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Polymeric Composites and Nanocomposites Containing Cellulose: A Brief Review

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ABSTRACT

The inherent properties of biocomposites, such as biodegradability, environmental compatibility, low production cost, high strength, and durability, make them suitable alternatives to traditional materials such as glass and nylon. Biopolymers have found broad applications because of their inherent characteristics, including low density, low thermal conductivity, corrosion resistance, and ease of fabrication into complex shapes. This article provides a brief review of polymeric biocomposites. It focuses primarily on reinforcements such as natural fibers, seed shells, animal fibers, and celluloses, which improve the mechanical properties of composites, including strength, Young's modulus, and creep behavior. Reports indicate a growing use of cellulosic materials as reinforcing components in biocomposites. Their low cost, recyclability, renewability, and high strength-to-weight ratio demonstrate the considerable potential of environmentally friendly composites for a wide range of applications.

1. Introduction

From a general perspective, the distinctive feature of composites is that they contain at least two microscopically different components that are essentially insoluble in one another, yet can be combined to address certain problems, such as inadequate properties and compatibility issues. The resulting material has improved properties relative to the matrix and exhibits new performance characteristics.

Based on the type of matrix used, composites can be divided into three categories: polymer matrix composites (PMCs), metal matrix composites (MMCs), and ceramic matrix composites (CMCs). Most synthetic composites use thermosetting resins and polymers, such as unsaturated polyester [1], phenolic resin [2], epoxy resin [3], and rubber [4], as well as thermoplastics such as polyethylene [5], polypropylene [6], polyvinyl chloride [7], and polyethylene oxide [8].

Reinforcements in composites can be classified structurally as woven forms, continuous fibers, short fibers, or particles. Alternatively, they can be categorized morphologically by physical size as

macroscopic, microscopic, or nanoscale. In composites, macroscopic fabrics or fibers and microscopic short fibers are commonly used as reinforcements.

Nanoscale reinforcements can improve composite properties because they have a high specific surface area. The use of synthetic-fiber-reinforced composites in the aerospace, automotive, and packaging industries has attracted considerable attention because of their high strength, flexibility, stiffness, and broad potential for diverse applications [9]. For many industries, composites are an important raw material in manufactured products.

However, composites are generally reinforced with synthetic fibers, which are usually non-biodegradable. Another disadvantage is that these composites are difficult to decompose and separate at the end of their useful life [10]. In view of their environmental impacts, researchers are developing environmentally compatible biocomposites that use natural fillers without compromising product quality. Such biocomposites are reinforced with natural fillers. These renewable fillers are readily available, environmentally friendly, low-cost, lightweight, and possess good mechanical properties [11].

Using biofibers instead of synthetic fibers as composite fillers can address environmental concerns, including plastic waste and fuel scarcity. Growing public attention to strategies for reducing the carbon footprint has also encouraged people to reconsider plastic consumption. More than 300 million tonnes of plastic are reportedly produced worldwide each year, indicating the large volume of waste generated by the plastics sector [12]. Accordingly, recent studies have sought potential alternatives based on more environmentally friendly and sustainable polymers and materials [13].

Researchers have reported significant value creation from renewable biological materials. Starch, cellulose, and woody biomass, along with other biological feedstocks, are known as biopolymers [14]. Compared with conventional plastics, these materials contribute substantially to reducing the carbon footprint [15]. Nevertheless, with rapid population growth, greater attention is being given to the efficient use of innovative and sustainable products made from these environmentally compatible feedstocks. Evidence in the scientific literature indicates that starch, cellulose, alginate, and fiber-rich materials such as flax, hemp, sisal, and jute can be partially combined or blended with other materials to form composites with distinctive scientific and commercial properties. The biodegradability and recyclability of these composites can accelerate their adoption in new applications.

This article briefly reviews progress in the use of environmentally friendly reinforcements in polymer composites and nanocomposites. Reports indicate increasing use of cellulosic materials as reinforcing components in biocomposites. Their low cost, recyclability, renewability, and high strength-to-weight ratio demonstrate the considerable potential of environmentally friendly composites for a wide range of applications.

2. Celluloses as Reinforcement

Wood is the primary source of cellulosic fibers. Wood fibers consist of the middle lamella, the primary wall, and the secondary wall. Cellulose microfibrils and hemicelluloses are present in all three regions. The third major component is pectin in the primary walls and lignin in the secondary walls. Wood is, in fact, a composite of these materials, in which cellulose microfibrils provide strength. Hemicelluloses are a group of carbohydrate polymers that form part of the cellular

structure in plant cell walls and play an important role in the strength and flexibility of those walls [16].

In addition to wood, natural-fiber-reinforced polymer composites using other fibers, such as hemp [17–21], cannabis [22–24], flax [25–28], and jute [29–34], have been widely studied. Natural fibers can also be combined with other reinforcements to form hybrid composites and further improve their overall properties. In a series of studies, Maldas and Kokta [35–39] investigated the properties of composites filled with wood fibers (fibers or sawdust) and glass fibers/mica. They found that surface treatments of the fillers were critical to composite performance.

Synthetic fibers have a particular range of properties, whereas the properties of natural fibers vary considerably according to the source, location, age, and processing of the plants. By source, fibers may be obtained from animals or plants. Natural plant fibers are divided into leaf, bast, wood, seed, and fruit fibers; these have attracted the attention of many researchers and have been investigated as reinforcing agents [40, 41]. Hemp, flax, kenaf, and jute fibers—all bast fibers—are obtained from plant stems and are widely used to reinforce composites because of their greater length, strength, and stiffness [42]. Indigenous plant fibers have also attracted scientific interest as reinforcing fibers. Available examples include rice, wheat, and corn-straw fibers, which can serve as highly economical reinforcements in biocomposite materials [43].

Natural fibers are hydrophilic, meaning that they absorb water molecules. Their hydrophilicity can cause separation between the fibers and the polymer matrix, reducing the mechanical properties of the resulting composites [44].

3. Biopolymers as Matrix

Biopolymers are biodegradable and environmentally friendly, and are obtained from agricultural resources, by-products, chemical processes, and microbial activity [45]. They can also be produced by combining two biopolymers. A polymer's structure, source, and degradation conditions determine its biodegradability [46]. During degradation, microorganisms attack the polymer and break it down into smaller molecules, with the release of CO_2 [47]. Biopolymers have poor mechanical properties on their own; however, adding natural fibers improves their mechanical performance [48]. Conventional polymers such as polypropylene, polyester, polyethylene, and epoxy are widely available and have passed through various stages of research and commercialization [49–51].

PHA is a renewable and environmentally friendly polymer obtained from fatty acids, sugar, sucrose, molasses, starch, wheat, methane, and corn [52]. Sucrose and glucose are used in the commercial production of PHA [52, 53]. The biodegradability of PHA depends on environmental conditions, water content, crystallinity, chemical composition, pH, and surface area [52].

PBS is biodegradable and is produced from 1,4-butanediol and succinic acid; it has favorable thermal performance, with a melting point of 115 °C [79]. Blending PBS with other biopolymers, such as PLA, starch, and carbohydrates, can improve its mechanical performance. PBS is used to manufacture bottles, packaging, shopping bags, and other products [54].

Polylactic acid, or polylactide (PLA), is a common biopolymer. It is an aliphatic (thermoplastic) polyester derived from lactic acid, which is found in many renewable resources, including wheat,

corn, cassava, sugarcane, and barley [55]. PLA is preferred for medical applications because of its biocompatibility; its degradation does not produce toxic by-products or interfere with tissue healing [56].

4. Biocomposites and Mechanical Properties

Biocomposites consist of natural fibers and a matrix component. The matrix may be made from biodegradable or non-biodegradable polymers. Polymer-matrix biocomposites can contain natural polymers such as PLA, PHA, and PCL, or synthetic polymers such as thermoplastics and thermosets. Adding one or more natural fibers to the matrix component forms a biocomposite. The fibers provide strength, while the resin binds them together, helping the product remain stiff and strong and protecting the fibers from moisture[57]. The effect of reinforcement on polymer-matrix composites has been examined [58].

The aspect ratio is defined as the ratio of fiber length to diameter. Fiber fraction and fiber size play essential roles in composite strength [59]. Although incorporating small particles can be effective in processing equipment, a low aspect ratio leads to stress concentration and lower strength than that of a pure polymer [60, 61]. A higher aspect ratio leads to superior mechanical properties because increasing the length-to-diameter ratio enables more effective load transfer [59]. Biocomposites made from biopolymers and natural fibers are attractive because they can provide the required performance at lower cost [62]. These materials are biodegradable and recyclable and can be readily disposed of after use without adversely affecting the environment. The same is not possible with synthetic composites derived from fossil fuels.

Table 1 presents an overview of the mechanical behavior affected by adding different types of cellulosic fibers to environmentally friendly polymer matrices, as reported in recent studies.

Table 1. Mechanical Behavior Affected by Adding Different Cellulosic Fibers to Biopolymer Matrices

References	Description	Matrix	Reinforcing fiber
[63]	Tensile strength and impact strength both increased by approximately 34%.	PLA	Banana fiber
[64]	Tensile strength improved by approximately 48% and impact strength by approximately 106%. Lower water absorption was observed in the processed composites.	Polypropylene	Seaweed fiber
[65]	Flexural stress and modulus increased, indicating better interfacial adhesion.	PLA	Khorasan rice and wheat bran
[66]	Tensile properties of the resulting composite increased when the fibers were processed at a higher temperature.	Polypropylene	Hemp fiber
[67]	Interfacial adhesion improved, resulting in better mechanical properties and thermal stability of the composites.	Modified sunflower oil	Alfa fiber
[68]	Mechanical properties increased.	PLA	Eucalyptus microfibers

References	Description	Matrix	Reinforcing fiber
[69]	Improved interfacial adhesion, water resistance, impact strength, and tensile properties were observed.	HDPE	Coffee grounds
[70]	The mechanical performance of the processed biocomposite was higher than that of the unprocessed sample.	PLA	Hemp fiber mat
[71]	Tensile properties and water resistance increased, and the biocomposites had greater thermal stability.	Polypropylene	Pineapple leaves
[72]	Rheological properties and thermal stability increased.	PHBH	Aloe vera fiber
[72]	Ultimate tensile strength and flexural strength increased by 7.64% and 76.19%, respectively, while impact strength decreased by 5.33%.	HDPE	*Combretum dolichopetalum* fiber
[72]	Ultimate tensile strength and impact strength increased by 18.78% and 58.73%, respectively, compared with the unprocessed sample.	HDPE	*Combretum dolichopetalum* fiber
[73]	Mechanical properties, water resistance, and thermal stability increased.	PLA	Hemp fiber
[74]	Tensile, flexural, and impact strengths of the processed composites increased by 98%, 58%, and 24%, respectively. Water absorption also decreased.	Polyvinyl alcohol	Banana fiber
[75]	Chemical and mechanical fiber–matrix bonding increased, improving mechanical performance.	Unsaturated polyester	Hemp fiber
[76]	Ultimate strength and Young's modulus increased by 46% and 248%, respectively, compared with untreated fibers.	PCL	Wood fiber
[77]	Interfacial adhesion improved, Young's modulus increased, and strain at break decreased.	HDPE	Wood fiber
[78]	Mechanical properties were unchanged, while moisture resistance increased significantly.	LDPE	Softwood pulp fiber
[79]	Interfacial bonding increased.	Starch	Hemp
[80]	Water resistance, tensile strength, and thermal stability increased.	HDPE	Hemp
[81]	Thermal stability and mechanical performance improved.	Polypropylene	Dissolving pulp based on kraft
[82]	Tensile and flexural strengths increased, and creep resistance also improved.	Polypropylene	Japanese cedar wood
[83]	Homogeneous dispersion, interfacial adhesion, water resistance, and thermal stability improved compared with untreated and alkali-treated samples.	Polypropylene	Banana fiber

5. Conclusion

Polymeric biocomposites are recognized as among the most notable materials in materials engineering and advanced technologies. These materials are developed particularly using natural reinforcements, derived mainly from plants or living organisms, as reinforcing components in composite production.

The principal challenge in developing composites is the weak interaction between the matrix phase and the reinforcing phase, which results in poor interfacial bonding and reduced composite properties. Researchers seek to improve composite properties through pretreatment processes, the addition of compatibilizers, and modification of the reinforcements. These approaches improve adhesion between the matrix and reinforcements and, in turn, the mechanical properties of the composite.

As shown in Table 1, polymeric biocomposites can improve mechanical properties and offer excellent environmental characteristics. However, in many cases, their thermal properties do not show significant improvement compared with the neat resin. Researchers continue to investigate the development of polymeric biocomposites from natural resources. Despite the challenges, environmentally friendly polymer composites and nanocomposites offer unique opportunities for developing advanced, bio-based materials. Research and development in this field, focused on reducing costs, increasing efficiency, and identifying new applications, can contribute significantly to a more sustainable future.

Table 2. List of Abbreviations and Terminology

Term	Meaning	Abbreviation	Meaning
PCL	Polycaprolactone	PLA	Polylactic acid
PHA	Polyhydroxyalkanoates	PMC	Polymer matrix composite
PP	Polypropylene	MMC	Metal matrix composite
PBS	Polybutylene succinate	CMC	Ceramic matrix composite
LDPE	Low-density polyethylene	HDPE	High-density polyethylene
PCL	Polycaprolactone	PHA	Polyhydroxyalkanoates

6. REFERENCES

The following reference list reproduces all 83 bibliographic entries from the original article, in the same order and numbering.

[1] Vilay V, Mariatti M, Taib RM, Todo M. Effect of fiber surface treatment and fiber loading on the properties of bagasse fiber–reinforced unsaturated polyester composites. Composites Science and Technology. 2008 Mar 1;68(3-4):631-8.
[2] Zarate CN, Aranguren MI, Reboredo MM. Thermal degradation of a phenolic resin, vegetable fibers, and derived composites. Journal of Applied Polymer Science. 2008 Mar 5;107(5):2977-85.
[3] Zhao Q, Yam RC, Zhang B, Yang Y, Cheng X, Li RK. Novel all-cellulose ecocomposites prepared in ionic liquids. Cellulose. 2009 Apr;16:217-26.
[4] De SK, Murty VM. Short fiber-rubber composites. Polymer Engineering Reviews. 1984;4(4):313-43.

[5] Lu W, Lin H, Chen G. Voltage-induced resistivity relaxation in a high-density polyethylene/graphite nanosheet composite. Journal of Polymer Science Part B: Polymer Physics. 2007 Apr 1;45(7):860-3.
[6] Rezaei F, Yunus R, Ibrahim NA, Mahdi ED. Development of short-carbon-fiber-reinforced polypropylene composite for car bonnet. Polymer-Plastics Technology and Engineering. 2008 Mar 31;47(4):351-7.
[7] Chazeau L, Cavaille JY, Canova G, Dendievel R, Boutherin B. Viscoelastic properties of plasticized PVC reinforced with cellulose whiskers. Journal of Applied Polymer Science. 1999 Mar 14;71(11):1797-808.
[8] Chen J, Tsubokawa N. Electric properties of conducting composite from poly (ethylene oxide) and poly (ethylene oxide)-grafted carbon black in solvent vapor. Polymer Journal. 2000 Sep;32(9):729-36.
[9] Rajak DK, Pagar DD, Kumar R, Pruncu CI. Recent progress of reinforcement materials: a comprehensive overview of composite materials. Journal of Materials Research and Technology. 2019 Nov 1;8(6):6354-74.
[10] Chandramohan D, Marimuthu K. A review on natural fibers. International Journal of Research and Reviews in Applied Sciences. 2011 Aug 2;8(2):194-206.
[11] Lu X, Zhang MQ, Rong MZ, Shi G, Yang GC. Self-reinforced melt processable composites of sisal. Composites Science and Technology. 2003 Feb 1;63(2):177-86.
[12] Liminana P, Garcia-Sanoguera D, Quiles-Carrillo L, Balart R, Montanes N. Development and characterization of environmentally friendly composites from poly (butylene succinate)(PBS) and almond shell flour with different compatibilizers. Composites Part B: Engineering. 2018 Jul 1;144:153-62.
[13] Lascano D, Quiles-Carrillo L, Balart R, Boronat T, Montanes N. Toughened poly (lactic acid)—PLA formulations by binary blends with poly (butylene succinate-co-adipate)—PBSA and their shape memory behaviour. Materials. 2019 Feb 19;12(4):622.
[14] Falua KJ, Pokharel A, Babaei-Ghazvini A, Ai Y, Acharya B. Valorization of starch to biobased materials: A review. Polymers. 2022 May 30;14(11):2215.
[15] Dolza C, Fages E, Gonga E, Gomez-Caturla J, Balart R, Quiles-Carrillo L. Development and characterization of environmentally friendly wood plastic composites from biobased polyethylene and short natural fibers processed by injection moulding. Polymers. 2021 May 22;13(11):1692.
[16] Sharma AK, Bhandari R, Aherwar A, Rimašauskienė R. Matrix materials used in composites: A comprehensive study. Materials Today: Proceedings. 2020 Jan 1;21:1559-62.
[17] Das Lala S, Deoghare AB, Chatterjee S. Effect of reinforcements on polymer matrix bio-composites–an overview. Science and Engineering of Composite Materials. 2018 Nov 27;25(6):1039-58.
[18] Migneault S, Koubaa A, Erchiqui F, Chaala A, Englund K, Wolcott MP. Effects of processing method and fiber size on the structure and properties of wood–plastic composites. Composites Part A: Applied Science and Manufacturing. 2009 Jan 1;40(1):80-5.
[19] Wolcott MP, Englund K. A technology review of wood-plastic composites. In: 33rd International Particleboard/Composite Materials Symposium 1999 Apr 13 (pp. 103-111). Washington State University, Pullman, WA.
[20] Gamstedt EK, Nygård P, Lindström M. Transfer of knowledge from papermaking to manufacture of composite materials. In: Proceedings of the 3rd Wood Fibre Polymer Composites International Symposium, Bordeaux 2007 Mar (p. 12).
[21] Satyanarayana KG, Arizaga GG, Wypych F. Biodegradable composites based on lignocellulosic fibers—An overview. Progress in Polymer Science. 2009 Sep 1;34(9):982-1021.
[22] John PA. Textbook of wood technology: structure, identification, properties, and uses of the commercial woods of the United States and Canada. McGraw-Hill Series in Forest Resources (USA).1980.
[23] Pan P, Zhu B, Dong T, Serizawa S, Iji M, Inoue Y. Kenaf fiber/poly (ε-caprolactone) biocomposite with enhanced crystallization rate and mechanical properties. Journal of Applied Polymer Science. 2008 Mar 15;107(6):3512-9.
[24] Nishino T, Hirao K, Kotera M, Nakamae K, Inagaki H. Kenaf reinforced biodegradable composite. Composites Science and Technology. 2003 Jul 1;63(9):1281-6.
[25] Zimmerman JM, Losure NS. Mechanical properties of kenaf bast fiber reinforced epoxy matrix composite panels. Journal of Advanced Materials. 1998;30(2):32-8.
[26] Chen HL, Porter RS. Composite of polyethylene and kenaf, a natural cellulose fiber. Journal of Applied Polymer Science. 1994 Dec 12;54(11):1781-3.

[27] Mehta G, Mohanty AK, Drzal LT, Misra M. Bio-composites from engineered kenaf natural fibers and unsaturated polyester resin for low cost housing applications. Polymeric Materials Science and Engineering. 2003;88:56-7.
[28] Thygesen A, Daniel G, Lilholt H, Thomsen AB. Hemp fiber microstructure and use of fungal defibration to obtain fibers for composite materials. Journal of Natural Fibers. 2006 Mar 15;2(4):19-37.
[29] Keller A. Compounding and mechanical properties of biodegradable hemp fibre composites. Composites Science and Technology. 2003 Jul 1;63(9):1307-16.
[30] Hokens D, Mohanty AK, Misra M, Drzal LT. The influence of surface modification and compatibilization on the performance of natural fiber reinforced biodegradable thermoplastic composite. Polymer Preprints (USA). 2002 Apr;43(1):482-3.
[31] Kaith BS, Singha AS, Dwivedi DK, Kumar S, Kumar D, Dhemeniya A. Preparation of polystyrene matrix based composites using flax-g-copolymers as reinforcing agent and evaluation of the mechanical behavior. International Journal of Plastic Technology. 2003;7:119-25.
[32] Bos HL, Molenveld K, Teunissen W, Van Wingerde AM, Van Delft DR. Compressive behaviour of unidirectional flax fibre reinforced composites. Journal of Materials Science. 2004 Mar;39:2159-68.
[33] López Manchado MA, Arroyo M, Biagiotti J, Kenny JM. Enhancement of mechanical properties and interfacial adhesion of PP/EPDM/flax fiber composites using maleic anhydride as a compatibilizer. Journal of Applied Polymer Science. 2003 Nov 21;90(8):2170-8.
[34] Bos HL, Van den Oever MJ. The large influence of flax fiber structure on composite strength. In: International Conference on Woodfiber-Plastic Composites, 5th, Madison, WI, United States 1999 May 26.
[35] Sarkhel G, Choudhury A. Dynamic mechanical and thermal properties of PE-EPDM based jute fiber composites. Journal of Applied Polymer Science. 2008 Jun 15;108(6):3442-53.
[36] Alam MK, Khan MA, Lehmann EH, Vontobel P. Study of the water uptake and internal defects of jute-reinforced polymer composites with a digital neutron radiography technique. Journal of Applied Polymer Science. 2007 Aug 15;105(4):1958-63.
[37] Khan MA, Haque N, Al-Kafi A, Alam MN, Abedin MZ. Jute reinforced polymer composite by gamma radiation: effect of surface treatment with UV radiation. Polymer-Plastics Technology and Engineering. 2006 Jun 1;45(5):607-13.
[38] Gao SL, Mäder E. Jute/polypropylene composites I. Effect of matrix modification. Composites Science and Technology. 2006 Jun 1;66(7-8):952-63.
[39] Sahoo PK, Sahu GC, Rana PK, Das AK. Preparation, characterization, and biodegradability of jute-based natural fiber composite superabsorbents. Advances in Polymer Technology: Journal of the Polymer Processing Institute. 2005 Sep;24(3):208-14.
[40] Datta C, Basu D, Roy A, Banerjee A. Mechanical and dynamic mechanical studies of epoxy/VAc-EHA/HMMM IPN-jute composite systems. Journal of Applied Polymer Science. 2004 Jan 15;91(2):958-63.
[41] Maldas D, Kokta BV. Effect of Fiber Treatment on the Mechanical Properties of Hybrid Fiber-Reinforced Polystyrene Composites: I. Use of Mica and Wood Pulp as Hybrid Filler. Composites Technology and Research. 1990 Dec 1;12(4):217-21.
[42] Maldas D, Kokta BV. Effect of fiber treatment on the mechanical properties of hybrid fiber reinforced polystyrene composites: IV. Use of glass fiber and sawdust as hybrid fiber. Journal of Composite Materials. 1991 Apr;25(4):375-90.
[43] Maldas D, Kokta BV. Performance of treated hybrid fiber reinforced-thermoplastic composites under extreme conditions. IV. Use of glass fiber and sawdust as hybrid fiber. Journal of Applied Polymer Science. 1991 Mar 5;42(5):1443-50.
[44] Maldas D, Kokta BV. Performance of treated hybrid fiber-reinforced thermoplastic composites under extreme conditions: part I—use of mica and wood pulp as hybrid fiber. Polymer Degradation and Stability. 1991 Jan 1;31(1):9-21.
[45] Maldas D, Kokta BV. Performance of hybrid reinforcements in PVC composites: III. Use of surface-modified glass fiber and wood pulp as reinforcements. Journal of Reinforced Plastics and Composites. 1992 Oct;11(10):1093-102.
[46] Summerscales J, Dissanayake NP, Virk AS, Hall W. A review of bast fibres and their composites. Part 1–Fibres as reinforcements. Composites Part A: Applied Science and Manufacturing. 2010 Oct 1;41(10):1329-35.

[47] Sorieul M, Dickson A, Hill SJ, Pearson H. Plant fibre: molecular structure and biomechanical properties, of a complex living material, influencing its deconstruction towards a biobased composite. Materials. 2016 Jul 26;9(8):618.
[48] Quarshie R, Carruthers J. Technology overview biocomposites. Materials KTN i NetComposites Ltd, United Kingdom. 2014 Mar.
[49] Aladejana JT, Wu Z, Fan M, Xie Y. Key advances in development of straw fibre bio-composite boards: An overview. Materials Research Express. 2020 Jan 20;7(1):012005.
[50] Faruk O, Bledzki AK, Fink HP, Sain M. Biocomposites reinforced with natural fibers: 2000–2010. Progress in Polymer Science. 2012 Nov 1;37(11):1552-96.
[51] Pannu AS, Singh S, Dhawan V. Effect of Alkaline Treatment on Mechanical Properties of Biodegradable Composite (BF/PLA) Rod. Materials Today: Proceedings. 2021;46:9367-9371.
[52] Abdullah NS, Salim N, Roslan R. Investigation on the effect of alkaline treatment on seaweed/polypropylene (SW/PP) blend composites. Materials Today: Proceedings. 2022 Jan 1;51:1362-6.
[53] Tran TP, Bénézet JC, Bergeret A. Rice and Einkorn wheat husks reinforced poly (lactic acid)(PLA) biocomposites: Effects of alkaline and silane surface treatments of husks. Industrial Crops and Products. 2014 Jul 1;58:111-24.
[54] Sunny T, Pickering KL, Lim SH. Alkali treatment of hemp fibres for the production of aligned hemp fibre mats for composite reinforcement. Cellulose. 2020 Mar;27(5):2569-82.
[55] Kadem S, Irinischemani R, Belhaneche-Bensemra N. Study of the interfacial adhesion between alfa fiber and synthetic resin in a new biocomposite material. Materials Today: Proceedings. 2022 Jan 1;53:209-12.
[56] Silva CG, Campini PA, Rocha DB, Rosa DS. The influence of treated eucalyptus microfibers on the properties of PLA biocomposites. Composites Science and Technology. 2019 Jul 28;179:54-62.
[57] Tan MY, Nicholas Kuan HT, Lee MC. Characterization of alkaline treatment and fiber content on the physical, thermal, and mechanical properties of ground coffee waste/oxobiodegradable HDPE biocomposites. International Journal of Polymer Science. 2017;2017(1):6258151.
[58] Mohamad M, Ting SW, Bakar MB, Osman WH. The Effect of Alkaline Treatment on Mechanical Properties of Polylactic Acid Reinforced with Kenaf Fiber Mat Biocomposite. In: IOP Conference Series: Earth and Environmental Science 2020 Dec 1 (Vol. 596, No. 1, p. 012002). IOP Publishing.
[59] Gnanasekaran S, Nordin NI, Hamidi MM, Shariffuddin JH. Effect of Alkaline treatment on the characteristics of pineapple leaves fibre and PALF/PP biocomposite. Journal of Mechanical Engineering and Sciences. 2021 Dec 15;15(4):8518-28.
[60] Dehouche N, Idres C, Kaci M, Zembouai I, Bruzaud S. Effects of various surface treatments on Aloe Vera fibers used as reinforcement in poly (3-hydroxybutyrate-co-3-hydroxyhexanoate)(PHBHHx) biocomposites. Polymer Degradation and Stability. 2020 May 1;175:109131.
[61] Oladimeji AT, Dominic OO, Echeng WP, Chukwudi MM. Influence of Chemical Surface Modifications on Mechanical Properties of Combretum dolichopetalum Fibre-High Density Polyethylene (HDPE) Composites. Pakistan Journal of Scientific & Industrial Research Series A: Physical Sciences. 2018 Apr 23;61(1):28-34.
[62] Chung TJ, Park JW, Lee HJ, Kwon HJ, Kim HJ, Lee YK, Tai Yin Tze W. The improvement of mechanical properties, thermal stability, and water absorption resistance of an eco-friendly PLA/kenaf biocomposite using acetylation. Applied Sciences. 2018 Mar 5;8(3):376.
[63] Kivade SB, Gunge A, Nagamadhu M, Rajole S. Mechanical and dynamic mechanical behavior of acetylation-treated plain woven banana reinforced biodegradable composites. Advanced Composites and Hybrid Materials. 2021 Apr 13:1-5.
[64] Wang H, Kabir MM, Lau KT. Hemp reinforced composites with alkalization and acetylation fibre treatments. Polymers and Polymer Composites. 2014 Mar;22(3):247-52.
[65] Lo Re G, Spinella S, Boujemaoui A, Vilaseca F, Larsson PT, Adås F, Berglund LA. Poly (ε-caprolactone) biocomposites based on acetylated cellulose fibers and wet compounding for improved mechanical performance. ACS Sustainable Chemistry & Engineering. 2018 Mar 27;6(5):6753-60.
[66] Mbarek TB, Robert L, Sammouda H, Charrier B, Orteu JJ, Hugot F. Effect of acetylation and additive on the tensile properties of wood fiber-high-density polyethylene composite. Journal of Reinforced Plastics and Composites. 2013 Nov;32(21):1646-55.
[67] Lepetit A, Drolet R, Tolnai B, Zerrouki R, Montplaisir D. Effect of acetylation on the properties of microfibrillated cellulose-LDPE composites. Journal of Applied Polymer Science. 2017 Aug 20;134(32):44933.

[68] Jung JS, Song KH, Kim SH. Biodegradable acetylated kenaf fiber composites. Fibers and Polymers. 2021 Dec;22:3437-43.
[69] Ismail H, Abdullah AH, Bakar AA. Influence of acetylation on the tensile properties, water absorption, and thermal stability of (High-density polyethylene)/(soya powder)/(kenaf core) composites. Journal of Vinyl and Additive Technology. 2011 Jun;17(2):132-7.
[70] Duan L, Liu R, Duan Y, Li Z, Li Q. A simultaneous strategy for the preparation of acetylation modified cellulose nanofiber/polypropylene composites. Carbohydrate Polymers. 2022 Feb 1;277:118744.
[71] Hung KC, Wu TL, Chen YL, Wu JH. Assessing the effect of wood acetylation on mechanical properties and extended creep behavior of wood/recycled-polypropylene composites. Construction and Building Materials. 2016 Apr 1;108:139-45.
[72] Zaman HU, Khan RA. Acetylation used for natural fiber/polymer composites. Journal of Thermoplastic Composite Materials. 2021 Jan;34(1):3-23.
[73] Mohanty AK, Misra M, Drzal LT. Sustainable bio-composites from renewable resources: opportunities and challenges in the green materials world. Journal of Polymers and the Environment. 2002 Apr;10:19-26.
[74] Mohanty AK, Misra MA, Hinrichsen GI. Biofibres, biodegradable polymers and biocomposites: An overview. Macromolecular Materials and Engineering. 2000 Mar 1;276(1):1-24.
[75] Van de Velde K, Kiekens P. Biopolymers: overview of several properties and consequences on their applications. Polymer Testing. 2002 Jan 1;21(4):433-42.
[76] Eagan JM, Xu J, Di Girolamo R, Thurber CM, Macosko CW, LaPointe AM, Bates FS, Coates GW. Combining polyethylene and polypropylene: Enhanced performance with PE/iPP multiblock polymers. Science. 2017 Feb 24;355(6327):814-6.
[77] Alavudeen A, Rajini N, Karthikeyan S, Thiruchitrambalam M, Venkateshwaren N. Mechanical properties of banana/kenaf fiber-reinforced hybrid polyester composites: Effect of woven fabric and random orientation. Materials & Design (1980-2015). 2015 Feb 5;66:246-57.
[78] Carrillo-Escalante HJ, Alvarez-Castillo A, Valadez-Gonzalez A, Herrera-Franco PJ. Effect of fiber-matrix adhesion on the fracture behavior of a carbon fiber reinforced thermoplastic-modified epoxy matrix. Carbon Letters. 2016;19:47-56.
[79] Zwawi M. A review on natural fiber bio-composites, surface modifications and applications. Molecules. 2021 Jan 14;26(2):404.
[80] Keshavarz T, Roy I. Polyhydroxyalkanoates: bioplastics with a green agenda. Current Opinion in Microbiology. 2010 Jun 1;13(3):321-6.
[81] Frollini E, Bartolucci N, Sisti L, Celli A. Biocomposites based on poly (butylene succinate) and curaua: Mechanical and morphological properties. Polymer Testing. 2015 Aug 1;45:168-73.
[82] Garlotta D. A literature review of poly (lactic acid). Journal of Polymers and the Environment. 2001 Apr;9:63-84.
[83] Rasal RM, Janorkar AV, Hirt DE. Poly (lactic acid) modifications. Progress in Polymer Science. 2010 Mar 1;35(3):338-56.