car seats, engine covers.	
Toyota ES3	Natural fiber	Pillar garnish , interior parts	[2]

Mitsubishi	Natural fiber	Door panels, instrument panels, floor panels, seat back linings, cargo area flooring, internal cladding, and floor mats.	[1], [2]

CONCLUSIONS

- Natural fiber filler composites, hybrid composite materials, and resin matrices have gained significant traction in the current automotive industry scenario.
- Natural fibers are obtained from various sources , primarily from plants , animals and minerals. I review many research paper , observed that flax, jute and pineapple leaf fibers mechanical properties results very good in automotive industry.
- The best properties it depends on the specific application and desired property. For instance: for high tensile strength , flax and jute appear promising. For stiffness (young's modulus) , flax and pineapple leaf fibers have high values.
- These materials offer a range of advantages, including weight reduction, sustainability, enhanced mechanical properties, noise and vibration damping, cost-effectiveness, automotive manufacturers can achieve lighter and more eco-friendly vehicles, contributing to improved fuel efficiency and reduced emissions.
- Applications in various components such as interior parts, door panels, seat backs, trunk liners, and instrument panels.
- Epoxy result was excellent adhesion to many subtrates , high chemical resistance , and good electrical properties. Epoxy resin are aften used in high performance applications, including aerospace , automobile and electronics , due to their durability and versatility.

REFERENCES

1. H. T. Sreenivas, N. Krishnamurthy, and G. R. Arpitha, "A comprehensive review on light weight kenaf fiber for automobiles," International Journal of Lightweight Materials and Manufacture, vol. 3, no. 4. KeAi Publishing Communications Ltd., pp. 328–337, Dec. 01, 2020. doi: 10.1016/j.ijlmm.2020.05.003.
2. M. Abu Shaid Sujon, M. A. Habib, and M. Z. Abedin, "Experimental investigation of the mechanical and water absorption properties on fiber stacking sequence and orientation of jute/carbon epoxy hybrid composites," Journal of Materials Research and Technology, vol. 9, no. 5, pp. 10970–10981, 2020, doi: 10.1016/j.jmrt.2020.07.079.
3. O. A. Balogun, O. O. Daramola, A. A. Adediran, A. A. Akinwande, and O. S. Bello, "Investigation of Jute/Tetracarpidium conophorum reinforced polypropylene composites for automobile application: Mechanical, wear and flow properties," Alexandria Engineering Journal, vol. 65, pp. 327–341, Feb. 2023, doi: 10.1016/j.aej.2022.10.026.
4. M. Imraan, R. A. Ilyas, A. S. Norfarhana, S. P. Bangar, V. F. Knight, and M. N. F. Norrrahim, "Sugar palm (Arenga pinnata) fibers: new emerging natural fibre and its relevant properties, treatments and potential applications," Journal of Materials Research and Technology, vol. 24. Elsevier Editora Ltda, pp. 4551–4572, May 01, 2023. doi: 10.1016/j.jmrt.2023.04.056.
5. S. C. Das et al., "On the use of wood charcoal filler to improve the properties of natural fiber reinforced polymer composites," in Materials Today: Proceedings, Elsevier Ltd, 2021, pp. 926–929. doi: 10.1016/j.matpr.2020.10.808.
6. J. Immanuel Durai Raj, K. Arun Vasantha Geethan, A. John Rajan, and S. Vijay Ananth, "Characterization of epoxy resin based banana fiber reinforced composite with waste CD powder filler," Mater Today Proc, 2023, doi: 10.1016/j.matpr.2023.04.152.
7. F. Gapsari et al., "Flammability and mechanical properties of Timoho fiber-reinforced polyester composite combined with iron powder filler," Journal of Materials Research and Technology, vol. 21, pp. 212–219, Nov. 2022, doi: 10.1016/j.jmrt.2022.09.025.
8. M. K. Singh, R. Tewari, S. Zafar, S. M. Rangappa, and S. Siengchin, "A comprehensive review of various factors for application feasibility of natural fiber-reinforced polymer composites," Results in Materials, vol. 17, Mar. 2023, doi: 10.1016/j.rinma.2022.100355.

9. M. H. Nazir, A. H. Al-Marzouqi, W. Ahmed, and E. Zaneldin, "The potential of adopting natural fibers reinforcements for fused deposition modeling: Characterization and implications," Heliyon, vol. 9, no. 4. Elsevier Ltd, Apr. 01, 2023. doi: 10.1016/j.heliyon.2023.e15023.
10. S. Doddamani, S. M. Kulkarni, S. Joladarashi, M. K. T S, and A. K. Gurjar, "Analysis of light weight natural fiber composites against ballistic impact: A review," International Journal of Lightweight Materials and Manufacture, vol. 6, no. 3. KeAi Publishing Communications Ltd., pp. 450–468, Sep. 01, 2023. doi: 10.1016/j.ijlmm.2023.01.003.
11. V. Yadav et al., "Dry sliding wear characteristics of natural fibre reinforced poly-lactic acid composites for engineering applications: Fabrication, properties and characterizations," Journal of Materials Research and Technology, vol. 23, pp. 1189–1203, Mar. 2023, doi: 10.1016/j.jmrt.2023.01.006.
12. R. Venkatesh, S. Ballal, A. M. Krishnan, S. Prabagaran, S. Mohankumar, and E. Ramaraj, "Effect of fiber layer formation on mechanical and wear properties of natural fiber filled epoxy hybrid composites," Heliyon, vol. 9, no. 5, May 2023, doi: 10.1016/j.heliyon.2023.e15934.
13. A. B. M. Supian et al., "Mechanical and physical performance of date palm/bamboo fibre reinforced epoxy hybrid composites," Journal of Materials Research and Technology, vol. 15, pp. 1330–1341, Nov. 2021, doi: 10.1016/j.jmrt.2021.08.115.
14. Mahboubizadeh, S., Sadeq, A., Arzaqi, Z. *et al.* Advancements in fiber-reinforced polymer (FRP) composites: an extensive review. *Discov Mater* **4**, 22 (2024). https://doi.org/10.1007/s43939-024-00091-9
15. S. O. Ismail, E. Akpan, and H. N. Dhakal, "Review on natural plant fibres and their hybrid composites for structural applications: Recent trends and future perspectives," Composites Part C: Open Access, vol. 9, Oct. 2022, doi: 10.1016/j.jcomc.2022.100322.
16. M. S. Preethi, C. H. Ramya, G. Sumathi, N. Mounika, and N. Sateesh, "Investigations on mechanical properties of jute fiber and epoxy resin composites with titanium oxide," Mater Today Proc, vol. 62, pp. 4310–4315, Jan. 2022, doi: 10.1016/j.matpr.2022.04.812.
17. M. Sharma, R. Sharma, and S. Chandra Sharma, "A review on fibres and fillers on improving the mechanical behaviour of fibre reinforced polymer composites," in Materials Today: Proceedings, Elsevier Ltd, 2020, pp. 6482–6489. doi: 10.1016/j.matpr.2021.03.667.
18. S. Ramu, N. Senthilkumar, and B. Deepanraj, "Mechanical characterization of E-glass fiber/aluminium powder filled with and without coconut fiber reinforced epoxy hybrid composite," Mater Today Proc, 2023, doi: 10.1016/j.matpr.2023.03.074.
19. A. S. Madival, D. Doreswamy, and R. Shetty, "A review on the physical and mechanical properties of natural fiber reinforced composites and its machinability using abrasive waterjet machining," Mater Today Proc, May 2023, doi: 10.1016/j.matpr.2023.04.519.
20. R. Girimurugan, C. Shilaja, S. Mayakannan, S. Rajesh, and B. Aravinth, "Experimental investigations on flexural and compressive properties of epoxy resin matrix sugarcane fiber and tamarind seed powder reinforced bio-composites," Mater Today Proc, vol. 66, pp. 822–828, Jan. 2022, doi: 10.1016/j.matpr.2022.04.386.
21. S. Deepan, R. Jeyakumar, V. Mohankumar, and A. Manojkumar, "Influence of rice husk fillers on mechanical properties of banana/epoxy natural fiber hybrid composites," Mater Today Proc, vol. 74, pp. 575–580, Jan. 2023, doi: 10.1016/j.matpr.2022.09.459.
22. K. Dattatreya, S. Sathees Kumar, V. V. S. H. Prasad, and P. Ranjan Pati, "Mechanical properties of waste natural fibers/fillers reinforced epoxy hybrid composites for automotive applications," Mater Today Proc, 2023, doi: 10.1016/j.matpr.2023.02.001.
23. S. dua et al., "Potential of natural fiber based polymeric composites for cleaner automotive component production -a comprehensive review," Journal of Materials Research and Technology, vol. 25, pp. 1086–1104, Jul. 2023, doi: 10.1016/j.jmrt.2023.06.019.
24. K. Hariprasad, K. Ravichandran, V. Jayaseelan, and T. Muthuramalingam, "Acoustic and mechanical characterisation of polypropylene composites reinforced by natural fibres for automotive applications," Journal of Materials Research and Technology, vol. 9, no. 6, pp. 14029–14035, 2020, doi: 10.1016/j.jmrt.2020.09.112.
25. F. Chegdani, B. Takabi, B. L. Tai, M. El Mansori, and S. T. S. Bukkapatnam, "Thermal Effects

on Tribological Behavior in Machining Natural Fiber Composites," Elsevier B.V., 2018, pp. 305–316. doi: 10.1016/j.promfg.2018.07.039.
26. T. Gobikannan et al., "Flexural properties and failure mechanisms of infusible thermoplastic- and thermosetting based composite materials for marine applications," Compos Struct, vol. 273, p. 114276, Oct. 2021, doi: 10.1016/j.compstruct.2021.114276.
27. M. H et al., "Effect of bio-fibers and inorganic fillers reinforcement on mechanical and thermal characteristics on carbon-kevlar-basalt-innegra fiber bio/ synthetic epoxy hybrid composites," Journal of Materials Research and Technology, vol. 23, pp. 5440–5458, Mar. 2023, doi: 10.1016/j.jmrt.2023.02.162.
28. M. K. Singh, R. Tewari, S. Zafar, S. M. Rangappa, and S. Siengchin, "A comprehensive review of various factors for application feasibility of natural fiber-reinforced polymer composites," Results in Materials, vol. 17, Mar. 2023, doi: 10.1016/j.rinma.2022.100355.
29. M. Mohammed et al., "Comprehensive insights on mechanical attributes of natural-synthetic fibres in polymer composites," Journal of Materials Research and Technology, vol. 25. Elsevier Editora Ltda, pp. 4960–4988, Jul. 01, 2023. doi: 10.1016/j.jmrt.2023.06.148.
30. M. H. Nazir, A. H. Al-Marzouqi, W. Ahmed, and E. Zaneldin, "The potential of adopting natural fibers reinforcements for fused deposition modeling: Characterization and implications," Heliyon, vol. 9, no. 4. Elsevier Ltd, Apr. 01, 2023. doi: 10.1016/j.heliyon.2023.e15023.
31. M. A. Karim, M. Z. Abdullah, A. F. Deifalla, M. Azab, and A. Waqar, "An assessment of the processing parameters and application of fibre-reinforced polymers (FRPs) in the petroleum and natural gas industries: A review," Results in Engineering, vol. 18. Elsevier B.V., Jun. 01, 2023. doi: 10.1016/j.rineng.2023.101091.
32. K. Hariprasad, K. Ravichandran, V. Jayaseelan, and T. Muthuramalingam, "Acoustic and mechanical characterisation of polypropylene composites reinforced by natural fibres for automotive applications," Journal of Materials Research and Technology, vol. 9, no. 6, pp. 14029–14035, 2020, doi: 10.1016/j.jmrt.2020.09.112.
33. I. Elfaleh et al., "A comprehensive review of natural fibers and their composites: An eco-friendly alternative to conventional materials," Results in Engineering, vol. 19. Elsevier B.V., Sep. 01, 2023. doi: 10.1016/j.rineng.2023.101271.
34. M. Y. Khalid, A. Kamal, A. Otabil, O. Mamoun, and K. Liao, "Graphene/epoxy nanocomposites for improved fracture toughness: A focused review on toughening mechanism," Chemical Engineering Journal Advances, vol. 16. Elsevier B.V., Nov. 15, 2023. doi: 10.1016/j.ceja.2023.100537.
35. A. S. Ismail et al., "Dynamic mechanical and thermal properties of Flax/bio-phenolic/epoxy reinforced hybrid composites," J King Saud Univ Sci, vol. 35, no. 7, Oct. 2023, doi: 10.1016/j.jksus.2023.102790.
36. V. Prasad, D. Suresh, M. A. Joseph, K. Sekar, and M. Ali, "Development Of Flax Fibre Reinforced Epoxy Composite With Nano Tio 2 Addition Into Matrix To Enhance Mechanical Properties," 2018. [Online]. Available: www.sciencedirect.comwww.materialstoday.com/proceedings
37. S. Prakash, M. Prathab, M. Dhanashekar, and V. S. S. Kumar, "Open Hole Tensile Behaviour of Nano Fillers (SiC & Banana) in CNSL/Epoxy Resin Reinforeced with Basalt fiber," in Materials Today: Proceedings, Elsevier Ltd, 2018, pp. 8631–8637. doi: 10.1016/j.matpr.2017.11.562.
38. K. V. Allamraju, "Mechanical behaviour of nano jute filler glass fiber self healing and epoxy resin composite," 2018. [Online]. Available: www.sciencedirect.comwww.materialstoday.com/proceedings2214-7853
39. S. Akash, S. Avinash, and M. Ramachandra, "A Study on Mechanical Properties of Silk Fiber Reinforced Epoxy Resin Bio-Composite with SiC As Filler Addition," in Materials Today: Proceedings, Elsevier Ltd, 2018, pp. 3219–3228. doi: 10.1016/j.matpr.2018.01.131.
40. K. P. Ashik, R. S. Sharma, and N. Raghavendra, "Evaluation of Tensile, Modal and Fracture Properties of Jute/Epoxy Natural Composites with addition of Silicon di Oxide as Filler Material," in Materials Today: Proceedings, Elsevier Ltd, 2017, pp. 9586–9591. doi: 10.1016/j.matpr.2017.06.229.

41. A. Atiqah, M. N. M. Ansari, and L. Premkumar, "Impact and hardness properties of honeycomb natural fibre reinforced epoxy composites," in Materials Today: Proceedings, Elsevier Ltd, 2019, pp. 138–142. doi: 10.1016/j.matpr.2020.05.645.
42. A. Vinay Reddy, G. Bharathiraja, and V. Jayakumar, "Experimental investigation on sugarcane powder filled glass fiber epoxy composite," in Materials Today: Proceedings, Elsevier Ltd, 2020, pp. 762–765. doi: 10.1016/j.matpr.2019.10.113.
43. G. R. Chavhan and L. N. Wankhade, "Improvement of the mechanical properties of hybrid composites prepared by fibers, fiber-metals, and nano-filler particles-A review," in Materials Today: Proceedings, Elsevier Ltd, Jan. 2020, pp. 72–82. doi: 10.1016/j.matpr.2019.08.240.
44. J. Saiteja, V. Jayakumar, and G. Bharathiraja, "Evaluation of mechanical properties of jute fiber/carbon nano tube filler reinforced hybrid polymer composite," in Materials Today: Proceedings, Elsevier Ltd, 2020, pp. 756–758. doi: 10.1016/j.matpr.2019.10.110.
45. M. J. M. Ridzuan, M. S. Abdul Majid, A. Khasri, E. H. D. Gan, Z. M. Razlan, and S. Syahrullail, "Effect of pineapple leaf (PALF), napier, and hemp fibres as filler on the scratch resistance of epoxy composites," Journal of Materials Research and Technology, vol. 8, no. 6, pp. 5384–5395, Nov. 2019, doi: 10.1016/j.jmrt.2019.09.005.
46. M. Sharma, R. Sharma, and S. Chandra Sharma, "A review on fibres and fillers on improving the mechanical behaviour of fibre reinforced polymer composites," in Materials Today: Proceedings, Elsevier Ltd, 2020, pp. 6482–6489. doi: 10.1016/j.matpr.2021.03.667.
47. T. Srinivasan, G. Suresh, K. Santhoshpriya, C. T. Chidambaram, K. R. Vijayakumar, and A. A. Munaf, "Experimental analysis on mechanical properties of banana fibre/epoxy (particulate) reinforced composite," in Materials Today: Proceedings, Elsevier Ltd, 2021, pp. 1285–1289. doi: 10.1016/j.matpr.2020.05.103.
48. V. Pujar, R. M. Devarajaiah, B. Suresha, and V. Bharat, "A review on mechanical and wear properties of fiber-reinforced thermoset composites with ceramic and lubricating fillers," in Materials Today: Proceedings, Elsevier Ltd, 2021, pp. 7701–7710. doi: 10.1016/j.matpr.2021.02.214.
49. V. Velmurugan, D. Dinesh Kumar, and S. Thanikaikarasan, "Experimental evaluation of mechanical properties of natural fibre reinforced polymer composites," in Materials Today: Proceedings, Elsevier Ltd, 2020, pp. 3383–3388. doi: 10.1016/j.matpr.2020.05.190.
50. L. Kerni, S. Singh, A. Patnaik, and N. Kumar, "A review on natural fiber reinforced composites," in Materials Today: Proceedings, Elsevier Ltd, 2020, pp. 1616–1621. doi: 10.1016/j.matpr.2020.04.851.
51. C. Elanchezhian, B. V. Ramnath, G. Ramakrishnan, M. Rajendrakumar, V. Naveenkumar, and M. K. Saravanakumar, "Review on mechanical properties of natural fiber composites.," in Materials Today: Proceedings, Elsevier Ltd, 2018, pp. 1785–1790. doi: 10.1016/j.matpr.2017.11.276.
52. Sivasubramanian Palanisamy, a,e,* Sumesh Keerthiveetil Ramakrishnan, b Carlo Santulli,c Tabrej Khan, d,* and Omar Shabbir Ahmed d "Mechanical and Wear Performance Evaluation of Natural Fiber/Epoxy Matrix Composites" bioresources.cnr.ncsu.edu doi: 10.15376/biores.19.4.8459-8478.
53. Sivasubramanian PALANISAMY1 , Thulasi Mani MURUGESAN2 , Murugesan PALANIAPPAN3 , Carlo SANTULLI4 , Nadir AYRILMIŞ*5 Fostering sustainability: The environmental advantages of natural fiber composite materials – a mini review Environmental Research and Technology doi: https://10.35208/ert.1397380
54. Sivasubramanian Palanisamy a, * , Kavimani Vijayananth b , Thulasi Mani Murugesan c , Murugesan Palaniappan d , Carlo Santulli e, ** "The prospects of natural fiber composites: A brief review" International Journal of Lightweight Materials and Manufacture doi.org/10.1016/j.ijlmm.2024.01.003.
55. Sivasubramanian Palanisamy 1,2 , Mayandi Kalimuthu 1,*, Rajini Nagarajan 1 , José Maria Fernandes Marlet 3 and Carlo Santulli 4,* "Physical, Chemical, and Mechanical Characterization of Natural Bark Fibers (NBFs) Reinforced Polymer Composites: A Bibliographic Review" Fibers is an International doi.org/10.3390/fib11020013

56. Rajesh K. Sahoo1 , Dharmendra Singh2,*, Amritraj Mahato1 , Nitin Sharma1 , Jagatjyoti Mohapatra1 , Lupteindu Chhura1 , Rahul Mahato1 , Pankaj K. Giri3 , Sneha B. Linda1 , Harish Kumar4 , Suhail A. Tali4 , Asif Ali4 , Rahbar Ali5 , S. Kumar6 , Nabendu K. Deb7 , N.P.M. Sathik8 , M. Afzal Ansari9 , R. Kumar10, S. Muralithar11, R.P. Singh12 "Breakup Fusion of 18O with 144Sm" Journal of Polymer & Composites doi (Journal): 10.37591/JoPC.

