The Pharma Innovation Journal 2022; 11(12): 4564-4567

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 4564-4567

www.thepharmajournal.com
Received: 15-10-2022
Accepted: 19-11-2022

Neenu Poonia
Department of Textile and Apparel Designing, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Neelam M Rose
Department of Textile and Apparel Designing, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Saroj Yadav
Department of Textile and Apparel Designing, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Shalini Rukhaya
Department of Textile and Apparel Designing, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Corresponding Author:
Shalini Rukhaya
Department of Textile and Apparel Designing, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Natural fibre based biocomposites for sustainability: A comprehensive review

Neenu Poonia, Neelam M Rose, Saroj Yadav and Shalini Rukhaya

Abstract
Composite materials, which first appeared in the middle of the 20th century, are currently one of the hottest research areas in contemporary technology. The benefit of creating composite materials is their superior electrical insulation, high thermal resistance, good fire behavior, high impact resistance, best abrasion resistance, and strong stiffness. Because of their outstanding qualities, flexibility in design, and aesthetic appeal, these materials continue to be used in more and more in industrial applications. This article provides an overview of composite materials, their components (reinforcement and matrix) and key benefits related to their physical and mechanical properties based on recent studies. It is emphasized how urgent it is to develop novel composites, whether they contain synthetic or natural components, in order to promote sustainability and create a cleaner, greener environment by reducing waste, hazardous emissions, and landfill waste.

Keywords: Biocomposite, reinforcement, matrix material, properties, applications

1. Introduction

The term "composite material" further clarifies that it is made up of various materials. When two or more constituent materials with vastly different physical or chemical properties are mixed, a new material with distinctive qualities that are distinct from the constituent elements is created. When compared to the qualities of individual materials, the augmentation makes composite material preferable. The components of a composite material mix and synergistically contribute their qualities to increase the final product's properties rather than blending, dissolving, or losing their unique identities (Nielsen *et al.* 2005 and Chawla *et al.* 2012) [16, 4]. When looking at the finished composite construction under a microscope, it may recognize the traits of various components. An amalgam of a base material with a filler material is a composite material. As it encloses and holds the reinforcement of other materials, base material is also known as a matrix or a binder substance. Fragments, particles, fibres, and whiskers made of natural or synthetic materials are used as filler material or reinforcement. In general, the matrix is viewed as a relatively soft phase having distinct physical and mechanical characteristics such as ductility, formability, and heat conductivity (Kumlutas *et al.* 2003) [10]. High strength, high stiffness, and low thermal expansion materials that serve as matrix reinforcement are integrated. In composites, the reinforcement phase transmits the applied load to the material, making it typically stronger and stiffer than the matrix. Owing to their ideal qualities that cannot be attained by any of the constituent materials acting alone, composite materials have become extremely popular in the research and industrial sectors.

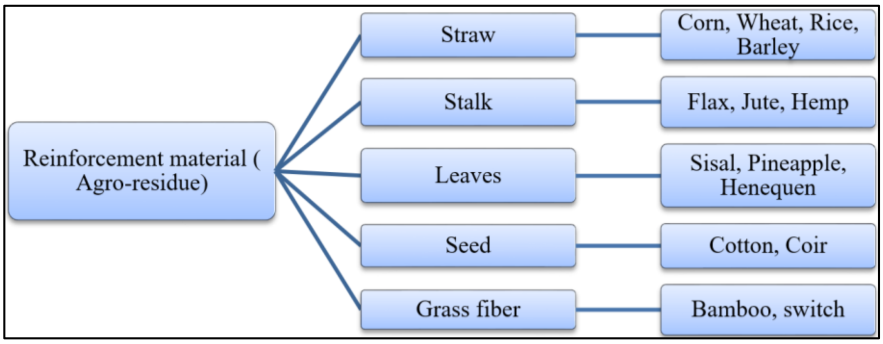
The industry is encouraged to explore the potential of the resources available locally for the production of new green composite (biocomposites) products that will enhance the industry‟s growth, competitiveness and sustainability. The development of biocomposites as a substitute for petroleum-based materials is reducing reliance on imported oil, lowering carbon dioxide emissions, and providing more cost-effective options for agriculture. Furthermore, biocomposites offer opportunities for environmental gains, reduced energy consumption, insulation and sound absorption properties (Pilla 2011) [18]. Declining supply and rising raw material prices are causing concern and biofibre materials can be seen as a good substitute material for the construction industry to manufacture value-added biocomposite goods in this respect. Thus, the biocomposite industry is a significant contributor to the global economy. One of the most significant benefits of biocomposites is its manageable capability for end-of-life disposal (Joshi *et al.* 2004) [8]. The first-generation and second-generation materials used in biocomposites were divided into two classes by (Sheldon 2021) [22]. Second-generation raw materials are lignocellulosic wastes gathered from food, forest, and agricultural residues as opposed to first-generation raw materials, which are wood. The usage of wood in greater amounts can cause deforestation and have an impact on biodiversity. Although its commercialization is still in its early stages, second-generation waste has mostly been used up to this point in the production of biocomposites (Sheldon and Norton 2020) [23].

2. Reinforcement Materials for Sustainable Biocomposites

Reinforcement is a constituent (phase or combination of phases) composite originating from the ingredient material which is combined with the matrix to form a composite. Composite industries are increasing their interests in lignocellulosic materials due to environmental issues. These industries are selecting some natural fibres as fillers or reinforcement material in composites such as straw, seed, leaves as shown in figure 1. In manufacturing, fibres are the most commonly used reinforcement that defers Fibre Reinforced Composite (FRC). Fibre as reinforcement to the composite had outstanding physical, chemical, thermal and mechanical performance, durability and biodegradable nature that highlighted and promoted its scope (Martina 2021) [12].

The type of fibre and orientation (unidirectional, random, chopped, short fibre, long fibre, bi-woven mat) of the fibre employed in the matrix determine the mechanical strength of the fibre-reinforced composite. Numerous studies claim that elements including the type of matrix, filler, reinforcements, and plasticizers have an impact on the performance of composite materials. Interfacial bonding of reinforcing material and volume fraction are additional considerations (Mngomezulu 2014) [14].

Natural fibres (NFs) are a widely available and easy-to-find substance in nature. They show biodegradability, renewable energy, carbon neutrality, cheap cost per unit volume, high strength, and particular stiffness as exceptional material characteristics. In addition, they have high specific properties and cause less health problems during handling when compared to synthetic resources. Composites made of NF reinforcements seem to carry some diverse properties over synthetic fibres, such as reduced weight, cost, toxicity, environmental pollution, and recyclability. (Bhargava 2020) [2] These economic and environmental benefits of NF composites make them predominant over synthetic fibre-reinforced composites for modern applications (Nair *et al.* 2014) [15]. However, the numerous characteristics that natural fibre provides make it the best material for the present and future generation (Dedov *et al.* 2017) [5]. The advantages and disadvantages of natural fibres used for biocomposites is given in Table 1.



Source: Kurki *et al.* 2016 [11]

Fig 1: Classification of reinforcing material

Table 1: Advantages and disadvantages of natural fibres used for biocomposites

Advantages	Disadvantages
Renewable resources, low CO_2 consumption	Homogeneous structure of fibre
Lower production cost	Dimensional instability
Low density of composite	Lower water and thermal resistance
Reduced energy consumption during manufacturing	Insufficient adhesion and incompatibility with the polymer matrix
Biodegradability and ecofriendly material	Degradation and ageing
Lower risk to human health	Restricted processing temperature (to avoid thermal degradation)
Good thermal and acoustic insulating properties	Poor fire resistance
Friendly processing, no wear of tool and no skin irritation	Poor moisture resistance, which causes swelling of fibres
Good electrical resistance	Lower durability
Lower specific weight results in higher specific strength and stiffness	Lower strength, especially impact strength

Source: Sreekumar 2008 [24] and Petar *et al.* 2017 [17]

3. Bio-matrix Materials for Sustainable Biocomposites

Matrix is one of the two components of biocomposites that hold and protect the fibres (or other reinforcing material geometries e.g., particles, platelets, short fibres, or whiskers, etc.) from environmental and physical damage. Keeping the fibres separated decreases cracking and redistributes the load equally among all fibres and also maintain the fibres in proper orientation and spacing (Anonymous 2015) [1]. Thus, the matrix contributes greatly to the properties of the biocomposites. The ability of biocomposites to withstand heat, or to conduct heat or electricity depends primarily on the matrix properties since this is the continuous phase. Therefore, the matrix selection depends on the desired properties of the biocomposite being constructed. In general, reinforcements affect mechanical and physical characteristics or on any other tailored characteristics improved from the matrix material. A wide range of characteristics can be acquired by combining many possible reinforcements and matrix, to alter material characteristics to meet specific requirements (Campbell 2010) [3].

In recent years, there has been a growing demand for a clean and pollution-free environment and an evident target to minimizing fossil fuel. Therefore, a lot of attention has been focused on research to replace petroleum-based commodity plastics by biodegradable materials arising from biological and renewable resources (El-Galy 2017) [6]. Different biopolymers, polymers produced from natural sources either chemically from a biological material or biosynthesized by living organisms, are also suitable alternatives to address these issues due to their outstanding properties including good barrier performance, biodegradation ability, and low weight. However, they generally present poor mechanical properties, a short fatigue life, low chemical resistance, poor long-term durability, and limited processing capability. In order to overcome these deficiencies and develop advanced materials for a wide range of applications, biopolymers can be reinforced with fillers to form biocomposites (Fitzgerald 2021) [7].

Biopolymers can be divided into four groups in which first three groups are obtained from renewable sources (biomass), while the fourth group is of fossil origin. Agro-polymers are the first group (eg. polysaccharides, proteins and lipids) obtained form biomass by fractioning. Polyesters make second and third group, obtained by fermentation of biomass or from genetically modified plants (PHA) that is by biomass monomer synthesis (PLA). Fourth group are polyesters completely synthesised in petrochemical process, like polycaprolactones (PCL), polyesteramides (PEA) and aliphatic oraromatic copolyesters (Stevens 2021) [25]. There are two raw material sources for synthesis of biodegradable matrices which are natural and synthetic (Table 2).

Table 2: Bases of natural and synthetic biodegradable polymer matrix

Natural	Synthetic
1. Polysaccharides	1. Poly(amides)
• Starch	2. Poly(anhydrides)
• Cellulose	3. Poly(amide-enamines)
• Chitin	4. Poly(vinyl-alcohols)
2. Proteins	5. Poly(vinyl-acetate)
• Collagen/gelatine	6. Polyester
• Casein	• Polyglycolic acid
• Albumin	• Polylactic acid
• Fibrogene	• Polycaprolactones
• Silk	• Poly ortho esters
3. Polyesters	7. Poly(ethylene-oxides)
• Polyhidroxyalkanoates	8. Polyphosphates
4. Other Polymers	
• Lignin	
• Lipids	
• Shellac	
• Natural Rubber	

Source: Stevens 2021 [25]

4. Application of Natural Fibre Reinforced Biocomposites

A reinforced composite made from natural fibre can partially replace wood, plastic, and traditional metallic and non-metallic materials in household furniture applications. Sapuan and Maleque (2005) [20] created a home telephone stand using biocomposites reinforced by naturally woven banana fabric. The most practical option seems to be natural fibre reinforced composites, which are used in place of raw materials to create ply wood for both interior and exterior household uses (Khalil *et al.* 2010) [9]. These composites have also been employed to create solid fuel briquettes, and their physical performance under ambient settings demonstrates good dimension stability. Rahman *et al.* (2008) [19] stated that rice husk-reinforced high-density biocomposites are fabricated by the injection molding process and thus stress on hollow and solid window frames was analyzed. These biocomposites are appropriate for the production of window frames because their hollow designs have less warpage during cooling and are thus low-cost to produce. As natural fibres are available in plenty and are very low cost materials, they are usually used in building, packaging, automobile, storage devices, and construction industries for manufacturing of panels, ceilings, and partition boards (Mishra *et al.* 2009) [13].

5. Conclusion

The current environmental crisis has sparked interest in the creation of more environmentally friendly materials. In this context, natural biodegradable materials used in biocomposites are now taking over the market and dominating it because they have unexpected environmental benefits. In order to overcome the material's mechanical shortcomings, particularly its low flexural strength and brittleness, fibres must be included in the creation of composites. These fibres can be combined with a number of matrix that protect them from the environmental and physical damage and also contributes largely to the properties and applications of the composites.

6. Future scope

a) It is worthwhile to continue researching the innovative biofibre for the composite construction in order to effectively incorporate it into the composite matrix and prevent fibre variability.
b) Combat moisture absorption linked to long-term durability (temperature, humidity, and UV radiation), fibre and matrix alteration, fire resistance, characteristics, and durability associated to particular final products.
c) Different biomatrix can be used with the reinforcing fibres in order to produce composites with required properties and applications.

7. References

1. Anonymous. Matrix materials; c2015. Retrieved from https://www.unsw.edu.au/science/our-schools/materials/engage-with-us/high-school-students-and-teachers/online-tutorials/composites/composites-structure/matrixmaterials#:~:text=There%20are%20three%20main%20types,type%20are%20polymer%20matrix%20composites on October 22, 2022.
2. Bhargava AK. Engineering materials: polymers, ceramics and composites. PHI Learning Pvt. Ltd, New Delhi; c2020.
3. Campbell FC. Structural composite materials. ASM International, Almere, Netherlands; c2010.
4. Chawla KK. Composite materials: science and engineering. Springer Science and Business Media; c2012.
5. Dedov AG, Ivanova EA, Sandzhieva DA, Lobakova ES, Kashcheeva PB, Kirpichnikov MP, *et al*. New materials and ecology: biocomposites for aquatic remediation. Theor Found Chem Eng. 2017;51(4):617-630.
6. El-Galy IM, Ahmed MH, Bassiouny BI. Characterization of functionally graded Al-SiCp metal matrix composites

manufactured by centrifugal casting. Alex Eng J. 2017;56(4):371-381.
7. Fitzgerald A, Proud W, Kandemir A, Murphy RJ, Jesson DA, Trask RS, *et al*. A life cycle engineering perspective on biocomposites as a solution for a sustainable recovery. Sustainability 2021;13(3):1160-1170.
8. Joshi SV, Drzal LT, Mohanty AK, Arora S. Are natural fibre composites environmentally superior to glass fibre reinforced composites? Composites, 2004;Part A 35(2):371-376.
9. Khalil HA, Fazita MN, Bhat AH, Jawaid M, Fuad NN. Development and material properties of new hybrid plywood from oil palm biomass. Mater Des. 2010;31(1):417-424.
10. Kumlutas D, Tavman IH, Coban MT. Thermal conductivity of particle filled polyethylene composite materials. Compos Sci Technol. 2003;63(1):113-117.
11. Kurki NB, Satyappa B. Applications of biocomposite materials based on natural fibres from renewable resources: a review. Sci Eng Compos Mater. 2016;23(2):123-133.
12. Martina RA, Oskam IF. Practical guidelines for designing recycling, collaborative, and scalable business models: a case study of reusing textile fibres into biocomposite products. J Clean Prod. 2021;318(5):128-134.
13. Mishra SC. Low cost polymer composites with rural resources. J Reinf Plast Compos. 2009;28(18):2183-2188.
14. Mngomezulu ME, John MJ, Jacobs V, Luyt AS. Review on flammability of biofibres and biocomposites. Carbohydr Polym. 2014;111(2):149-182.
15. Nair AB, Joseph R. Eco-friendly biocomposites using natural rubber (NR) matrices and natural fibre reinforcements. In Chemistry, Manufacture and Applications of Natural Rubber; Woodhead Publishing: Sawston, UK; c2014.
16. Nielsen. Composite materials. Springer; c2005.
17. Petar A, Victor S, Nikolay N. Utilization of agricultural waste and wood industry residues in the production of natural fibre-reinforced composite materials. Wood Sci Technol. 2017;6(1):64-71.
18. Pilla S. Handbook of bioplastics and biocomposites engineering applications. John Wiley & Sons, USA; c2011.
19. Rahman WA, Sin LT, Rahmat AR. Injection moulding simulation analysis of natural fibre composite window frame. J Mater Process Technol. 2008;197(1-3):22-30.
20. Sapuan SM, Maleque MA. Design and fabrication of natural woven fabric reinforced epoxy composite for household telephone stand. Mater Des. 2005;26(1):65-71.
21. Sharma AK, Bhandari R, Aherwar A, Rimasauskiene R. Matrix materials used in composites: a comprehensive study. Mater Today: Proc. 2020;21(3):1559-1562.
22. Sheldon RA. Biomass processing with biocatalysis. Biomass Valorization: Sustainable Methods for the Production of Chemicals, 2021, 113-146.
23. Sheldon RA, Norton M. Green chemistry and the plastic pollution challenge: towards a circular economy. Green Chem. 2020;22(4):6310-6322.
24. Sreekumar PA. Matrices for natural fibre reinforced composites. In: properties and performance of natural-fibre composite, K. L. Pockering (ed.), Woodhead Publication Limited, Birmingham, UK; c2008. p. 67-126.
25. Stevens ES. Green plastics. Princeton University Press, USA; c2021.