# CHAPTER 8

# PROCESSING AND CHARACTERIZATION OF BIOMASS-BASED WOOD COMPOSITES

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## Abstract

Wood composites are gaining increased attention as sustainable alternatives to traditional building materials. This chapter explores the processing and characterization of biomass-based wood composites. We discuss various methods of processing biomass materials, including particle preparation, resin formulation, and composite manufacturing techniques. Additionally, we delve into the characterization techniques used to evaluate these composites' physical, mechanical, and thermal properties. The chapter aims to provide insights into the production and evaluation of biomass-based wood composites, highlighting their potential for a wide range of applications.

## 8.1 Introduction

Wood composites are engineered materials that combine wood fibers or particles with a matrix material to create products with enhanced properties (Sormunen and Kärki, 2019, Khoaele et al., 2023b). Biomass-based wood composites utilize renewable and sustainable resources, making them environmentally friendly alternatives to conventional composites (Das et al., 2022, Shukla et al., 2021, Chang et al., 2021, Gbadeyan et al., 2021). This chapter focuses on the processing and characterization aspects of biomass-based wood composites, exploring the steps involved in their production and the methods used to evaluate their performance. Wood composites have recently gained significant attention as sustainable alternatives to conventional building materials (Jones et al., 2020). With growing concerns about deforestation and environmental sustainability, biomass-based wood composites offer a promising solution utilizing renewable and abundant resources (Sanyang et al., 2016, Senthil and Lee, 2021). These composites combine wood fibers or particles with a matrix material to create products with enhanced properties, such as improved strength, durability, and dimensional stability.

Biomass-based wood composites can be produced using various biomass materials, including wood chips, sawdust, agricultural residues, and recycled wood fibers (Hua et al., 2022, Procházka et al., 2021, Braghiroli and Passarini, 2020). These materials are often sourced from forestry operations, sawmills, and agricultural industries, reducing the reliance on virgin timber and minimizing waste. The development and utilization of biomass-based wood composites align with the principles of the circular economy, as they enable biomass valorization by transforming it into high-value products (Braghiroli and Passarini, 2020). By diverting biomass from traditional disposal methods, such as burning or landfilling, these composites contribute to waste reduction and the efficient use of natural resources.

The processing and characterization of biomass-based wood composites are crucial steps in their production (Jawaid et al., 2017, Jayamani et al., 2014). Effective processing techniques ensure the proper preparation and compatibility of the biomass materials with the matrix material, enabling uniform dispersion and optimal bonding within the composite structure. Characterization techniques allow for the evaluation of the composite's performance and properties, ensuring they meet the desired requirements for specific applications (Jayamani et al., 2014).

This chapter explores biomass-based wood composites' processing and characterization aspects in depth. It delves into the methods used to process biomass materials, including mechanical size reduction, chemical treatments, and drying. It also discusses resin formulation, where selecting appropriate resins, additives, and fillers plays a critical role in achieving the desired properties of the composite. Furthermore, the chapter covers various manufacturing techniques employed to fabricate biomass-based wood composites, such as compression molding, extrusion, injection molding, and hot-pressing.

Additionally, the chapter addresses the characterization techniques used to assess the physical, mechanical, and thermal properties of biomass-based wood composites. These techniques provide valuable insights into the composite's strength, stiffness, impact resistance, moisture absorption, thermal conductivity, and other essential properties. By understanding these properties, manufacturers can make informed decisions about the suitability of biomass-based wood composites for specific applications.

Overall, the processing and characterization of biomass-based wood composites are crucial for their successful implementation in various industries. These composites offer a sustainable alternative to traditional building materials, supporting the transition towards a more environmentally friendly and resource-efficient future. By exploring the intricacies of processing and characterization, this chapter provides valuable insights into the production and evaluation of biomass-based wood composites, fostering their broader adoption and utilization.

## 8.2 Processing of Biomass Materials

The first step in manufacturing biomass-based wood composites involves processing biomass materials, such as wood fibers or particles. Several techniques are employed to prepare the biomass, including mechanical size reduction, chemical treatment, and drying (Menon et al., 2017, Bhutto et al., 2017). Mechanical size reduction methods, such as milling or grinding, are used to reduce the size of wood particles or fibers to the desired dimensions (Gbadeyan, 2020). Drying the biomass is crucial to reduce its moisture content and ensure uniform dispersion within the matrix (Vo and Navard, 2016, Khoaele et al., 2023b). Processing biomass materials is a critical step in producing biomass-based wood composites. The goal is to prepare the biomass, such as wood fibers or particles, in a form that can be effectively incorporated into the matrix material. Several techniques are employed to achieve this, including mechanical size reduction, chemical treatments, and drying (Vo and Navard, 2016, Khoaele et al., 2023b).

### 8.2.1 Mechanical Size Reduction

Mechanical size reduction methods are commonly used to reduce the size of biomass materials to the desired dimensions, accomplished through milling, grinding, or chopping processes (Gbadeyan et al., 2021, Gbadeyan et al.) The choice of size reduction method depends on the specific requirements of the composite and the desired size and shape of the particles or fibers. For instance, milling often produces fine particles, while chopping or grinding may be employed for coarser fibers (Gbadeyan et al., 2021, Gbadeyan et al., Alshahrani and Prakash, 2022).

### 8.2.2 Chemical Treatments

Chemical treatments can be applied to biomass materials to enhance their compatibility with the matrix material and improve the overall performance of the composite. Alkaline treatments, such as sodium hydroxide or ammonium hydroxide, can remove lignin and hemicellulose from the biomass, resulting in increased surface area and improved bonding with the matrix (Vo and Navard, 2016, Menon et al., 2017, Gbadeyan, 2020). Enzymatic treatments involving cellulase or ligninase enzymes can also break down complex biomass components and enhance the accessibility of fibers or particles.

### 8.2.3 Drying Biomass Materials

Drying biomass materials is essential to reduce their moisture content and ensure uniform dispersion within the matrix material. Excess moisture in the biomass can lead to inadequate resin penetration, poor bonding, and dimensional instability of the final composite (Zhou et al., 2016, Qasim et al., 2020). Drying methods, such as hot air or kiln drying, remove moisture from the biomass while maintaining its structural integrity. Care must be taken to avoid excessive drying, resulting in brittleness or damage to the fibers or particles.

The processing of biomass materials requires careful consideration of factors such as particle size, shape, moisture content, and chemical composition. These factors influence the compatibility between the biomass and matrix material and the resulting composite's mechanical and physical properties. Optimization of the processing parameters is crucial to ensure uniformity and consistency in the performance of biomass-based wood composites (Gbadeyan et al., 2021, Gbadeyan et al., Alshahrani and Prakash, 2022).

In recent years, advances in processing techniques have focused on improving the uniformity and dispersion of biomass materials within the composite (Shen et al., 2020). Novel methods, such as a steam explosion or extrusion, have been developed to enhance the bonding between biomass and matrix materials and improve the overall mechanical properties of the composites (Tiwari et al., 2022, Zhang et al., 2014, Yu et al., 2022, Andrew and Dhakal, 2022). Overall, the processing of biomass materials plays a vital role in the production of biomass-based wood composites. By employing appropriate size reduction techniques, chemical treatments, and drying methods, manufacturers can optimize the compatibility and dispersion of biomass within the matrix, leading to composites with improved properties and broader applications.

## 8.3 Resin Formulation

The matrix material in biomass-based wood composites is typically polymer resin (Khoaele et al., 2023b). The choice of resin depends on the desired properties of the final composite (Gbadeyan, 2020). Commonly used resins include thermosetting resins like phenolic, melamine-urea-formaldehyde, epoxy resins, and thermoplastic resins like polypropylene or polyethylene. The resin formulation involves the selection of appropriate resins, additives, and fillers to achieve the desired mechanical, physical, and thermal properties of the composite. The matrix resin's selection and formulation significantly impact the final composite's performance and properties. Various resins can be used, including thermosetting and thermoplastic resins, each offering unique characteristics and advantages (Khoaele et al., 2023a).

### 8.3.1 Thermosetting Resins

Thermosetting resins, such as phenolic, melamine-urea-formaldehyde, and epoxy resins, are widely used in biomass-based wood composites. These resins undergo a chemical reaction during curing, transforming from a liquid or semi-liquid state into a solid, crosslinked network (Khoaele et al., 2023b, Khoaele et al., 2023a). This crosslinking gives the composite excellent dimensional stability, high strength, and resistance to heat and chemicals. Thermosetting resins are particularly suitable for applications that require high structural integrity and durability, such as construction materials and load-bearing components.

## 8.3.2 Thermoplastic Resins

Thermoplastic resins, such as polypropylene (PP), polyethylene (PE) or polylactic acid (PLA), are also utilized in biomass-based wood composites. Unlike thermosetting resins, thermoplastics soften when heated and solidify when cooled without chemical change (Khoaele et al., 2023b, Khoaele et al., 2023a, Gbadeyan, 2020). This property allows for multiple processing cycles, such as recycling and reshaping. Thermoplastic-based composites offer advantages such as improved impact resistance, flexibility, and ease of processing. They are commonly used in applications with desired flexibility, design freedom, and recyclability, such as automotive components, furniture, and packaging materials.

In resin formulation, additives and fillers are often incorporated to enhance specific properties of the composite. Additives such as coupling agents, antioxidants and flame retardants can be included to improve the adhesion between the biomass and the matrix, enhance the resistance to environmental factors, and meet regulatory requirements (Khoaele et al., 2023b, Khoaele et al., 2023a). Fillers, such as calcium carbonate or talc, can improve dimensional stability, reduce material costs, and modify the physical properties of the composite.

The resin formulation process involves carefully considering several factors, including the compatibility between the resin and the biomass material, the desired mechanical and physical properties of the composite, and the processing requirements (Khoaele et al., 2023b, Khoaele et al., 2023a, Gbadeyan, 2020). The appropriate resin and additives selection depends on the targeted application and the performance criteria that must be met. Furthermore, ongoing research and development efforts aim to improve resin formulations for biomass-based wood composites. Scientists are exploring using bio-based resins derived from renewable sources, such as lignin or tannin, to enhance the sustainability of the composites (Braghiroli and Passarini, 2020). These bio-based resins offer the potential for reduced reliance on petroleum-based materials and provide opportunities for biodegradability and recyclability.

The resin formulation is critical in producing biomass-based wood composites. The matrix resin selection, additives, and fillers influence the composite's mechanical, physical, and environmental performance (Friedrich et al., 2005). The choice of resin depends on the application's specific requirements, such as strength, durability, flexibility, recyclability, and sustainability (Gbadeyan et al., 2022a). Continued research in resin formulation will contribute to developing biomass-based wood composites with improved properties, expanding their potential applications and promoting a greener and more sustainable future (Gbadeyan, 2020)

(Khoaele et al., 2023b, Khoaele et al., 2023a). The manufacturing process of biomass-based wood composites involves combining the processed biomass materials with the resin formulation to create a homogeneous mixture.

## 8.4 Composite Manufacturing Techniques

Once the biomass materials and resin are prepared, the next step is manufacturing the composite. Several techniques can be employed, including compression molding, extrusion, injection molding, and hot-pressing (Walkare et al., 2023, Urquijo et al., 2015). Compression molding involves placing the biomass and resin mixture into a mound and subjecting it to heat and pressure to cure the resin and form the composite. Extrusion and injection molding are continuous processing techniques that enable the production of complex shapes. Hot-pressing involves applying heat and pressure to the mixture to consolidate and cure the composite. Resin formulation is a crucial aspect of biomass-based wood composite production.

### 8.4.1 Various Manufacturing Techniques

Various manufacturing techniques transform this mixture into the desired composite shape. The selection of the manufacturing technique depends on factors such as the composite's intended application, the complexity of the part, and the desired production efficiency. Some commonly used manufacturing techniques for biomass-based wood composites include:

#### 8.4.1.1 Compression Molding

Compression molding is widely employed for producing biomass-based wood composites. It involves placing the biomass and resin mixture into a mound and subjecting it to heat and pressure to cure the resin and form the composite. The mould can be heated using hot plates or a heated press. Compression molding allows to produce composites with complex shapes and precise dimensions. The process offers reasonable control over resin distribution and fiber alignment, resulting in composites with excellent mechanical properties.

### 8.4.1.2 Extrusion

Extrusion is a continuous manufacturing process for producing biomass-based wood composites with a consistent cross-section. The biomass and resin mixture are fed into an extruder, which applies heat and pressure to melt and mix the materials. The molten mixture is then forced through a die to form a continuous profile or shape (Walkare et al., 2023, Urquijo et al., 2015). Cooling and solidification occur after extrusion, resulting in a solid composite product. Extrusion enables the production of composites with consistent dimensions and high production rates, making it suitable for applications such as decking, fencing, and profiles.

### 8.4.1.3 Injection Molding

Injection molding is another continuous processing technique for biomass-based wood composites (Li et al., 2020). It involves melting the resin and mixing it with the biomass in an injection molding machine. The molten mixture is then injected into a mould under high pressure, where it cools and solidifies to form the final composite product. Injection molding offers precise control over part dimensions, high production rates, and the ability to produce intricate shapes. It is commonly used for manufacturing small to medium-sized parts, such as furniture components, consumer goods, and automotive interior parts (Coats et al., 2008).

### 8.4.1.4 Hot-Pressing

Hot-pressing is a manufacturing technique for producing flat panels and boards from biomass-based wood composites (Urquijo et al., 2015). The process involves placing the biomass and resin mixture between two heated platens and applying pressure to consolidate and cure the composite. Hot-pressing is typically conducted in a hydraulic or mechanical press (Singh et al., 2019). The combination of heat and pressure ensures proper resin curing and bonding of the biomass particles or fibers. This technique is commonly used for manufacturing plywood, particleboard, and medium-density fiberboard (MDF).

Each manufacturing technique has its advantages and considerations. Factors such as production efficiency, complexity of the desired shape, material distribution, and cost must be considered when selecting the appropriate technique for a specific application (Ngo et al., 2018). Optimization of manufacturing parameters, such as temperature, pressure, and curing time, is crucial to achieve the desired composite properties and ensure consistent quality throughout production. Furthermore, advancements in manufacturing techniques are ongoing to improve the efficiency and versatility of biomass-based wood composite production. Novel methods, such as 3D printing and continuous lamination processes, are being explored to expand the design possibilities and reduce waste in composite manufacturing (Ngo et al., 2018).

Inherently, selecting an appropriate manufacturing technique for biomass-based wood composites depends on various factors (AL-Oqla et al., 2017). The chosen technique should allow for the effective incorporation of biomass and resin while enabling the production of composites with the desired shape, dimensions, and properties (Tanasă et al., 2020). By employing suitable manufacturing techniques, biomass-based wood composites can be efficiently produced for a wide range of applications, contributing to sustainable and eco-friendly material solutions.

## 8.5 Characterization of Biomass-Based Wood Composites

Characterization of biomass-based wood composites is essential to evaluate their performance and ensure compliance with specific requirements. Various techniques assess the composites' physical, mechanical, and thermal properties. Physical properties such as density, moisture content, and dimensional stability are determined using standardized methods (Han et al., 2020, Camuffo, 2018, Gbadeyan et al., 2021, Gbadeyan, 2020). Mechanical properties, including tensile strength, flexural strength, and impact resistance, are evaluated using tensile, flexural, and impact testing. Thermal properties, such as thermal conductivity and heat resistance, are determined using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) (Gbadeyan, 2020, Ford and Mann, 2012). Characterization of biomass-based wood composites is essential to evaluate their performance, ensure quality control, and facilitate material selection for specific applications. Various techniques assess these composites' physical, mechanical, and thermal properties. The characterization process provides valuable insights into the composite's behavior under different conditions and helps optimize its performance.

### 8.5.1 Physical Properties

Physical properties of biomass-based wood composites include density, moisture content, and dimensional stability. Density is typically measured using standard methods such as the ASTM D792 test (Han et al., 2020). Moisture content is determined by weighing the sample before and after drying, following standardized procedures like ASTM D4442 (Camuffo, 2018). Dimensional stability refers to the composite's ability to maintain its shape and size under varying environmental conditions and is evaluated through tests such as water absorption and swelling measurements.

### 8.5.2 Mechanical Properties

Mechanical properties are crucial for assessing biomass-based wood composites' strength, stiffness, and durability. Tensile testing, performed according to standards like ASTM D638, measures the material's resistance to forces applied in tension (Hambali et al., 2017). Following ASTM D790, Flexural testing evaluates the composite's resistance to bending or flexing (Vidakis et al., 2019). Impact resistance testing, conducted using methods such as the Izod or Charpy test, assesses the material's ability to withstand sudden impacts according to ASTM D6110-10. Other mechanical tests, including compression, shear, and hardness tests, may also be performed depending on the application's specific requirements (Gbadeyan, 2020).

### 8.5.3 Thermal Properties

Thermal properties characterize the behavior of biomass-based wood composites under different temperature conditions. Thermal conductivity, which measures the material's ability to conduct heat, is evaluated using techniques such as the ASTM C518 test (Trofimov et al., 2020). Heat resistance and thermal stability can be determined through thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). TGA measures the weight loss of the composite as a function of temperature, providing information about its thermal decomposition behaviors (Gbadeyan et al., 2022b). DSC measures changes in heat flow, allowing the determination of melting, crystallization, and glass transition temperatures (Ford and Mann, 2012).

### 8.5.4 Microstructural Analysis Techniques

Microstructural analysis techniques such as investigation under scanning electron microscopy (SEM), and optical microscopy, provide valuable insights into the composite's internal structure, fiber/ matrix interface, and distribution of biomass particles or fibers (Udayakumar et al., 2021, Costa et al., 2023). SEM allows for high-resolution imaging, enabling the observation of the composite's morphology, fiber orientation, and any defects or failures. Optical microscopy provides a broader view of the composite, assisting in the assessment of the dispersion of biomass within the matrix and the overall composite quality (Parveen et al., 2017).

### 8.5.5 Durability and Environmental Testing

Durability and environmental testing assess the composite's performance under specific conditions such as moisture, UV exposure, or chemical exposure. Accelerated weathering tests, such as ASTM G155 or ASTM D2244, simulate long-term exposure to UV radiation and evaluate the composite's resistance to degradation (Elsafty and Hsuan, 2020, González-López et al., 2020). Moisture resistance testing, including water immersion or accelerated ageing, examines the composite's ability to withstand moisture absorption, swelling, and dimensional changes. Chemical resistance testing assesses the composite's behavior when exposed to specific chemicals or environments relevant to the application.

By employing these characterization techniques, manufacturers and researchers can comprehensively understand the performance and properties of biomass-based wood composites. This knowledge aids in material development, quality control, and selecting appropriate composites for specific applications. Additionally, standardized characterization methods contribute to accurate comparisons between different composites and promote biomass-based wood composite technology advancement (Ead et al., 2021, Mohanty et al., 2022).

## 8.6 Applications of Biomass-Based Composites

Wood composites biomass-based wood composites have a wide range of applications, including construction, furniture, automotive, and packaging industries (Ead et al., 2021, Mohanty et al., 2022, Gbadeyan, 2020). These composites can be used to manufacture structural components, such as beams, panels and boards, as well as non-structural elements, like decorative items and furniture (Gbadeyan, 2020, Fernholz and Bowyer, 2015). Also, biomass-based wood composites can be used for packaging materials, such as pallets and crates, due to their high strength and durability. The automotive industry also benefits from using biomass-based composites for interior components, such as door panels and dashboards, as they offer lightweight alternatives with good mechanical properties (Gbadeyan, 2020). Biomass-based wood composites have a wide range of applications across various industries. Their unique combination of renewable biomass resources and enhanced properties makes them attractive alternatives to traditional materials. These are some unique applications:

### 8.6.1 Construction and Building Materials

Biomass-based wood composites find extensive use in the construction industry. They can be used to manufacture structural components such as beams, columns, and panels (Bhagia et al., 2021, Mohanty et al., 2022). These composites offer excellent strength, durability, and dimensional stability, making them suitable for load-bearing applications. Additionally, they can be used in wall panels, flooring, and roofing materials, providing eco-friendly alternatives to conventional materials like concrete, steel, and traditional wood products (Mohanty et al., 2022).

### 8.6.2 Furniture and Interior Design

The furniture industry benefits significantly from using biomass-based wood composites. They are used to produce furniture components, such as table tops, cabinets, and decorative items (Gbadeyan, 2020, Fernholz and Bowyer, 2015). These composites offer a wide range of design possibilities due to their ability to be molded into intricate shapes. They provide the aesthetics of natural wood while offering enhanced durability and resistance to warping, cracking, and moisture absorption (Gbadeyan, 2020, Fernholz and Bowyer, 2015).

### 8.6.3 Automotive Components

Biomass-based wood composites are increasingly used in the automotive industry for interior components. They are employed in the manufacturing of door panels, seat backs, dashboards, and various trim parts (Ead et al., 2021, Mohanty et al., 2022, Gbadeyan, 2020). These composites offer weight reduction, which contributes to improved fuel efficiency and reduced emissions. They also provide excellent acoustic and thermal insulation, enhancing vehicles' comfort and performance.

### 8.6.4 Packaging Materials

Biomass-based wood composites are suitable for producing packaging materials such as pallets, crates and containers (Mohanty et al., 2022, Gbadeyan et al., 2022b, Khoaele et al., 2023b). These composites offer high strength, durability, and moisture resistance, making them ideal for transporting and storing goods. Moreover, they provide a sustainable alternative to traditional packaging materials like plastic and plywood.

### 8.6.5 Consumer Goods

Biomass-based wood composites also find application in a wide range of consumer goods. They are used to produce household items like kitchenware, toys and decorative items (Gbadeyan, 2020, Yeh et al., 2013). These composites offer the aesthetics of natural wood, along with improved strength and durability, making them an appealing choice for consumer products.

### 8.6.6 Environmental Solutions

Biomass-based wood composites contribute to environmental sustainability by utilizing renewable resources and reducing waste. They enable the valorization of biomass materials that would otherwise be discarded or burned, thereby minimizing the carbon footprint. Additionally, these composites can be recycled or reused, reducing environmental impact (Khoaele et al., 2023b, Khoaele et al., 2023a). It is worth noting that the applications mentioned above are not exhaustive, and the versatility of biomass-based wood composites continues to expand. Ongoing research and development efforts aim to explore new application areas and optimize the properties of these composites for specific industry needs. As sustainability and eco-consciousness drive material choices, biomass-based wood composites are poised to play an increasingly significant role in various industries.

## 8.7 Future Perspectives and Challenges

The field of biomass-based wood composites continues to evolve, driven by the need for sustainable materials and the advancements in processing and characterization techniques (Khoaele et al., 2023b, Andrew and Dhakal, 2022). Future research aims to enhance the properties of these composites by developing novel processing methods, optimized resin formulations, and an improved understanding of the interactions between biomass and matrix materials (Friedrich et al., 2005, Gbadeyan, 2020). Furthermore, efforts are underway to improve biomass-based composites' recycling and disposal methods, ensuring their end-of-life sustainability. Challenges in the processing and characterizing of biomass-based wood composites include the variability of biomass feedstock, achieving consistent dispersion of biomass particles or fibers in the matrix, and optimizing the curing process to avoid defects and ensure uniform properties (Bhagia et al., 2021). Standardizing testing methods and characterization protocols is crucial for accurately comparing and evaluating biomass-based composites.

The field of biomass-based wood composites holds promising future perspectives as researchers and industries continue to explore their potential. However, several challenges and focus areas must be addressed to advance these composites further and maximize their benefits.

*Enhanced Processing Techniques:* Improving the processing techniques for biomass-based wood composites is crucial for better dispersion and bonding between the biomass particles or fibers and the matrix. Innovative methods, such as steam explosion, ultrasonication, or plasma treatment, can be explored to enhance the compatibility and adhesion at the interface (Bhagia et al., 2021, Liu et al., 2019). These techniques can help optimize the processing parameters to achieve uniformity, minimize defects, and enhance the overall performance of the composites.

### 8.7.1 Sustainable Resin Formulation

Further research is needed to develop sustainable, eco-friendly resin formulations for biomass-based wood composites. Using bio-based resins derived from renewable sources, such as lignin or tannin, can enhance sustainability and reduce the reliance on petroleum-based materials (Antov et al., 2020). The development of new resin formulations should focus on maintaining or improving the mechanical and physical properties of the composites while considering aspects such as biodegradability, recyclability, and reduced environmental impact (Urquijo et al., 2015, Gbadeyan, 2020).

### 8.7.2 Improved Durability and Weathering Resistance

Ensuring biomass-based wood composites' long-term durability and weathering resistance is crucial for their wide-scale adoption. Research should focus on enhancing their resistance to moisture absorption, UV degradation, and other environmental factors (Elsafty and Hsuan, 2020, González-López et al., 2020). Developing effective coating systems, surface treatments, and additive incorporation can help improve the composites' durability and extend their service life.

### 8.7.3 Standardization and Certification

Establishing standardized testing methods, performance criteria, and certification processes for biomass-based wood composites is essential for quality assurance and market acceptance (Rabbat et al., 2022, Kusuma et al., 2022). Standardization enables accurate comparison of composites, facilitates regulatory compliance, and ensures consistent performance across various applications (Bhuiyan et al., 2021). Collaboration among researchers, manufacturers, and regulatory bodies is necessary to develop comprehensive standards and certification schemes for these composites.

### 8.7.4 Recycling and End-of-Life Management

Effective recycling and end-of-life management strategies for biomass-based wood composites are crucial to maximize their sustainability (Rabbat et al., 2022, Shanmugam et al., 2021). Research efforts should focus on developing efficient recycling methods that recover valuable materials from the composites while minimizing environmental impact. Additionally, exploring sustainable disposal options, such as composting or energy recovery, can help address the waste management challenges associated with these composites (Rabbat et al., 2022, Shanmugam et al., 2021).

### 8.7.5 Cost-Effectiveness and Market Adoption

The cost-effectiveness and market competitiveness of biomass-based wood composites play a significant role in their widespread adoption (Kusuma et al., 2022, Antov et al., 2020, Andrew and Dhakal, 2022). Efforts should be made to optimize production processes, reduce material costs, and increase manufacturing efficiency. Collaborative initiatives between researchers, industries, and government bodies can promote investments, innovation, and market acceptance of biomass-based wood composites. By addressing these challenges and focusing on future perspectives, biomass-based wood composites can continue to evolve as sustainable alternatives to conventional materials. Advancements in processing techniques, resin formulation, durability, recycling, and market adoption will expand their applications and foster a more sustainable and environmentally friendly material-use approach.

## 8.8 Conclusion

Biomass-based wood composites offer a sustainable and eco-friendly alternative to traditional building materials. These composites' processing and characterization involve carefully selecting and preparing biomass materials, resin formulation, and manufacturing techniques. Characterization techniques help evaluate the composites' physical, mechanical, and thermal properties, ensuring their performance and suitability for various applications. Continued research and development in this field hold the potential for further advancements in biomass-based wood composites, contributing to a greener and more sustainable future.

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