Preface

The editors are pleased to present the book *Biodegradable Composites: Materials, Manufacturing and Engineering* under the book series Advanced Composites. The book title was chosen as it depicts upcoming trends in composite materials for the next decade. This book is a compilation of different biodegradable and natural composites being used as well as achievements, progress, and recent developments that are being made with them.

In the material science and engineering world, most researchers often refer to pivotal eras in human history by the materials that dominated them – most notably, starting from the Stone Age, then Bronze Age, and the Iron Age. All these periods lasted for a long period of time. Since two centuries ago, the development and discovery of cement (1824), carbon fiber (1879), fiber glass (1938), polyester (1941), and nanostructural materials like the fullerence molecule (1985) and carbon nanotubes (1991) has revolutionized new research focuses on designing new structural materials with better properties and qualities, for different kinds of engineering applications.

Over the past 50 years composite materials have grown rapidly. Due to its versatility, the volume and number of areas of use of composite materials have increased constantly, developing new solutions in order to improve product quality and attractiveness for new markets. They are no longer the privilege of the aerospace or defense industry or even high-value goods. They have made way to become medium for achieving high structural applications at a low cost and are evidently present all around us. Initially usage of the same was to achieve increased strength and stiffness properties in comparison to classical materials wherein these properties could not be improved further. From this point of view it is understood that the maximum efficiency of the reinforcement of a certain material is obtained by introducing some reinforcement elements in its structure. Representing the most well-known category and marking the beginning of the industrial application of the new materials, the polymeric composites were mainly considered in the form of polymer matrices reinforced with fibers or fillers. As a result of using high-performance fibers, polymeric composites are continuously replacing traditional materials in all domains. The unique properties of the polymeric materials as well as the possibility of their adaptation to the applicative needs have dominating factor for their usage in all the domains of human activity and industrial applications. However, due to the shortage of natural resources, such as fossil fuels, many countries have been striving for better alternatives to use renewable resources for new material development and energy harvesting.

Thus, the return to nature, both through the processes of obtaining polymers from renewable raw materials and by inducing their end-of-life biodegradability, is the strategy to build the sustainability of nowadays society. The only solution to meet material needs is to obtain synthetic materials to replace natural materials

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and whose production can be adjusted as needed. A variation of synthetic materials that has conquered all current fields of activity, through the extraordinary ability to adapt their properties to the applicative requirements, is the composite polymeric materials.

Mankind has realized that unless environment is protected and steps are taken to protect it, he himself will be threatened by the pollution by various sources. In tune to this, recently, there has been a rapid growth in research and innovation in the biodegradable and natural composite area. Over the past decade, several studies have been done to look at the possibilities of using natural materials such as plant- or animal-based fibers to mix with different types of soft materials to form a new class of biocomposites. The term "biocomposite" refers to a material which is formed by a matrix and a reinforcement of natural fiber. The matrix can be a polymeric or cementitious material depending on applications. The fiber normally plays a role in taking load while the matrix protects the fiber by holding them together, avoiding environmental degradation, and maintaining the shape of resultant structures. The major purpose of biocomposites is to ensure that the new materials are either recyclable or biodegradable after disposal. The resin is also made of renewable resources, to allow a new composite to be degraded naturally, without the need for extra chemicals or energy to decompose it.

Common types of plant-based fibers are crop fibers which are extracted from cotton, flax, hemp, sisal, or regenerated cellulose materials. Biocomposites made from plant-based fiber are commonly seen in automobile, construction, and some interior components inside aircraft or railway coaches. In fact, plant-based fiber has been commonly used since ancient times; for example, straw was added into mud to make a wall for a house. Animal-based fibers, commonly extracted from spiders, silkworm cocoons, chicken feathers, and even human hair, have also demonstrated their effectiveness of reinforcing biocompatible and bioresorbable polymers for implant applications. As the major content of these fibers is protein, it is suitable to be mixed with bioresorbable polymers for temporary reinforcing elements used inside the human body.

In present time, biodegradable composite is the key for major discipline and many researchers and scholars are working in these areas. This book provides an insight for all researchers, academicians, post graduate or senior undergraduate students working in the area.

The chapters in the book have been provided by researchers and academicians working in the field and have gained considerable success in the field.

The book is divided into three parts, namely, Part I: Introduction and Material (Chapters 1 and 2); Part II: Manufacturing and Properties (Chapters 3–7); and Part III: Machining and Application (Chapters 8 and 9).

Chapter 1 provides the readers an insight into plant-based biodegradable composites. The chapter reviews the research trends, production techniques, challenges, and future prospects for the biodegradable composites derived from plant proteins and biopolymers. It starts with increasing concern over the depleting petroleum resources with added concerns for environment. It then moves to one alternative solution, that is, biodegradable materials, a key replacement to the petroleum-based products, which has motivated the research community to use them to meet the needs of mankind to the extent possible.

Chapter 2 discusses the fibers, polymers, composites, and applications of corn or maize. Corn, a tropical cereal plant, domesticated about 8,000 years ago mainly as a food. In recent times the demand for corn has flourished dramatically, for use in production of various food and edible oils as well as manufacturing biocomposites, and biopolymers. Furthermore, corn plant is the second largest source of renewable energy in the form of bioethanol via fermentation process for the sugar glucose of the corn starch and cellulose of corn fibers. The main aim of this review chapter is to present a comprehensive study about corn plant as an essential source of biodegradable polymers and fiber-based biocomposites, along with its current and potential applications. The chapter also provides information on most recent developments of corn biocomposites and presents a detailed report on surface treatments, extraction methods, and mechanical properties of corn starch and corn fibers as well.

Chapter 3 reviews production of biodegradable composites from agricultural waste. The chapter discusses some of the literature available on biodegradable composites developed mainly from common agricultural products, their properties, production method, challenges, and sustainability. Although recent researchers have led to the development of biodegradable composites with reasonable tensile and flexural characteristics, there are short falls with regard to some of the biodegradable composites when they come in contact with moisture, which affects their performance under certain conditions like in aqueous medium or under high humidity. The chapter has considered and reported works on rice husk, soybean, sugarcane bagasse, and cassava peel.

Chapter 4 illustrates effect of orientation on mechanical properties of natural fiber-based biocomposites. It indicates that the mechanical properties of the final product depend largely on the adjustment of the fiber orientation field during processing. The chapter deals with the study of the fiber orientation prediction using Jeffrey and Folgar-Tucker descriptions and their effect on composite mechanical properties by evoking several models, namely, Voigt, Reuss, Halpin-Tsai, Hashin and Shtrikman, and Hirsch and Tsai Pagano.

Chapter 5 discusses mechanical properties of bamboo yarn, a biodegradable composite material for structural works. Bamboo yarn as reinforcement of polymer composite is nonabrasive, ecofriendly, and biodegradable, and it can serve as a raw material for industrial engineering application. In this chapter investigation to study mechanical properties of bamboo yarn, both woven or bidirectional and unwoven or 45° orientation, as reinforcement in polymer composite have been extensively done and influence of bamboo yarn orientation, yarn content, size, and treatment agents on the mechanical properties of the composite were investigated. The impact, flexural, tensile, and scanning electron microscope (SEM) have been performed to evaluate the properties and surface morphology. The chapter further discusses the thermal stability and thermal degradation of the composite utilizing thermogravimetric analysis (TGA) and differential thermogravimetry analysis (DTA) under a nitrogen atmosphere.

Chapter 6 deals with aggrandized flexural properties of assorted natural biological materials. The chapter starts with the fact that natural biocomposites such as molluscan shell, teeth, and bone exhibit mutually exclusive mechanical properties due to their hierarchical stratified microarchitectures comprise of mineral tablets and interweaved with organic biomaterials – hence, all engineering applications like construction, defense, energy, and aerospace. Therefore, biomimicking of these high flexural natural materials (e.g., the flexural strength of the nacreous structure is 220 MPa) can help the engineering community in developing high flexural materials. The chapter discusses the biomimicking of various animal- and plant-based biologically inspired materials for the developing composites materials that have high flexural strength and concludes with the discussion on the future scope of the natural composites.

Chapter 7 highlights mechanisms and formalism of hygrothermoelastic behavior of natural fiber-based composites. It underlines the hygrothermoelastic behavior of composites reinforced with natural fibers with various behaviors including hygroscopic, thermal, hygrothermal, hygroelastic, thermoelastic, and hygrothermoelastic behaviors. The chapter concludes with application of the equations governing the hygrothermoelastic effect on the case of the laminated composite structure.

Chapter 8 relates the influence of drilling parameters on the thrust force and mechanical properties of biodegradable particleboard composite panels. The present chapter provides an overview review on the same. It commences the discussion with the fact that among the numerous conventional machining, drilling is the most commonly used procedure for machining of particleboard, whereas milling and turning are less frequently used. The different machining parameters like feed rate, spindle speed, and drill bit diameter/point angle are found to have major influence on the thrust force during drilling operation. The chapter provides a detailed review considering the effect of machining parameters in the drilling of particleboard. Summarized outlines are presented on surface characteristics of the hole produced in drilling operation. The chapter also provides optimized delamination factor of particle board using optimization techniques like Taguchi and Response Surface Methodology. Fuzzy approach in assessment of frequency response function (FRF) analysis of functionally graded plates (FGP) was also undertaken. The fuzziness has been considered due to variability in material properties corresponding to the various α-cuts. The Power law was implied for characterizing the material modeling, and a parametric study was carried out to observe the effect of location of drive point and cross points on uncertain bounds of frequency response function with respect to crisp values.

Chapter 9, the last chapter of the book, does a numerical study of rotating functionally graded annular fin made of biodegradable composite. The governing differential equation for such fins of rectangular and triangular profiles has been derived to evaluate the temperature distribution and efficiency of the fins with insulated tip boundary condition. Nonlinearity in the governing equation material heterogeneity and rotation at various speeds is imposed and analyzed to compare the performance for both rectangular and triangular cross section. The formulation has been validated with benchmark results, and good agreement was observed.

First and foremost the editors would like to thank God. In the process of putting this book together, it was realized how true this gift of writing is for anyone. You have given the power to believe in passion, do hard work, and pursue dreams. This could never have been done without the faith in You, the Almighty. The editors would also like to thank all the chapter contributors, the reviewers, the editorial board members, project development editor, and the complete team of publisher Verlag Walter de Gruyter GmbH for their availability for work on this editorial project.

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