

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

5,800

Open access books available

142,000

International authors and editors

180M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.

For more information visit www.intechopen.com



Introductory Chapter: An Overview of Biogas

J. Rajesh Banu and R. Yukesh Kannah

1. Introduction

According to the International Energy Agency Report 2018, the global energy demands (GED) elevated 2.1% from the previous year. However, 70% of GED was met through oil, coal and fossil fuel. Among these, fossil fuel accounts for 81% of total energy demand (TED). The percentage of fossil fuel remains unchanged for the past three decades. Exploitation of fossil fuel extended the emission of carbon dioxide (CO₂) to 32.5 GT (gigatonnes) in the year 2017. Surplus emission of greenhouse gases (GHG) into the atmosphere is the major contributor for global warming and climate change. On considering, the profile of GHG emission researchers comes out with innovative ideas to minimize the emission. Nowadays, researchers and policymakers are working together to recognize alternative energy source to encounter the energy demand and global warming impacts.

Anaerobic digestion (AD) process is the cost-effective and emerging technology to derive biogas from various liquids and solid wastes. AD process is more suitable for valorization of high-strength organic waste under both mesophilic (30–40°C) and thermophilic (50–60°C) conditions. AD process is otherwise termed as biomethanation or biochemical degradation. AD process is a more environmental-friendly, energy-yielding and more efficient bioenergy production method than other waste processing technologies.

AD process dominant by anaerobic microbes, which plays major role in conversion of organic rich waste biomass into two valuable products such as methane and nutrient rich digested/effluent. Anaerobic breakdown of complex organic waste biomass follows four major steps, and these are (i) hydrolysis, (ii) acidogenesis, (iii) acetogenesis and (iv) methanogenesis. **Figure 1** represents the pathway of anaerobic degradation of organic waste.

Among them, hydrolysis is the rate-limiting and first step of AD process. During hydrolysis, complex organics (C₆H₁₀O₄) such as protein, carbohydrate and fat are converted into simple digestible amino acids, monosaccharides and fatty acids. Eq. (1) shows that the reaction occurs during hydrolysis phase; enzymes convert the complex organic substrate into simple monomers (C₆H₁₂O₆) and hydrogen (H₂) as shown below:



Hydrolysis is a very slow process when compared with other steps involved in AD process. Inadequate hydrolysis of organic waste affects the efficiency of AD. In order to increase the rate of hydrolysis, many researchers have adopted various pre-treatment methods. Banu and Kavitha [1] have reviewed in detail regarding various pretreatment methods and their effects on anaerobic digestion.

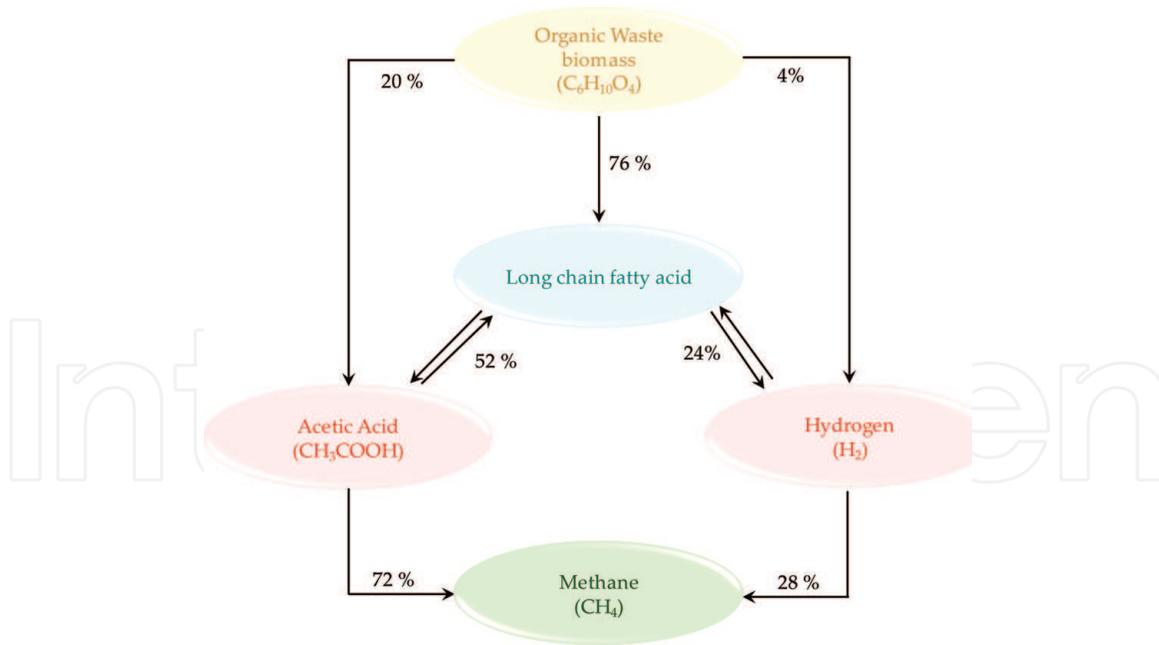
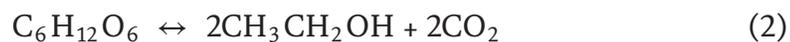


Figure 1.
Pathway of anaerobic degradation of organic waste.

Pretreatment enhances the digestibility of organic substrate, and it is broadly classified into five major groups. They are physical, chemical, biological, mechanical and combinative pretreatments. **Figure 2** shows pretreatment methods and their classification. Physical pretreatment is further classified into two: thermal [2] microwave [3] and freezing and thaw [4] pretreatments. Chemical pretreatment is further classified into two: alkaline [5] and acidic [6] pretreatments. Biological pretreatment is further classified into two: enzyme [7] and fungal [8] pretreatments. Mechanical pretreatment is further classified into two: high-pressure homogenizer [9] and ultrasonic [10] pretreatments. Combinative pretreatment such as thermo-chemo-sonic [11], thermo-chemo-disperser [12], thermo-chemo-ozone [13] and hydrothermal [14] pretreatment, etc. Many researchers have experimentally proven the positive effect of pretreatment on hydrolysis and subsequent biogas production [15].

Acidogenesis is the second step involved in AD process; in this step, acidogenic microbes are responsible for conversion of hydrolyzed organics into ethanol (C_2H_5OH), acetate (CH_3COO^-), hydrogen (H_2), carbon dioxide (CO_2) and other acids (propionic, formic, lactic, butyric, succinic acids). In some cases, amino acids cause formation of ammonia. Eqs. (2)–(4) show that the reaction occurs during acidogenesis phase as shown below:



Acetogenesis is the third step involved in AD process. In this step, acetogenic microbes are responsible for conversion of long-chain fatty acid, volatile fatty acid and alcohols into acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide

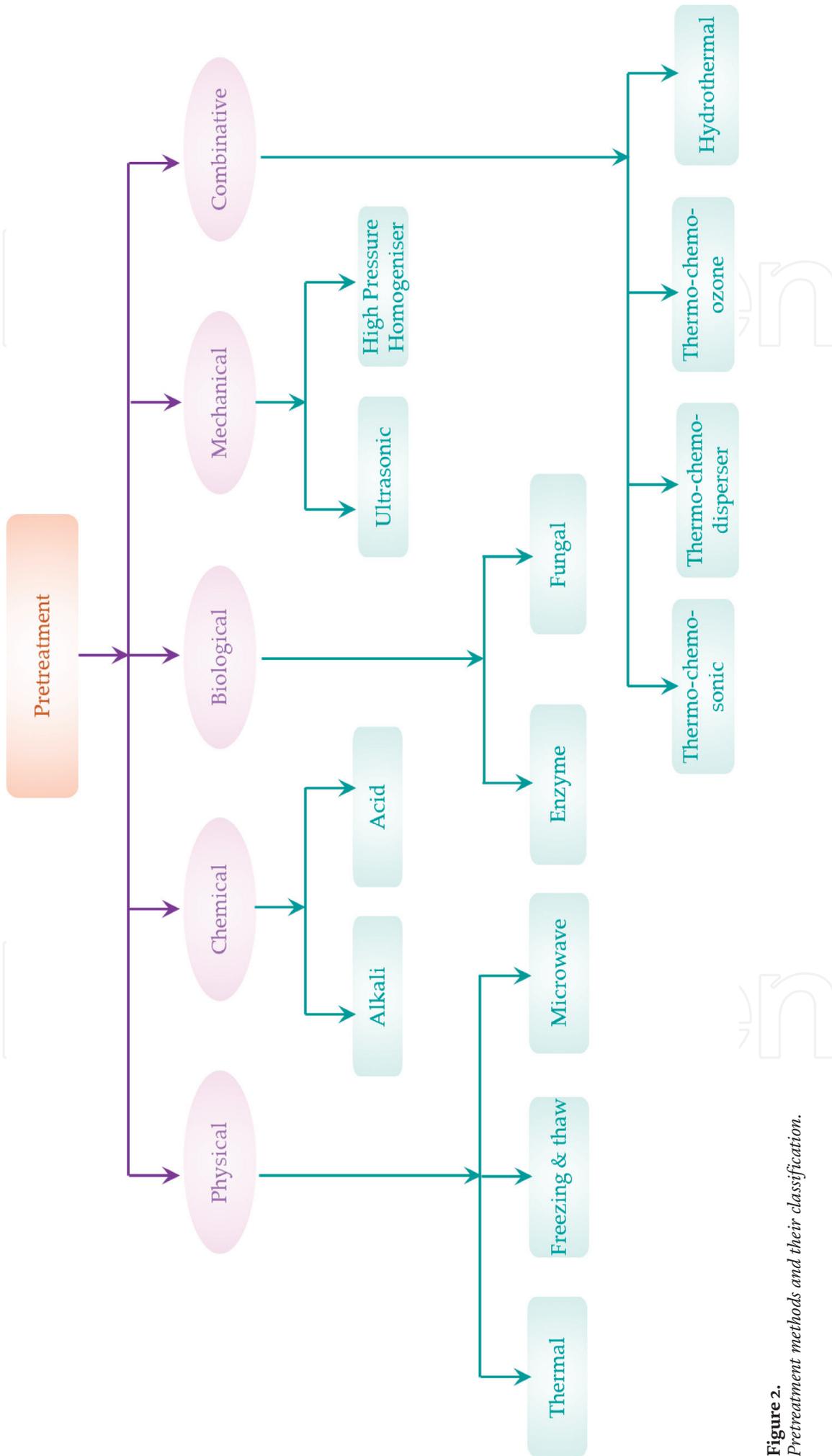


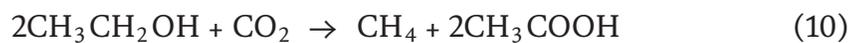
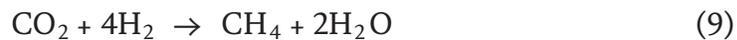
Figure 2.
Pretreatment methods and their classification.

(CO₂). Eqs. (5)–(7) show that the reaction occurs during acetogenesis phase as shown below:



During this conversion process, the concentration of biological and chemical oxygen demand in the medium gets reduced. On the other hand, the hydrogen partial pressure is generated due to the presence of hydrogen gas inside the reactor. Methanogenic microbes, present in the digester, consume accumulated hydrogen gas.

Methanogenesis is the final step of anaerobic degradation of organic waste. In this step, methanogenic microbes are responsible for converting the acetic acid and hydrogen into methane (CH₄) gas and carbon dioxide (CO₂). Eqs. (8)–(10) show that the reaction occurs during methanogenesis phase as shown below:



Methane-enriched biogas can be a promising source to displace the use of conventional fossil fuel. Biogas acts as a flexible energy source, which can be used for various applications like power, heat, transport and feedstock for chemical production. Biogas is the most significant product of (AD) process, and it comprises 60–70% of methane (CH₄) gas, 25–35% of carbon dioxide (CO₂) and remaining 5–10% of other corrosive gases. Biogas was more suitable to replace the demand of conventional fuel. Biogas has a calorific value of 6.0–6.5 kWh/m³, which varies according to the percentage of biomethane content in the biogas. In addition to this, AD process indirectly reduces the cost of energy and fuel production. On the other hand, anaerobically digested residues have market value due to its nutrient content. It can be used as bio-fertilizer for agriculture crop production. AD process is termed as a golden process to eliminate the emission of GHG and reduce global warming issues.

According to the World Bioenergy Association 2017 report, the global biomethane production was approximately 35 billion m³ of methane. Overall, global biogas production was 1.28 EJ in the year 2014. Developed countries like the United States and Europe are the major contributors of biogas production throughout the world. Among them Europe is the world's largest biomethane producer. Around 18 billion m³ of biomethane was produced in the year 2015; it was half of the global biogas production. The produced biomethane was utilized for generation heat, electricity and transportation (vehicle fuel). Nearly 50% of total biogas was utilized for heat generation, and around 697 biomethane filling stations were employed in Europe [16]. Developing countries in Asia (India,

China, Bangladesh, Pakistan, Sri Lanka and Nepal) and Africa (Burkina Faso, Ethiopia, Tanzania, Kenya and Uganda) are very successful in the operation of domestic scale digester. In Asia, approximately 47.876 million of domestic scale digesters were effectively operated to meet their daily needs. In that, China holds first place and accounts for 43 million domestic scale digester, India 4.75 million, Nepal 330,000, Bangladesh 36,000, Sri Lanka 6000 and Pakistan 4000. Similarly, Africa holds 60,000 domestic scale digesters, in that Kenya leads first place and accounts for 16,419, Ethiopia 13,584, Tanzania 13,037, Uganda 6504 and Burkina Faso 7518. Produced biogas was utilized for cooking and lighting purposes.

IntechOpen

IntechOpen

Author details

J. Rajesh Banu* and R. Yukesh Kannah
Department of Civil Engineering, Anna University Regional Campus, Tirunelveli,
India

*Address all correspondence to: rajeshces@gmail.com

IntechOpen

© 2018 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Banu JR, Kavitha S. In: Singh L, Kalia VC, editors. *Various Sludge Pretreatments: Their Impact on Biogas Generation BT—Waste Biomass Management—A Holistic Approach*. Cham: Springer International Publishing; 2017. pp. 39-71
- [2] Raj SE, Banu JR, Kaliappan S, Yeom I-T, Adish Kumar S. Effects of side-stream, low temperature phosphorus recovery on the performance of anaerobic/anoxic/oxic systems integrated with sludge pretreatment. *Bioresource Technology*. 2013;**140**:376-384
- [3] Kavitha S, Rajesh Banu J, Kumar G, Kaliappan S, Yeom IT. Profitable ultrasonic assisted microwave disintegration of sludge biomass: Modelling of biomethanation and energy parameter analysis. *Bioresource Technology*. 2018;**254**:203-213
- [4] Zhang X, Chen M, Huang Y. Isothermal drying kinetics of municipal sewage sludge coupled with additives and freeze-thaw pretreatment. *Journal of Thermal Analysis and Calorimetry*. 2017;**128**:1195-1205
- [5] Banu JR, Do Khac U, Kumar SA, Ick-Tae Y, Kaliappan S. A novel method of sludge pretreatment using the combination of alkalis. *Journal of Environmental Biology*. 2012;**33**:249
- [6] Devlin DC, Esteves SRR, Dinsdale RM, Guwy AJ. The effect of acid pretreatment on the anaerobic digestion and dewatering of waste activated sludge. *Bioresource Technology*. 2011;**102**:4076-4082
- [7] Kavitha S, Preethi J, Rajesh Banu J, Yeom IT. Low temperature thermochemical mediated energy and economically efficient biological disintegration of sludge: Simulation and prediction studies for anaerobic biodegradation. *Chemical Engineering Journal*. 2017;**317**:481-492
- [8] Cheng X-Y, Liu C-Z. Fungal pretreatment enhances hydrogen production via thermophilic fermentation of cornstalk. *Applied Energy*. 2012;**91**:1-6
- [9] Fang W, Zhang P, Shang R, Ye J, Wu Y, Zhang H, et al. Effect of high pressure homogenization on anaerobic digestion of the sludge pretreated by combined alkaline and high pressure homogenization. *Desalination and Water Treatment*. 2017;**62**:168-174
- [10] Divyalakshmi P, Murugan D, Sivarajan M, Sivasamy A, Saravanan P, Rai CL. Effect of ultrasonic pretreatment on secondary sludge and anaerobic biomass to enhance biogas production. *Journal of Material Cycles and Waste Management*. 2018;**20**:481-488
- [11] Kavitha S, Yukesh Kannah R, Yeom IT, Do K-U, Banu JR. Combined thermo-chemo-sonic disintegration of waste activated sludge for biogas production. *Bioresource Technology*. 2015;**197**:383-392
- [12] Kavitha S, Jayashree C, Kumar SA, Kaliappan S, Banu JR. Enhancing the functional and economical efficiency of a novel combined thermo chemical disperser disintegration of waste activated sludge for biogas production. *Bioresource Technology*. 2014;**173**:32-41
- [13] Kannah RY, Kavitha S, Rajesh Banu J, Yeom IT, Johnson M. Synergetic effect of combined pretreatment for energy efficient biogas generation. *Bioresource Technology*. 2017;**232**:235-246
- [14] Li C, Wang X, Zhang G, Li J, Li Z, Yu G, et al. A process combining

hydrothermal pretreatment, anaerobic digestion and pyrolysis for sewage sludge dewatering and co-production of biogas and biochar: Pilot-scale verification. *Bioresource Technology*. 2018;**254**:187-193

[15] Kavitha S, Rajesh Banu J, Subitha G, Ushani U, Yeom IT. Impact of thermo-chemo-sonic pretreatment in solubilizing waste activated sludge for biogas production: Energetic analysis and economic assessment. *Bioresource Technology*. 2016;**219**:479-486

[16] Scarlat N, Dallemand J-F, Fahl F. Biogas: Developments and perspectives in Europe. *Renewable Energy*. 2018;**129**:457-472

IntechOpen