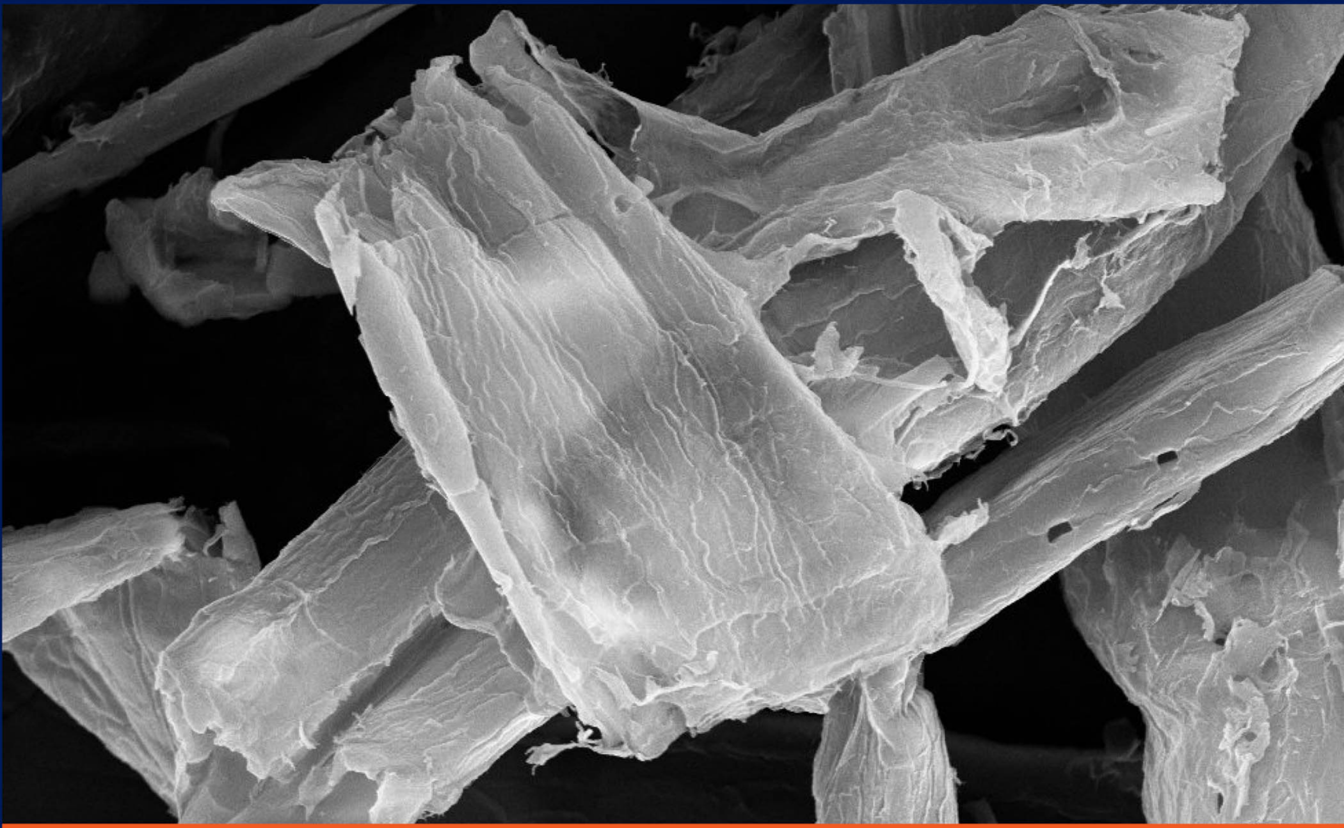
CELLULOSE

Development, Processing, and Applications



Edited by

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Cellulose

Cellulose: Development, Processing, and Applications covers topics related to advanced cellulose development and processing, as well as the utilization of major agricultural and biomass waste. It discusses the utilization of cellulose from other agricultural and biomass materials, including oil palm biomass, bamboo, and other non-wood forest products in emerging areas. It covers the treatments used to improve the quality of cellulosic materials in specific applications. Following that, the book delves into the use of cellulosic materials in the application of composting science and technology.

Features:

- Delves into the specific agriculture waste/biomass waste materials used for the advanced cellulose-based production
- Outlines the potential use of the covered materials for energy production and other emerging applications
- Includes composting technology and processes using cellulosic materials
- Overviews industrial applications of cellulose from agricultural waste/biomass waste and composting technology
- Discusses the main agricultural waste/biomass in the Asian region

This book is aimed at researchers and graduate students in chemical engineering, bioprocessing, composites, and biotechnology.

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We dedicate this book to our family, friends, and researchers who are always passionate about sharing, crowdsourcing, and gaining knowledge to build a sustainable future.

Contents

Preface

Cellulose, as a next-generation material, will evolve in terms of its research and developments, spurred on by technological innovation. Cellulose is used in a wide range of applications, including paper, textiles, construction materials, food additives, bulking agents, and pharmaceuticals. It is also a promising renewable resource for the production of biofuels, bioplastics, compost, and other sustainable materials. The adoption of the Sustainable Development Goals as a vision has established a framework toward a more sustainable future. Given that it can be efficiently recovered not just from wood but also from agricultural waste or lignocellulosic materials, it looks promising as a sustainable resource with a low environmental impact. This eco-friendly material has the potential to address resource depletion experienced by many sectors. However, recent advances in cellulose chemistry and processing have opened up new opportunities for its use in emerging technologies, such as biocomposites, energy storage, and the biomedical field.

The book *Cellulose: Development, Processing, and Applications* aims to provide an in-depth overview of the current knowledge of cellulose and its many promising applications. This book covers a wide range of issues related to cellulose, from its molecular structure and synthesis through its processing into various forms, such as all-cellulose and nanocellulose, and its regeneration, as well as its diverse applications in different industries. Future research directions are also outlined, along with a discussion of current issues and potential solutions associated with the development of cellulose-based products. It also features a variety of processing methods, including mechanical and thermal conversion, as well as chemical and enzymatic modification. The book also delves into the various applications of cellulose, including its use in paper, textiles, construction materials, automotive applications, leather processing, and absorption materials in wastewater. It explores the emerging trends in cellulose research, including new methods for cellulose regeneration. It highlights emerging cellulose-relevant research such as new cellulose production methods, the development of innovative cellulose-based products, and the implementation of cellulose into new technologies.

The chapters in this book have been written by experts in the field of cellulose research, including scientists from academia, industry, and government research organizations. The contributors have been invited based on their expertise and their contributions to the field of cellulose research. It will be of interest to researchers working on cellulose-based materials and their applications, as well as its potential for new and innovative applications. The book will also be a valuable resource for engineers, technologists, and students in materials science, chemistry, biology, and related fields.

We hope that this book will not only contribute to the corpus of cellulose research and societal knowledge but also benefit future generations who aspire to enhance and improve the way they live through sustainable living. We extend our gratitude to the reviewers: AA Rushdan, AH Abdul Hair, AZM Asa'ari, A Ahmad, A Embrandiri, JG Boon, CK Saurabh, HK Abdul Razak, MH Mohd Roslim, J Lamaming, MN Islam, CH Ng, NI Saharudin, R Alkarimiah, SF Mhd Ramle, S Saallah, T Simioni, TNH Tuan Ismail, and ZA Abdul Hamid for their valuable comments and suggestions for the chapters in this book.

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1 Introduction

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CONTENT

Cellulose, as the main biopolymers derived from either wood or lignocellulosic materials, can be utilized in diversified products in various applications, including the energy, food and beverage industries, pharmaceutical and biomedical fields, pulp and paper industries, electric and electronic industries, as well as construction. In a report on the cellulose market, Pulidindi and Prakash of Future Business Insights (2022) estimated that the market was worth USD 219.53 billion in 2018 and that it would expand by 4.2% between 2018 and 2026 to reach USD 305.08 billion. Growing consumer demand and the development of cellulose usage and its derivatives boost increased production. Technology and engineering evolution have prompted the advanced development of new methods, inventions as well as new products which are greener and more sustainable. For example, food and beverage applications are being driven by rising demand for processed foods such as ready-to-eat meals and bakery products. Furthermore, a shift in consumer preference for plant-based ingredients in personal care and cosmetics is spurring market product development. This has led to the introduction and usage of sustainable non-wood-based alternatives made from agricultural waste. This lignocellulosic biomass includes oil palm fibers, rice husks and stalks, banana stems, bamboo, corn stalks, walnut shells, kenaf, bagasse, hemp fibers, and others.

In this book, a few lignocellulosic biomasses development, processing method, and application of cellulose have been highlighted. Among them are bamboo, oil palm wastes, including empty fruit bunches (EFB) and palm oil mill effluent (POME), allium (onion) peels, as well as sugarcane bagasse. This cellulose-rich material can be processed further using a variety of processing methods to produce desired end products. Thermochemical, biochemical, chemical, and bioconversion processes can convert lignocellulosic materials into bioenergy and biofertilizer. The isolation process of lignocellulosic materials into cellulose and nanocellulose includes pretreatment, chemo-mechanical, mechanical, chemical, liquefaction, and enzymatic processes. The properties of the produced cellulose and nanocellulose can be tailored to specific applications, such as biomaterials manufacturing, leather production, paper production, gels, biomedical applications, and bioadsorbent for wastewater treatment and animal waste.

With the right processing technologies and improvements, the potential of bamboo is unlimited (Lamaming et al., 2022). Bamboo lignocellulosic biomass has a lot of potential as a fossil fuel substitute. Bamboo biomass can be converted in a variety of methods (thermoelectric or biological conversion) to provide a variety of energy products (charcoal, syngas, and biofuels) that can be used as alternatives to currently available fossil fuels. Comparing bamboo biomass to other renewable resources reveals that it has both benefits and limitations. Compared to other biomass feedstocks, it has improved fuel properties and is appropriate for both thermodynamic and biochemical routes. Bamboo biomass has limitations related to the establishment, logistics, and land occupation. If poorly managed, it can also have detrimental effects on the environment, so choosing bamboo as an energy-specific feedstock requires careful consideration to avoid or reduce any potential concerns. The energy requirements cannot be met entirely by biomass from bamboo. To fully realize

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their potential and deliver a sustainable energy supply, they must be combined with other sources. Chapter 2 explored more on the suitability of bamboo biomass as an energy source as well as process of recovering energy in bamboo biomass.

Oil palm is an essential crop commodity in Malaysia, and one of the world's major manufacturers of items derived from oil palm. The by-products of oil palm trees include a wealth of biomass resources, which enables them to be put to a variety of further productive uses. These include the production of biodiesel, palm composite, pulp, and paper. Oil palm biomass is an intriguing option for high biorefinery production efficiency because of its high cellulose content. In order to successfully execute a circular economy over the long term, biorefineries are a necessary component. They must be created extensively and reclaimed as building blocks from items that have been converted because they are dependent on renewable resources. The utilization of lignocellulosic biomass as a feedstock results in significant value addition and is an essential component of a bio-based economy. The separation of the substrate specificity of biomass enables the production of distinct product flows that were previously conceivable. Even though biorefineries investigate biochemical, morphological, and physiological processes to perform fractionation, hydrolysis, and fermentation, the amount of fresh water that is used raises worries about the quality of the water as well as economic costs. In order for biorefineries to become financially and environmentally sustainable systems, it is vital for these facilities to implement technologies that make use of non-potable resources for biomass. In order to reduce the amount of fresh water needed, efforts are being undertaken to switch to using salt water instead. Therefore, Chapter 3 delves into a comprehensive analysis of biorefineries that are supported by salt water, with an emphasis on the transformation of lignocellulosic biomass into biofuel and other value-added products.

Production of biofuel from renewable resources has gained great attention as a potential candidate to replace fossil fuels partially or completely as transportation fuels. Due to its sugary structure, cellulose has the potential to be used for biofuel production, which requires the depolymerization and isolation of smaller sugar units that could then be transformed into fuel. Production of biofuels such as biogas, bioethanol, biodiesel, and biogas can be carried out through different pathways, namely biochemical and thermochemical. Currently, both technologies are commercially available for producing biofuel, and additional research and development are being conducted to reduce the delivered cost of biofuels. To ensure the feasibility of biofuel production, selecting the most suitable technology that is eco-friendly, has less energy consumption, and is cost-effective is among the issues that need consideration. Furthermore, the biofuel production process through biochemical and thermochemical pathways can also be influenced by the type of feedstock used for the processes. Thus, Chapter 4 presents the technologies involved in the production of biofuel through current thermochemical (pyrolysis, gasification, and pyrolysis) and biochemical technologies. This chapter also describes the technological development of biofuels (bioethanol, biobutanol, liquid fuel, solid biofuel, and syngas) from different types of feedstocks.

Apart from an energy source, the enormous amount of biomass produced by the oil palm fields and mills, where it produces a large amount of lignocellulosic biomass such as oil palm trunks, oil palm fronds, EFB, palm-pressed fibers, palm shells, and palm oil mill effluent (POME), can be used as biofertilizer through composting. Composting is a widely adopted way to transform agricultural waste into organic fertilizer. This material contains a high concentration of cellulose, hemicellulose, and lignin, and its degradation affects composting efficiency (Liu et al., 2022). The oil palm biomass also contains a high concentration of nutrients, and the nutrient composition could be used as biocompost and organic fertilizer, assisting in soil conditioning, and reducing the use of inorganic fertilizer in agriculture sectors while also reducing environmental impact. The high amount of biomass generated in oil palm fields and mills is a major concern because it leads to the bioconversion of biomass into fertilizer as part of their waste management strategy, which helps reduce waste discharge into rivers while restoring nutrients to the plant nutrition cycle. Chapter 5 provides an extensive review of the latest updates on the conversion of different types of waste from the palm oil industry into fertilizer in Malaysia.