Bionanotechnology to Save the Environment

Pierfrancesco Morganti (Ed.)

Bionanotechnology to Save the Environment

Plant and Fishery's Biomass as Alternative to Petrol

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MDPI
St. Alban-Anlage 66
4052 Basel, Switzerland

For citation purposes, cite each article independently as indicated below:

LastName, A.A.; LastName, B.B.; LastName, C.C. Chapter Title. In *Bionanotechnology to Save the Environment. Plant and Fishery's Biomass as Alternative to Petrol*; Pierfrancesco Morganti, Ed.; MDPI: Basel, Switzerland, 2018; Page Range.

ISBN 978-3-03842-692-9 (Hbk)
ISBN 978-3-03842-693-6 (PDF)

doi:10.3390/books978-3-03842-693-6

Cover image courtesy of Pierfrancesco Morganti.

This book is dedicated to my loving wife Paola, my children Gianluca and Adriana, my daughter-in-law Daniela, my beloved nephew Alessandro and to all the professionals who make the world a healthier and happy place and helped me thinking the education as a discovery of our ignorance.

Who neglects learning in his youth, loses the past and is dead for the future.
– Euripides

The authority of those who teach is often an obstacle to those who want to learn.
– Cicero

Learning without thought is a labor, thought without learning is perilous.
– Confucius

Education is the key to unlock the golden door of freedom.
– George Washington Carver

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About the Editor

Pierfrancesco Morganti is a Temporary Professor of Skin Pharmacology and Applied Cosmetic Dermatology in the Department of Physical and Mental Health and Preventive Medicine of the Dermatology Unit, at the University of Campania "Luigi Vanvitelli" in Naples, Italy, as well as a Visiting Professor at China Medical University of Shenyang.

He is also an industrial expert; in fact, since 1980 he is CEO and R&D Director of the Nanoscience Centre of MAVI sud Srl, an Italian company manufacturing and distributing clinically correct cosmetics.

In 1960 he brilliantly graduated from the University of Roma "La Sapienza", and over the years has taught as temporary professor of Applied Cosmetic Dermatology and Skin Pharmacology at the universities of L'Aquila, Milan, Pavia, and Rome, in addition to chairing many scientific seminars as keynote speaker expert in Cosmetic Dermatology at international conferences in Europe, Russia, China, East Asia, Asia-Pacific and the USA.

His current research interests are focused on the development of biomaterials based on the use of chitin nanofibrils and other polymers obtained from agricultural and industrial waste by a nanotechnological biomimetic approach. Due to this expertise, as R&D Director of MAVI, he has been the coordinator of two innovative European research projects: Chitofarma about the production of non-woven tissues to be used in advanced medications, n-Chitopack about production of biodegradable and compostable food grade packaging, participating also in Bio-mimetic and Polybioskin projects about production of bio-based films to be applied in cosmetic emulsions, and innovative and smart beauty masks to be used as innovative cosmeceuticals.

Author of over 400 publications, including peer-reviewed journal papers, conference proceedings, book chapters, authored books, edited books and patents relevant to cosmetic dermatology and bio-nanomaterials, he is a fellow of the Italian Society of Pharmacology, the European Academy of Dermatology, the American Academy of Dermatology, the Italian Society of Chemistry and Cosmetic Sciences, and he is the co-founder and Secretary General of the International Society of Cosmetic Dermatology.

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Foreword

Nanotechnology is the science of manipulating atoms and molecules in the nanoscale thousand times smaller than the width of a human hair.

The world market for products that contain nanomaterials is expected to increase enormously in the future. The use of nanotechnology has stretched across various streams of science, from electronics to medicine and has also found applications in the field of cosmetics.

How will this revolution impact our lifestyle and our planet?

Very often the progresses of science, human knowledge and evolution of our lifestyle has been associated with devastating effects on our forests, oceans and more in general on our planet. The real challenge in the years to come is the sustainability of human evolution.

The reader of this interesting book will discover how nanotechnology, and in particular nanomaterials derived from plant biomass and fishery's waste, can improve the quality of our environment by reducing carbon emissions, improving the recycling of materials and even, in the long run, became a profitable business.

Green nanotechnologies can be applied to a huge number of products ranging from intelligent textiles to smart drugs or functional polymers which can have a big impact on our daily lives, but nevertheless help us in saving our biodiversity and our planet.

However, to fully achieve all these benefits, companies and scientists should be supported by National and International Agencies and Institutions in order to facilitate and support scientific development in this field allowing from one side the protection of intellectual property, but on the other giving accessibility of these technologies to emerging countries for improving the quality of life and the environment all over the world equally.

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Preface

The main aim of the current policy is to keep the environment in orbit with economics at the center, not considering *nature* or *environment* as simple commodities. Preserving planet Earth's biodiversity is crucial in order to keep its ecosystems in equilibrium.

For this purpose, it is necessary to produce goods and tools using bio and eco-compatible methodologies whilst also increasing knowledge on the concept of industrial sustainability. In fact, sustainability has to be based on the 3P pillars: Planet, People and Profit, i.e., (a) the preservation of the planet's environment; (b) the respect of people's safety and well-being, to meet the social expectations; (c) the maintenance of the industrial profit to manufacture and compete at a global level.

Without entering into any kind of neoliberal education policy, this book aims to present new ideas to encourage those in the manufacturing industry to use both industrial and agricultural biomass in order to produce goods in a greener way. It may also encourage scientists and marketing professionals to educate the consumer on the necessity of maintaining biodiversity without impoverishing our planet of crucial raw materials.

The book is organized in the following five parts:

Part I *INTRODUCTION*, where, in *Chapter 1*, the necessity to recycle waste using bionanotechnology is reported, underlining that our health, together with economical and social progress, is closely linked to the quality of the environment. For this purpose, the strategic necessities to use plant biomass and waste from fisheries as raw materials are reported and discussed in six chapters (Chapters 2 to 7) in **Part II** *BIOMASS AS RENEWABLE RAW MATERIAL FOR A GREEN ECONOMY*.

Chapter 2 deals with the current Chemical Industry Strategy of Innovation, based on the necessity to maintain the ecosystem and biodiversity of our earth by increasing the use of by-products, as basic raw material for producing goods. Sustainability, in fact, must be the key factor dictating the progress of the European Chemical Industry in the next decade.

Chapter 3 describes the quality and quantity of available biomass as a basic source of raw material; therefore, much effort has to be devoted to converting it into useful industrial and commercially viable products. Biomass represents, in fact, an immense and renewable source for the production of bio-fuels and valuable ingredients, despite only a small amount being utilized to make goods. For this reason, *Chapter 6* reports the most fundamental chemicals and fuels that can be produced by a bio-refinery, simply by processing feedstock rich in cellulose and lignin. Therefore, the use of biomass in nanobiotechnological processes is

useful to achieve a sizeable bio-green economy as a base for our future progress, indispensable to reduce the social differences as well. In *Chapters 4* and *5*, availability, production and use of Chitin, Cellulose, and Lignin are discussed. These polymers, which represent the most abundant natural and underutilized materials present in the world, are precious raw materials that are useful to the manufacture of many kinds of products.

Chitin Nanofibrils (CN), obtained from crustacean waste, and lignin, from plant biomass, have been shown to be interesting natural polymers useful for producing, for example, non-woven tissues to make innovative beauty masks and/or advanced medications. It is worth noting that the use of nanocomposites made from the CN–Lignin block copolymeric micro/nanoparticles has shown to be effective for producing non-woven tissues and emulsions with interesting anti-ageing and/or anti-inflammatory effectiveness. During the polymerization process—necessary to produce the micro/nanoparticles—it is possible, in fact, to entrap different active ingredients to characterize the activity of the final products.

Chapter 7 explains and reviews the definition of bio-based, recyclable, biodegradable and compostable materials by the current standards and legislation. The general assessment of biodegradability of a plastic material, in fact, is not sufficient for fulfilling the requirements of the consolidated international standard for composting waste. Indeed, if not properly planned and addressed, the production of compostable materials might be less sustainable than that of petrol-derived, non-biodegradable polymers.

Part III *FUNDAMENTALS*, comprises five chapters, reporting and discussing (from Chapters 8 to 12) the physicochemical characteristics of the principal biopolymers obtained by the plant biomass, such as cellulose and lignin, together with the more known chitin from fisheries' waste. Thus, *Chapter 8* introduces the general characteristics and peculiarities of lignin as a biopolymer, presenting its structural issues. For this purpose, the techniques necessary to investigate these interesting macromolecules are reported, highlighting the latest technologies created to isolate lignin from plant biomass, controlling and valorizing its interesting polyphenolic structure.

Chapter 9 is focused on the biomedical applications of cellulose nanocrystals, highlighting their use in drug-delivery systems and in tissue engineering. Cellulose, in fact, as a natural polymer and biomaterial, plays an important role in regenerative medicine to control cellular activities and functions, when used to produce and reinforce non-woven tissues, because of its non-toxic and biodegradable properties.

Chapter 10 reports the structural (morphological and crystalline) and dynamic (rheological) properties of chitosan (CS) and chitin nanofibrils (CNs), used to produce composite films by casting technology. The rheological tests provide

useful information about the rheological changes of CS/CN slurries over time, which are necessary to determine the limit of their storage. Based on the analysis of the permeability for gases and water vapor, thermal and mechanical stability of these innovative films it can be concluded that they are suitable as disposable packages for dry products. Replacing cellulose paper with CS/CN-based films may have an effect on reducing deforestation and the associated climate change.

Chapter 11 gives an excursus on the possible use of biodegradable raw materials to make safe baby diapers. It shows the historical use of these diapers for protecting the baby skin from the common rash problem, reporting the different shapes used during the years and the safety and security of the actual based baby diapers.

Chapter 12 reports data and operating conditions of the electrospinning technique used to produce non-woven-tissues by a blend of chitin nanofibrils and other natural polymers.

Part IV *APPICATIONS* contains five chapters (from Chapters 13 to 17), reporting the industrial applications that chitin and its derivatives could have in different and important economical fields, such as cosmetics, advanced medications, and food packaging.

Chapter 13 describes the safeness and effectiveness of the block co-polymeric chitin nanofibril–hyaluronan (CN–HA) as a skin anti-wrinkling agent, underlining its efficacy to neutralize the free radical activity and to regularize the correct cell turnover. Moreover, it has also been shown that the controlled delivery and release of active ingredients throughout the skin layers is of fundamental importance to achieve the effectiveness of the topically applied products.

Chapter 14 highlights the recent researches in tissue engineering, underlining the different aspects of chitin-based nanocomposites to produce skin-friendly scaffolds. *Chapter 15* reports the employment of different polymers obtained from biomass in the production of soft container packaging to reduce waste production and related greenhouse emissions. *Chapter 16* is focused on the possibility to use bio-based polymers for the industrial processing of hard containers for food and cosmetic purposes, reporting the more recent technologies adopted for maximum valorization of bio-based polymers. This application outlines the potentiality and the growing attention, not only from researchers but also from producers and consumers, towards bio-based materials. The modification and processing of bio-based products with additives, polymers, and natural fibers is also discussed.

Part V *BIOLOGICAL ACTIVITY, SAFETY,* PATENT APPLICATIONS AND LEGAL CONSIDERATIONS, consisting of four chapters (from Chapters 17 to 20), reports update studies, in vitro and in vivo, showing the safeness and effectiveness of chitin nanofibrils used for medical purposes, underlining the necessity to patent all the innovations achieved.

In the last few years, many studies have focused their attention on the biomedical application of natural biocompatible polymers used to produce nanocomposites for tissue regeneration.

Chapter 17 is therefore focused on the study of the biological properties of the new polymeric nanoconstructs which, being biodegradable and biocompatible, have the capacity to exploit the body's natural biological response, at the same time respecting the environment equilibrium. This is the reason why chitin nanofibrils and lignocellulosic polymers, possessing these characteristics, are at the center of many therapeutic applications.

Chapter 18 reports the latest in vivo studies on innovative non-woven tissues made by chitin nanofibrils entrapping nanostructured silver**,** in a very low dose. These particular tissues, typically applied for a period of 6 days on skin affected by first- and second-degree burns, resulted in quickly regenerating the skin tissues, temporarily slowing down the bacterial growth, without causing any toxic side effect. It is worth noting that the non-woven tissues, made prevalently by chitin nanofibrils, have shown *in vitro*, in keratinocyte cultures, an interesting effectiveness to modulate the cell production of defensines, balancing the imetalloproteinases activity also.

The last two chapters are concerned with the EU regulations on c osmetic products and the use of nanomaterials, underlining the necessity to protect the industrial innovations by organized patent applications. *Chapter 19* outlines the main features of the recent European recast of the Cosmetic Regulation, touching upon the use of nanomaterials and the necessity to respect the environment's equilibrium. *Chapter 20* highlights how the protection of nanotechnological inventions implies a new interpretation and application of the general requirements of patent ability.

This book represents a good asset for graduate students, researchers, academicians, and industrial experts working in the field of natural polymers who wish to maintain the biodiversity of our planet, improving our quality of life by the use of green bionanotechnologies.

Pierfrancesco Morganti
Editor

Acknowledgments

I express my sincere gratitude to Dr. Maria Luisa Nunziata for the continuous support given during the different steps of this work.

I thank the Publisher for giving me the opportunity to write this book, and all the professionals who accepted to be part of it, contributing to enrich the content with their great experience. Moreover I have to thank Biobased Industries and Horizon 2020 for the fund received to support part of the reported studies.

Last but not least, I'd like to thank TEXOL Srl, Italy for the support given in the making of this book.