Biofuel and Biorefinery Technologies 7

Neha Srivastava · Manish Srivastava
P. K. Mishra · S. N. Upadhyay
Pramod W. Ramteke · Vijaj Kumar Gupta
Editors

Sustainable Approaches for Biofuels Production Technologies

From Current Status to Practical Implementation

Springer

Biofuel and Biorefinery Technologies

Volume 7

Series editors

Vijai Kumar Gupta, Department of Chemistry and Biotechnology, Tallinn University of Technology, Tallinn, Estonia
Maria G. Tuohy, School of Natural Sciences, National University of Ireland Galway, Galway, Ireland

This book series provides detailed information on recent developments in biofuels & bioenergy and related research. The individual volumes highlight all relevant biofuel production technologies and integrated biorefinery methods, describing the merits and shortcomings of each, including cost-efficiency. All volumes are written and edited by international experts, academics and researchers in the respective research areas.

Biofuel and Biorefinery Technologies will appeal to researchers and post-graduates in the fields of biofuels & bioenergy technology and applications, offering not only an overview of these specific fields of research, but also a wealth of detailed information.

More information about this series at http://www.springer.com/series/11833

Neha Srivastava · Manish Srivastava
P. K. Mishra · S. N. Upadhyay
Pramod W. Ramteke · Vijai Kumar Gupta
Editors

Sustainable Approaches for Biofuels Production Technologies

From Current Status to Practical Implementation

Springer

Editors
Neha Srivastava
Department of Chemical Engineering and Technology
Indian Institute of Technology (BHU) Varanasi
Varanasi, Uttar Pradesh, India

S. N. Upadhyay
Department of Chemical Engineering and Technology
Indian Institute of Technology (BHU) Varanasi
Varanasi, Uttar Pradesh, India

Manish Srivastava
Department of Physics and Astrophysics
University of Delhi
New Delhi, India

Pramod W. Ramteke
Department of Biological Sciences
Sam Higginbottom Institute of Agriculture, Technology and Sciences
Allahabad, Uttar Pradesh, India

P. K. Mishra
Department of Chemical Engineering and Technology
Indian Institute of Technology (BHU) Varanasi
Varanasi, Uttar Pradesh, India

Vijai Kumar Gupta
Department of Chemistry and Biotechnology, School of Science
Tallinn University of Technology
Tallinn, Estonia

ISSN 2363-7609 ISSN 2363-7617 (electronic)
Biofuel and Biorefinery Technologies
ISBN 978-3-319-94796-9 ISBN 978-3-319-94797-6 (eBook)
https://doi.org/10.1007/978-3-319-94797-6

Library of Congress Control Number: 2018946595

Printed on acid-free paper

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

Biofuels are the potential and sustainable alternative sources of fossil fuels. Efforts are continuously being made to develop economically competitive biofuels and bioenergy. Despite having tremendous efforts, green energy/fuels option did not the make the substantial move and still far from practical implementation globally. To develop economic and viable biofuels, all processing aspects of biomass conversion including mapping, logistic, transportation and storage of feedstock should also be given high priority. Research at laboratory level should be done focusing on the industrial parameters which directly influence the biofuels yield and productivity. Selection of right feedstock and its handling at shop floor, and mechanization of biomass pretreatment need to be taken into consideration. Biofuels production process should be robust and consolidated having minimum processing steps with zero waste discharge. Publication of the book on '*Sustainable Approaches for Biofuels Production Technologies: From Current Status to Practical Implementation*' is a timely and good effort in this direction. This book consists of 10 specific chapters focusing on different kinds of biofuels, existing technologies and sustainable approaches to improve biofuels production process. This book is directed towards presenting drawbacks in existing process and technologies in current biofuels options. The book comprehensively presents the kind of available biofuels options and analyses their potential for using as an alternative to conventional fossil fuel. I am sure this book will serve as one of the key collections of information for the scientists, researchers, teachers and students working in area of biofuels research and development.

I congratulate Dr. Neha Srivastava from IIT-BHU, Varanasi, Dr. Manish Srivastava from DU, Delhi, Prof. (Dr.) P. K. Mishra from IIT-BHU, Varanasi, Prof. (Dr.) S. N. Upadhyay from IIT-BHU, Varanasi, Prof. (Dr.) Pramod W. Ramteke from SHUATS, Allahabad, and Dr. Vijai Gupta from Tallinn University of Technology, Estonia for bringing out this valuable publication on '*Sustainable Approaches for Biofuels Production Technologies: From Current Status to Practical Implementation*' to satisfy the current demand of industries, scientists, teachers, researchers and students.

My sincere thanks go to the editors for their hard work and dedication in this attempt. All the authors and editors of the Series of Biofuels and Biorefinery Technologies deserve sincere appreciation for their efforts in preparing this valuable publication.

Sao Paulo, Brazil

Anuj K. Chandel, Ph.D, M.B.A
Department of Biotechnology
Engineering School of Lorena (EEL)
University of Sao Paulo (USP)

The original version of the book was revised: The editor name has been corrected to "Vijai Kumar Gupta" on the cover and in the front matter. The correction to the book is available at https://doi.org/10.1007/978-3-319-94797-6_11

Acknowledgements

The editors are grateful to all the academicians and scientists who have made their effortful contribution to complete this book. We all editors also express our gratitude towards our parents whose continuous support and blessings have always encouraged us to pursue academic activities. It is fairly possible that while completing this task, some mistakes might have snuck in text unintentionally and for these we owe unadulterated responsibility. We are grateful to all authors for their contribution to present book. We are also thankful to our institution/university IIT (BHU) Varanasi, DU, SHUATS and Tallinn University of Technology for giving this opportunity to facilitate this work. We thank them from the core of our heart.

Contents

About the Editors

Dr. Neha Srivastava Institute Post-Doctoral Fellow, IIT (BHU) Varanasi-221005, U.P., India; Mobile no.: +91-9988062681, E-mail: sri.neha10may@gmail.com.

Field of expertise: Biofuels production, microbial bioprocessing and enzyme technologies.

She is currently working as post-doctorate fellow in the Department of Chemical Engineering and Technology, IIT (BHU) Varanasi, India. She has published 23 research articles in the peer-reviewed journals and has three patents. She has been completed her Ph.D. from the Department of Molecular and Cellular Engineering, SHIATS, India in 2016 in the area of bioenergy. She has been received 06 Young Scientist Awards. Presently, she is working on biofuels production (Cellulase enzymes; production and enhancement, biohydrogen production from waste biomass and bioethanol production).

Dr. Manish Srivastava DST-INSPIRE Faculty Fellow, Department of Physics and Astrophysicsm, University of Delhi, 110007, India; Mobile no.: + 91 - 7503757601, E-mail: 84.srivastava@gmail.com, manish_mani84@rediffmail.com.

Field of expertise: Synthesis of nanomaterials and their application as catalyst for development of electrode materials in energy storage, biosensors and biofuels productions.

He is working as DST-INSPIRE faculty in the Department of Physics and Astrophysics, University of Delhi, India. He has published 39 research articles in the peer-reviewed journals, authored several book chapters and filed 1 patent. He worked as a post-doctorate fellow in the Department of BIN Fusion Technology, Chonbuk National University from August 2012 to August 2013. He was an Assistant Professor in the Department of Physics, DIT School of Engineering, Greater Noida, from July 2011 to July 2012. He received his Ph.D. in Physics from the Motilal Nehru National Institute of Technology, Allahabad, India in 2011. Presently, he is working on the synthesis of graphene-based metal oxide hybrids and their applications as catalysts. His area of interest is synthesis of nanostructured materials and their applications as catalyst for the development of electrode materials in energy storage, biosensors and biofuels production.

Prof. P. K. Mishra IIT (BHU), Varanasi-221005, India; Mobile no.: 9415301462, E-mail: pkmishra.che@itbhu.ac.in.

Field of expertise: Biofuels production, microbial bioprocessing and enzyme technologies.

He is currently Professor and Head in the Department of Chemical Engineering and Technology, Indian Institute of Technology (BHU), Varanasi, India. He obtained his Ph.D. degree in Chemical Engineering from Institute of Technology (Banaras Hindu University) in 1995. He has authored/co-authored over 60 technical papers published in reputed national/international journals and supervised more than 20 doctoral students. He has received several awards and honours and has five patents. He is Fellow of Institution of Engineers India. He has received several awards and honours at National/International levels. He has also made significant contribution towards the development of entrepreneurship ecosystem in Eastern part of the country. He is coordinator of Technology Business Incubator at the Institute and member of Executive committee NISBUD, Ministry of Skill Development, Government of India.

Prof. S. N. Upadhyay Emeritus Professor, Department of Chemical Engineering and Technology, Indian Institute of Technology (BHU)-221005, Varanasi, India; Mobile no.: 9415372465, E-mail: snupadhyay.che@itbhu.ac.in.

Field of expertise: Biofuels production, microbial fuel cell, membrane technology and wastewater treatment.

He is an Emeritus Professor in the Department of Chemical Engineering and Technology, Indian Institute of Technology (BHU), Varanasi, India. He has made significant contributions to the institute as professor for 50 years and also served as the institute's director for the academic year (2005–2010). He obtained his Ph.D. (Chemical Engineering) degree from Banaras Hindu University in 1969. He has authored/co-authored over 180 technical papers published in reputed international journals and supervised more than 30 doctoral students in the field of Biochemical and Chemical Engineering. He is Fellow of National Academy of Sciences India, Indian National Academy of Engineering, Biotechnology Research Society, India and Institutions of Engineers, India. He has received several awards and honours at National/International levels. He has made significant contributions to the field of energy/engineering including bioenergy.

Prof. Pramod W. Ramteke Dean of Biological Sciences, SHUATS, Allahabad, U.P., India; Mobile no.: 9415124985; E-mail: pwramteke@gmail.com.

Field of expertise: Biofuels production, plant biology and microbial technology.

He is presently Dean of Post Graduate Studies and Head of the Department of Biological Sciences and Genetics and Plant Breeding at Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Allahabad, India.

He is elected Fellow of National Academy of Agricultural Sciences, National Academy of Biological Sciences, The Linnean Society of London, Academy of Microbial Sciences India (AMI), The Biotech Research Society of India, Society for Plant Protection Sciences, Mycological Society of India, Uttar Pradesh Academy of Agricultural Sciences, Maharashtra Academy of

Sciences, Association for Biotechnology and Pharmacy, Society of Biological Sciences and Rural Development and The Academy of Environmental Biology.

He is recipient of J. C. Bose Gold Medal, SCON Memorial Award for Excellence in Science, Dr. J. C. Edward Medal, Prof. K. S. Bilgrami Memorial Award, Er. V. S. Chauhan Gold Medal, Biotechnology Overseas Associateship and International Fellowship by Biotechnology and Biology Research Council, UK. He is member of editorial board of several journals. He has been a visiting scientist to Hacettepe University, Turkey; Institute of Food Research, UK; University of Liege, Belgium; Korea Institute of Science and Technology, South Korea, University of Szeged, Hungary and Hydrobiological Institute, Czech Republic.

In addition to three patents, three books and over 150 research papers are to his credit. He has implemented seven major projects from DBT, DST, CSIR, UPCAR and CST, UP and supervised 21 Ph.D.s and more than 40 PG Thesis/projects. He was a member of 18th Indian Scientific Expedition to Antarctica (1998–1999).

Dr. Vijai Kumar Gupta ERA Chair of Green Chemistry, Department of Chemistry and Biotechnology, School of Science, Tallinn University of Technology, Akadeemia tee 15, 12618 Tallinn, Estonia; Phone: +372 620 2833, Mobile no.: +372 5671 1014, E-mail: vijai.gupta@ttu.ee; vijaifzd@gmail.com.

He from ERA Chair of Green Chemistry, Department of Chemistry and Biotechnology, School of Science, Tallinn University of Technology, Tallinn, Estonia, is one of the leading experts in the area of microbial biology and biotechnology. He is the member of International Sub-commission on Trichoderma and Hypocrea, Austria; International Society for Fungal Conservation, UK; and Secretary of European Mycological Association. He is the Fellow of Prestigious—The Linnaean Society, London, UK; Fellow of Indian Mycological Association; and Fellow of Mycological Society of India. He has been honoured with several awards in his career including Indian Young Scientist Award for his advanced research achievements in the field of fungal biology and biotechnology. He is the editor of few leading scientific journals of high repute and having many publications in his hands with h-index 21. He has edited many books for publishers of international renown such as CRC Press, Taylor and Francis, USA; Springer, USA; Elsevier Press, The Netherlands; Nova Science Publisher, USA; De Gruyter, Germany; and CABI, UK.

Bioprocessing Perspective in Biorefineries

Sheelendra M. Bhatt and Jatinder Singh Bal

Abstract In the current chapter, the various strategies for biofuel production focusing on rice straw have been discussed. The basic aim is to address the technical applications in enhancing biofuel production using lignocellulosic biomass. The overall price can be minimized using lignocellulosic biomass fractionation at biological platform, where lignin separation and also conversion of biomass into biofuel production is possible at a single platform. The inclusion of chemical pretreatment methods often produces toxic components thus inhibiting the cell to grow during further conversion, thus results in low productivity. In such case, microbial consortia may be a good option. Understanding of bioprocessing steps can lead to the development of sustainable technology for pilot-scale economical productions, to meet the current demand for biofuel.

Keywords Bioprocessing · Microbial consortia · Xylanase · Pectinase
Cellulase · Biorefineries · Biofuel

1 Introduction

In the current scenario, the principal requirements of human being are food feed and fuel. Regarding fossil fuel its going to deplete very soon in coming years. Biofuel is the only alternative to rapidly depleting fossil fuel, because of its sustainability, efficiency, and economics when used for blending thus helps in reducing overall cost. A variety of biofuels exist today of which bioethanol always being in great demand and thus high production is required.

According to a report of 2014, around 74% of biofuel ethanol was produced, while biodiesel is produced in second highest amount (Gupta and Verma 2015). In 2016, the growth rate of global biofuel production was 2.6%, while in current scenario biofuel demand is increasing at 6.5% per annum, while petroleum reserve is decreasing

S. M. Bhatt (✉) · J. S. Bal
CSE Department, Sant Baba Bhag Singh University, Jalandhar, Punjab, India
e-mail: drsmbhatt@gmail.com

N. Srivastava et al. (eds.), *Sustainable Approaches for Biofuels Production Technologies*, Biofuel and Biorefinery Technologies 7,
https://doi.org/10.1007/978-3-319-94797-6_1

Table 1 Composition of biomass

Lignocellulosic biomass	Cellulose	Hemicellulose	Lignin	References
Sugarcane (top)	29.85	18.85	25.69	Sindhu et al. (2011)
Corn stalk	34.45	27.55	21.81	Wu et al. (2011)
Bagasse	30	35	18	Sarkar et al. (2012)
Sugarcane bagasse	44	27	24	de Souza et al. (2013)
Sweet sorghum bagasse	36.9	17.8	19.5	Umagiliyage et al. (2015)
Wheat straw	38.7	19	17.3	Valdez-Vazquez et al. (2015)
Rice straw	35.8	21.5	24.4	Imman et al. (2015)
Rapeseed	51.3	17.3	44	López-Linares et al. (2015)
Corn stover	36.3	31.4	17.2	Saha et al. (2016)

day by day. Of all global productions, India is producing only 1% of biofuel, while consumption rate is high up to 3.1%. Consequently, options are available where many biomasses can be converted into ethanol, biodiesel (Mofijur et al. 2015), and other gaseous or liquid biofuels. There are various advantages of using biofuel such as (1) high energy (2) CO_2 mitigation (3) renewable (4) eco-friendly (5) and can be produced from nonedible biomass.

According to a report of European Union, the target of ethanol production has been set to 8 billion liters up to 2020. Japan has a target of 6 billion liters of ethanol up to 2030. India has a target of 4 billion gallon tons (Energetica India Report 2009). The current costs of biochemical cellulosic ethanol are estimated to be between US$4.03 and $5.60 per US gallon of annual capacity (Binod et al. 2010). The current cost of ethanol today is $1.22 per gallon while it may reduce further up to $70 per gallon (http://www.biofuelsdigest.com/bdigest/2017/05/18/ethanol-and-biodiesel-dropping-below-the-production-cost-of-fossil-fuels/).

The utilization of lignocellulosic biomass includes delignification, hydrolysis, and saccharification before final conversion into ethanol. Complex bonding of lignocellulosic plant structure makes it a recalcitrant owing to the presence of lignin, hemicellulose, and other materials with cellulosic content. Table 1 shows cellulosic composition in various biomasses. Pretreatment is one of the mandatory requirements, in order to get rid of lignin from lignocellulosic biomass. Therefore, delignification is one of the costly and challenging procedures and need technical improvement for pilot-scale applications (Bhatt 2014; Phitsuwan et al. 2013).

In this context, biorefineries concept seems practicable, where every fraction of biomass is processed into value-added product. In the current chapter, we will discuss issues of bioprocessing steps in biofuel ethanol production with a special focus on rice straw which is the globally largest available biomass (Abedinifar et al. 2009).

Sustainable Biofuel Production: Indian Scenario

As per as the report of NUiCONE proceedings, India has now changed strategies to enhance its biofuel production beyond 1%. Therefore, around 85% increase in

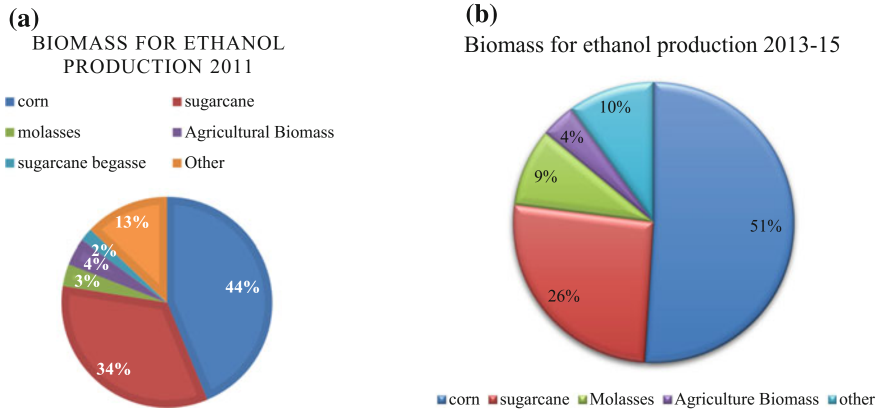

Fig. 1 **a** Bioethanol production from 2013 to 2015. *Source* Araújo et al. (2017), Sindhu et al. (2017). **b** Major biomass for bioethanol production. *Source* Mood et al. (2013), Balan (2014)

biofuel production has been observed since 2009. Also, the Government of India has now changed the blending mandate from 5 to 20% in 2017. Therefore, sustainable technology is required for the enhancing current production of 52.32–83.58 Mt (around >26%). In 2008, the US participation was around 51%, Brazil was 36%. EU's contribution was only 4% to ethanol production, while in 2011, US contribution was around 46%, Brazil was 22%, while EU was 17% see Fig. 1.

The United States is the world's largest producer of ethanol, and has produced nearly 15 billion gallons in 2015 alone. Together, the U.S. and Brazil produce 85% of the world's ethanol. The vast majority of U.S. ethanol is produced from corn, while Brazil primarily uses sugar.

2 Biofuel Classifications

Based on the types of biomass, biomass can be classified as mentioned in Table 2 and various feedstock used in biofuel production has also been mentioned. Out of which corn and molasses are used mainly for biofuel ethanol production. Biodiesel production is another strategy to cope up with demand in the current scenario, which uses various agricultural and nonagricultural waste as a source. Ethanol production has been mentioned in billions of gallons of different biomasses.

First generation (1st G) biofuel includes sugar crops (sugar beet, sugarcane), edible crops (corn, sorghum), oilseed crops (soybean, canola), and animal fats. Second generation (2nd G) biofuel includes all types of cellulosic biomass, nonfood crops, and waste biomass, while third (3rd G) generation biofuel is based on the use of algae and municipal solid wastes (Singh et al. 2011).

Table 2 Biofuel classification

Fuel	Feedstock
First generation	
Bioalcohol ethanol, Propanol butanol	Starches from wheat, corn, sugar cane, molasses, potatoes, other fruits
Biodiesel	Oils and fats including animal fats, vegetable oils, nut oils, hemp, and algae
Green Diesel	Made from hydrocracking oil and fat feedstock
Second generation	
Ethanol	Lignocellulosic biomass straw, bagasse
Biobutanol	Lignocellulosic biomass straw, bagasse
Third generation	
Bio-oil	Algae
Fourth generation	
Photobiological solar fuels and electrofuels	

There are various generations of biofuel such as first, second, third, and fourth generation biofuel. First generation biofuel includes all kind of edible feedstock which can be hydrolyzed by simple steam and further by enzymatic conversion into ethanol. Second generation biofuel is mostly based on the use of lignocellulosic biomass for biofuel production. These are less competitive to edible crops and are mostly available as agriculture, municipal, or industrial waste (Araújo et al. 2017). This biomass is rich in cellulose and hemicellulose which can be converted into ethanol after several bioprocessing steps. Recent research shows that production of bioethanol from these wastes is little expansive due to (1) feedstock cost, (2) feedstock harvesting, (3) feedstock densification, (4) feedstock pretreatment, (5) by-product separations (6) environmental and health impact. Biobutanol is another fuel which is obtained using the same feedstock but with different microbes (Araújo et al. 2017). Third-generation biofuel is obtained as bio-oil using algae as feedstock while fourth-generation biofuel is obtained as bio-solar fuel and electro-fuel as shown in Table 2.

Economically sustainable lignocellulosic-based ethanol production depends on

(1) Suitable substrate
(2) Suitable pretreatment applications without inhibitors productions
(3) Suitable biocatalyst
(4) Robust yeast cell bioethanol conversion (e) proper detoxification.

The order of cost of production is 3G > 2G > 1G. The ethanol production cost of molasses-based feedstock varies between 0.78 and 0.97 US$/L. However, production of ethanol at pilot scale is still in process of demonstration scale from the 3G feedstock. The cheapest ethanol production is in Brazil, where a combination of readily available resources and cheap labor makes prices of about $0.20 per liter possible.

3 Lignocellulosic Ethanol: Production Technology

There are various modes of ethanol production using rice straw such as SSF, SHF, sequential hydrolysis and fermentation process, SSMSF, SESF (Abedinifar et al. 2009; Karimi et al. 2006; Shinozaki and Kitamoto 2011; Ko et al. 2009). Each technique has its own merits and demerits but the basic idea is to utilize the pentose sugar present in hemicellulose. Thus, much novel work has been reported such as the use of lactic acid bacteria which has the capability to produce lactic acid during fermentation and helpful in the insolubilization of cellulose that is able to ferment glucose and (Kim et al. 2010). Thus, it was an integration of enzymatic hydrolysis and fermentation in one step called separate hydrolysis and fermentation. Ethanol production by *Mucor indicus* and *Rhizopus oryzae* from rice straw was successful in bypassing the end product inhibition (Abedinifar et al. 2009).

The bioconversion of cellulosic materials includes the formation of soluble sugars from cellulose in paper/agricultural residues and depends on the coordinated action of individual components such as β-exoglucanase, β-endoglucanase, β-glucosidase of cellulase enzyme.

3.1 Ethanol from Lignocellulosic Biomass

There are various biomasses used for lignocellulosic-based ethanol production such as rice and paddy straw because, water hyacinth corn stover. Predominantly, bioethanol is derived from stover and switchgrass in the U.S., while sugarcane bagasse is used mainly in Brazil and India, and rice husk and straw from China and India (Khoo 2015).

3.1.1 Corn Stover

Ethanol production from corn stover (Saha et al. 2013) was studied by many workers. Corn stover is rich in cellulose, i.e., 37% while having less lignin comparatively. Hydrothermal pretreatment combined with enzymatic saccharification leads to conversion of 72% glucose (Saha et al. 2013) while ethanol yield was 0.49 g/g biomass. Corncob was reported to produce more furfural as compared to corn stover, which is a toxic component released after pretreatment and should be an inhibitor for the growth of microbes involved in hydrolysis and saccharification. Therefore, corn stover is suitable for ethanol production (Kadam and McMillan 2003). Microbial pretreatment of corn stover with *Ceriporiopsis subvermispora* was attempted with enzymatic hydrolysis by some workers, which resulted in 66% production of glucose in 35 days (Wan and Li 2010). In another work, steam pretreatment was given in SSF mode which resulted in 70% ethanol with 10% insoluble solid biomass with yeast concentration 5 g/l. In SSF mode, alkaline pretreatment of corn stover coupled with fungal treatment with *Phanerochaete chrysosporium or Gloeophyllum trabeum* and fermentation with *Saccharomyces cerevisiae or Escherichia coli K011* resulted in 3.09. g/100. g stover at day 4 (Vincent et al. 2014). In an attempt to resolve the problem of released toxic during pretreatments such as furfural and other inhibitory compounds, corn stover were hydrolyzed and hemicellulose fraction was treated with by roto-evaporation and lime neutralization resulted in removal of more than 50% furfural and acetic acid, which was volatile and resulted in enhanced ethanol production of 31.1 g/L and the corresponding ethanol yield on fermentable sugars of 0.406 g/g were obtained within 72 h in batch fermentation of the detoxified hydrolysate with immobilized cells (Zhao and Xia 2010). In another report, corn stover was pretreated with dilute H_3PO_4 (0.0–2.0%, v/v) or 1% acid combined with biological treatments with Escherichia coli strain FBR and condition were optimized by response surface methodology resulted in 85% glucose yield. In a similar effort to produce butanol using ABE technology, simultaneous saccharification, fermentation, and recovery (SSFR) were attempted which resulted in hydrolysis of 97% sugar from corn stover (Qureshi et al. 2014).

3.1.2 Rice Straw

Rice straw burning was recently in the news in Punjab at a large level, and as a proof images were released as shown in Fig 2. As an estimate, around 2.5 tons of rice straw has been burnt per acre of land due to the season of next crop within 20 days. In Punjab, around 11 MT (million tons) of rice is grown which produces around 21 MT of rice straw alone which resulted in the release of >70% CO_2 7% CO, and 0.66% CH_4 along with 2.09% N_2O (Binod et al. 2010). Besides warning by the government and court, farmers are burning this useful biomass due to the lack of appropriate technology. One such attempt has been done to convert them into pellets which later can be used into fuel generations by using techniques of pyrolysis. The need is to develop farmer-friendly technology, which can be used in one step to yield glucose and thus ethanol.

4 Bioprocessing of Lignocellulosic Biomass

Removal of recalcitrant lignin requires various complex chemical or biochemical processing to get rid of cellulose and hemicellulose, which is the main carbohydrate to be used in fermentation and sachharification.

Different studies show that composition of biomass depends on various biotic and abiotic factors, ecosystems and time of harvesting. Variation of lignin content varies from 3 to 20%, cellulose content from 17 to 14%, which is the most suitable for ethanol production. After separation of cellulosic biomass, enzymatic hydrolysis and fermentation lead to the conversion of ethanol production. Owing to environmental issue combination of treatment is preferred to make biochemical process feasible in