Chapter 1
Introduction to Biosynthetic Technology and Environmental Challenges

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Abstract Bio-based processes and products are getting more and more acceptance nowadays mainly because of the environmental friendly process. Many current petroleum-derived products would be replaced by less expensive and better performing products based on renewable materials in near future. This will help for achieving economic and environmental sustainability. Bioeconomy is now emerging as a major industrial breakthrough and new biomass-based products are emerging due to the advancement in technologies. These potential benefits of bio-based products could justify future public policies that encourage a transition to renewable raw materials for production of organic chemicals, fuels and materials. Biosynthetic approaches for production of various industrially important chemicals and products through microbial and plants routes have been discussed in this book. The environmental challenges for its production under biorefinery approach and the various methods for addressing the environmental issues have been discussed in detail.

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Lignocellulosic biomass is one of the most abundant renewable resources available on earth. Huge amount of lignocellulosic biomass is generated from agricultural and food industries as a waste material, commonly known as agro-industrial waste. It has low value for industries and also a big problem as environmental pollutant, therefore its proper management is needed. Several technologies have been applied to recover maximal quantity of valuable product from agro-industrial waste but applications of emerging synthetic biology in production of high value product seem to be more promising for its management. Agro-industrial waste is a good source of carbon and energy for the growth of microorganisms. The lignocellulosic biomass can be converted easily to fermentable sugars and these sugars can be converted to valuable products such as biofuels, bioactive molecules, rare sugars, prebiotic oligosaccharides, biochemicals and many more by applying engineered enzymes or organisms.

The complete utilization of lignocellulosic biomass for various products leads to the emergence of biorefinery concept. This also leads to more advanced interdisciplinary area of techno-economic analysis. The development of the biorefinery concept is based on the techno-economic feasibility of the proposed process considering raw materials, process options, mass and energy integration, market constraints, etc. Nevertheless, along with all these considerations, the environmental assessment must be taken into account at the same time, and concepts like sustainability, land uses, environmental impacts and other related issues must be included in the biorefinery design. A detailed information on this aspect based on different case studies covering a wide range of raw materials and products is also presented in this book. Comparing technological options for biorefinery development is usually done based on economic criteria, but environmental aspects have gained a key role in addition to economic factors for the selection of the best production scheme. Although different approaches, methodologies and data bases are available, the combined consideration of economic and environmental factors can be used as a right tool for decision-making.

Microorganisms such as bacteria, fungi, yeasts and algae are used for production of various chemicals of industrial and pharmaceutical importance. Biopharmaceuticals are important part of modern medical biotechnology and current commercial market of pharmaceutics show annual growth rates between 7 and 15%. The microbial production systems offer several advantages in production of pharmaceutically important proteins due to its unicellular nature, easy gene manipulation, cost-effective and fast growth. Recently major industries focus on biological method for production of chemicals such as 2,5-Furandicarboxylic acid, 1,3 propanediol, biosurfactants, etc. Biopolymers are another important entity of commercial importance. Poly γ-glutamic acid is a promising biodegradable polymer from bacterial sources with intense applications in the field of medicine,

wastewater treatment, food and cosmetics, etc. Another polymer having wide application is Pullulan. This microbial pullulan acts as the promising biomaterial that is currently used for packaging of readily oxidized food materials, controlled drug delivery, tissue engineering and can also function as artificial molecular chaperones. Biosurfactants also constitute an important compound having wide application. The realm of surfactant activity widespread to different industries including food, environmental remediation, textiles, fuel extraction, biotechnology, antimicrobials and many more. Recent developments in the production of these chemicals and polymers are described in this edition of book.

The enormous amount of by-products produced in food and agricultural sector and current attention towards sustainability is attracting researchers to look into possibilities of its utilization in recovery of nutraceuticals. Nutraceuticals are food or food products that confer health and medical benefits, and are instrumental in prevention and treatment of diseases. The agri-food industry by-products are an excellent source of proteins, lipids, fibre and other bioactive compounds. Among different methods used for extraction of these bioactive compounds (nutraceuticals), fermentation by lactic acid bacteria is one of the economical and eco-friendly approaches. During fermentation, chemical changes induced in organic substrate by action of microorganisms aid in formation of bioactive compounds, either by a process of hydrolysis of large polymers to simple molecules or transformation of substrates. One of the chapters in this book discusses the role of lactic acid fermentation in transformation/hydrolysis of by-products for efficient recovery of nutraceuticals. The bioprocess of nutraceuticals recovery from waste by lactic acid fermentation with better efficiency adds value to food waste, reduces environmental pollution and has positive impact on the economy.

Prebiotics constitute non-digestible food ingredient that promotes growth of beneficial microorganisms in the intestines. The oligosaccharides are highly stable and are used as dietary supplement possessing prebiotic, antioxidant activity and potential immune-modulating properties. A detailed information on manno-oligosaccharides has been included in one of the chapters in the book.

Plants also constitute an important source for biosynthetic products. They are well responding to environmental factors and endow rapid adaptation for survival under multiple environmental stress. These various environmental perturbations not only affect productivity of plant but also cause different variations in plant morphology and anatomy, growth, development and metabolism as well. During commencement of environmental stress, majority of biological processes are directly affected, such as photosynthesis, transpiration, respiration, stomatal conductance, pigment concentrations, energy and metabolism. To improve plant secondary metabolism production, it is essential to understand its biosynthetic pathway at the transcription level.

Energy crops such as Miscanthus, switchgrass, etc., represent important sources for biofuel production. The cultivation of perennial bioenergy crop on a drained peatland is an interesting approach. Peatlands are globally important because of their high carbon content. While the use of peatlands as an economic resource was deemed necessary, the fact that such land use (drainage) leads to environmental

problems is increasingly being realized the world over since the 1990s. Hence, continued attempts are being made to find suitable land use options for drained peatlands after their intended land use. Simply abandoning these lands is considered environmentally untenable. Therefore, several options have been suggested as after-use options: intensive forestry, rewetting, restoration to a functional peatland, creation of artificial wetlands, use of cutover peatlands for agriculture and cultivation of energy crops, etc. Decision on which option to use at a given drained peatland is complex. As an after-use option on a cutover peatland, the cultivation of a perennial bioenergy crop on a drained peatland in eastern Finland was explored during 2004–2011. The long-term measurements of greenhouse gas exchange from this study site showed that the benefits from bioenergy crop cultivation vary strongly depending on the climatic conditions during the crop cultivation phase.

Another plant-based residue is the oil palm biomass from oil palm mills which need a proper waste utilization application. Pyrolysis is the commonly used method to utilize this waste. The kinetics of this process and the recently available kinetic models such as lumped and distributed models are discussed in detail in one of the chapters in this book.

Cultivation of microalgae has appeared as an emerging alternative approach for removing pollutants and heavy metals present in the water bodies. Biomass production in the alga depends on rapid utilization of the organic content and other nutrients present in the effluent and can be considered as an attractive and eco-friendly means for treating waste streams, other than removing the pollution load, algal cultivation adds value to the process by production of commercially valuable products such as fuels and various chemicals from biomass. The recent developments and perspectives in bioremediation of waste streams by algae for removal of various pollutants for value addition of waste have been discussed in the book. Various computational modelling methods applied to microalgae growth in various environmental conditions have been reviewed. The possibility and potential of employing these models for better lipid production have also been highlighted, as better predictability of models can lead to better transgenic algal platform.

Increasing amount of waste due to urbanization, lifestyle and shift of huge masses from rural to urban largely contribute for the need of waste management. This developed a need of categorizing the waste into municipal waste, industrial waste, agricultural waste, hospital waste, etc., which would make it easy for the proper disposal, reuse and recycling of waste so determined effort should be taken for management of waste. Vermicomposting is the biocomposting process of organic waste by earthworms and bacterial action directing the stabilization of organic matter. The final product produced in this process is known as vermicompost and it assists in enrichment of soil as well as useful for sustainable agriculture. This technology is a boon for recycling of the solid waste generated from various sources including aquatic weeds. Vermicompost production from water hyacinth (*Eichhornia crassipes*) and its application to a commercial crop groundnut (*Arachis hypogaea*) for total yield and biomass production have been described in one of the chapters. Deliberation on the variations of life cycle computation of solid

waste management that involved to different global warming potential of composting is also a topic of discussion in this book.

Another important issue in waste management is handling and disposing the hazardous wastes as antibiotics residue, municipal solid waste and agricultural waste. These wastes contain lots of organic matter and nutrients, while also contain various kinds of toxic materials or elements (e.g. heavy metals, pathogens and antibiotics). The improper disposal of these wastes would result in environmental pollution and potential risk of human health. One chapter in this book discusses benefit and challenge of composting of organic and hazardous waste. It also discusses current method to promote the compost quality and reduce the environmental risk.

Water bodies are subject to a considerable pressure from sewage and industrial wastes. Monitoring methods adopted so far have helped in assessment level of contaminants in water but not interaction of these pollutants with living organisms. Water quality testing programs use two traditional methods for water quality assessment that includes physico-chemical parameters and bio-monitoring. Looking at the limitations of these two traditional methods, a new method known as 'biomarkers of pollution' should be adopted. Evaluating various biomarkers in sentinel species can be of great help in environmental monitoring program as they forecast various risks and hazards associated with the habitats of aquatic animals. The major advantage of biomarkers is that bioavailability or potential exposure to toxicants can be demonstrated which is not possible in chemical analysis.

The topics are organized in five different sections: (i) General, (ii) Biosynthetic approaches and products and (iii) Environmental assessment and waste management.