

BioEnergy and BioChemicals Production from Biomass and Residual Resources

Authors:

Dimitar Karakashev, Yifeng Zhang

Date Submitted: 2018-10-04

Keywords: Residual Resources, Biochemicals, Bioenergy, Biomass

Abstract:

(no abstract)

Record Type: Published Article

Submitted To: LAPSE (Living Archive for Process Systems Engineering)

Citation (overall record, always the latest version):

LAPSE:2018.0701

Citation (this specific file, latest version):

LAPSE:2018.0701-1

Citation (this specific file, this version):

LAPSE:2018.0701-1v1

DOI of Published Version: <https://doi.org/10.3390/en11082125>

License: Creative Commons Attribution 4.0 International (CC BY 4.0)

Editorial

BioEnergy and BioChemicals Production from Biomass and Residual Resources

Dimitar Karakashev ^{1,*},† and Yifeng Zhang ^{2,*}

¹ Danish Technological Institute, Biomass and Biorefinery, 2630 Taastrup, Denmark

² Department of Environmental Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark

* Correspondence: mitac_bg@yahoo.com (D.K.); yifz@env.dtu.dk (Y.Z.)

† Current address: Snogegårdsvej 139 D, 2860 Søborg, Denmark.

Received: 17 July 2018; Accepted: 13 August 2018; Published: 15 August 2018



1. Introduction

Research and technology developments in bioenergy and biochemical production systems are of the utmost important for the development of next generation, highly efficient biomass conversion concepts maximizing the total energy and chemical output. The utilization of non-conventional biomasses and unexploited residual resources (e.g., agriculture and agroindustry wastes), innovative solutions for online monitoring and process control, novel biochemical pathways, microbial platforms and reactor technologies are key issues to be addressed. Though conventional technologies are constantly developing and novel processes are continually emerging, major challenges have still to be solved, such as the design of high performance and cost-effective technologies for the production of bioenergy (gaseous, liquid, solid biofuels, heat, renewable electricity) and biochemicals from residual resources in a biorefinery concept, where the potential of the biomass and residual waste streams is fully valorized. In this context, evaluation of the environmental, technological, economical, and social sustainability of the concepts developed are of extreme importance. The main objective of this Special Issue is, hence, to provide cost-effective and technologically sound solutions for next generation bioenergy and biochemical production systems.

The particular topics of interest in the original call for papers included, but were not limited to:

- Novel and unexploited residual resources for next generation biorefineries
- New emerging bioenergy and biochemicals production technologies
- Biochemicals pathways involved in biofuels and biochemicals production
- Microbial ecology of the biomass conversion processes
- Bioreactors for bioenergy and biochemicals production
- Novel approaches for biosystems sustainability evaluation

This book contains the successful invited submissions [1–21] to a Special Issue of *Energies* on the subject of “BioEnergy and BioChemicals Production from Biomass and Residual Resources”.

2. Statistics of the Special Issue

The response to our call had the following statistics:

- Submissions (33);
- Publications (21);
- Rejections (12);
- Article types: research article (19); review article (2).

The authors’ geographical distribution (published papers) is:

- China (3);
- USA (2);
- Italy (2);
- Germany (2);
- Poland (2);
- Mexico (2);
- Austria (1);
- Denmark (1);
- Iceland (1);
- Hungary (1);
- Portugal (1);
- Costa Rica (1);
- Thailand (1);
- United Arab Emirates (1).

Published submissions are related to the most important techniques and analysis applied to the bioeconomy of biofuels and biochemicals derived from varied residual biomasses.

We found the edition and selections of papers for this book very inspiring and rewarding. We also thank the editorial staff and reviewers for their efforts and help during the process.

3. Brief Overview of the Contributions to This Special Issue

The twenty-one published papers cover a variety of biomass or waste residuals that have been converted into different types of energy, biofuels or biochemicals including heat [1,11,16], methane [2,4,7–9,17,19–21], electricity [2,11,16], short chain fatty acids [2,19], ethanol [3,12,19], syngas [5,19], nutrient pellets [6], hydroxymethylfurfura [15], and hydrogen [2,10,14,18,19]. The key information including biomass or residuals, products, and technology for the production and type of research are summarized in Table 1. Among the published papers, fourteen papers were experiment-based research, while five papers were based on sustainability and tech–economic analysis. For more specific information, a brief description of each paper is provided in the following.

The first contribution by Fuller et al. [1] assessed the impact of co-combustion of an herbaceous biomass with low-quality Greek lignite on the quality of the fly ash. The authors compared the results with those of fly ash samples from an industrial facility using the same fuel qualities. Their work offers insights into ash management, a circular economy of herbaceous biomass, and sustainable power plant operations.

Bastidas-Oyanedel and Schmidt [2] conducted a techno-economic analysis of a food-waste-based biorefinery process. It was found in their study that dark fermentation with separation and purification of acetic and butyric acids could gain the highest profit among other scenarios.

Safarian and Unnthorsson [3] made a comprehensive assessment of the sustainability of producing lignocellulosic bioethanol from municipal organic wastes in Iceland, including timber, wood, paper and paperboard, and garden waste. They also evaluated the potential of the total wastes and bioethanol production in Iceland.

Small-volume bioreactors could serve as a test platform to provide an indication of potential challenges that are important for the development of large-scale bioreactors. Kasprzycka and Kuna [4] investigated the fermentation process in small-volume fermenters with a volume of 100–120 mL, which was an effective methodology to facilitate the preliminary selection before large-scale operation.

Syngas is a promising feedstock for the chemical and energy industries. Biomass residues from agriculture and agroindustry with less water content are ideal sources of syngas. Cerone and Zimbardi [5] investigated the effect of air and steam supply on the overall process performance and syngas composition in a pilot updraft gasifier.

Nagy et al. [6] conducted an economic analysis of a process that utilized digestate and waste heat from a biogas plant as the raw materials to produce a pellet. The pellet can be subsequently used as a nutrient in soil or heat energy. The authors reported that the pellets can be produced at a cost of 88–90 EUR/ton with a dry matter substrate content around 6 to 10%.

Seneesrisakul et al. [7] discussed the effect of temperature on the activity of methanogens in relation to the availability of micronutrients. The authors conducted the experiment using anaerobic sequencing batch reactors treating ethanol wastewater at 37 °C (mesophilic) and 55 °C (thermophilic) temperatures.

Beside temperature, organic loading is also a key factor for successful anaerobic digestion. Gao et al. [8] investigated the effect of the organic loading rate on the microbial responses in both mesophilic and thermophilic anaerobic digestion reactors treating municipal solid waste.

Microorganisms are key players in the anaerobic digestion process for biogas production. Jin et al. [9] explored the feasibility of using rumen microorganisms as an inoculum to produce biogas from corn straw and livestock manure in a modified pilot-scale anaerobic digestion system under different solid contents and mixture ratios.

While the conversion of biomass and waste into syngas in gasification systems is technically mature, the production of hydrogen as the primary product is rarely reported, which still requires development and optimization to address various technical and economic challenges. Smoliński et al. [10] conducted experimental work on hydrogen production through the gasification of energy crop biomass and sewage sludge.

The European Union (EU) has ambitious targets to increase the use of renewable energy in the near future. Bioenergy is expected to meet these targets for 2020 and beyond. This situation has created the need to evaluate potential bioenergy technologies and related feedstocks. Madsen and Bentsen [11] analyzed the carbon debt and payback time of using forest residues to replace coal for heat and power generation. Unlike most other studies, the authors conducted the analysis based on empirical data from a retrofit of a heat and power generation plant in northern Europe.

Coffee is one of the most popular food commodities all over the world. During the coffee manufacture process, mucilage, husk, skin (pericarp), parchment, silver-skin, and pulp can be produced as by-products. Using these residual by-products such as mucilage for bioenergy production has rarely been studied. Orrego et al. [12] investigated for the first time the production of bioethanol from mucilage.

The thermal treatment of biomass, for example through torrefaction, could increase the energy density of the biomass and reduce its hygroscopicity. Gaitán-Álvarez et al. [13] studied the thermogravimetric and devolatilization rates of hemicellulose and cellulose from five tropical woody species using three torrefaction temperatures and three torrefaction times. The calorimetric behavior of the torrefied biomass was demonstrated.

Hamedani et al. [14] conducted a life cycle assessment of an agro-industrial residue-based gasification process for hydrogen production. The authors found that an improvement in the hydrogen production efficiency does not necessarily lead to a decrease in environmental impacts.

Steinbach et al. [15] reported a novel process to synthesize hydroxymethylfurfural using highly available disaccharide sucrose as raw material. Hydroxymethylfurfural, as high-value polymer, has unique merits among the bio-based platform chemicals used as precursors and fuel additives. The authors demonstrated that sucrose is the ideal feedstock for the large-scale production of hydroxymethylfurfural.

Ramos et al. [16] provided a case study for the environmental analysis and life cycle assessment of the waste-to-energy process in Portugal. Nine environmental impact categories were grouped from the raw data for the energy recovery plant. The authors also compared the results to two European average situations (incineration plant and sanitary landfill without pre-treatment). This paper showed that these facilities in Portugal were better or at the same level as the average European situation.

Tapia-Tussell et al. [17] investigated the potential for energetic macroalgae conversion to biomethane using biological pretreatment. Their results revealed that an increase in methane yield of 20% was achieved by using fungus for pretreatment. The authors concluded that macroalgae with high concentrations of ash and alkali metal biological processes is more suitable for the biomass utilization for than combustion or pyrolysis.

Rodríguez-Félix et al. [18] for the first time identify and quantify the volatile compounds in tequila vinasses from two different processes of tequila production. The authors also determined the correlation between the volatile compounds and the type of production process (cooked or uncooked stems). The results could serve as a basis for the further development of bioenergy processes using vinasses as the feedstock.

Sharara and Sadaka [19] provided a comprehensive review of the opportunities and barriers for swine manure conversion technologies. This work shed light on the gaps for further investigation and improvement of the technical applicability. The global growth of swine production brings challenges to manure management. The review discussed various technologies that were developed for the production of energy, fuels and bioproducts from swine manure. The authors found that full-scale research in the area of the thermochemical conversion of swine manure could be a core research interest in the future.

Co-digestion is a more cost-effective strategy, compared to dilution with water, to increase the biodegradability of waste streams. Duan et al. [20] investigated the feasibility of the co-digestion of chicken manure and algal digestate water. The kinetic parameters and mass flow involved in such processes were compared and discussed.

Lignocellulosic materials are regarded as an inexhaustible, ubiquitous natural resource, and using them as a basis for the second-generation of biofuel and biogas contributes significantly to social and environmental sustainability. Wagner et al. [21] reviewed the existing pretreatment techniques that have been developed to overcome the structural impediments of lignocellulosic materials. Special attention has been paid to biological pretreatment for the downstream processing of lignocellulosic biomass in an anaerobic digestion.

Table 1. Brief summary of the key information from the submissions to this Special Issue.

Biomass	Products	Technology	Type of Research		Reference
			Experimental	Assessment	
Herbaceous biomass	Heat	Combustion	√ ^a		[1]
Food waste	Methane, Power, lactic acid, polylactic acid, hydrogen, acetic acid & butyric acid	Biorefinery		√	[2]
Lignocellulosic municipal organic wastes	Ethanol	Pretreatment & Fermentation		√	[3]
Chopped maize silage	Biogas	Anaerobic digestion	√		[4]
Agroresidues	Syngas	Gasification	√		[5]
Digestate	Pellet	Anaerobic digestion		√	[6]
Ethanol wastewater	Biogas	Anaerobic digestion	√		[7]
Organic fraction of municipal solid waste	Biogas	Anaerobic digestion	√		[8]
Corn straw & livestock manure	Biogas	Anaerobic digestion	√		[9]
Crops biomass & sewage sludge	Hydrogen	Gasification	√		[10]

Table 1. Cont.

Biomass	Products	Technology	Type of Research		Reference
			Experimental	Assessment	
Forest residues	Heat and power generation	Combustion	✓		[11]
Coffee Mucilage	Ethanol	Fermentation	✓		[12]
Tropical woody species	Torrefied biomass	Torrefaction	✓		[13]
Agro-industrial residue	Hydrogen	Gasification		✓	[14]
Disaccharide sucrose	Hydroxymethylfurfura	Acid-catalyzed conversion	✓		[15]
Organic residues	Heat/electricity	Incineration & landfill		✓	[16]
Macroalgae	Biogas	Anaerobic digestion	✓		[17]
Tequila vinasses	Hydrogen	Dark fermentation	✓		[18]
Swine Manure	Multiple products	Multiple products		✓	[19]
Chicken manure & algal digestate	Biogas	Anaerobic digestion	✓		[20]
Lignocellulosic Resources	Biogas	Anaerobic digestion		✓	[21]

^a The type of research conducted in the selected study.

Funding: This research was supported financially by The Danish Council for Independent Research (DFR-1335-00142) and Novo Nordisk Foundation (NNF16OC0021568).

Conflicts of Interest: The author declares no conflict of interest.

References

- Fuller, A.; Maier, J.; Karampinis, E.; Kalivodova, J.; Grammelis, P.; Kakaras, E.; Scheffknecht, G. Fly Ash Formation and Characteristics from (co-)Combustion of an Herbaceous Biomass and a Greek Lignite (Low-Rank Coal) in a Pulverized Fuel Pilot-Scale Test Facility. *Energies* **2018**, *11*, 1581. [[CrossRef](#)]
- Bastidas-Oyanedel, J.-R.; Schmidt, J.E. Increasing Profits in Food Waste Biorefinery—A Techno-Economic Analysis. *Energies* **2018**, *11*, 1551. [[CrossRef](#)]
- Safarian, S.; Unnthorsson, R. An Assessment of the Sustainability of Lignocellulosic Bioethanol Production from Wastes in Iceland. *Energies* **2018**, *11*, 1493. [[CrossRef](#)]
- Kasprzycka, A.; Kuna, J. Methodical Aspects of Biogas Production in Small-Volume Bioreactors in Laboratory Investigations. *Energies* **2018**, *11*, 1378. [[CrossRef](#)]
- Cerone, N.; Zimbardi, F. Gasification of Agroresidues for Syngas Production. *Energies* **2018**, *11*, 1280. [[CrossRef](#)]
- Nagy, D.; Balogh, P.; Gabnai, Z.; Popp, J.; Oláh, J.; Bai, A. Economic Analysis of Pellet Production in Co-Digestion Biogas Plants. *Energies* **2018**, *11*, 1135. [[CrossRef](#)]
- Seneesrisakul, K.; Sutabutr, T.; Chavadej, S. The Effect of Temperature on the Methanogenic Activity in Relation to Micronutrient Availability. *Energies* **2018**, *11*, 1057. [[CrossRef](#)]
- Gao, Y.; Kong, X.; Xing, T.; Sun, Y.; Zhang, Y.; Luo, X.; Sun, Y. Digestion Performance and Microbial Metabolic Mechanism in Thermophilic and Mesophilic Anaerobic Digesters Exposed to Elevated Loadings of Organic Fraction of Municipal Solid Waste. *Energies* **2018**, *11*, 952. [[CrossRef](#)]
- Jin, W.; Xu, X.; Yang, F. Application of Rumen Microorganisms for Enhancing Biogas Production of Corn Straw and Livestock Manure in a Pilot-Scale Anaerobic Digestion System: Performance and Microbial Community Analysis. *Energies* **2018**, *11*, 920. [[CrossRef](#)]
- Smoliński, A.; Howaniec, N.; Bąk, A. Utilization of Energy Crops and Sewage Sludge in the Process of Co-Gasification for Sustainable Hydrogen Production. *Energies* **2018**, *11*, 809. [[CrossRef](#)]

11. Madsen, K.; Bentsen, N.S. Carbon Debt Payback Time for a Biomass Fired CHP Plant—A Case Study from Northern Europe. *Energies* **2018**, *11*, 807. [[CrossRef](#)]
12. Orrego, D.; Zapata-Zapata, A.D.; Kim, D. Optimization and Scale-Up of Coffee Mucilage Fermentation for Ethanol Production. *Energies* **2018**, *11*, 786. [[CrossRef](#)]
13. Gaitán-Álvarez, J.; Moya, R.; Puente-Urbina, A.; Rodríguez-Zúñiga, A. Thermogravimetric, Devolatilization Rate, and Differential Scanning Calorimetry Analyses of Biomass of Tropical Plantation Species of Costa Rica Torrefied at Different Temperatures and Times. *Energies* **2018**, *11*, 696. [[CrossRef](#)]
14. Rajabi Hamedani, S.; Villarini, M.; Colantoni, A.; Moretti, M.; Bocci, E. Life Cycle Performance of Hydrogen Production via Agro-Industrial Residue Gasification—A Small Scale Power Plant Study. *Energies* **2018**, *11*, 675. [[CrossRef](#)]
15. Steinbach, D.; Kruse, A.; Sauer, J.; Vetter, P. Sucrose Is a Promising Feedstock for the Synthesis of the Platform Chemical Hydroxymethylfurfural. *Energies* **2018**, *11*, 645. [[CrossRef](#)]
16. Ramos, A.; Afonso Teixeira, C.; Rouboa, A. Environmental Analysis of Waste-to-Energy—A Portuguese Case Study. *Energies* **2018**, *11*, 548. [[CrossRef](#)]
17. Tapia-Tussell, R.; Avila-Arias, J.; Domínguez Maldonado, J.; Valero, D.; Olguin-Maciel, E.; Pérez-Brito, D.; Alzate-Gaviria, L. Biological Pretreatment of Mexican Caribbean Macroalgae Consortia Using Bm-2 Strain (*Trametes hirsuta*) and Its Enzymatic Broth to Improve Biomethane Potential. *Energies* **2018**, *11*, 494. [[CrossRef](#)]
18. Rodríguez-Félix, E.; Contreras-Ramos, S.M.; Davila-Vazquez, G.; Rodríguez-Campos, J.; Marino-Marmolejo, E.N. Identification and Quantification of Volatile Compounds Found in Vinasses from Two Different Processes of Tequila Production. *Energies* **2018**, *11*, 490. [[CrossRef](#)]
19. Sharara, M.A.; Sadaka, S.S. Opportunities and Barriers to Bioenergy Conversion Techniques and Their Potential Implementation on Swine Manure. *Energies* **2018**, *11*, 957. [[CrossRef](#)]
20. Duan, N.; Ran, X.; Li, R.; Kougias, P.G.; Zhang, Y.; Lin, C.; Liu, H. Performance Evaluation of Mesophilic Anaerobic Digestion of Chicken Manure with Algal Digestate. *Energies* **2018**, *11*, 1829. [[CrossRef](#)]
21. Wagner, A.O.; Lackner, N.; Mutschlechner, M.; Prem, E.M.; Markt, R.; Illmer, P. Biological Pretreatment Strategies for Second-Generation Lignocellulosic Resources to Enhance Biogas Production. *Energies* **2018**, *11*, 1797. [[CrossRef](#)]



© 2018 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).