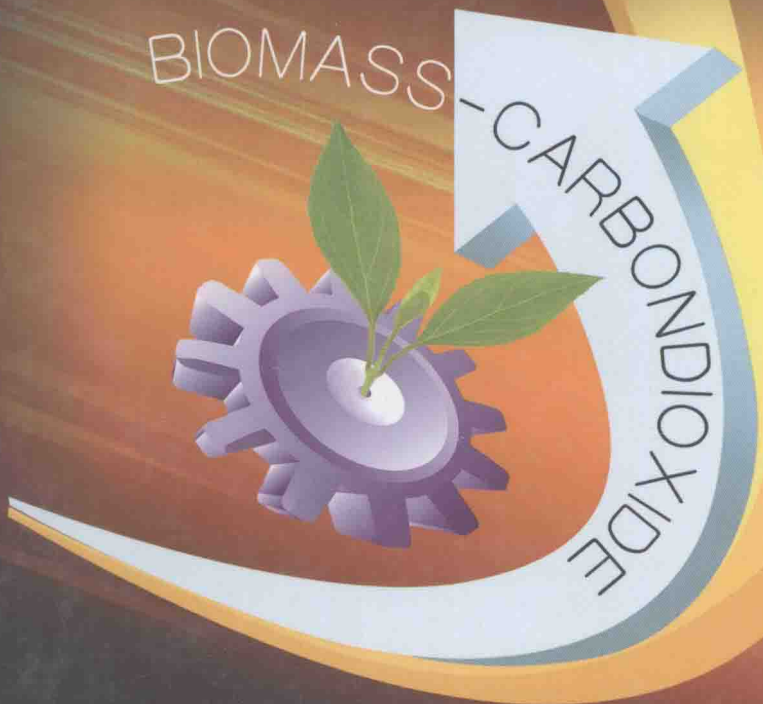
Bioenergy Technology and Engineering

生物能源技术与工程化

Zhang Bailiang



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Preface Ⅰ

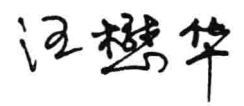
How to maintain sustainable development of economic society and protect eco-environment have become research focus of nations around the world since over 10 years ago. The frequent extreme disasters such as drought, flood, etc., and crop failure, threatening food security all can be attributed to the climate changes caused by human activities. Huge consumption of fossil energy has caused greenhouse gas emission, environmental pollution, and shortage of fossil resource, which make nations around the world to take development of renewable energy seriously, and to enhance the research on renewable energy science and techniques, and industrialized projects. The dramatical fluctuation of international oil price has been enhanced by every country's particular concern to the future of fossil energy utilization. Every economic power has stipulated relevant mid-long-term development strategy, drawn technique route map, multiplied its investment on development and research of bioenergy and other kinds of renewable energy, and looked for new approaches to remedy the national insufficient energy supply and to solve the energy problem. Biomass has become one of the major directions in global renewable clean energy research, since there is abundant biomass resource, and can be regenerated and utilized in many ways.

Biomass has become one kind of the energy on which human lives, ever since Suirenshi invented artificial fire. The main source of biomass is plant and waste of animal. Plant biomass contains high heat-value lignin, which can be directly burnt. It also contains high-content of cellulose, hemicellulose, starch and sugar, which can be converted into liquid energy of high-energy-density such as bioethanol, methanol, and dimethyl ether, some also, contains high-content fat and oil, which can be refined into diesel and other kinds of liquid fuel. Biomass resource is mainly consisted of hydrocarbon; therefore it brings relatively less air pollution in the process. But it also has the problems such as the wide distribution of resource, low energy density, and high cost of pretreatment, etc. Now that the science and techniques and multiple types of valid application method of biomass has become a good basis, people focused on how to efficiently convert them to liquid fuel, such as bioethanol, biodiesel, etc. so to partly replace the oil, and to reduce greenhouse gas emission. In this process, research on engineered implemention of biomass energy utilization is one of the keys, because engineering is the key link to convert science knowledge and technological invention into practical productivity. Engineering research can bridge scientific discovery, technological invention and industrial development. It is a powerful lever to promote industrial revolution and social improvement. Engineering of research on science and techniques should pay attention to the integration, selection and optimization of various elements, such as science, techniques, economy, management, society, cultural, system

and environment, etc. The goal pursued by engineering thought is the fusion of knowledge and economic value, social value, environmental value and cultural value, etc. New engineering notion and engineering perspective require engineering activity to be built on the basis of conformation to natural law and social regular pattern, to be people-oriented, environmental-friendly and to improve the coordinated development of human, nature and society. We can not leave the key link of engineering to create large-scale direct productivity from science and techniques even in modern society.

Professor Zhang Bailiang has been engaged in bioenergy research for a long term. He pays attention to the research and experiments of engineering techniques, and takes engineering experiments as important research content of subject. For instance, the research of solid biofuel includes the physical and chemical characteristics of straw, combustion characteristic, mechanical property, manufacture and application of biomass densification press complete equipment. The research also included collection, transportation, management and policy advices of widely distributed resources, aimed at recycling biomass and turning densified biomass fuel into an environment friendly renewable energy and a new industry to improve farmer income. The research on gaseous biofuel focused on the collection and storage of straw to the design of biogas digester-power generating system, and systematic engineering experiments transferred from labs to factory. On liquid biofuel, the author started from the basic research of straw pretreatment, such as steam explosion pretreatment, to the bioethanol production technology and which has been tried in enterprise engineering experiments. Large quantities of experiments results and analyses published in this book, tens of thousands of experimental data, hundreds of tables and graphs are all from the experiments conducted by academic team leaded by the Zhang, and many kinetic models reflected laws gained in research, which has significant reference value to improving the agricultural bioenergy development and its industrialization engineering techniques research in our country.

Therefore, I'd like to recommend this innovative, rich-content monograph to those in the same field. I hope that there will be more experts, scholars to do better and greater contribution to cooperative promotion of the bioenergy science and techniques in our country.



Wang Maohua (signature)
Academician from the Chinese Academy of Engineering
Director-general of Chinese Society of Agricultural Engineering
December, 2008

Preface II

Energy shortage, especially oil shortage, has become a shared problem of the world. More than a half of the oil consumption in China relies on import. Development and utilization of bioenergy has become a key point in energy development of our country.

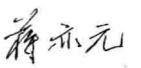
It obviously does not conform to our national strategy of food security to solve energy problem by measures like producing ethanol from foodstuff. This book *Bioenergy Technology and Engineering* written by Professor Zhang Bailiang and his team is mainly about the by-products in agricultural production——straws. It contains researches on how to manufacture methane, ethanol with them, or how to press them into densified biomass fuel, convert them into biodiesel with enzyme catalysis. These are all the major aspects of research both at home and abroad.

This book is not a compiling of old knowledge, but is focusing on the key problems in the development and application fields of bioenergy in the world, exploring new techniques. For instance, in exploration for the ethanol preparation techniques with straw fibers rather than starch (food) as raw material, the author successfully realized this goal by steam explosion technique in pretreatment of straws. Many points are obviously innovative and have achieved international level, such as improved rate of output of methane. A special advantage of this book is that, rather than staying at the stage of experiment research in lab and publication of thesis, it aims at engineering as much as possible. For example, author's research on densified biomass fuel is more than the briquetting mechanism of biomass and development of densification equipment; it also successfully developed a combustion boiler suitable for this kind of fuel, helping to popularize the achievements.

To help readers get familiar with the research results in this new field of bioenergy, basic knowledge related to thermodynamic engineering and biology, and evaluation methods of technical economy have been included in this book. This book has realistic significance and can be used as a reference at the core techniques, bottleneck problems, current development status, and route maps of bioenergy development.

In a word, this book has the following characteristics, research field is closely attached to key techniques, theory is closely linked to practice, and the engineering research is tried to realize

as much as possible. The publication of this book will have great significance to the research, development and popularization of bioenergy, and cultivation of high-level talented people in this field.



Jiang Yiyuan (signature)
Academician from the Chinese Academy of Engineering
Professor of Northeast Agricultural University
November 16th, 2008

Preface III

Mr. Zhang Bailiang used to be President of Henan Agricultural University. He is an educationalist as well as a famous expert in agricultural engineering field. Facing global energy crisis and relative shortage of fossil energy in China, Professor Zhang Bailiang had the foresight and sagacity to focus on China's rural energy. After authorization of Ministry of Education of China, he established China's first rural energy science in Henan Agricultural University in 1981. He also quickly converted his energy into the teaching and scientific research of rural energy. After more than 10 years of research, he published the monograph *Rural Energy Engineering* in 1995, which significantly promoted the rural energy business in China.

After another more than 10 years have passed, Mr. Zhang's new book *Bioenergy Technology and Engineering*, is going to be published. I express warm congratulation and praise to him. The biggest feature of this book is that the theoretical research is deep, technical engineering research is distinguished. The rich content is based on the research results of more than 30 doctor candidates and master candidates. The subjects include biogas fuel, such as "research on biogas anaerobic (IC) reactor", "steam explosion techniques of straw and its application in fermentation", etc.; liquid biofuel, such as "research on key techniques of cellulose ethanol and pretreatment of straw", etc.; solid biofuel, such as "dual-direction hydraulic biomass densification techniques and complete set of equipment", etc.

China is a big agricultural country. Along large-scale food production, large quantities of straw are also inevitably produced. Straw have been used as fuel by farmers for a long time. However, with the rural population growing and society developing, straw utilization in traditional style is no longer suitable for modern society. Further more, direct and dispersed burning utilization style can bring serious environmental pollution.

Therefore, the research and development of energy-saving and environmentally friendly utilization techniques of straw has become a subject which should be paid special attention in China. Professor Zhang Bailiang leads his team to solve this urgent problem for 20 years. Some achievement of straw densification techniques and so on were written in this book. They have also taken it as a demonstration of engineering realization of domestic bioenergy techniques, and in-depth research for it. They have edited the essence in an upcoming book for readers as well as transfer the achievements to practical production. This is just an example to illustrate the feature

of integrating theory with practice on the book *Bioenergy Technology and Engineering*.

Here I'm writing preface for this book to express my congratulation to the publication of this book, and to convey my support and concern for the bioenergy development of our country.

Li Peicheng (signature)
Academician from the Chinese Academy of Engineering
Professor in Changan University
December 18th, 2008

Foreword

China economy has grown at an annual rate higher than 9% continuously, steadily and fast for recent 10 years, at the same time, energy consumption has also increased significantly. China has turned from an oil exporter in 1980s into the second largest energy consumption country in the world, with half of its consumption depending on import. The environmental and ecological problems caused by continuous fast growth of energy consumption have aroused attention from China and even from the world.

During the first world energy crisis in 1973, forward price of oil in New York surged from 3USD/barrel to 12USD/barrel. 2008 is also a year when oil price swings a lot, with forward price of oil decreased from 147.27USD/barrel in May to less than 40USD/barrel in December. This sort of irregular and uncontrollable dramatic change of oil price has touched the nerves of the whole world and caused the world to panic. Oil price also influenced coal price. The raw coal price in China has increased nearly 10 times during last 10 years. The rise of energy price caused world food price rise as well. CIP and PPI fluctuate dramatically, threatening the healthy development of world economy, harmony and steadiness of human life. To deal with this situation, nations around the world, especially developed countries and developing countries which are quickly doing modernized construction, all take countermeasures in the aspects of politics, economy, diplomacy, and even military to ensure the energy security of their own country.

Other renewable energy can not be compared with bioenergy in the properties of storage, transportability, convertibility, and renewability. Therefore, nations around the world have all taken powerful economic and political measures to promote the development of bioenergy in this new situation. There is hundreds of millions of bioenergy sources in China, which has always been the main energy source in rural life and production of China. So, it's predictable that bioenergy shall take an important position in the future composition of high quality energy.

It is declared in the whitepaper book of energy policy published by China government in December, 2007 that China will take an energy development route with Chinese characteristics, and never threaten the energy of other countries and regions now and in the future. China has established the strategic vision based on long-term interest. Its basic point is to take exploration of fossil energy, development of alternative energy, highly efficient utilization of energy and the problem of environmental security into a construction system, and offer dependent conditions to promote development. The specific content includes the import, exploration and storage of energy, utilization of nuclear energy, development of renewable energy such as bioenergy, energy conservation and system reform, etc.

The author has prepared at least 10 years for today's timely publication of this book. Comparing to other common books of knowledge and technique, this book has several obvious features, first, it has outstanding innovation. All the basic material of the whole book is from the

author and his over 30 master and doctor candidates' research and practice results on the theme of bioenergy for more than 10 years. The research of every subject is developed around the core problem in this field of China or even around the world. Secondly, it is very practical. The author has published more than 100 theses during the research process, but rather than hold still in the thesis phrase, he didn't loose the chance to convert research results into productivity and actively promote the engineering process of techniques. Among the research results, some have gained national patent and been successfully used in production, some went through trials in enterprises, and some have gone into deeper research in domestic and international cooperation. Finally, it embodies strong basic property. Every chapter in this book is related to basic research content, and fully retained the process and results of research.

This book has five parts. *Review* and *Commentary of Bioenergy* is written by Professor Zhang Bailiang. Chapter Ⅰ, *Gaseous Biofuel* is written by Doctor Yang Shiguan of North China Electric Power University (Postdoctor of Nanjing University), Doctor Zhang Jie (Postdoctor of Tsinghua University), Doctor Wang Xutao of Hernan University of Urban Construction, etc. And the whole chapter is organized and edited by Doctor Yang Shiguan. Chapter Ⅱ, *Liquid Biofuel* is written by Doctor Song Andong of Henan Agricultural University(Postdoctor of Shandong University), Doctor Zhu Lingfeng of North China University of Water Resources and Electric Power, Doctor Xu Guizhuan and Doctor Songhuamin of Henan Agricultural University, etc. And the whole chapter is organized and edited by Doctor Song Andong. Chapter Ⅲ, *Densified Biomass Fuel* is written by Doctor Fan Fengming of National Bioenergy Company, Doctor Ma Xiaoqin(Postdoctor of Zhejiang University), Doctor Zhao Qingling of North China University of Water Resources and Electric Power, Doctor Liu Junhong of Hernan University of Urban Construction, etc. and the whole chapter is organized and edited by Doctor Fan Fengming; Chapter Ⅳ, *Bioenergy Resource* is written by Postdoctor Wu Mingzuo of Henan Agricultural University, Doctor Ding Yi of China National Offshore Oil Corporation, Master Wang Jiuchen of Science and education department in Ministry of Agriculture, China, etc. The whole chapter is organized and edited by Doctor Wang Xutao. Doctor Xu Guizhuan, Doctor Yang Shiguan and Doctor Wang Jiqing have edited the whole book. The whole book is checked and finalized by Professor Zhang Bailiang.

As the whole world exhibit great attention to bioenergy, hopefully the publication of this book can be a modest spur to induce others to come forward with valuable contributions. Due to differences in experiment conditions and technical routes, readers might find some differences against the datas and conclusions in this book during their research or practice. This is normal in academic activities. We wish to discuss and cooperate with various research workers, engineers and technicians. As a new subject, the development of bioenergy embarks on various fields of science and technology. We feel very inadequate and level-limited; therefore, this book inevitably has some oversights and flaws. We respect and invite relevant experts and many readers to criticize and comment.

Author

December, 2008

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Chapter Ⅱ Liquid Biofuel