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Review Article

Effect of Various Factors on Plant Fibre-Reinforced Composites with Nanofillers and Its Industrial Applications: A Critical Review

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The growing awareness of the environmental damage caused by petroleum-based fibres has led to an increase in renewable and biodegradable resources. The continually growing demand for eco-friendly and sustainable materials pushes automakers and material researchers to consider the ecological importance of their materials during fabricating, recovering, and disposal. Natural fibre-reinforced composites (NFRC) have been introduced into the automobile market substantially over the last ten years due to their renewability, eco-friendliness, recyclability, biodegradability, light weight, better specific strength, good resistance to impact and corrosion, abundantly available, ease of processing, and cost-effectiveness. Due to cost-effectiveness and weight reduction, NFRC is becoming a better replacement for petroleum/synthetic fibres like aramid, kevlar, carbon, and glass fibre-reinforced composites, and the transportation sector has instigated the use of these materials in many applications like car interiors and exteriors, dash boards, bumpers, spoilers, seat covers, and mirror casings. NFRC with nanofillers is gaining more attention in the field of engineering, particularly for automotive, defense, building, and construction applications due to better aspect ratio, larger surface area, and attractive properties. The mechanical, tribological, and thermal properties of plant fibre-reinforced composites can be improved through the incorporation of organic or inorganic nanofillers. The present review profoundly explores the effects of various factors influencing NFRC with nanofillers. This paper also summarises the effects of various chemical reagents, fabrication techniques, and industrial applications of NFRC.

1. Introduction

Increasing ecological threats and the diminution of petroleum-based products are dynamic forces that cause chemical industries to shift from petrochemicals to eco-friendly resources [1]. Material selection is crucial in the design and manufacture of a sustainable product [2]. Materials are investigated for their mechanical and thermal properties to improve the product efficiency and increase customer satisfaction [3]. Cellulosic fibres derived from plants will play a vital role in this evolution as a significant renewable resource. NFRCs are one such material that offers flexibility during fabrication, desirable properties, and lower cost [4, 5]. Natural fibres act as reinforcing elements (discontinuous phase) in the composites used for various purposes. As a result, they have a more significant impact on a country's socioeconomic progress. Therefore, the exploitation of natural fibres to make sustainable and renewable products has engendered considerable attention. For example, NFRC has become increasingly important in the transportation segment where better strength characteristics and nondimensional change have to be combined amid less weight [6–8]. Biofibres are often derived from three sources: plants, animals, and minerals. Mineral-based fibres are underutilised in fibre-reinforced composite (FRC) research because they include asbestos, which is harmful to human health [9, 10]. On the other hand, plant-based fibres are endowed with hopeful distinctiveness, for example, cost effectiveness, biodegradability, ease of use, and excellent strength properties [11–15]. Figure 1 shows the classifications of natural fibres based on various categories. The performance of natural fibre is influenced by numerous factors such as plant seed quality, soil performance, fertiliser used, fibre maturity duration and age, fibre retting techniques, cultivation timing, retting degree, climatic change, fibre microfibrillar angle, fibre structure, fibre layer cell dimensions, fibre storage place, and fibre testing procedures [16–24]. Constituents such as cellulose, lignin, hemicellulose, pectin, waxes, oils, and moisture content make up natural fibres. The physical, mechanical, and thermal performance of NFRC can be influenced by many factors, including the selection of reinforcement and matrix, form of reinforcement, manufacturing methods adopted, volume/weight fraction of the reinforcement or matrix, the fibre aspect ratio, fibre matrix interaction, chemical reagents adopted for fibre treatment, stacking sequence, and orientation of the fibres, laminate curing temperature, and time [25–32]. Natural fibres are constructed as chemical constituents like cellulose, hemicellulose, lignin, wax, moisture, and ash content. The chemical constituents considerably vary between fibres to fibres and also affect the overall mechanical properties of the natural fibres. The diameters of the fibres varied considerably from the length of the individual filaments. The disadvantage of cellulosic fibres as reinforcement is that their hydrophilic nature makes them incompatible with thermoset or thermoplastic polymers, resulting in weak adhesion between the matrix and reinforcement because the polymer matrix is hydrophobic in nature [33–35]. However, adhesion between fibre and petroleum-based polymer should be enhanced with appropriate chemical treatment [36–38]. It is critical to building a better interphase for better composites in terms of performance; the external stress should be passed to fibres from polymeric resin. Chemical treatment is one method for natural fibres to maximise the adhesion at the interface. Since it minimises the amount of OH placed over the surface of the fibre and reduces the aspect ratio of the fibre, which improves the adhesion at the interface zone due to superior effective fibre surface area and aspect ratio. The outcome of fibre surface treatment depends on treatment time, type of reagent and its concentration, and temperature [39–44]. Different chemical reagents for various natural fibres include alkaline, benzoylation, acrylation, peroxide, silane, potassium permanganate, dewaxing, maleated coupling agent, stearic acid, graft copolymerization, acetylation, and isocyanate treatment [45–51].

Appropriate manufacturing techniques should be adopted to convert the raw materials into the final product without causing any defects. For the selection of proper manufacturing techniques to develop fibre reinforced composites, design and manufacturing experts would primarily consider a few factors. Such factors are size and shape of the end product, properties of reinforcement and matrix, processing characteristics of raw materials like processing temperature, pressure, curing time and curing temperature, production time, and manufacturing cost [52–57]. Conventionally, fibre-reinforced composites have been fabricated through various methods like autoclave, vacuum bag molding, compression molding, resin transfer molding, injection molding, filament winding, spray-up, and pultrusion [58–66]. The fibre/nanofiller-reinforced polymer composites are used in automobiles, aerospace, construction materials, packaging applications, and medical applications. Nanofillers could belong to organic and inorganic groups in nature. The particles like nanographeme, nanoclay, silica (SiO2), nanomontmorillonite (MMT), titanium dioxide (TiO2), carbon nanotube (CNT), calcium carbonate (CaCO3), and n-SiC are inorganic fillers. However, the fillers, such as rice husk, coconut shell nanofiller, pinecone char, wood shaving char, and cellulosic nanofillers, are extracted from renewable sources and represent organic nanofillers [67–71]. For the nanocomposite preparation, nanofillers are mostly added using a weight fraction method in order to analyse the effect of filler loadings. Wagner et al. [72] revealed that the addition of just below 6 vol.% of polymer nanoparticles as reinforcements to make composite materials improved a wide array of properties like reduction in weight, dimensional stability, heat conductivity, and electrical conductivity. Saba et al. [73] in their research article showed that kenaf and jute fibres have a low density of 1.3 g/cm3 and bond well with thermosets (epoxy) and thermoplastic polymers. They also claimed that nanosized reinforcements develop better properties in the composite materials compared to their microsized counterparts. The review aims to summarise the effects of various factors influencing natural fibre-reinforced composites with nanofillers and various chemical reagents on different natural fibres. Furthermore, it summarises the effects of various manufacturing methods and industrial applications of NFRCs.

2. Effect of Various Factors on NFRC with Nanofillers

The influence of fibre length and weight fraction on the mechanical characteristics of agave/polypropylene composites was studied by Jayaraman [74]. He concluded that

Figure 1: Classification of plant fibres.

composite materials with a fibre length of more than 10 mm and a fibre weight fraction of between 15% and 35% revealed excellent mechanical performance. Stalin et al. [75] studied the mechanical properties of vetiver/banana/vinyl ester composites by varying the weight fraction of fibres. The mechanical properties of composites were improved by the hybridization of vetiver and banana fibre. Vinayagamoorthy and Rajeswari [76] examined the mechanical properties of Vetiveria zizanioides/jute/glass composites by varying the weight fraction of fibres. Flexural, impact, compression, and hardness of hybrid composites were increased by 26.8%, 30.44%, 59.1%, and 28.65%, respectively. Sathishkumar et al. [77] analysed the mechanical characteristics of randomly oriented snake grass/banana/coir fibre hybrid composites. They revealed that the snake grass/banana and snake grass/coir fibre composites had better mechanical properties than banana/coir composites. Sanjay and Yogesha [78] studied the physical and mechanical properties of jute/kenaf/E-glass/epoxy hybrid composites. The mechanical properties of the laminates are influenced by the fibre arrangements and adhesion levels of the fabrics and the sequencing of high-strength fibre plies in the laminates. [79] examined the density and [1]thermal stability of Furcraea foetida (FF) fibre-reinforced composites. The density of the Furcraea foetida fibre (778 kg/m3) was relatively reduced in comparison with synthetic fibres, which are useful for making less dense products. FF fibres have a thermal stability of 320.5°C, which is much greater than thermoplastic polymerization temperatures. The effect of the volume fraction of snake grass fibre on tensile and flexural strength was analysed by Sathishkumar et al. [80]. They noticed that an increase in snake grass fibre of up to 25% exhibited the highest properties. Arpitha et al. [81] fabricated five different hybrid composites by using conventional manufacturing methods and varying fibre stacking sequences and studied the water absorption and tensile strength of sisal/glass/epoxy/filler composite laminates. They discovered that adding E-glass and SiC filler to composites can reduce voids and water absorption intake. Also, they revealed that the tensile strength of sisal/glass/epoxy/filler composites increased with an increase in glass fibre volume fraction. Sanjay and Yogesha [82] examined the effect of the fibre stacking sequence of jute, kenaf, and E-glass woven fabric composites on water absorption properties. The water absorption tests were performed on specimens immersed in three different water conditions: normal, distilled, and salt water. They observed that the hybridization of E-glass with jute and kenaf fibres decreases the maximum water absorption. Sanjay et al. [83] investigated the

Table 1: Effect of various factors on NFRC.

S. no	Fibres used	Factors influenced	Effects	Reference
1	Pineapple leaf	Fibre content	Tensile and flexural properties increase with fibre content.	[96]
2	Bamboo	Moisture absorption	An increase in moisture resulted in decreased interfacial shear strength.	[97]
3	Palmyra	Length and weight fraction	Better mechanical properties were obtained with a length of 55 mm and a weight of 55%.	[98]
4	Jute	Water absorption	An increase in water absorption resulted in poor flexural and compressive properties.	[99]
5	Banana/sisal	Length and weight	Up to 50% by weight, mechanical properties increased and water absorption decreased.	[100]
6	Banana/sisal	Weight fraction	The highest mechanical properties were obtained at 0.4%.	[101]
7	Chopped snake grass	Volume fraction	Improved mechanical properties when the volume fraction increases.	[80]
8	Abaca	Fibre loading	The mechanical properties showed an increasing tendency up to 40 wt.% of fibre loading.	[102]
9	Banana/sisal	Microfibrillar angle (MFA)	High tensile characteristics are seen in fibres with high cellulose content and a low MFA content.	[103]
10	Kenaf	Fibre content	Improved mechanical properties at 25% and 30% fibre content.	[104]
11	Luffa	Volume fraction of fibres	The mechanical characteristics of treated fibre composites were found to be optimal at 40% fibre volume fraction.	[105]
12	Snake grass	Volume fraction and fibre length	Improved mechanical properties of the short fibre isophthalic polyester composite were achieved at 25% V_f for the 30 mm fibre length.	[106]
13	Luffa cylindrica	Fibre content	Improved mechanical properties at 40% fibre content.	[107]
14	Oil palm	Aging and wear behavior	The wear test was carried out in dry conditions, and it was discovered that the composites immersed in engine oil and diesel performed better than the others.	[108]
15	Lantana camara	Load and fibre content	(1) The proportional wear loss increased in direct proportion to the increase in normal load (2) The optimum wear resistance property was obtained at a fibre content of 40%	[109]
16	Agave	Fibre length (3, 5, and 7 mm)	3 mm agave fibre reinforcement that has been alkali-treated had better mechanical properties.	[110]
17	Sansevieria cylindrica	Fibre length and weight	The mechanical characteristics of composites were optimal at 30 mm fibre length and then deteriorated beyond that.	[111]
18	Vakka	Volume fraction	Tensile characteristics improved as the percentage of vakka fibre in the composite increased.	[86]
19	Coir/silk	Fibre length	The mechanical characteristics of composites with 2 cm fibre length were the best.	[112]
20	Palm/coir fibre	Fibre weight fraction	The mechanical characteristics of composites with 30% fibre reinforcement were the best.	[113]
21	Sisal/nanoclay/polyester	Fibre and filler weight fraction	Improvement in tensile strength and water absorption when 25% sisal and 3% nanoclay.	[114]
22	Bagasse/nano-SiO_2/HDPE	Filler loading (2% to 5%)	Improvement in tensile strength by 71.46%.	[115]
23	Bagasse/nano-TiO_2/vinyl acetate	Filler loading (2%)	10% improvement in tensile strength.	[116]
24	Ramie/CNT/epoxy	Filler loading (0 to 0.6%)	Flexural strength and modulus were increased by 34% and 37%, respectively.	[117]
25	Bagasse/nanographene/PP	Filler loading	Improvement in mechanical properties such as tensile, flexural, and impact strength.	[118]
26	Jute/nanographeme/epoxy	Filler loading	Improvement in mechanical properties such as tensile, flexural, and impact strength.	[119]

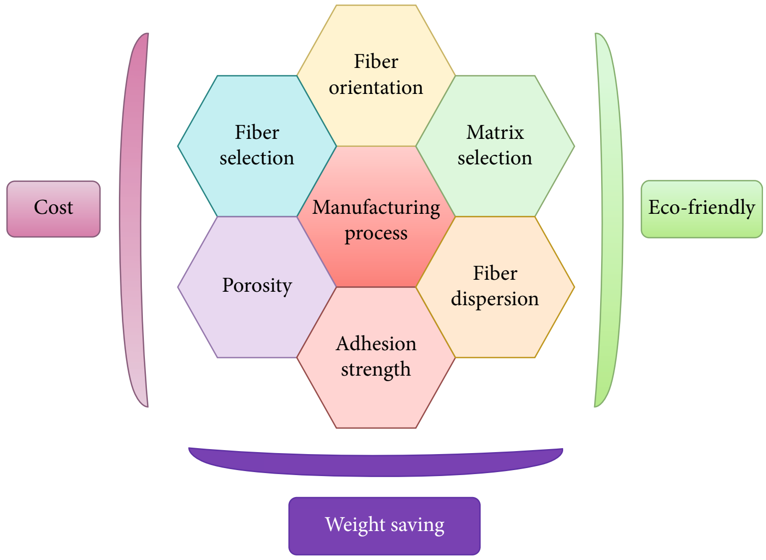

Figure 2: Various factors affecting NFRC.

hybridization effect of jute, kenaf, and E-glass fibres-reinforced hybrid composites on mechanical properties as a function of varying fibre layer sequences. They observed that incorporating glass fibre with jute and kenaf fibres enhanced the impact and interlaminar shear strength over pure NFRC. Compared to other laminates, the hybrid laminate with glass and kenaf fibre plies on the outside and jute fibre plies on the inside has improved characteristics. Vijay et al. [84] investigated the tensile strength, thermal stability, and surface properties of untreated and NaOH-treated Tridax procumbens fibres. They found that there was an increase in cellulose level after NaOH treatment and a decrease in hemicellulose, pectin, and wax, which improved thermal stability, tensile strength, and surface roughness. Sanjay et al. [85] assessed the tensile, flexural, and impact characteristics of hemp/glass fibre-reinforced hybrid composites as a function of fibre-layering sequences. They revealed that the incorporation of synthetic fibre with natural fibre decreased the water absorption and increased the mechanical properties of the composites. Murali Mohan Rao et al. [86] studied the tensile and flexural strength of composites made by strengthening vakka fibre into a polyester polymer as a function of the volume fraction of fibre. They revealed that vakka fibre composites had better tensile and flexural properties than banana and sisal fibre composites and were similar to bamboo-composite at the maximum volume fraction of fibre. Okubo et al. [87] analysed the flexural properties of bamboo/polypropylene composites. Due to enhanced bonding at the interface and fewer voids, the composite's flexural strength and flexural modulus increase by roughly 22% and 40%, respectively. Shanmugam and Thiruchitrambalam [88] studied the dynamic mechanical analysis of palmyra palm/jute/polyester hybrid composites. They observed that combining jute fibres with palmyra palm increased the impact and ILSS by 18% and 25%, respectively. Raghul et al. [89] present a detailed survey on the mechanical behavior of glass fibre reinforced epoxy composites with nanofillers. This composite is manufactured by the compression modelling method in the form of laminates. The weight fraction of the nanofiller in the matrix ranges from 1%wt to 7%wt. This nanocomposite consists of improved mechanical properties suitable for industrial manufacturing. Biswas [90] prepared an effect of silicon carbide (SiC) in bamboo/epoxy composites as a function of weight percentage of filler loadings. The optimum tensile and flexural strengths were observed at 10 wt.% SiC and 5 wt.% SiC, respectively. The highest hardness was found at 15 wt.% SiC. From the SEM analysis, it was concluded that poor adhesion is responsible for low mechanical strengths. Nguong et al. [91] studied the effect of n-SiC on polymer matrix composites with different weight loadings of fillers. They observed that the mechanical properties were increased when 1 wt.% of n-SiC was reinforced into the epoxy matrix. The tensile strength, flexural strength, and fracture toughness of the composites were significantly increased when fillers were added to the composites. The effect of the addition of silicon carbide to jute fibre-reinforced epoxy hybrid composite was studied by Ramadan et al. [92]. Jute fabric-reinforced epoxy composites with silicon carbide ranging from 2 to 8% were fabricated by the vacuum assisted resin infusion method. The jute fibre-reinforced composites with 4 vol.% SiC exhibited excellent tensile and flexural strength. The mechanical properties of the composite were decreased when the SiC content was exceeded by 4 vol.%. Finally, they observed that the addition of SiC to jute fibre reinforced epoxy composites significantly increased their tensile, flexural, and impact strength. Ali and Ahmad [93] have investigated the compressive strength, thermal stability, and morphology of the empty fruit bunch and nanoclay-reinforced hybrid polyurethane foam composites. The result reveals that the hybridization of empty fruit bunch and nanoclay enhances the mechanical and thermal

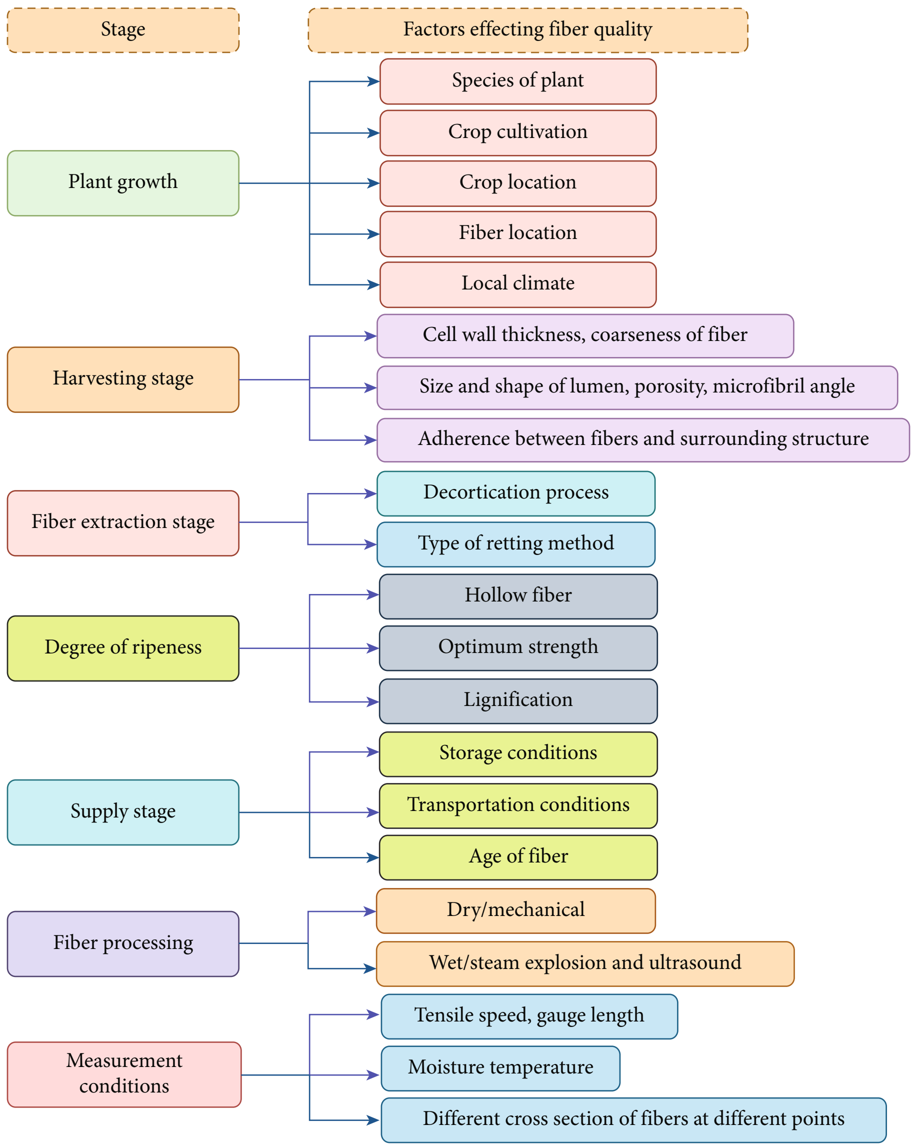

Figure 3: Various factors affecting quality of natural fibres.

stabilities of the composites more than the empty fruit bunch alone filled composites. Olumuyiwa et al. [94] have studied the tensile, hardness, and impact strength of the coconut shell powder-reinforced polyethylene composite for different nanofiller loadings (5–25 wt.%). The hardness is found to be increased when the coconut shell filler loadings increase and the tensile strength, modulus of elasticity, impact energy, and ductility of the composite decrease with the increasing coconut shell filler loadings. They have also suggested that coconut shell powder-reinforced polyethylene composites are suitable for interior parts of automobiles. The thermal stability, electrical conductivity, water sorption, and mechanical properties of three different nanofillers (plastic waste char (PWC), wood shavings char (WSC), and pinecone char (PCC)) reinforced epoxy composites are analysed by Ahmetli et al. [95]. The result has revealed that the incorporation of nanochar particles enhances the mechanical and thermal stability of the composites. Among three nanochar-filled composites, plastic waste char-filled composites have produced more thermal stability and decreased the moisture diffusivity of neat epoxy. Table 1 presents the effects of various factors influencing NFRC. Figure 2 shows various factors influencing NFRC. Figure 3 shows various factors influencing the quality of the natural fibre.

3. Effect of Chemical Treatments on NFRC with Nanofillers

Plant fibres generally consist of cellulose, hemicellulose, lignin, pectin, water-soluble, and waxy elements [120]. From the chemical point of view, the primary constituents of plant fibres are cellulose, in which Dglucopyranose units are linked together by b-(1-4)-glucosidic bonds; hemicelluloses consist mainly of D-pentose sugar units strongly bonded with cellulose fibrils through hydrogen

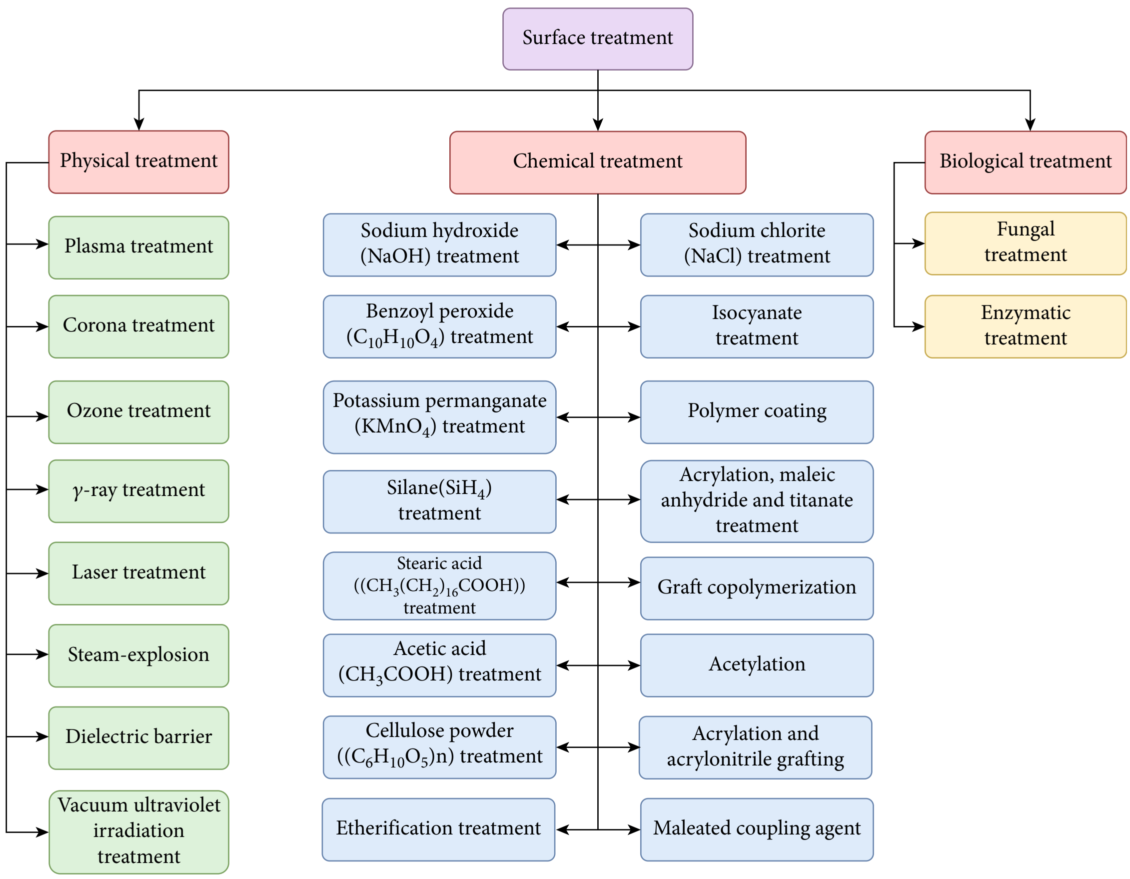

Figure 4: Types of chemical treatments.

bonding; and lignin, consisting of aromatic alcohol units such as coniferyl alcohol, sinapyl alcohol, and coumaryl alcohol [121, 122]. Pectin acts as an adhesive to hold fibres together in bundles and bundles to nonfibrous tissues. Hemicellulose, pectin, and lignin act like a matrix, whereas cellulose acts as reinforcement to the matrix, contributing to the strength of the fibre. Plant fibres are amenable to modifications as they bear hydroxyl groups (OH) from cellulose and lignin. The hydroxyl groups may be involved in hydrogen bonding within the cellulose molecules, thus reducing the matrix activity. Surface modifications can either stimulate OH groups or create new moieties that can interconnect with the polymer effectively [123]. Fibre surface characteristics such as adhesion, porosity, surface tension, and wetting can be enhanced upon chemical treatment. Surface modification of natural fibres can result in significant physical changes such as the removal of an oil or waxy layer, changes in fibre structure, density changes, and surface roughness changes [124, 125]. The interfacial adhesion of the composites can be enhanced by altering the fibre surface, altering the matrix, or altering both. Chemical treatment is necessary to improve the adhesion and wettability at the interface [126]. Figure 4 shows the types of various chemical treatments of natural fibres. Mwaikambo and Ansell [127] reported that alkalization improved the characteristics of kapok, sisal, jute, and hemp fibres, resulting in increased fibre–resin adhesion and more incredible interfacial energy. Teli and Jadhav [128] studied the influence of NaOH reagent on the mechanical properties of Agave augustifolia fibres with changing reagent concentrations (i.e., 2, 5, 10, 15, and 20%) for 1 h and found the most extraordinary mechanical properties at 15%. Sawpan et al. [35] showed that the flexural properties of hemp fibre were enhanced by mercerization treatment with a NaOH concentration of 5%.

Dhanalakshmi et al. [129] assessed the alkali treatment effect on the flexural strength of areca fibre-reinforced epoxy composites and observed that flexural strength improved after treatment due to eliminating the hemicellulose, lignin, pectin, and waxes. After mercerization treatment, the characteristics of henequen fibres/high-density polyethylene composites improved owing to the elimination of a few lignin and hemicelluloses from the fibre surface, resulting in a larger contact surface area at the interface zone [130]. The 5% NaOH treatment increased the mechanical characteristics of Borassus fruit fibres by increasing their surface area and improving their interfacial properties [131]. Paul et al. [132] subjected banana fibre to permanganate treatment and investigated the influence of permanganate treatment on the tensile and flexural properties of banana-polypropylene composites. They found that the tensile and flexural properties increased by 5% and 10%, respectively. Lopez Manchado et al. [133] subjected flax fibre to acetylation treatment and analysed the influence of acetylation

Table 2: Effect of various chemical treatments on NFRC.

S. no	Fibres used	Type of chemical treatment	Effects	Reference
1	Sisal and roselle	Alkaline	Increased mechanical properties.	[141]
2	Alfa	Acetylation	Improved resistance to moisture absorption	[142]
3	Continuous henequen fibres	Silane (0.015 wt. %)	Improved mechanical properties.	[143]
4	Borassus fruit fibres	Alkaline	Thermal stability and tensile properties have been slightly improved.	[144]
5	Agave fourcroydes	Alkaline	Improved fibre matrix adhesion	[145]
6	Bagasse	Mercerization and acrylic acid	Superior tensile and flexural properties and reduced moisture absorption.	[145]
7	Unidirectional Roystonea regia	Alkaline	Improved tensile and flexural properties.	[146]
8	Sisal	Alkaline	Intracrystalline lignin and waxy, and resulted in improved mechanical interlocking.	[147]
9	Oil palm	Alkaline, acrylonitrile grafting, silane, acrylation, permanganate, acetylation, peroxide treatment	(1) Silane treatment-tensile strength reduced (2) Acrylation-enhanced tensile strength (3) Alkali and permanganate-tensile modulus increased (4) Silane and acrylate treatments showed optimum mechanical properties	[148]
10	Coir fibre	Alkaline	Interfacial adhesion between coir fibre and natural rubber was improved.	[149]
11	Sisal	Alkaline	The internal structure that resulted in a specific stiffness that was approximately the same as steel.	[150]
12	Kenaf	Alkaline	Improved mechanical properties	[151]
13	Ramie	Alkaline	Tensile strength of the ramie fibre improved from 4 to 18% compared to untreated fibre while Young's modulus decreased. Tensile strength increases as a result of a change in microfibrillar angle.	[152]
14	Bagasse	Alkaline	Improvement in tensile, flexural, and impact strength by 13%, 14%, and 16% compared to untreated fibres.	[153]
15	Sisal	Alkaline and benzoyl chloride treatment	Higher thermal stability.	[154]
16	Flax	Benzoyl chloride	Moisture absorption is reduced, and tensile properties are improved.	[155]
17	Jute	Alkaline	Improved dynamic mechanical properties.	[156]
18	Alfa	Styrene, acrylic acid, and maleic anhydride	These treatments resulted in reduced water uptake.	[157]
19	Kenaf	Alkaline	3% NaOH treatment led to ineffective removal of impurities. 9% NaOH cleaned the fibre surface.	[158]
20	Coir	Alkali and UV radiation	Higher shrinkage of the polymer grafted with fibre resulted in physicomechanical properties.	[159]
21	Sisal/5% nanomontmorillonite (MMT)/PP	Maleic anhydride grafted polypropylene	Improvement in tensile strength	[160]

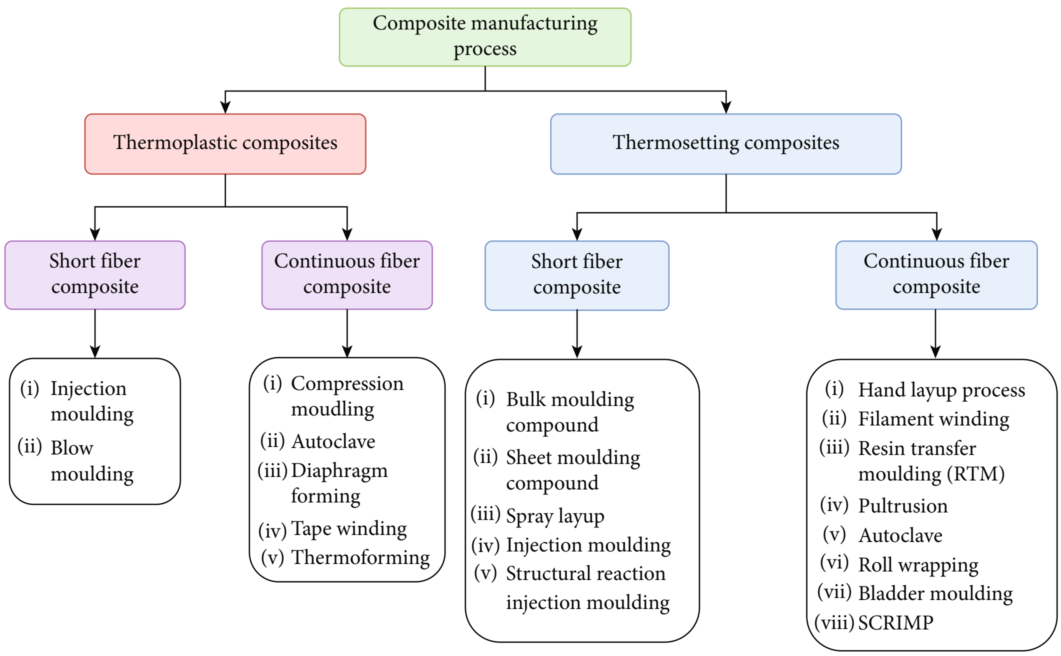

Figure 5: Classifications of manufacturing methods.

treatment on the thermal and mechanical properties of flax fibre-reinforced polypropylene composites. They found that the thermal and mechanical properties were enhanced by 50% and 25%, respectively. Singh et al. [134] discovered that an alkali-treated agave reinforced epoxy composite has better fracture strain and interfacial adhesion between fibre and matrix than an untreated fibre. Shanmugam and Thiruchitrambalam [88] revealed that the maleated anhydride-treated jute fibre-reinforced high-density polyethylene composite exhibits improved adhesion between fibre and matrix, which enhances the dynamic and static properties such as tensile, flexural, and impact strength. Singh et al. [134] investigated whether an alkali-treated agave-reinforced epoxy composite exhibits greater fracture strain and interfacial adhesion between the hydrophilic fibre and the hydrophobic matrix than an untreated fibre. Arbelaiz et al. [135] studied that 20 wt% of NaOH-treated flax fibre-reinforced polypropylene (PP) composites exhibited greater maximum interfacial shear strength (ILSS) than untreated flax fibre-reinforced composites. De Rosa et al. [136] observed that the composite containing 10% acetic acid-treated okra fibre has less tensile strength and Young's modulus than those containing untreated okra fibre-reinforced composites. Mwaikambo et al. [137] investigated the effect of alkaline treatment on the tensile and impact strength of hemp/euphorbia composites and reported that the tensile and impact strength increased by 30% each compared to untreated composites. Lopez Manchado et al. [133] examined the influence of alkaline treatment on the tensile and flexural properties of bamboo/polyester composites and found that the tensile and flexural strength increased by 10% and 2%, respectively, over untreated composites. [138] reported the result of alkali treatments on the mechanical properties of a jute/polyester composite. They observed that 10% NaOH-treated fibre composites for 3 h provided an improvement in tensile strength, flexural strength, and impact strength. Shanmugam and Thiruchitrambalam [88] attempted to increase the mechanical properties of palmyra palm/jute/polyester hybrid composites by alkaline treatment with 5% NaOH for a duration of 30 min. They found that the mechanical properties such as tensile, flexural, and impact strength increased by 40%, 55%, and 4%, respectively. The new cane fibres were alkali treated for 24 hours at different concentrations of 2, 4, 6, and 8%, with the highest tensile and flexural strength being revealed at 6% [139]. The effect of mercerization on the flexural and impact strength of coir fibre-reinforced polyester composites was investigated by Prasad et al. [140]. The treated fibre composites outperformed the untreated ones due to stronger interfacial bonding between fibre and matrix after 72 hours of treatment with a 5% NaOH solution. Ragunathan et al. have fabricated rice husk powder-reinforced polypropylene/recycled acrylonitrile butadiene rubber composites by a melt mixing technique. The rice husk-filled composite is fabricated with silane and anhydride. The composites are characterised by mechanical, FTIR, and morphological properties. The composites influenced by anhydride exhibit better mechanical strength than the composites treated with silane. The coupling agent increases the bond between the rice husk filler and the matrix. Table 2 presents the effects of various chemical treatments on NFRC.

4. Effect of Various Manufacturing Methods on NFRC with Nanofillers

Shibata et al. [161] investigated the influence of the volume fraction of kenaf and bagasse fibres on reinforced corn starch composites manufactured by compression molding

Table 3: Effect of various manufacturing methods on NFRC.

S. no	Fibre/matrix	Manufacturing method used	Effects	Reference
1	Long discontinuous kenaf and jute-reinforced polypropylene	Hot-press	Maximum tensile strength and modulus were obtained at 40% fibre weight fraction.	[179]
2	Short bamboo fibre	Injection molding	Improved mechanical properties.	[180]
3	Chicken feather fibre/PLA	Injection molding	The SEM image indicated that an even distribution of CFF in the PLA matrix existed.	[181]
4	Sisal, banana, jute, and flax/propylene	Extrusion and compression molding	Enhanced the mechanical properties.	[182]
5	Silk/gelation	Compression molding	Mechanical properties were increased.	[183]
6	Agave/epoxy	Hand layup	Wear properties were improved.	[184]
7	Luffa/coir/PP	Injection molding	Mechanical properties were improved.	[185]
8	Luffa/thermoplastic starch	Compression molding	Mechanical properties were improved.	[107]
9	Luffa and groundnut/epoxy	Hand layup	Mechanical properties were improved.	[105]
10	Alfa/polyester	Hand layup	Mechanical properties increased up to 5% NaOH treatment.	[186]
11	Snake grass/polyester	Hand layup	Mechanical properties were improved.	[187]
12	Tea/epoxy	Compression molding	Mechanical properties were improved.	[188]
13	Cissus quadrangularis stem fibre/ unsaturated polyester	Compression molding	Mechanical properties were improved.	[189]
14	Short Sansevieria cylindrica/polyester	Compression molding	Mechanical properties were improved.	[111]
15	Tapsi fibre	Hand layup	Mechanical properties were improved.	[190]
16	Prosopis juliflora/epoxy	Hand layup	Mechanical properties were improved.	[14]
17	Tea leaf fibre	Compression molding	Mechanical properties were improved.	[191]
18	Flax	Compression molding	Mechanical properties were improved.	[192]
19	Long jute fibre yarn	Injection molding	Mechanical properties were improved.	[173]
20	Short date palm leaves	Injection molding	Mechanical properties were improved.	[193]
21	Wood flour/6% MMT/PP	Injection molding	Tensile and flexural strength were improved by 20% and 13%, respectively.	[194]
22	Sisal/2-5% MMT/epoxy	Compression molding	Tensile strength and tensile modulus were improved by 27% and 47%, respectively.	[195]
23	Sisal/5% nanoclay/epoxy	Compression molding	Water absorption was reduced by 1/3 times.	[195]
24	Hemp/nanoclay/polyester	Compression molding	Water absorption and tensile strength were reduced by 8% and 20%, respectively.	[196]
25	Bamboo/MMT/HDPE	Melt compounding	Mechanical properties were decreased.	[197]
26	Bamboo/CNT/epoxy	Hand layup	Tensile strength and flexural strength were increased by 6.67% and 5.8%, respectively.	[198]

techniques and found that an increase in the volume fraction of kenaf and bagasse fibres led to an increase in the flexural modulus of composites by 60% and 66%, respectively. Barone [162] studied the influence of fibre length on the tensile, impact, and flexural strength of abaca fibre-reinforced phenolic composites manufactured by the compression molding technique and found that the fibre length of 30 mm was optimum for obtaining higher mechanical properties such as tensile, impact, and flexural strength. Kafi et al. [163] assessed the effect of styrene chemical treatment on the crack propagation of jute fibre-reinforced polyester composites manufactured by compression molding technique and reported that the resistance to crack propagation was enhanced when jute fibre was treated with styrene. Sharma and Kumar [164] investigated the effect of the weight fraction of fibre on the flexural strength of banana fibre-reinforced polyurethane composites manufactured by a compression molding technique. They found that a fibre content of 15% by weight was optimum for achieving better flexural strength. Alamri and Low [165] reported that recycled cellulose fibre-reinforced epoxy composites manufactured by compression molding techniques with the weight content of fibre up to 46% had higher fracture toughness. Cao et al. [153] discovered that bagasse fibre-reinforced polyester composites manufactured by compression molding with 65% fibre content by weight had a 30% higher impact strength than other weight fractions of fibre. Jandas et al. [166] studied the effect of the volume fraction of banana fibres on the polylactic acid composite manufactured by the compression molding technique with 25% fibre

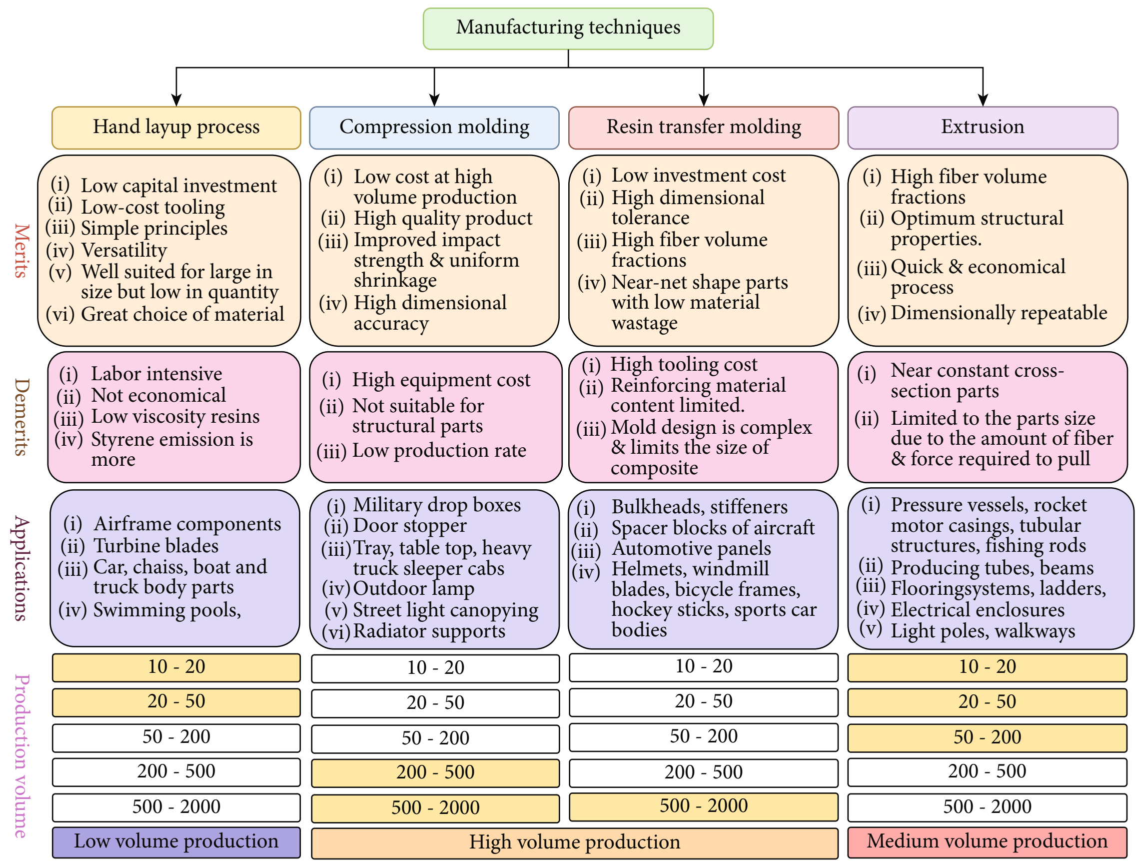

Figure 6: Merits, demerits, and applications of NFRC.

content by volume, resulting in higher impact strength compared to other volume fractions of fibres. Bledzki et al. [167] studied the influence of volume fraction on the impact strength of jute and flax fibre-reinforced epoxy hybrid composites manufactured by compression molding. They found that the impact strength of the hybrid composite was improved when there was an increase in the fibre content by volume and also reported that flax fibre-reinforced composites had greater maximum impact strength than jute reinforced composites. Yousif and El-Tayeb [168] studied the effect of fibre length and fibre diameter on the wear rate of oil palm fibre-reinforced polyester composites manufactured by hand layup technique and found that the fibre length of 1–1.5 mm and fibre diameter of 350 micro m ^{2}notably reduced the wear rate by about three to four times compared to pure polyester resin. El-Tayeb [169] investigated the influence of fibre length on the wear resistance of sugarcane fibre-reinforced polyester composites manufactured by hand layup technique and found that the composite with a fibre length greater than 5 mm has increased wear resistance due to less fibre pullout present at that length. Assarar et al. [170] studied the flax fibre-reinforced epoxy composite manufactured by hand layup technique and reported that water aging significantly increased the strain rate by 61% and decreased the Young's modulus by 40% of the composite compared to the manmade glass fibre. Venkateshwaran et al. [171] analysed the influence of NaOH reagent on the mechanical properties of banana/epoxy composite manufactured by hand layup technique. They concluded that 1% alkaline-treated fibre increased the mechanical properties of untreated fibre composites. Ray et al. [172] analysed the influence of NaOH reagent on the ILSS of a jute/vinyl ester composite manufactured by hand layup technique and concluded that the fibre treated with 5% NaOH for 4 hrs gave 20% progress in the ILSS. Prasad et al. [140] studied the influence of NaOH reagent on the impact and flexural strength of coir/polyester composites manufactured by hand layup technique and noticed that the coir fibre bleached with 5% NaOH for 3 days gave a 40% enhancement in the impact and flexural strength. Gao and Mader [173] fabricated a jute fibre reinforced polypropylene composite using injection molding techniques and noticed that the fibre length was significantly influencing the tensile properties of the composite. Karmaker and Schneider [174] fabricated jute and kenaf fibre-reinforced polypropylene hybrid composites using injection molding techniques and reported that the hybrid composite had higher mechanical properties with maximum jute fibre than kenaf fibre. Bledzki et al. [175] analysed the influence of acetylation treatment on the mechanical characteristics of a flax fibre-reinforced polypropylene composite fabricated by injection molding technique. They concluded that the mechanical characteristics of the treated fibre composite increased by up to 35% compared to untreated fibre. Yang

Manufacturer	Model	Applications
Rover	2000 and others	Rear storage shelf/panel and insulations
Opel	Vectra, Astra, Zafira	Door panels, pillar cover panel and instrumental panel
Volkswagen	Passat, Golf, A4, Bora	Seat back, boot-lid finish panel and boot-liner
Audi	A2, A4, A6, A8, Roadstar, Coupe	Back door panel, spare tire lining, seat back and boot-liner
Daimle chrysler	A, C., E and S class, Evobus	Car dashboard/windshield, door panels and pillar cover panel
BMW	3,5,7 series and other pilot	Headliner panel, door panels noise insulations panels, seat back and moulded foot well things
Peugeot	406	Parcel shelf, seat backs and rear/front door panels
Fiat	Marea, punto, brava, alfa romeo 146, 156, 15	Door panel
General motors	Cadillac De Ville, Chevrolet Trail blazer	Corgo area floor mat and seat backs
Toyota	ES3	Interior parts and pillar garnish
Saturn	L300	Door panel and package trays
Volvo	V70, C70	Natural foams, seat padding and cargo floor tray
Ford	Mondeo CD 162, Focus	Door panels, boot-liner, B pillar, door inserts and food trays
Saab	9S	Door panels, roof cover, trunk panel
Renault	Clio, Twingo	Rear parcel shelf
Toyota	Brevis, Harrier, Celsior	Seat backs, floor mats, door panels and spare tire cover
Mitsubishi	-	Instrumental panel, door panels and cargo area floor
Mercedes benz	A, C., E and S classes	Glove box, door panels, Instrumental panel support insulation, Moulding rod/apertures, seat backrest panel, trunk panel, seat surface/backrest, internal engine cover, engine insulation, sun visor, bumper, interior insulation, wheel box and roof cover.

Figure 7: Automobile applications of NFRC [213–217].

et al. [176] investigated the influence of maleated anhydride treatment on the tensile strength of a rice husk fibre-reinforced polypropylene composite fabricated by injection molding technique and noticed that the tensile strength of the treated fibre composite was improved due to enhanced adhesion between the hydrophilic fibre and the hydrophobic matrix. Pickering et al. [177] analysed the influence of fungal and NaOH reagents on the mechanical characteristics of a hemp/polypropylene composite fabricated by injection molding technique. They noticed that the mechanical characteristics of fungal-treated and combined fungal/alkaline-treated composites were increased by 22% and 32%, respectively. Wielage et al. [178] fabricated flax and hemp fibre-reinforced polypropylene composites using injection molding techniques and noticed that maleated anhydride-grafted treatment significantly enhanced the dynamic

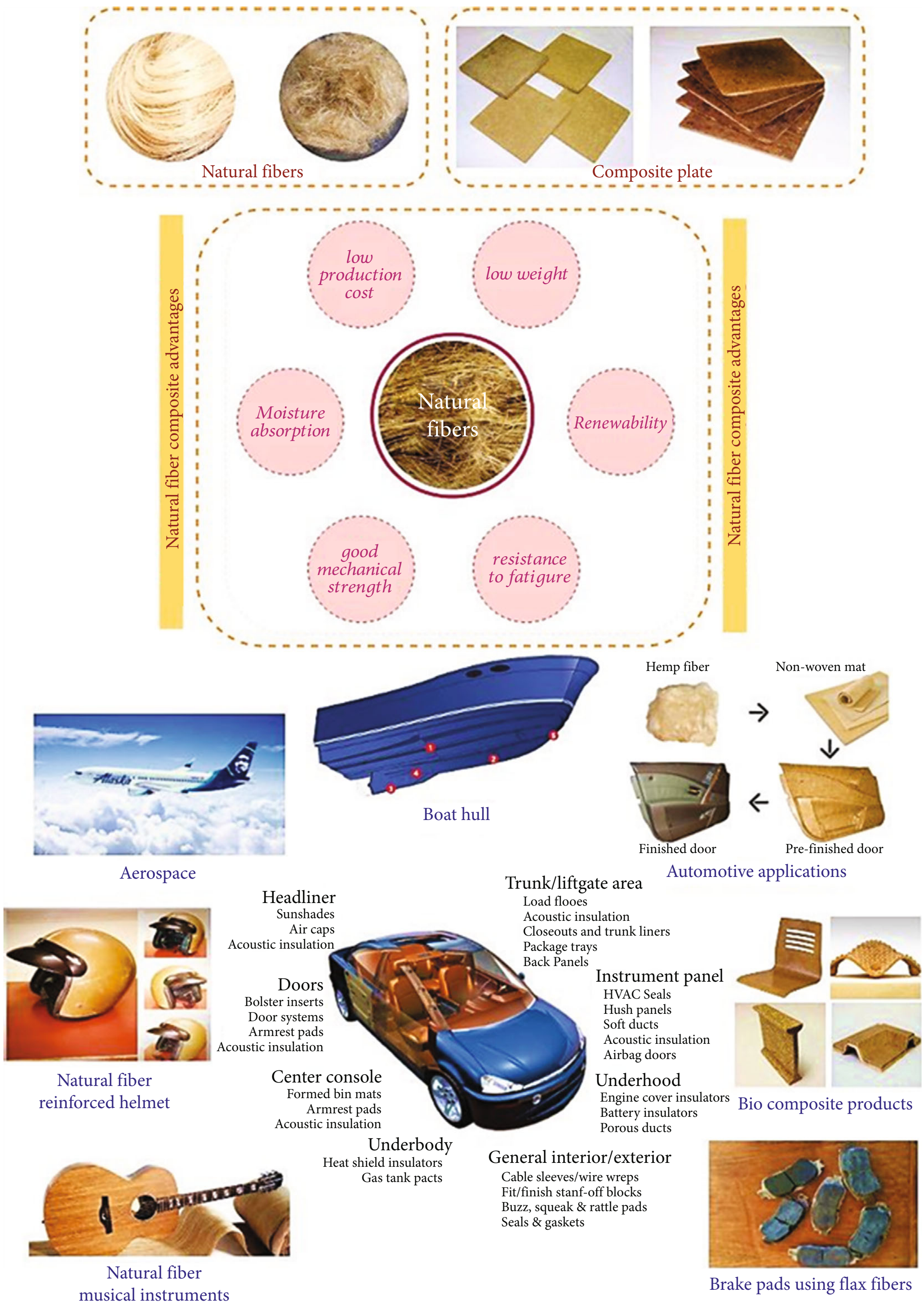

Figure 8: Industrial applications of NFRC [218–220].

mechanical properties of the composites compared to untreated fibre composites. Figure 5 shows the classifications of manufacturing methods for the NFRC. Table 3 presents the effect of various manufacturing methods on NFRC. Figure 6 presents the merits, demerits, and applications of NFRC.

5. Industrial Applications of NFRC

Composites reinforced with natural fibres are gaining more attention in the market right now, as demand for high strength-to-weight ratios for industrial applications grows. The NFRC material has a high strength-to-weight ratio,

Table 4: Applications of NFRC in various fields.

S. no	Fibre	Components	Reference
1	Flax/sisal	Door trim panels and cable linings	[221]
2	Kenaf	Automobile dashboards, carpet padding, and products as rope, twine, bagging, and rugs	[222]
3	Jute	Brake pad and car insulation	[223]
4	Sisal	Ropes, mats, carpets, and fancy articles	[15]
5	Soybean oil	High-quality paint enamel	[224]
6	Coconut	Interior trim and seat cushioning	[225]
7	Banana	Household telephone stand	[226]
8	Soy oil	Structural panels	[227]
9	Kenaf/glass	Car bumper	[228]
10	Coir	Liquid storage tanks	[229]
11	Sugar palm fibre	Brushes, ropes	[230]
12	Mature coconut	Textiles (mats and carpets), building (thermal insulation), and automobile (cushion and seat covers)	[231]
13	Ichu fibre	Construction material	[232]
14	Tapsi/karaya gum	Food and pharmaceutical industries	[233]
15	Date palm	Insulation material in buildings	[234]
16	Azadirachta indica	Car roofing, interior and exterior panels, home appliances, container boxes, particle boards, and parcel shelves.	[235]
17	Tridax procumbens	Ayurvedic medicines to treat liver disorders	[84]

moderate stiffness, impact resistance, durability, improved corrosion resistance, and excellent fatigue strength. Because of these numerous benefits, NFRC has found applications in construction, aircraft, defense, hockey sticks, homes, surgical equipment, leisure, ship hulls, and automobile parts [199–203]. Snake grass, bamboo, kenaf, flax, vetiver, areca, and ramie fibres are used in various applications like office furniture, textile products, ropes, home appliances, fishing nets, the paper industry, packing materials, and building materials [204]. Textiles, households, oil pipes, packing products, and structural panels were all made with hemp/epoxy composites. The roof cover, electronic panels, trunk panels, seatback covers, packing items, and support insulation are all made from kenaf. Fibre-reinforced composites in the bast and seed category were used in the glove box, back rest panels, filter cloths, wheel boxes, and household furnishings [205]. The pineapple and sisal fibre-reinforced hybrid composites were used in underfloor-body panels, partition panels, door cladding, parcel shelves, two-wheeler bumpers, crates, drainage pipe, table mats, fishing boats, and automobile body building [206]. The coir/epoxy composites were used in the seat cushions, mirror casings, storage tanks, postboxes, helmet casings, brushes, ropes, bags, brooms, door shutters, and building panels [207].

Daimler Chrysler used flax, cotton, sisal, and banana fibres for floor panels, dashboards, seat back rests, door panels, and pillar cover panels of A, C, and E class models. Lotus Peugeot used hemp and sisal fibre reinforced composites for packaging trays, door panels, interior mats, seat backs, and body panels of the eco-elsie 406 [208]. The coir/natural latex rubber-reinforced hybrid composites were used in seat belt lining, soundproofing panels, particle boards, and parcel shelves. Flax, sisal, and coir fibres with thermoplastic matrix such as PP, PE, PS, and PVC were used in automobile components, containers for logistics, interior parts, and household products. Nippon Electric Company (NEC) used kenaf fibres to reinforce PLA biocomposite for mobile phone casings. Museeuw Bikes used flax and hemp fibres reinforced with epoxy composites for racing bicycle frames and casings for musical instruments [209]. Flax/sisal/epoxy composites were used in parcel shelves, curtains, seat backs, back cushions, floor mats, and interior panels for top-class vehicles [210]. Door bolsters, centre consoles, carriers for covered door panels, seat back panels, covered components for instrument panels, rear deck trays, pillars, covered inserts, seat backs, carriers for hard and soft armrests, door panels, headliners, side and backwalls, load floors, and trunk trim were all made from bast fibre-reinforced PP/polyester composites [211].The sisal/glass/filler/epoxy-reinforced composites were used in the frames, toys, and electronic panels [81]. The flax/epoxy composites were used in the aerospace-military aviation fuselage, rudder, slats, and wings [212]. Figure 7 presents various automobile applications of NFRC. Figure 8 shows industrial applications of NFRC. Table 4 presents applications of NFRC in various fields.

6. Conclusions

The exploitation of natural fibre-reinforced composites by using an emerging technology transforms the future of the coming days. The hydrophilic nature of natural fibres affects bonding to a hydrophobic polymer, which results in poor mechanical properties. To overcome this issue, the natural fibre surface must be modified to promote better interaction between fibre and matrix. The innovative and commercial applications of natural fibre-reinforced composites can help develop new revolts to maintain our natural properties. Natural fibres such as flax, snake grass, ramie, vetiver, areca, kenaf, hemp, kenaf, pineapple, and bamboo are gifted to the transportation industry because of their renewability, sustainability, eco-friendliness, and biodegradability. Composites reinforced with natural fibres are gaining traction in the market as the market's demand for high strength-to-weight ratio for industrial applications grows. This extensive range of different benefits has led fibre-reinforced composites to find more applications in the automobile, aerospace, marine, biomedical, construction, household, and sports industries. Incorporating nanofillers to plant fibre-reinforced composites introduces a positive effect on physical and mechanical properties. Many investigations are revealed, reviewed, and presented in this article concerning the effects of various factors influencing different types of chemical treatment and manufacturing methods and industrial applications of natural fibres and reinforced composites.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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References

[1] M. R. Sanjay and S. Suchart, "Lightweight natural fiber composites," *Journal of Applied Agricultural Science and Technology*, vol. 3, no. 2, p. 178, 2019.

[2] A. Lotfi, H. Li, D. V. Dao, and G. Prusty, "Natural fiber-reinforced composites: a review on material, manufacturing, and machinability," *Journal of Thermoplastic Composite Materials*, vol. 34, no. 2, pp. 238–284, 2021.

[3] H. Altenbach, J. Altenbach, W. Kissing, H. Altenbach, J. Altenbach, and W. Kissing, "Classification of composite materials," in *Mechanics of Composite Structural Elements*, pp. 1–14, Springer, Singapore, 2004.

[4] F. M. Al-Oqla and S. M. Sapuan, "Natural fiber reinforced polymer composites in industrial applications: feasibility of date palm fibers for sustainable automotive industry," *Journal of Cleaner Production*, vol. 66, pp. 347–354, 2014.

[5] M. Ramesh, C. Deepa, L. Rajesh Kumar, M. R. Sanjay, and S. Siengchin, "Life-cycle and environmental impact assessments on processing of plant fibres and its bio-composites: a critical review," *Journal of Industrial Textiles*, 2020.

[6] S. Sathish, T. Ganapathy, and T. Bhoopathy, "Experimental testing on hybrid composite materials," *Applied Mechanics and Materials*, vol. 592-594, pp. 339–343, 2014.

[7] M. Ramesh and L. Rajesh Kumar, "Bioadhesives," in *Green Adhesives*, R. B. Inamuddin, M. I. Ahamed, and A. M. Asiri, Eds., pp. 145–161, Wiley-Scrivener Publisher, 2020.

[8] A. Saravana Kumar, S. Maivizhi Selvi, and L. Rajeshkumar, "Delamination in drilling of sisal/banana reinforced composites produced by hand lay-up process," *Applied Mechanics and Materials*, vol. 867, pp. 29–33, 2017.

[9] R. Karnani, M. Krishnan, and R. Narayan, "Biofiber-reinforced polypropylene composites," *Polymer Engineering and Science*, vol. 37, no. 2, pp. 476–483, 1997.

[10] B. Singh, A. Verma, and M. Gupta, "Studies on adsorptive interaction between natural fiber and coupling agents," *Journal of Applied Polymer Science*, vol. 70, no. 9, pp. 1847–1858, 1998.

[11] S. Sathish, K. Kumaresan, L. Prabhu, and S. Gokulkumar, "Experimental investigation on mechanical and FTIR analysis of flax fiber/epoxy composites incorporating SiC, Al_2O_3 and graphite," *Romanian Journal of Materials*, vol. 48, pp. 476–482, 2018.

[12] S. Sathish, K. Kumaresan, L. Prabhu, and N. Vigneshkumar, "Experimental investigation on volume fraction of mechanical and physical properties of flax and bamboo fibers reinforced hybrid epoxy composites," *Polymers and Polymer Composites*, vol. 25, no. 3, pp. 229–236, 2017.

[13] D. G. Devadiga, K. Subrahmanya Bhat, and G. T. Mahesha, "Sugarcane bagasse fiber reinforced composites: recent advances and applications," *Cogent Engineering*, vol. 7, no. 1, article 1823159, 2020.

[14] P. Venkateshwar Reddy, R. V. Saikumar Reddy, J. Lakshmana Rao, D. Mohana Krishnudu, and P. Rajendra Prasad, "An overview on natural fiber reinforced composites for structural and non- structural applications," *Materials Today: Proceedings*, vol. 45, pp. 6210–6215, 2021.

[15] O. Akampumuza, P. M. Wambua, A. Ahmed, W. Li, and X. H. Qin, "Review of the applications of biocomposites in the automotive industry," *Polymer Composites*, vol. 38, no. 11, pp. 2553–2569, 2017.

[16] M. Ramesh, L. Rajeshkumar, A. Khan, and A. M. Asiri, "Self-healing polymer composites and its chemistry," in *Self-Healing Composite Materials, Woodhead Publishing*, pp. 415–427, Elsevier, 2020.

[17] S. Sathish, N. Karthi, L. Prabhu et al., "A review of natural fiber composites: extraction methods, chemical treatments and applications," *Materials Today: Proceedings*, vol. 45, pp. 8017–8023, 2021.

[18] N. Karthi, K. Kumaresan, G. Rajeshkumar, S. Gokulkumar, and S. Sathish, "Tribological and thermo-mechanical performance of chemically modified musa acuminata/corchorus capsularis reinforced hybrid composites," *Journal of Natural Fibers*, pp. 1–14, 2021.

[19] L. Prabhu, V. Krishnaraj, S. Sathish, S. Gokulkumar, M. R. Sanjay, and S. Siengchin, "Mechanical and acoustic properties of alkali-treated sansevieria ehrenbergii/camellia sinensis fiber–reinforced hybrid epoxy composites: incorporation of glass fiber hybridization," *Applied Composite Materials*, vol. 27, no. 6, pp. 915–933, 2020.

[20] S. Gokulkumar, P. R. Thyla, S. Sathish et al., "Acoustical and mechanical optimization of camellia sinensis/ananas comosus/

GFRP/epoxy composites by TOPSIS & weighted aggregates sum product assessment method," *Materials Today: Proceedings*, vol. 45, pp. 7980–7985, 2021.

[21] M. S. Sreekala, M. G. Kumaran, and S. Thomas, "Oil palm fibers: morphology, chemical composition, surface modification, and mechanical properties," *Journal of Applied Polymer Science*, vol. 66, no. 5, pp. 821–835, 1997.

[22] P. Herrera-Franco, A. Valadez-GonzaÂlez, and M. Cervantes-Uc, "Development and characterization of a HDPE-sand-natural fiber composite," *Composites Part B: Engineering*, vol. 28, no. 3, pp. 331–343, 1997.

[23] K. L. Pickering, A. Abdalla, C. Ji, A. G. McDonald, and R. A. Franich, "The effect of silane coupling agents on radiata pine fibre for use in thermoplastic matrix composites," *Composites: Part A*, vol. 34, no. 10, pp. 915–926, 2003.

[24] N. Karthi, K. Kumaresan, S. Sathish et al., "Effect of weight fraction on the mechanical properties of flax and jute fibers reinforced epoxy hybrid composites," *Materials Today: Proceedings*, vol. 45, pp. 8006–8010, 2021.

[25] M. Ramesh and L. Rajeshkumar, "Wood flour filled thermoset composites," *Thermoset Composites: Preparation, Properties and Applications, Materials Research Forum*, vol. 38, pp. 33–65, 2018.

[26] M. Kumaresan, S. Sathish, and N. Karthi, "Effect of fiber orientation on mechanical properties of sisal fiber reinforced epoxy composites," *Journal of Applied Science and Engineering*, vol. 18, pp. 289–294, 2015.

[27] M. Zwawi, "A review on natural fiber bio-composites, surface modifications and applications," *Molecules*, vol. 26, no. 2, p. 404, 2021.

[28] S. C. R. Furtado, A. L. Araújo, A. Silva, C. Alves, and A. M. R. Ribeiro, "Natural fibre-reinforced composite parts for automotive applications," *International Journal of Automotive Composites*, vol. 1, no. 1, pp. 18–38, 2014.

[29] L. Mohammed, M. N. M. Ansari, G. Pua, M. Jawaid, and M. S. Islam, "A review on natural fiber reinforced polymer composite and its applications," *International Journal of Polymer Science*, vol. 2015, 15 pages, 2015.

[30] S. Sathish, M. Kumaresan, N. Karthi, and T. D. Kumar, "Tensile and impact properties of natural fiber hybrid composite materials," *International Journal of Modern Engineering Research*, vol. 4, no. 9, pp. 9–12, 2014.

[31] L. Prabhu, V. Krishnaraj, S. Sathish, and V. Sathyamoorthy, "Experimental and finite element analysis of GFRP composite laminates with combined bolted and bonded joints," *Indian Journal of Science and Technology*, vol. 10, no. 14, pp. 1–7, 2017.

[32] N. Mohanta and S. K. Acharya, "Investigation of mechanical properties of luffa cylindrica fibre reinforced epoxy hybrid composite," *International Journal of Engineering, Science and Technology*, vol. 7, no. 1, pp. 1–10, 2016.

[33] L. G. Angelini and S. Tavarini, "Ramie [Boehmeria nivea (L.) gaud.] as a potential new fibre crop for the Mediterranean region: growth, crop yield and fibre quality in a long-term field experiment in Central Italy," *Industrial Crops and Products*, vol. 51, pp. 138–144, 2013.

[34] M. B. Hoque, M. Z. I. Mollah, M. R. I. Faruque, M. Abdul Hannan, and R. A. Khan, "Review on the mechanical properties of pineapple leaf fiber (PALF) reinforced epoxy resin based composites," *Research Journal of Engineering and Technology*, vol. 6, no. 4, pp. 855–860, 2021.

[35] M. A. Sawpan, K. L. Pickering, and A. Fernyhough, "Effect of various chemical treatments on the fibre structure and tensile properties of industrial hemp fibres," *Composites Part A: Applied Science and Manufacturing*, vol. 42, no. 8, pp. 888–895, 2011.

[36] N. M. Nurazzi, M. R. M. Asyraf, S. F. Athiyah et al., "A review on mechanical performance of hybrid natural fiber polymer composites for structural applications," *Polymers*, vol. 13, no. 13, 2021.

[37] A. Geremew and P. De Winne, "Treatment of natural fiber for application in concrete pavement," *Advances in Civil Engineering*, vol. 2021, Article ID 6667965, 13 pages, 2021.

[38] V. Mahesh, V. Mahesh, and D. Harursampath, "Influence of alkali treatment on physio-mechanical properties of jute–epoxy composite," *Advances in Materials and Processing Technologies*, pp. 1–12, 2021.

[39] S. Gokulkumar, P. R. Thyla, L. Prabhu, and S. Sathish, "Measuring methods of acoustic properties and Influence of physical parameters on natural fibers: a review," *Journal of Natural Fibers*, vol. 17, no. 12, pp. 1719–1738, 2020.

[40] L. Prabhu, V. Krishnaraj, S. Gokulkumar, S. Sathish, and M. Ramesh, "Mechanical, Chemical and Acoustical Behavior of Sisal - Tea Waste - Glass Fiber Reinforced Epoxy Based Hybrid Polymer Composites," *Materials Today: Proceedings*, vol. 16, pp. 653–660, 2019.

[41] A. Khenblouche, D. Bechki, M. Gouamid et al., "Extraction and characterization of cellulose microfibers from Retama raetam stems," *Polímeros*, vol. 29, no. 1, pp. 1–8, 2019.

[42] S. Das, "Mechanical properties of waste paper/jute fabric reinforced polyester resin matrix hybrid composites," *Carbohydrate Polymers*, vol. 172, pp. 60–67, 2017.

[43] M. S. Rahman, "Jute-a versatile natural fiber. Cultivation, extraction and processing," in *Industrial Applications of Natural Fibers Industrial Applications of Natural Fibers: Structure, Properties and Technical Applications*, J. Müssig, Ed., pp. 135–161, Wiley, 2010.

[44] H. Ku, N. Hao Wang, P. Koop, and M. Trada, "A review on the tensile properties of natural fiber reinforced polymer composites," *Composites Part B: Engineering*, vol. 42, no. 4, pp. 856–873, 2011.

[45] N. Karthi, K. Kumaresan, S. Sathish, S. Gokulkumar, L. Prabhu, and N. Vigneshkumar, "An overview: natural fiber reinforced hybrid composites, chemical treatments and application areas," *Materials Today: Proceedings*, vol. 27, no. 3, pp. 2828–2834, 2020.

[46] S. Sathish, L. Prabhu, S. Gokulkumar, N. Karthi, D. Balaji, and N. Vigneshkumar, "Extraction, treatment and applications of natural fibers for bio-composites–a critical review," *International Polymer Processing*, vol. 36, no. 2, pp. 114–130, 2021.

[47] A. Bartos, K. Nagy, J. Anggono et al., "Biobased PLA/sugarcane bagasse fiber composites: effect of fiber characteristics and interfacial adhesion on properties," *Composites Part A: Applied Science and Manufacturing*, vol. 143, article 106273, 2021.

[48] E. F. Rodriguesa, T. F. Maiaa, and D. R. Mulinaria, "Tensile strength of polyester resin reinforced sugarcane bagasse fibers modified by estherification," *Procedia Engineering*, vol. 10, pp. 2348–2352, 2011.

[49] A. Lavoratti, D. Romanzini, S. C. Amico, and A. J. Zattera, "Influence of fibre treatment on the characteristics of buriti

and ramie polyester composites," *Polymers & Polymer Composites*, vol. 25, no. 4, pp. 247–256, 2017.

[50] M. T. Zafar, S. N. Maiti, and A. K. Ghosh, "Effect of surface treatment of jute fibers on the interfacial adhesion in poly (lactic acid)/jute fiber biocomposites," *Fibers and Polymers*, vol. 17, no. 2, pp. 266–274, 2016.

[51] S. Sudha and G. Thilagavathi, "Effect of alkali treatment on mechanical properties of woven jute composites," *Journal of the Textile Institute*, vol. 107, no. 6, pp. 691–701, 2016.

[52] E.-R. Kenawy, A. A. Ghfar, S. Wabaidur et al., "Cetyltrimethylammonium bromide intercalated and branched polyhydroxystyrene functionalized montmorillonite clay to sequester cationic dyes," *Journal of Environmental Management*, vol. 219, pp. 285–293, 2018.

[53] S. M. Wabaidur, M. A. Khan, M. R. Siddiqui et al., "Oxygenated functionalities enriched MWCNTs decorated with silica coated spinel ferrite – a nanocomposite for potentially rapid and efficient de-colorization of aquatic environment," *Journal of Molecular Liquids*, vol. 317, p. 113916, 2020.

[54] M. Alok Mittal, G. S. Naushad, Z. A. ALothman, S. M. Wabaidur, and M. Alam, "Fabrication of MWCNTs/ThO2-nanocomposite and its adsorption behavior for the removal of Pb(II) metal from aqueous medium," *Desalination and Water Treatment*, vol. 57, no. 46, pp. 21863–21869, 2016.

[55] Z. A. Alothman, A. H. Bahkali, M. A. Khiyami et al., "Low cost biosorbents from fungi for heavy metals removal from wastewater," *Separation Science and Technology*, vol. 55, no. 10, pp. 1766–1775, 2020.

[56] M. Khan, A. A. Alqadami, S. M. Wabaidur et al., "Oil industry waste based non-magnetic and magnetic hydrochar to sequester potentially toxic post-transition metal ions from water," *Journal of Hazardous Materials*, vol. 400, article 123247, 2020.

[57] Z. ALOthman, "A review: fundamental aspects of silicate mesoporous materials," *Materials*, vol. 5, no. 12, pp. 2874–2902, 2012.

[58] L. Prabhu, V. Krishnaraj, S. Sathish et al., "A review on natural fiber reinforced hybrid composites: chemical treatments, manufacturing methods and potential applications," *Materials Today: Proceedings*, vol. 45, pp. 8080–8085, 2021.

[59] S. Sathish, K. Kumaresan, L. Prabhu, S. Gokulkumar, N. Karthi, and N. Vigneshkumar, "Experimental investigation of mechanical and morphological properties of flax fiber reinforced epoxy composites incorporating SiC and Al_2O_3," *Materials Today: Proceedings*, vol. 27, pp. 2249–2253, 2020.

[60] S. Gokulkumar, P. R. Thyla, L. Prabhu, S. Sathish, and N. Karthi, "A comparative study on epoxy based composites filled with pineapple/areca/ramie hybridized with industrial tea leaf wastes/GFRP," *Materials Today: Proceedings*, 2020.

[61] M. Y. Khalid, R. Imran, Z. U. Arif et al., "Developments in chemical treatments, manufacturing techniques and potential applications of natural-fibers based biodegradable composites," *Coatings*, vol. 11, no. 3, p. 293, 2021.

[62] M. J. Suriani, H. Z. Rapi, R. A. Ilyas, M. Petru, and S. M. Sapuan, "Delamination and manufacturing defects in natural fiber-reinforced hybrid composite: a review," *Polymers*, vol. 13, no. 8, p. 1323, 2021.

[63] T. T. Silva, P. H. P. M. Silveira, M. P. Ribeiro et al., "Thermal and chemical characterization of kenaf fiber (*Hibiscus cannabinus*) reinforced epoxy matrix composites," *Polymers*, vol. 13, no. 12, p. 2016, 2021.

[64] P. Sathiamurthi, K. S. Karthi Vinith, T. P. Sathishkumar, S. Arunkumar, and A. S. Anaamalaai, "Fiber extraction and mechanical properties of Agave Americana/kenaf fiber reinforced hybrid epoxy composite," *Materials Today: Proceedings*, vol. 46, pp. 8594–8601, 2021.

[65] H. Abdellaoui, H. Bensalah, J. Echaabi, R. Bouhfid, and A. Qaiss, "Fabrication, characterization and modelling of laminated composites based on woven jute fibres reinforced epoxy resin," *Materials and Design*, vol. 68, pp. 104–113, 2015.

[66] M. Maruf Billah, M. S. Rabbi, and A. Hasan, "A review on developments in manufacturing process and mechanical properties of natural fiber composites," *Journal of Engineering Advancements*, vol. 2, no. 1, pp. 13–23, 2021.

[67] M. Naushad, G. Sharma, and Z. A. Alothman, "Photodegradation of toxic dye using Gum Arabic-crosslinked- poly(-acrylamide)/$Ni(OH)_2$/FeOOH nanocomposites hydrogel," *Journal of Cleaner Production*, vol. 241, article 118263, 2019.

[68] A. Azhar, Y. Yamauchi, A. E. Allah et al., "Nanoporous iron oxide/carbon composites through in-situ deposition of prussian blue nanoparticles on graphene oxide nanosheets and subsequent thermal treatment for supercapacitor applications," *Nanomaterials*, vol. 9, no. 5, p. 776, 2019.

[69] A. Alqadami, M. A. Khan, M. R. Siddiqui, and Z. A. Alothman, "Development of citric anhydride anchored mesoporous MOF through post synthesis modification to sequester potentially toxic lead (II) from water," *Microporous and Mesoporous Materials*, vol. 261, pp. 198–206, 2018.

[70] I. Ali, O. M. L. Alharbi, Z. A. Alothman, and A. Alwarthan, "Facile and eco-friendly synthesis of functionalized iron nanoparticles for cyanazine removal in water," *Colloids and Surfaces B: Biointerfaces*, vol. 171, pp. 606–613, 2018.

[71] I. Ali, O. M. L. Alharbi, Z. A. ALOthman, A. M. al-Mohaimeed, and A. Alwarthan, "Modeling of fenuron pesticide adsorption on CNTs for mechanistic insight and removal in water," *Environmental Research*, vol. 170, pp. 389–397, 2019.

[72] S. Wagner, C. Collet, P. Madsen, T. Nakashizuka, R. D. Nyland, and K. Sagheb-Talebi, "Beech regeneration research: from ecological to silvicultural aspects," *Forest Ecology and Management*, vol. 259, no. 11, pp. 2172–2182, 2010.

[73] N. Saba, M. T. Paridah, K. Abdan, and N. A. Ibrahim, "Physical, structural and thermomechanical properties of oil palm nano filler/kenaf/epoxy hybrid nanocomposites," *Materials Chemistry and Physics*, vol. 184, pp. 64–71, 2016.

[74] K. Jayaraman, "Manufacturing sisal–polypropylene composites with minimum fibre degradation," *Composites Science and Technology*, vol. 63, no. 3-4, pp. 367–374, 2003.

[75] A. Stalin, S. Mothilal, V. Vignesh, M. Sanjay, and S. Siengchin, "Mechanical properties of hybrid vetiver/banana fiber mat reinforced vinyl ester composites," *Journal of Industrial Textiles*, vol. 152808372093816, p. 152808372093816, 2020.

[76] R. Vinayagamoorthy and N. Rajeswari, "Mechanical performance studies onVetiveria zizanioides/jute/glass fiber-reinforced hybrid polymeric composites," *Journal of Reinforced Plastics and Composites*, vol. 33, no. 1, pp. 81–92, 2014.

[77] T. P. Sathishkumar, P. Navaneethakrishnan, S. Shankar, and J. Kumar, "Mechanical properties of randomly oriented snake grass fiber with banana and coir fiber-reinforced hybrid composites," *Journal of Composite Materials*, vol. 47, no. 18, pp. 2181–2191, 2013.

[78] M. R. Sanjay and B. Yogesha, "Studies on hybridization effect of jute/kenaf/E-glass woven fabric epoxy composites for potential applications: effect of laminate stacking sequences," *Journal of Industrial Textiles*, vol. 47, no. 7, pp. 1830–1848, 2018.

[79] P. Manimaran, P. Senthamaraikannan, M. R. Sanjay, M. K. Marichelvam, and M. Jawaid, "Study on characterization of Furcraea Foetida new natural fiber as composite reinforcement for lightweight applications," *Carbohydrate Polymers*, vol. 181, pp. 650–658, 2018.

[80] T. P. Sathishkumar, P. Navaneethakrishnan, and S. Shankar, "Tensile and flexural properties of snake grass natural fiber reinforced isophthallic polyester composites," *Composites Science and Technology*, vol. 72, no. 10, pp. 1183–1190, 2012.

[81] G. R. Arpitha, M. R. Sanjay, P. Senthamaraikannan, C. Barile, and B. Yogesha, "Hybridization effect of sisal/glass/epoxy/filler based woven fabric reinforced composites," *Experimental Techniques*, vol. 41, no. 6, pp. 577–584, 2017.

[82] M. R. Sanjay and B. Yogesha, "Study on water absorption behavior of jute and kenaf fabric reinforced epoxy composites: hybridization effect of E-glass fabric," *International Journal of Composite Materials*, vol. 6, no. 2, pp. 55–62, 2016.

[83] M. R. Sanjay, G. R. Arpitha, P. Senthamaraikannan, M. Kathiresan, M. A. Saibalaji, and B. Yogesha, "The hybrid effect of jute/kenaf/E-glass woven fabric epoxy composites for medium load applications: impact, inter-laminar strength, and failure surface characterization," *Journal of Natural Fibers*, vol. 16, no. 4, pp. 600–612, 2019.

[84] R. Vijay, D. Lenin Singaravelu, A. Vinod et al., "Characterization of raw and alkali treated new natural cellulosic fibers from Tridax procumbens," *International Journal of Biological Macromolecules*, vol. 125, pp. 99–108, 2019.

[85] M. R. Sanjay, G. R. Arpitha, L. Laxmana Naik, K. Gopalakrishna, and B. Yogesha, "Experimental investigation on mechanical properties of hemp/E-glass fabric reinforced polyester hybrid composites," *Journal of Materials and Engineering Structures*, vol. 3, pp. 117–128, 2016.

[86] K. M. M. Rao, K. M. Rao, and A. V. R. Prasad, "Fabrication and testing of natural fibre composites: vakka, sisal, bamboo and banana," *Materials and Design*, vol. 31, no. 1, pp. 508–513, 2010.

[87] K. Okubo, T. Fujii, and Y. Yamamoto, "Development of bamboo-based polymer composites and their mechanical properties," *Composites Part A Applied Science and Manufacturing*, vol. 35, no. 3, pp. 377–383, 2004.

[88] D. Shanmugam and M. Thiruchitrambalam, "Static and dynamic mechanical properties of alkali treated unidirectional continuous palmyra palm leaf stalk fiber/jute fiber reinforced hybrid polyester composites," *Materials and Design*, vol. 50, pp. 533–542, 2013.

[89] K. S. Raghul, D. Nandakumar, and R. Jeyakumar, "Mechanical behaviour of glass fiber/epoxy modified with nano composites: a review," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 5, no. 7, pp. 76–81, 2016.

[90] S. Biswas, "Mechanical properties of bamboo-epoxy composites a structural application," *Advances in Materials Research*, vol. 1, no. 3, pp. 221–231, 2012.

[91] C. W. Nguong, S. N. B. Lee, and D. Sujan, "A review on natural fiber reinforced polymer composites," *International Journal of Materials and Metallurgical Engineering*, vol. 7, pp. 52–59, 2013.

[92] N. Ramadan, I. Taha, R. Hammouda, and M. H. Abdellatif, "Behaviour of hybrid SiC/jute epoxy composites manufactured by vacuum assisted resin infusion," *Polymers and Polymer Composites*, vol. 25, no. 5, pp. 333–344, 2017.

[93] E. S. Ali and S. Ahmad, "Bionano-composite hybrid polyurethane foam reinforced with empty fruit bunch and nanoclay," *Composites Part B: Engineering*, vol. 43, no. 7, pp. 2813–2816, 2012.

[94] T. I. Olumuyiwa and S. Samuel, "Study of mechanical behaviour of coconut shell reinforced polymer matrix composite," *Journal of Minerals and Materials Characterization and Engineering*, vol. 11, no. 8, pp. 774–779, 2012.

[95] G. Ahmetli, S. Kocaman, I. Ozaytekin, and P. Bozkurt, "Epoxy composites based on inexpensive char filler obtained from plastic waste and natural resources," *Polymer Composites*, vol. 34, no. 4, pp. 500–509, 2013.

[96] R. M. N. Arib, S. M. Sapuan, M. M. H. M. Ahmad, M. T. Paridah, and H. M. D. Khairul Zaman, "Mechanical properties of pineapple leaf fibre reinforced polypropylene composites," *Materials and Design*, vol. 27, no. 5, pp. 391–396, 2006.

[97] C. Honygan, M. Menghe, and D. Xin, "Influence of moisture absorption on the interfacial strength of bamboo/vinyl ester composites," *Composites: Part A*, vol. 40, no. 12, pp. 2013–2019, 2009.

[98] R. Velmurugan and V. Manikandan, "Mechanical properties of palmyra/glass fiber hybrid composites," *Composites Part A Applied Science and Manufacturing*, vol. 38, no. 10, pp. 2216–2226, 2007.

[99] M. D. Hazizan, L. Akil, C. Wei, Z. A. Mohd Ishak, A. Abu Bakar, and M. A. Abd Rahman, "Water absorption study on pultruded jute fibre reinforced unsaturated polyester composites," *Computer Science and Technology*, vol. 69, no. 11-12, pp. 1942–1948, 2009.

[100] N. Venkateshwaran, A. ElayaPerumal, A. Alavudeen, and M. Thiruchitrambalam, "Mechanical and water absorption behaviour of banana/sisal reinforced hybrid composites," *Materials & Design*, vol. 32, no. 7, pp. 4017–4021, 2011.

[101] M. Idicula, S. K. Malhotra, K. Joseph, and S. Thomas, "Dynamic mechanical analysis of randomly oriented intimately mixed short banana/sisal hybrid fibre reinforced polyester composites," *Composites Science and Technology*, vol. 65, no. 7-8, pp. 1077–1087, 2005.

[102] A. K. M. Bledzki, A. A. Mamun, and O. Faruk, "Abaca fibre reinforced PP composites and comparison with jute and flax fibre PP composites," *Journal of Express Polymer Letters*, vol. 1, no. 11, pp. 755–762, 2007.

[103] M. Idicula, P. A. Sreekumar, K. Joseph, and S. Thomas, "Natural fiber hybrid composites-a comparison between compression molding and resin transfer molding," *Polymer Composites*, vol. 30, no. 10, pp. 1417–1425, 2009.

[104] O. M. L. Asumani, R. G. Reid, and R. Paskaramoorthy, "The effects of alkali–silane treatment on the tensile and flexural properties of short fibre non-woven kenaf reinforced polypropylene composites," *Composites Part A: Applied Science and Manufacturing*, vol. 43, no. 9, pp. 1431–1440, 2012.

[105] R. Panneerdhass, A. Gnanavelbabu, and K. Rajkumar, "Mechanical properties of luffa fiber and ground nut reinforced epoxy polymer hybrid composites," *Procedia Engineering*, vol. 97, pp. 2042–2051, 2014.

[106] T. Sathishkumar, P. Navaneethakrishnan, S. Shankar, R. Rajasekar, and N. Rajini, "Characterization of natural fiber

and composites – a review," *Journal of Reinforced Plastics and Composites*, vol. 32, no. 19, pp. 1457–1476, 2013.

[107] K. Kaewtatip and J. Thongmee, "Studies on the structure and properties of thermoplastic starch/luffa fiber composites," *Materials and Design*, vol. 40, pp. 314–318, 2012.

[108] B. F. Yousif and N. S. M. EI-Tayeb, "Adhesive wear performance of T-OPRP and UT-OPRP composites," *Tribology Letters*, vol. 32, no. 3, pp. 199–208, 2008.

[109] C. Deo and S. K. Acharya, "Effect of moisture absorption on mechanical properties of chopped natural fiber reinforced epoxy composite," *Journal of Reinforced Plastics and Composites*, vol. 29, no. 16, pp. 2513–2521, 2010.

[110] K. Mylsamy and I. Rajendran, "Influence of fibre length on the wear behaviour of chopped Agave Americana fibre reinforced epoxy composites," *Tribology Letters*, vol. 44, no. 1, pp. 75–80, 2011.

[111] V. S. Sreenivasan, D. Ravindran, V. Manikandan, and R. Narayanasamy, "Influence of fibre treatments on mechanical properties of short Sansevieria cylindrica/polyester composites," *Materials and Design*, vol. 37, pp. 111–121, 2012.

[112] P. Noorunnisa Khanam, G. Ramachandra Reddy, K. Raghu, and S. Venkata Naidu, "Tensile, flexural, and compressive properties of coir/silk fiber-reinforced hybrid composites," *Journal of Reinforced Plastics and Composites*, vol. 29, no. 14, pp. 2124–2127, 2010.

[113] M. M. Haque, M. Hasan, M. S. Islam, and M. E. Ali, "Physico-mechanical properties of chemically treated palm and coir fiber reinforced polypropylene composites," *Bioresource Technology*, vol. 100, no. 20, pp. 4903–4906, 2009.

[114] B. Venkatram, C. Kailasanathan, P. Seenikannan, and S. Paramasamy, "Study on the evaluation of mechanical and thermal properties of natural sisal fiber/general polymer composites reinforced with nanoclay," *International Journal of Polymer Analysis and Characterization*, vol. 21, no. 7, pp. 647–656, 2016.

[115] S. B. Hosseini, S. Hedjazi, L. Jamalirad, and A. Sukhtesaraie, "Effect of nano-SiO2 on physical and mechanical properties of fiber reinforced composites (FRCs)," *Journal of the Indian Academy of Wood Science*, vol. 11, no. 2, pp. 116–121, 2014.

[116] G. D. Vilakati, A. K. Mishra, S. B. Mishra, B. B. Mamba, and J. M. Thwala, "Influence of TiO 2- modification on the mechanical and thermal properties of sugarcane bagasse-EVA composites," *Journal of Inorganic and Organometallic Polymers and Materials*, vol. 20, no. 4, pp. 802–808, 2010.

[117] X. Shen, J. Jia, C. Chen, Y. Li, and J. K. Kim, "Enhancement of mechanical properties of natural fiber composites via carbon nanotube addition," *Journal of Materials Science*, vol. 49, no. 8, pp. 3225–3233, 2014.

[118] M. Chaharmahali, Y. Hamzeh, G. Ebrahimi, A. Ashori, and I. Ghasemi, "Effects of nano-graphene on the physico-mechanical properties of bagasse/polypropylene composites," *Polymer Bulletin*, vol. 71, no. 2, pp. 337–349, 2014.

[119] V. Sridharan, T. Raja, and N. Muthukrishnan, "Study of the effect of matrix, fibre treatment and graphene on delamination by drilling jute/epoxy nanohybrid composite," *Arabian Journal for Science and Engineering*, vol. 41, no. 5, pp. 1883–1894, 2016.

[120] U. K. Komal, V. Verma, T. Ashwani, N. Verma, and I. Singh, "Effect of chemical treatment on thermal, mechanical and degradation behavior of banana fiber reinforced polymer composites," *Journal of Natural Fibers*, pp. 1–13, 2018.

[121] B. Sutradhar, M. Mesbah, and M. Hasan, "Effect of fiber ratio and chemical treatment on properties of banana and betel nut fiber reinforced hybrid polypropylene composites," *IOP Conference Series: Materials Science and Engineering*, vol. 438, 2018.

[122] A. Ashori, "Wood-plastic composites as promising green-composites for automotive industries!," *Bioresource Technology*, vol. 99, no. 11, pp. 4661–4667, 2008.

[123] H. Awais, Y. Nawab, A. Amjad, A. Anjang, H. M. Akil, and M. S. Abidin, "Environmental benign natural fibre reinforced thermoplastic composites: a review," *Composites Part C: Open Access*, vol. 4, article 100082, 2021.

[124] P. T. R. Swain and S. Biswas, "Influence of fiber surface treatments on physico-mechanical behaviour of jute/epoxy composites impregnated with aluminium oxide filler," *Journal of Composite Materials*, vol. 51, no. 28, pp. 3909–3922, 2017.

[125] A. Geremew, P. De Winne, T. A. Demissie, and H. De Backer, "An overview of the characterization of natural cellulosic fibers," *Key Engineering Materials*, vol. 881, pp. 107–116, 2021.

[126] A. R. Bunsell, Ed., "Introduction to the science of fibers," in *Handbook of Properties of Textile and Technical Fibers*, pp. 1–20, Woodhead Publishing, 2018.

[127] L. Y. Mwaikambo and M. P. Ansell, "Chemical modification of hemp, sisal, jute, and kapok fibers by alkalization," *Journal of Applied Polymer Science*, vol. 84, no. 12, pp. 2222–2234, 2002.

[128] M. Teli and A. Jadhav, "Effect of mercerization on the properties of pandanus odorifer lignocellulosic fibre," *IOSR Journal of Polymer and Textile Engineering*, vol. 4, no. 1, pp. 7–15, 2017.

[129] S. Dhanalakshmi, P. Ramadevi, and B. Basavaraju, "Effect of chemical treatments on tensile strength of areca fibre reinforced natural rubber composites," *IOSR Journal of Applied Chemistry*, vol. 8, pp. 43–52, 2015.

[130] A. Valadez Gonzalez, J. M. Cervantes Uc, and R. Olayo, "Chemical modification of henequen fibers with an organosilane coupling agent," *Composites Part B: Engineering*, vol. 30, no. 3, pp. 321–331, 1999.

[131] K. Obi Reddy, C. Uma Maheswari, J. I. Mukul Shukla, and A. Song, "Tensile and structural characterization of alkali treated borassus fruit fine fibers," *Composites Part B: Engineering*, vol. 44, no. 1, pp. 433–438, 2013.

[132] S. A. Paul, K. Joseph, G. G. Mathew, L. A. Pothen, and S. Thomas, "Influence of polarity parameters on the mechanical properties of composites from polypropylene fiber and short banana fiber," *Composites Part A: Applied Science and Manufacturing*, vol. 41, no. 10, pp. 1380–1387, 2010.

[133] M. A. Lopez Manchado, M. Arroyo, J. Biagiotti, and J. M. Kenny, "Enhancement of mechanical properties and interfacial adhesion of PP/EPDM/flax fiber composites using maleic anhydride as a compatibilizer," *Journal of Applied Polymer Science*, vol. 90, no. 8, pp. 2170–2178, 2003.

[134] J. I. Singh, V. Dhawan, S. Singh, and A. S. Pannu, "Effect of alkali treatment on mechanical properties of jute, sisal, banana, hemp and abaca fibres for polymer composite reinforcement," *International Journal of Mechanical Engineering and Technology*, vol. 8, pp. 1775–1784, 2017.

[135] A. Arbelaiz, G. Cantero, B. Fernández, I. Mondragon, P. Gañán, and J. M. Kenny, "Flax fiber surface modifications: effects on fiber physico mechanical and flax/ polypropylene

interface properties," *Polymer Composites*, vol. 26, no. 3, pp. 324–332, 2005.

[136] I. M. De Rosa, J. M. Kenny, D. Puglia, C. Santulli, and F. Sarasini, "Morphological, thermal and mechanical characterization of okra (*Abelmoschus esculentus*) fibres as potential reinforcement in polymer composites," *Composites Science and Technology*, vol. 70, no. 1, pp. 116–122, 2010.

[137] L. Y. Mwaikambo, N. Tucker, and A. J. Clark, "Mechanical properties of hemp-fibre-reinforced euphorbia composites," *Macromolecular Materials and Engineering*, vol. 292, no. 9, pp. 993–1000, 2007.

[138] A. C. de Albuquerque, K. Joseph, L. H. de Carvalho, and J. R. M. d'Almeida, "Effect of wettability and ageing conditions on the physical and mechanical properties of uniaxially oriented jute-roving-reinforced polyester composites," *Composites Science and Technology*, vol. 60, no. 6, pp. 833–844, 2000.

[139] M. D. Chikouche, A. Merrouche, A. Azizi, M. Rokbi, and S. Walter, "Influence of alkali treatment on the mechanical properties of new cane fibre/polyester composites," *Journal of Reinforced Plastics and Composites*, vol. 34, no. 16, pp. 1329–1339, 2015.

[140] S. V. Prasad, C. Pavithran, and P. K. Rohatgi, "Alkali treatment of coir fibres for coir-polyester composites," *Journal of Materials Science*, vol. 18, no. 5, pp. 1443–1454, 1983.

[141] A. Athijayamani, M. Thiruchitrambalam, U. Natarajan, and B. Pazhanivel, "Effect of moisture absorption on the mechanical properties of randomly oriented natural fibers/polyester hybrid composite," *Materials Science and Engineering: A*, vol. 517, no. 1-2, pp. 344–353, 2009.

[142] A. Bessadok, S. Marais, F. Gouanvé et al., "Effect of chemical treatments of alfa (Stipa tenacissima) fibres on water-sorption properties," *Composites Science and Technology*, vol. 67, no. 3-4, pp. 685–697, 2007.

[143] P. J. Herrera-Franco and A. Valadez-González, "Mechanical properties of continuous natural fibre-reinforced polymer composites," *Composites Part A: Applied Science and Manufacturing*, vol. 35, no. 3, pp. 339–345, 2004.

[144] K. Obi Reddy, C. Uma Maheswari, A. Varada Rajulu, and B. R. Guduri, "Thermal degradation parameters and tensile properties of borassus flabellifer fruit fiber reinforcement," *Journal of Reinforced Plastics and Composites*, vol. 28, no. 18, pp. 2297–2301, 2009.

[145] V. Vilay, M. Mariatti, R. Mat Taib, and M. Todo, "Effect of fiber surface treatment and fiber loading on the properties of bagasse fiber reinforced unsaturated polyester composites," *Composites Science and Technology*, vol. 68, no. 3-4, pp. 631–638, 2008.

[146] G. Govardhan and R. N. Rao, "Effect of fiber content and alkali treatment on mechanical properties of roystonea regia-reinforced epoxy partially biodegradable composites," *Bulletin of Materials Science*, vol. 34, no. 7, pp. 1575–1581, 2011.

[147] E. T. N. Bisanda, "The effect of alkali treatment on the adhesion characteristics of sisal fibers," *Applied Composite Materials*, vol. 7, no. 5/6, pp. 331–339, 2000.

[148] M. S. Sreekala, M. G. Kumaran, J. Seena, J. Maya, and S. Thomas, "Oil palm fiber reinforced phenol formaldehyde composites: influence of fiber surface modifications on the mechanical performance," *Applied Composite Materials*, vol. 7, no. 5/6, pp. 295–329, 2000.

[149] V. G. Geethamma, K. Thomas Mathew, R. Lakshminarayanan, and T. Sabu, "Composite of short coir fibres and natural rubber: effect of chemical modification, loading and orientation of fibre," *Polymer*, vol. 39, no. 6-7, pp. 1483–1491, 1998.

[150] L. Y. Mwaikambo and M. P. Ansell, "Mechanical properties of alkali treated plant fibres and their potential as reinforcement materials II. Sisal fibres," *Journal of Materials Science*, vol. 41, no. 8, pp. 2497–2508, 2006.

[151] A. M. Edeerozey, H. M. Akil, A. B. Azhar, and M. Z. Ariffin, "Chemical modification of kenaf fibers," *Materials Letters*, vol. 61, no. 10, pp. 2023–2025, 2007.

[152] K. Goda, M. S. Sreekala, A. Gomes, T. Kaji, and J. Ohgi, "Improvement of plant based natural fibers for toughening green composites– Effect of load application during mercerization of ramie fibers," *Composites Part A: Applied Science and Manufacturing*, vol. 37, no. 12, pp. 2213–2220, 2006.

[153] Y. Cao, S. Shibata, and I. Fukumoto, "Mechanical properties of biodegradable composites reinforced with bagasse fibre before and after alkali treatments," *Composites Part A: Applied Science and Manufacturing*, vol. 37, no. 3, pp. 423–429, 2006.

[154] K. Joseph, S. Thomas, and C. Pavithran, "Effect of chemical treatment on the tensile properties of short sisal fibre-reinforced polyethylene composites," *Polymer*, vol. 37, no. 23, pp. 5139–5149, 1996.

[155] B. Wang, S. Panigrahi, L. Tabil, and W. Crerar, "Pre-treatment of flax fibers for use in rotationally molded biocomposites," *Journal of Reinforced Plastics and Composites*, vol. 26, no. 5, pp. 447–463, 2007.

[156] D. Ray, B. K. Sarkar, S. Das, and A. K. Rana, "Dynamic mechanical and thermal analysis of vinylester-resin-matrix composites reinforced with untreated and alkali-treated jute fibres," *Composites Science and Technology*, vol. 62, no. 7-8, pp. 911–917, 2002.

[157] A. Bessadok, S. Roudesli, S. Marais, N. Follain, and L. Lebrun, "Alfa fibres for unsaturated polyester composites reinforcement: effects of chemical treatments on mechanical and permeation properties," *Composites Part A: Applied Science and Manufacturing*, vol. 40, no. 2, pp. 184–195, 2009.

[158] M. A. M. Edeerozey, M. A. Hazizan, A. B. Azhar, and M. I. Zainal Ariffin, "Chemical modification of kenaf fibers," *Materials Letters Journal*, vol. 61, no. 10, pp. 2023–2025, 2007.

[159] M. M. Rahman, A. K. Malik, and M. A. Khan, "Influence of various surface pre-treatment on the mechanical and degradable properties of photo grafted oil palm fibers," *Journal of Applied Polymer Science*, vol. 105, no. 5, pp. 3077–3086, 2007.

[160] I. D. Ibrahim, T. Jamiru, R. E. Sadiku, W. K. Kupolati, and S. C. Agwuncha, "Dependency of the mechanical properties of sisal fiber reinforced recycled polypropylene composites on fiber surface treatment, fiber content and nanoclay," *Journal of Polymers and the Environment*, vol. 25, no. 2, pp. 427–434, 2017.

[161] S. Shibata, Y. Cao, and I. Fukumoto, "Press forming of short natural fiber-reinforced biodegradable resin: effects of fiber volume and length on flexural properties," *Polymer Testing*, vol. 24, no. 8, pp. 1005–1011, 2005.

[162] J. R. Barone, "Polyethylene/keratin fiber composites with varying polyethylene crystallinity," *Composites. Part A, Applied Science and Manufacturing*, vol. 36, no. 11, pp. 1518–1524, 2005.

[163] A. A. Kafi, K. Magniez, and B. L. Fox, "Effect of manufacturing process on the flexural, fracture toughness, and thermo-mechanical properties of bio-composites," *Composites. Part A, Applied Science and Manufacturing*, vol. 42, no. 8, pp. 993–999, 2011.

[164] N. K. Sharma and V. Kumar, "Studies on properties of banana fiber reinforced green composite," *Journal of Reinforced Plastics and Composites*, vol. 32, no. 8, pp. 525–532, 2013.

[165] H. Alamri and I. M. Low, "Mechanical properties and water absorption behaviour of recycled cellulose fibre reinforced epoxy composites," *Polymer Testing*, vol. 31, no. 5, pp. 620–628, 2012.

[166] P. J. Jandas, S. Mohanty, and S. K. Nayak, "Mechanical properties of surface-treated banana fiber/polylactic acid biocomposites: a comparative study of theoretical and experimental values," *Journal of Applied Polymer Science*, vol. 127, no. 5, pp. 4027–4038, 2013.

[167] A. K. Bledzki, J. Gassan, and W. Zhang, "Impact properties of natural fiber-reinforced epoxy foams," *Journal of Cellular Plastics*, vol. 35, no. 6, pp. 550–562, 1999.

[168] B. F. Yousif and N. S. M. El-Tayeb, "The effect of oil palm fibers as reinforcement on tribological performance of polyester composite," *Surface Review and Letters*, vol. 14, no. 6, pp. 1095–1102, 2007.

[169] N. S. M. El-Tayeb, "A study on the potential of sugarcane fibers/polyester composite for tribological applications," *Wear*, vol. 265, no. 1–2, pp. 223–235, 2008.

[170] M. Assarar, D. Scida, A. El Mahi, C. Poilaˆne, and R. Ayad, "Influence of water ageing on mechanical properties and damage events of two reinforced composite materials: flax–fibres and glass–fibres," *Materials and Design*, vol. 32, no. 2, pp. 788–795, 2011.

[171] N. Venkateshwaran, A. E. Perumal, and D. Arunsundaranayagam, "Fiber surface treatment and its effect on mechanical and visco-elastic behaviour of banana/epoxy composite," *Materials and Design*, vol. 47, pp. 151–159, 2013.

[172] D. Ray, B. K. Sarkar, A. K. Rana, and N. R. Bose, "Effect of alkali treated jute fibres on composite properties," *Bulletin of Materials Science*, vol. 24, no. 2, pp. 129–135, 2001.

[173] T.-T.-L. Doan, S.-L. Gao, and E. Mäder, "Jute/polypropylene composites I. Effect of matrix modification," *Composites Science and Technology*, vol. 66, no. 7–8, pp. 952–963, 2006.

[174] A. C. Karmaker and J. P. Shneider, "Mechanical performance of short jute fibre reinforced polypropylene," *Journal of Materials Science Letters*, vol. 15, no. 3, pp. 201-202, 1996.

[175] A. K. Bledzki, A. A. Mamun, M. Lucka-Gabor, and V. S. Gutowski, "The effects of acetylation on properties of flax fibre and its polypropylene composites," *Express Polymer Letters*, vol. 2, no. 6, pp. 413–422, 2008.

[176] H.-S. Yang, H.-J. Kim, H.-J. Park, B.-J. Lee, and T.-S. Hwang, "Effect of compatibilizing agents on rice-husk flour reinforced polypropylene composites," *Composite Structures*, vol. 77, no. 1, pp. 45–55, 2007.

[177] K. L. Pickering, Y. Li, R. L. Farrell, and M. Lay, "Interfacial modification of hemp fiber reinforced composites using fungal and alkali treatment," *Journal of Biobased Materials and Bioenergy*, vol. 1, no. 1, pp. 109–117, 2007.

[178] B. Wielage, T. Lampke, H. Utschick, and F. Soergel, "Processing of natural-fibre reinforced polymers and the resulting dynamic—mechanical properties," *Journal of Materials Processing Technology*, vol. 139, no. 1-3, p. 140, 2003.

[179] S. Lee, S. Q. Shi, L. H. Groom, and Y. Xue, "Properties of unidirectional kenaf fiber-polyolefin laminates," *Polymer Composites*, vol. 31, no. 6, pp. 1067–1074, 2010.

[180] M. M. Thwe and K. Liao, "Durability of bamboo-glass fiber reinforced polymer matrix hybrid composites," *Composites Science and Technology*, vol. 63, no. 3-4, pp. 375–387, 2003.

[181] S. Cheng, K. Lau, T. Liu, Y. Zhao, P.-M. Lam, and Y. Yin, "Mechanical and thermal properties of chicken feather fiber/PLA green composites," *Composites Part B: Engineering*, vol. 40, no. 7, pp. 650–654, 2009.

[182] K. Oksman, A. P. Mathew, R. Långström, B. Nyström, and K. Joseph, "The influence of fibre microstructure on fibre breakage and mechanical properties of natural fibre reinforced polypropylene," *Composites Science and Technology*, vol. 69, no. 11-12, pp. 1847–1853, 2009.

[183] Q. T. H. Shubhra, A. K. M. M. Alam, and M. D. H. Beg, "Mechanical and degradation characteristics of natural silk fiber reinforced gelatin composites," *Materials Letters*, vol. 65, no. 2, pp. 333–336, 2011.

[184] K. Wong, U. Nirmal, and B. Lim, "Impact behavior of short and continuous fiber-reinforced polyester composites," *Journal of Reinforced Plastics and Composites*, vol. 29, no. 23, pp. 3463–3474, 2010.

[185] M. Sakthivel, S. Vijayakumar, and S. Ramesh, "Production and characterization of luffa/coir reinforced polypropylene composite," *Procedia Materials Science*, vol. 5, pp. 739–745, 2014.

[186] M. Rokbi, H. Osmani, A. Imad, and N. Benseddiq, "Effect of chemical treatment on flexure properties of natural fiber-reinforced polyester composite," *Procedia Engineering*, vol. 10, pp. 2092–2097, 2011.

[187] T. Sathishkumar, "Development of snake grass fiber-reinforced polymer composite chair," *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications*, vol. 230, no. 1, pp. 273–281, 2016.

[188] S. Gokulkumar, P. R. Thyla, L. Prabhu, and S. Sathish, "Characterization and comparative analysis on mechanical and acoustical properties ofCamellia sinensis/ananas comosus/glass fiber hybrid polymer composites," *Journal of Natural Fibers*, vol. 18, no. 7, pp. 978–994, 2021.

[189] S. Indran and R. E. Raj, "Characterization of new natural cellulosic fiber from Cissus quadrangularis stem," *Carbohydrate Polymers*, vol. 117, pp. 392–399, 2015.

[190] K. H. Reddy, R. M. Reddy, M. Ramesh, D. Mohana Krishnudu, B. M. Reddy, and H. R. Rao, "Impact of alkali treatment on characterization of Tapsi (Sterculia Urens) natural bark fiber reinforced polymer composites," *Journal of Natural Fibers*, vol. 18, no. 3, pp. 378–389, 2021.

[191] L. Prabhu, V. Krishnaraj, S. Sathish, S. GokulKumar, and N. Karthi, "Study of mechanical and morphological properties of jute-tea leaf fiber reinforced hybrid composites: effect of glass fiber hybridization," *Materials Today: Proceedings*, vol. 27, pp. 2372–2375, 2020.

[192] M. Aly, M. S. J. Hashmi, A. G. Olabi et al., "Optimization of alkaline treatment conditions of flax fiber using Box–Behnken method," *Journal of Natural Fibers*, vol. 9, no. 4, pp. 256–276, 2012.

[193] R. Malkapuram, V. Kumar, and Y. S. Negi, "Recent development in natural fiber reinforced polypropylene composites,"

Journal of Reinforced Plastics and Composites, vol. 28, no. 10, pp. 1169–1189, 2009.

[194] A. Ashori and A. Nourbakhsh, "Preparation and characterization of polypropylene/wood flour/nanoclay composites," *European Journal of Wood and Wood Products*, vol. 69, no. 4, pp. 663–666, 2011.

[195] T. P. Mohan and K. Kanny, "Water barrier properties of nanoclay filled sisal fibre reinforced epoxy composites," *Composites. Part A, Applied Science and Manufacturing*, vol. 42, no. 4, pp. 385–393, 2011.

[196] M. Haq, R. Burgueño, A. K. Mohanty, and M. Misra, "Hybrid bio-based composites from blends of unsaturated polyester and soybean oil reinforced with nanoclay and natural fibers," *Composites Science and Technology*, vol. 68, no. 15-16, pp. 3344–3351, 2008.

[197] G. Han, Y. Lei, Q. Wu, Y. Kojima, and S. Suzuki, "Bamboo-fiber filled high density polyethylene composites: effect of coupling treatment and nanoclay," *Journal of Polymers and the Environment*, vol. 16, no. 2, pp. 123–130, 2008.

[198] P. K. Kushwaha, C. N. Pandey, and R. Kumar, "Study on the effect of carbon nanotubes on plastic composite reinforced with natural fiber," *Journal of the Indian Academy of Wood Science*, vol. 11, no. 1, pp. 82–86, 2014.

[199] D. Balaji, M. Ramesh, T. Kannan, S. Deepan, V. Bhuvaneswari, and L. Rajeshkumar, "Experimental investigation on mechanical properties of banana/snake grass fiber reinforced hybrid composites," *Materials Today: Proceedings*, vol. 42, pp. 350–355, 2021.

[200] M. Ramesh, C. Deepa, M. Tamil Selvan, L. Rajeshkumar, D. Balaji, and V. Bhuvaneswari, "Mechanical and water absorption properties of Calotropis gigantea plant fibers reinforced polymer composites," *Materials Today: Proceedings*, vol. 46, pp. 3367–3372, 2021.

[201] M. Ramesh, L. Rajeshkumar, C. Deepa et al., "Impact of Silane treatment on characterization of Ipomoea staphylina plant fiber reinforced epoxy composites," *Journal of Natural Fibers*, pp. 1–12, 2021.

[202] S. Sathish, K. Kumaresan, L. Prabhu, and S. Gokulkumar, "Experimental testing on mechanical properties of various natural fibers reinforced epoxy hybrid composite," *International Journal of Pure and Applied Mathematics*, vol. 11, no. 25, pp. 1–6, 2018.

[203] L. Prabhu, V. Krishnaraj, S. GokulKumar, S. Sathish, M. R. Sanjay, and S. Siengchin, "Mechanical, chemical and sound absorption properties of glass/kenaf/waste tea leaf fiber-reinforced hybrid epoxy composites," *Journal of Industrial Textiles*, vol. 51, no. 10, pp. 1674–1700, 2022.

[204] M. J. John and S. Thomas, "Biofibres and biocomposites," *Carbohydrate Polymers*, vol. 71, no. 3, pp. 343–364, 2008.

[205] T. Sen and H. N. Reddy, "Various industrial applications of hemp, kinaf, flax and ramie natural fibres," *International Journal of Innovation, Management and Technology*, vol. 2, pp. 192–198, 2011.

[206] S. M. A. Tawakkal, M. J. Cran, and S. W. Bigger, "Effect of kenaf fibre loading and thymol concentration on the mechanical and thermal properties of PLA/kenaf/thymol composites," *Industrial Crops and Products*, vol. 61, pp. 74–83, 2014.

[207] T. A. Ticoalu and F. Cardona, "A review of current development in natural fiber composites for structural and infrastructure applications," in *Proceedings of the Southern Region Engineering Conference (SREC '10)*, pp. 113–117, Toowoomba, Australia, November 2010.

[208] D. Verma and S. Sharma, "Green biocomposites: a prospective utilization in automobile industry," in *Green Biocomposites: Design and Applications*, M. Jawaid, M. S. Salit, and O. Y. Alothman, Eds., pp. 167–191, Springer, Cham, Switzerland, 2017.

[209] Lucintel, *Opportunities in Natural Fiber Composites*, Lucintel, Las Colinas, TX, USA, 2011.

[210] M. H. Norhidayah, A. A. Hambali, M. Y. bin Yaakob, M. Zolkarnain, and H. Y. S. Taufik, "A review of current development in natural fiber composites in automotive applications," *Applied Mechanics and Materials*, vol. 564, pp. 3–7, 2014.

[211] S. Witayakran, W. Smitthipong, R. Wangpradid, R. Chollakup, and P. L. Clouston, "Natural fiber composites: review of recent automotive trends," in *Reference Module in Materials Science and Materials Engineering*, pp. 166–174, Elsevier Publishing, Amherst, MA, USA, 2017.

[212] M. Ramesh, L. Rajeshkumar, and D. Balaji, "Influence of process parameters on the properties of additively manufactured fiber-reinforced polymer composite materials: a review," *Journal of Materials Engineering and Performance*, vol. 30, no. 7, pp. 4792–4807, 2021.

[213] O. Faruk, A. K. Bledzki, H. P. Fink, and M. Sain, "Biocomposites reinforced with natural fibers: 2000–2010," *Progress in Polymer Science*, vol. 37, no. 11, pp. 1552–1596, 2012.

[214] L. Yan, N. Chouw, and K. Jayaraman, "Flax fibre and its composites - a review," *Composites Part B Engineering*, vol. 56, pp. 296–317, 2014.

[215] T. Koizumi, N. Tsujiuchi, and A. Adachi, "The development of sound absorbing materials using natural bamboo fibers," *High-Performance Composite Structures*, vol. 4, no. 1, pp. 157–166, 2002.

[216] Y. Zou, S. Huda, and Y. Yang, "Lightweight composites from long wheat straw and polypropylene web," *Bioresource Technology*, vol. 101, no. 6, pp. 2026–2033, 2010.

[217] S. D. Dogan, U. Tayfun, and M. Dogan, "New route for modifying cellulosic fibres with fatty acids and its application to polyethylene/jute fibre composites," *Journal of Composite Materials*, vol. 50, no. 18, pp. 2477–2485, 2016.

[218] D. Zhao and Z. Zhou, "Applications of lightweight composites in automotive industries," in *Lightweight Materials from Biopolymers and Biofibers*, Y. Yang, H. Xu, and X. Yu, Eds., pp. 143–158, American Chemical Society, Washington, DC, USA, 2014.

[219] K. Roy, S. C. Debnath, A. Pongwisuthiruchte, and P. Potiyaraj, "Recent advances of natural fibers based green rubber composites: properties, current status, and future perspectives," *Journal of Applied Polymer Science*, vol. 138, no. 35, p. 50866, 2021.

[220] N. Ramli, N. Mazlan, Y. Ando et al., "Natural fiber for green technology in automotive industry: a brief review," in *The Wood and Biofiber International Conference (WOBIC 2017)*, pp. 1–7, Selangor, Malaysia, 2017.

[221] S. Kalia, B. S. Kaith, and I. Kaur, "Pretreatments of natural fibers and their application as reinforcing material in polymer composites-a review," *Polymer Engineering & Science*, vol. 49, no. 7, pp. 1253–1272, 2009.

[222] C. Xia, S. Q. Shi, L. Cai, and J. Hua, "Property enhancement of kenaf fiber composites by means of vacuum-assisted resin

transfer molding (VARTM)," *Holzforschung*, vol. 69, no. 3, pp. 307–312, 2015.

[223] N. Chand and U. K. Dwivedi, "Effect of coupling agent on abrasive wear behaviour of chopped jute fibre-reinforced polypropylene composites," *Wear*, vol. 261, no. 10, pp. 1057–1063, 2006.

[224] M. K. Gupta and R. K. Srivastava, "Mechanical properties of hybrid fibers-reinforced polymer composite: a review," *Polymer-Plastics Technology and Engineering*, vol. 55, no. 6, pp. 626–642, 2016.

[225] F. X. Espinach, "Advances in natural fibers and polymers," *Materials*, vol. 14, no. 10, p. 2607, 2021.

[226] R. D. Anandjiwala and S. Blouw, "Composites from bast fibres—prospects and potential in the changing market environment," *Journal of Natural Fibers*, vol. 4, no. 2, pp. 91–109, 2007.

[227] M. A. Dweib, B. Hu, H. W. Shenton, and R. P. Wool, "Bio-based composite roof structure: manufacturing and processing issues," *Composite Structures*, vol. 74, no. 4, pp. 379–388, 2006.

[228] M. M. Davoodi, S. M. Sapunan, D. Ahma, A. Aidy, A. Khalina, and M. Jonobi, "Mechanical properties of hybrid kenaf/glass reinforced epoxy composite for passenger car bumper beam," *Material Design*, vol. 31, no. 10, pp. 4927–4932, 2010.

[229] B. F. Yousif and H. Ku, "Suitability of using coir fiber/polymeric composite for the design of liquid storage tanks," *Materials and Design*, vol. 36, pp. 847–853, 2012.

[230] A. Atiqah, M. Jawaid, S. M. Sapuan, and M. R. Ishak, "Dynamic mechanical properties of sugar palm/glass fiber reinforced thermoplastic polyurethane hybrid composites," *Polymer Composites*, vol. 40, no. 4, pp. 1329–1334, 2019.

[231] G. C. Silva, D. A. Souza, J. C. Machado, and D. J. Hourston, "Mechanical and thermal characterization of native Brazilian coir fiber," *Journal of Applied Polymer Science*, vol. 76, no. 7, pp. 1197–1206, 2000.

[232] S. Mori, C. Tenazoa, S. Candiotti, E. Flores, and S. Charca, "Assessment of Ichu fibers extraction and their use as reinforcement in composite materials," *Journal of Natural Fibers*, 2020.

[233] D. L. Cerf, F. Irinei, and G. Muller, "Solution properties of gum exudates from *Sterculia urens* (Karaya gum)," *Carbohydrate Polymers*, vol. 13, no. 4, pp. 375–386, 1990.

[234] M. E. Ali and A. Alabdulkarem, "On thermal characteristics and microstructure of a new insulation material extracted from date palm trees surface fibers," *Construction and Building Materials*, vol. 138, pp. 276–284, 2017.

[235] P. Manimaran, P. Senthamaraikannan, K. Murugananthan, and M. R. Sanjay, "Physicochemical properties of new cellulosic fibers fromAzadirachta indicaPlant," *Journal of Natural Fibers*, vol. 15, no. 1, pp. 29–38, 2018.