

Review Paper on Anaerobic Digestion of Lignocellulosic Waste

Mrs.S.Alagammai¹; Mrs. R.Chitra, Assistant Professor², Saradhambal M³

¹Department of Food Processing and Preservation Technology

²School of Engineering, Avinashilingam Institute; Department of ECE

³School of Engineering, Avinashilingam Institute, Coimbatore, India

-----***-----

Abstract: Anaerobic digestion victimizes the lignocellulosic material because the substrate may be a cost-efficient strategy for biomethane production, that provides nice potential to convert biomass into renewable energy. However, the intractability of lignocellulosic biomass makes it proof against microbial reaction, that reduces the bioconversion potency of organic matter into biogas. Therefore, it's necessary to critically investigate the correlation between lignocellulose characteristics and bioconversion potency. consequently, this review comprehensively summarizes the anaerobic digestion method and rate-limiting step, structural and integrative properties of lignocellulosic biomass, intractability and inhibitors of lignocellulose and their major effects on anaerobic digestion for biomethane production. Moreover, varied variety of pre-treatment methods applied to lignocellulosic biomass was mentioned very well, which might contribute to cell membrane degradation and improvement of biomethane yields. within the read of current information, high energy input and price necessities square measure the most limitations of those pre-treatment ways. additionally, to improve fermentation method, some studies also focus more on key structural influence factors of biomass intractability and anaerobic digestion potency, which can contribute to improvement of biomethane production from lignocellulose.

Keywords: Lignocellulose, Biomethane production, Acetogenic, Anaerobic digestion, biomass, bio-conversion.

Introduction

Lignocellulose is one in every of the foremost luxuriant renewable organic resources with associate increasing annual yield of two hundred billion tons, which may be created from agriculture, forestry and urban wastes. The distinguished abundance and low value of lignocellulose build it a possible substrate for second generation bioenergy production, like bioethanol and biomethane. throughout these, biomethane production is one in every of the foremost cost-efficient ways for energy generation from lignocellulosic polyose, that has been enforced worldwide.

Biomethane production through anaerobic digestion may be a present organic process, which may be divided into four steps. within the starting of the method, complicated organic polymers area unit rotten to their part units, e.g., amino acids, fatty acids, and sugars, severally. Then, these monomers area unit regenerate into a mix of short chain volatile fatty acids by fermentative microorganism (Acidogens). Acetogenic microorganism or acetogens any convert the volatile fatty acids to acetate, dioxide, and element, that area unit natural substrates for Methanogenesis to get biomethane. in theory, AD method will decompose the organic fraction of any feedstocks to supply biomethane, like crop and stock residues, waste and lignocellulosic feedstocks. However, methane series production varies greatly with differing kinds of substrates. as an example, high methane series yields up to 450 cc CH₄/g volatile solids is achieved with sugar and starch crops, whereas no over 330 cc CH₄/g volatile solids is created from lignocellulosic biomass. The complexness of biomass structure is that the major challenge, that makes lignocellulosic biomass extremely recalcitrant to anaerobic degradation and ultimately ends up in low biomethane yield. The stubborn anti-degradation characteristics of native lignocellulose was referred to as biomass intractability, that extraordinarily restricts the reaction throughout the primary step of anaerobic digestion method and at last limits the industrial biomethane production from lignocellulose.

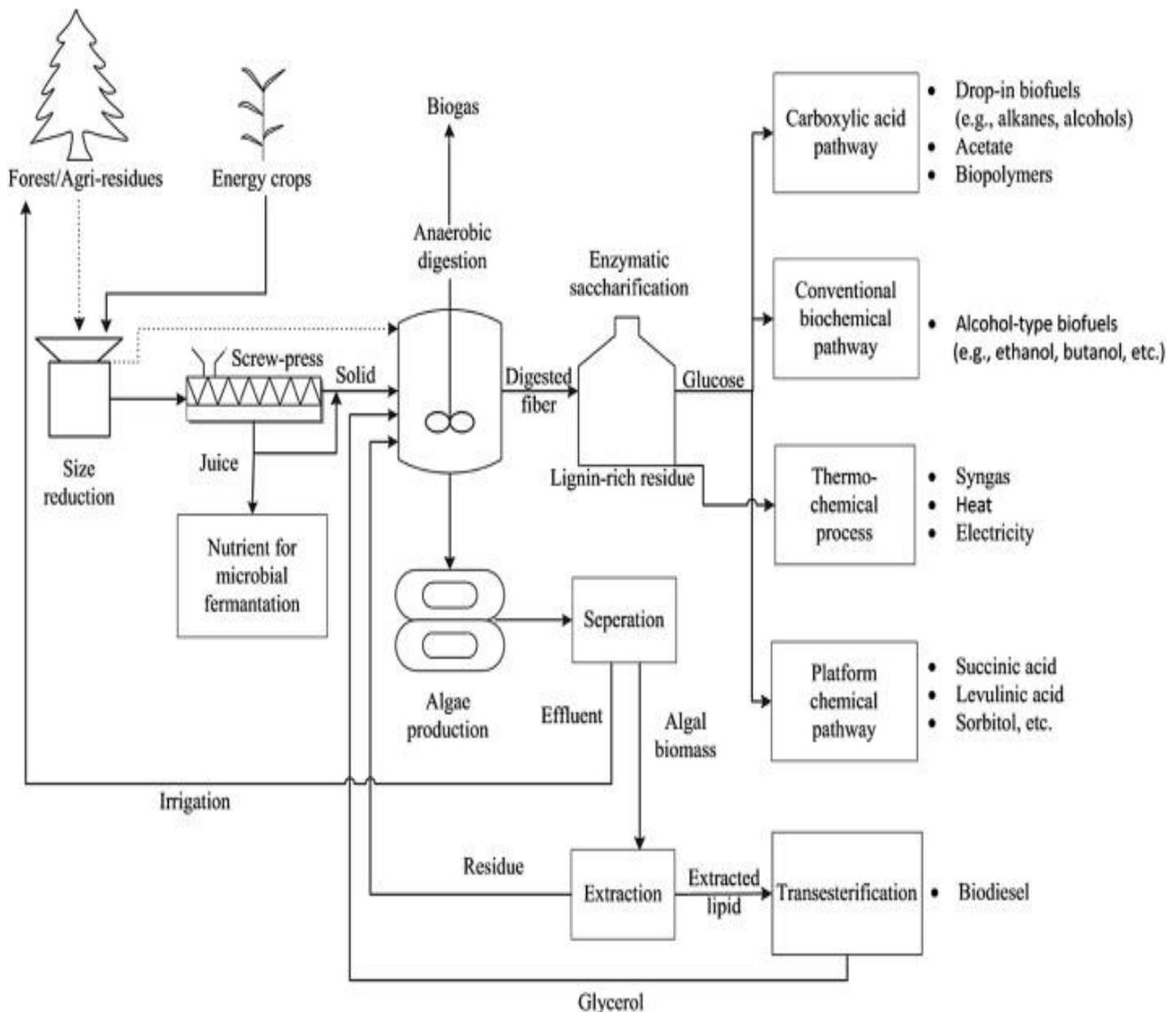


Fig:1 Anaerobic digestion of lignocellulosic biomass

Composition of Lignocellulosic Biomass

The main parts of avoirdupois unit are polysaccharides, that are polysaccharide (40–50%), hemicellulose (25–35%), and polymer (15–20%). The ratios between these fractions vary with the plant age, stage of growth and alternative conditions. polysaccharide is that the major mass constituent of most natural biomass and it's found within the walls of the cells of plants. it's a structural polyose in plants and it's a vicinity of supporting tissues.

Basic Structural Properties of Plant Cell Wall and Lignocellulose Recalcitrance

Lignocellulosic biomass is especially composed of polyose, hemicellulose and polymer, that vary heaps supported kinds of plants, growth conditions and maturation each in amount and quality. The elaborated structure has been comprehensively reviewed elsewhere. Biomass unmanageableness refers to the anti-degradation characteristics of native lignocellulose, that defend plant semipermeable membrane from microorganism attack or degradation by microorganisms and enzymes. it absolutely was caused by the sophisticated compositions and structure of plant semipermeable membrane. polyose could be a relative homogenized substance in terms of the composition and structure, that provides the essential backbone to lignin-carbohydrate complexes. Hemicellulose area unit embedded through the semipermeable membrane and kind valence bonds to the surface of polyose fibrils, that facilitate strengthen the semipermeable membrane. As a filler compound, polymer wrappers itself within the interspace of polyose and hemicellulose chains and fashioned a hydrophobic lignification structure, that plays a vital role in maintaining the structural integrity of the semipermeable membrane. Besides the 3 main compositions, semipermeable membrane proteins, lipids, pectin, mineral and alternative

matters are concerned within the formation of biomass unmanageableness. Moreover, additionally to chemical composition and body, the arrangement and density of the tube-shaped structure bundles, cuticular protection and a few process-induced causes additionally play right smart role in building the semipermeable membrane matrix.

Biomass unmanageableness refers to lignocellulosic building blocks that area unit naturally evolved to dam their microbial and accelerator philosophical doctrine. this can be the results of a classy combination of the crystalline polyose in microfibrils, heteropolysaccharides, lignin, and alternative parts. within the opening of anaerobic digestion method, biomass unmanageableness protects itself from degradation by microorganisms and enzymes, that end in lower simple sugar production and eventually limits the biomethane potency. it's known that the degree of unmanageableness varies counting on the composition of the lignocellulosic biomass, that closely correlative to genotype, environmental conditions, crop management practices and plant components. However, there area unit some basic parts and major influencing factors that typically exist in several plants.

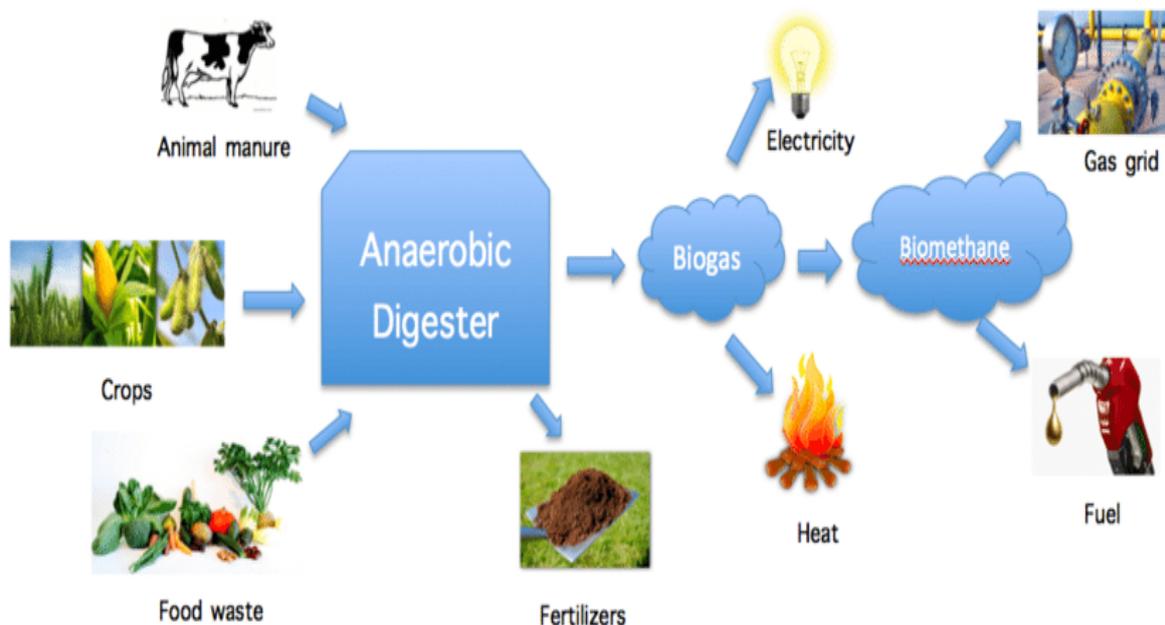


Fig 2: Anaerobic digestion of lignocellulosic biomass

Accessible Surface Area of Cellulose

Accessible extent of substrate refers to the extent, by that cellulases can contact with carbohydrate. In anaerobic digestion methodology, it's going to directly have an impression on the biodegradability of lignocellulosic materials, that limits the contact between lignocellulose and catalyst, being or chemical reagents and finish in poor potential sugars for subsequent methodology. Accessible extent is stricken by many indirect factors, e.g., dermal feature, particle size of stuff powder, chemical and physical characteristics of plant plasma membrane. Accessible extent is split into two forms: interior extent that's set by substrate consistence and exterior extent that's correlative with particle size. Generally, natural lignocellulosic substrates have really very little interior surfaces, notably for dried material have reported that carbohydrate accessibility to enzymes or chemical reagents is very through the among pores of substrate (about 90%) rather than the external surface, suggesting that the external surface alone plays belittled role in reaction progress.

Lignocellulosic biomass is hydrolyzed by hydrolytic being to unleash sacharides for biomethane production. These microorganisms will bind to the lignocellulose surface through physical contact, then secrete animate thing multi-enzyme complexes to initiate the reaction. Accessible extent is taken into consideration as a awfully vital issue for the biodegradability of lignocellulosic materials and so the substrate got to have enough pores for economical reaction. Generally, the diameter of the pore ranged from zero.2 to 20 μm , that's analogous to the size of the being. throughout the anaerobic digestion progress, the accessible extent will increase in conjunction with the removal of partial plasma membrane component, resulting in higher surface availability. However, catalyst reaction is usually faster at the beginning and slower among the latter stages indicating that the extent is not the sole dominant issue for the reaction. At the initial stage, lager extent permits ample contact between enzymes and digestible amorphous carbohydrate, resulting in faster reaction. but among the later quantity of anaerobic digestion, even though the accessible extent is increasing, the

remaining higher crystalline carbohydrate and so the compact structure become the foremost factors that finally limit the reaction efficiency.

Non-structural and Other Factors Restricting Lignocellulose Degradation

Besides physical and chemical characteristics of cytomembrane as mentioned on top of, there also are another factors which can cut back lignocellulose biodegradation. For instance, bioconversion processes could generate some further inhibitors or negative variation of cytomembrane structure. Reduction of particle size to zero.36–0.55 millimetre and zero.71–1.0 millimetre may succeed lower methane series yield in comparison with size of one.4–2.0 mm. This result may be attributed to inhibitors (e.g., overrun of volatile fatty acid) and chemical transformation generated from excessive particle size reduction. Moreover, delignification on the far side five hundredth would possibly cause collapse of polysaccharide matrix, leading to compact and chaotic structure and ulterior decrease in polysaccharide accessibility. For instance, alkali extraction will remodel polysaccharide I to polysaccharide II, and polysaccharide II area unit parallel configuration that usually don't exist within the natural cytomembrane. Such structural changes or unsafe substances caused by the pre-treatment processes area unit further inhibitors to anaerobic digestion, and will be taken into thought as a part of the biomass unmanageableness. Compared with the native structures and characteristics of the plant cytomembrane, these further inhibitors area unit by-products of the method of cracking cytomembrane unmanageableness and area unit simply minor contributors to limit the fermentation potency. within the method of biomethane production from lignocellulose, the best method strategy is with efficiency breaking down the lignocellulosic unmanageableness whereas minimizing the assembly of by-products.

Physical Pre-treatment of Lignocellulose

Physical (mechanical) pre-treatment refers to the pre-treatment processes while not chemicals or microorganisms, which has comminution (e.g., edge and grinding), irradiation (e.g., ultrasound, gamma ray, and microwave), steam explosion, liquid predicament pre-treatment.

Comminution is principally accustomed cut back the particle size, that will increase the accessible area, alters the ultrastructure, and reduces the polysaccharide crystallinity and chemical action degree of polysaccharide for improved edibility. Generally, comminution is that the most typical pre-treatment technique and continuously the primary step before the full biomethane production method. Biogas production would be augmented with the reduction of particle size. However, to the various lignocellulose compositions of the assorted particle size ranges, excessive particle size reduction might turn out inhibitors and reduce biogas production. Therefore, particle size ought to be rigorously thought of once totally different lignocellulose substrate was utilized. Irradiation might preferentially dissociate the glycoside bonds of the polysaccharide and degrade polysaccharide chains into brittle fibres, oligosaccharides, or maybe polysaccharide. However, some analysis reported that excessive microwave pre-treatment at hot temperature might have adverse result on paraffin yield thanks to the aspect result of heat-induced inhibitors, like phenoplast compounds and aldehyde. Steam explosion has been accustomed treat varied styles of lignocellulosic biomass for sweetening of paraffin production. when steam explosion, hemicellulose was hydrolysed and polymer was reduced to a definite degree, therefore leading to degradation of lignin-carbohydrate complexes. Moreover, steam explosion is commonly expedited by further acids, like 6 June 1944 SO₂, diluted H₂SO₄, and alternative chemicals. Liquid predicament pre-treatment will enlarge the accessible area of substrate for higher polysaccharide degradability to cellulase. underneath hot temperature and pressure, water will penetrate into the inside of cytomembrane structure, solubilize hemicellulose, slightly take away polymer and hydrate polysaccharide. This technique causes less corrosion to reactors and produces very little amounts of byproducts and inhibitors, thereby has appreciable potential of monosaccharose recovery.

Chemical Pre-treatment of Lignocellulose

Chemical pre-treatment refers to the utilization of chemicals (e.g., acids, bases, oxidizing agents, organic solvents) to alter physical and chemical characteristics of native lignocellulose. it's attracted the foremost analysis interest thanks to its higher potency on decreasing the resistant characteristics for higher bioconversion performance.

Acid pre-treatment will conspicuously hydrolyse hemicellulose to mono saccharides, which is able to increase the pore size or volume of semipermeable membrane and create polysaccharide additional liable to protein degradation. It can even disrupt polymer to a high degree, however solely will dissolve very little polymer in most cases. Considering the value, toxicity by-products and instrumentality needs, dilute acid is typically used for pre-treatment in sensible applications. Alkali is another common pre-treatment technique. The operate of alkali is believed to be 2 necessary effects: saponification and association of lignin-carbohydrate linkages, that lead to the enlargement and de-crystallization of substrates. The association will considerably take away polymer, ethanoyl group teams and uronic acid of hemicellulose, that disrupts the polymer structure and breaks down the unit bonds between polymer and different elements. Therefore,

the effectiveness of alkali pre-treatment is associated closely with polymer content of lignocellulosic feedstock. Compared with ancient chemicals, ionic liquids possess some benefits of low toxicity, thermal stability, low property, increased chemistry stability and then on. it's been tested to be positive on the development of biofuel production. throughout the pre-treatment, ionic liquid will dissolve great amount of polysaccharide at delicate conditions, and it's possible to recover virtually 100% of used liquid with high purity and leave very little residues for the downstream anaerobic fermentation. The dissolution mechanism of polysaccharide in ionic liquids is that the chemical interaction between its molecules and therefore the element and chemical element atoms of polysaccharide hydroxyl radical teams. within the interaction, separation of element and chemical element atoms leads to the gap of the chemical element bonds between polysaccharide chains, that results in the dissolution of polysaccharide. Then, dissolved polysaccharide will be regenerated by adding some specific chemical solvents which may precipitate polysaccharide from ionic liquid, like ethyl alcohol, methanol, acetone, or water. The p mprecipitates have the next protein edibility than native polysaccharide because of the changes in macro- and micro-structures. Crystallinity analysis of dissolved lignocellulose showed that the polysaccharide precipitates square measure completely different with either amorphous polysaccharide or polysaccharide II.

Process Controlling and Optimization of Anaerobic Fermentation Process

Compared to mono-digestion, co-digestion of lignocellulose with animal feces shows significant potential for commercial biomethane production. The higher efficiency of co-digestion mainly associated with process stability, e.g., optimal C/N ratio, ammonia reduction, and essential trace elements, which help maintain a steady condition for better performance of microorganisms to break down lignocellulose recalcitrance. Moreover, microbial reinforcement is another promising option to enhance enzymatic hydrolysis of lignocellulose and improve the biogas yield. Utilized 10% inoculation of *Acetobacteroides hydrogenigenes* as reinforcement, and got 19–23% increase of methane yield finally. Due to abundant enzymes (e.g., cellulase and xylanase) and sufficient nutrient content, digested manures have better adaptability in digesting lignocellulose for higher biomethane production. There are some basic requirements for anaerobic microorganism those degrade the particular lignocellulose in terms of environmental conditions and feed compositions inside the reactor. Different from pre-treatment and cell wall modification, process optimization is an indirect strategy, which aims to provide a more reasonable environment for anaerobic bacteria to grow better and secrete more relevant enzymes to degrade lignocellulose more efficiently. For example, thermophilic microaerobic pre-treatment (oxygen loads of 5 ml/g volatile solids substrate) on corn straw could promote the growth of aerobic microorganisms which secreted more hydrolytic enzymes in the early stage of the fermentation process. These enzymes would decrease cellulose crystallinity and cause substantial structural disruption of plant cell wall, which finally resulted in 16.24% higher methane production than that of untreated.

Anaerobic Digestion of Lignocellulosic Biomass the AD methodology consists among the transformation of the organic matter contained among the waste into a gaseous effluent (biogas) in conjunction with a solid stable effluent named 'digestate'. The strategy is developed by a very sophisticated microorganism population operating in absence of molecular part among the medium. Utterly completely different stages is also distinguished among the general AD process: reaction, acidogenesis, acetogenesis, and methanogenesis. However, the standard of the pound structure greatly hinders its AD because of the high level of crystallinity of saccharide, still as a result of the cross-linking of carbohydrates and compound. Thus, lignocellulosic biomass is ingrained chiefly by saccharide, hemicellulose, and compound and conjointly the preceding interactions among these fractions cause a very stable and recalcitrant structure. This sophisticated structure of lignocellulosic material makes it proof against supermolecule attack. Solid material and macromolecules constituting organic matter got to be hydrolysed and therefore labialised among the medium so on use by the microorganisms.

Therefore, this is often a key step for the appropriate development of the AD methodology. Moreover, for lignocellulosic solid wastes, reaction is mostly the rate-limiting step of the globe methodology. This stage is performed by living thing enzymes excreted by the acidogenic microorganisms. However, it got to be taken into thought that compound is that the foremost hard decayable half in lignocellulose materials and its cross-linking with the carbohydrates reduces the extent offered for catalyst attack. The structure of pound is weakened by the hemicellulose removal and, thus, the supermolecule solubilization of the plastic fraction is flavoured. Therefore, considering the extraordinary connectedness of this stage on the performance of the globe methodology, multiple pre-treatments of the feedstock (mechanical, physical, chemical and biological) tested, despite the increase in costs which can result by applying them. The aim of these pre-treatments is to push and enhance the organic matter solubilization and conjointly the succeeding transformation into bioenergy or biobased merchandise. Consequently, the applying of these pre-treatments becomes relevant to spice up the paraffin production from pound and their effectiveness has been proven in several studies. Among the pre-treatment technologies studied, the hydrothermal pre-treatment is taken into consideration associate degree environmentally-friendly methodology because of not mistreatment any chemicals. It collectively decreases the formation of fermentation inhibitors, that is formed chiefly through sugar degradation at warmth

Conclusion

Lignocellulosic biomass could be a difficult-to-degrade substrate once subjected to anaerobic digestion. A substantial increase in gas, atomic number 1 and bioethanol production may well be achieved, once choosing hydrothermal pre-treatment of lignocellulosic biomass. The assembly of recalcitrant like furfurals, and 5-HMF takes place throughout hydrothermal pre-treatment of lignocellulosic biomass at terribly hot temperature, that ends up in method inhibition. So as to convert the inhibitors into less deadly compounds, organic process engineering is being applied victimization genetically designed microbes (e.g., *S. cerevisiae*, a yeast) as a promising detoxification method. Hydrothermal pre-treatment comes bent be a helpful possibility for production of bio-energy from lingo-cellulosic biomass, that otherwise is tough to degrade in anaerobic digestion alone.

References

1. Sawatdeenarunat, C.; Surendra, K.C.; Takara, D.; Oechsner, H.; Khanal, S.K. Anaerobic digestion of lignocellulosic biomass: Challenges and opportunities. *Bioresour. Technol.* 2015, 178, 178–186.
2. Sen, S.M.; Han, J.; Luterbacher, J.S.; Alonso, D.M.; Dumesic, J.A.; Maravelias, C.T. Synthesis of catalytic biomass-to-fuels strategies. *Comput. Aided Chem. Eng.* 2014, 34, 615–620.
3. De Jong, E.; Gosselink, R.J.A. Lignocellulose-Based Chemical Products. In *Bioenergy Research: Advances and Applications*; Elsevier: Amsterdam, The Netherlands, 2014; pp. 277–313.
4. Zhu, J.Y.; Pan, X.J. Woody biomass pretreatment for cellulosic ethanol production: Technology and energy consumption evaluation. *Bioresour. Technol.* 2010, 101, 4992–5002.
5. Tye, Y.Y.; Lee, K.T.; Wan Abdullah, W.N.; Leh, C.P. The world availability of non-wood lignocellulosic biomass for the production of cellulosic ethanol and potential pretreatments for the enhancement of enzymatic saccharification. *Renew. Sustain. Energy Rev.* 2016, 60, 155–172. [CrossRef]
6. Popa, V.I. Biomass for Fuels and Biomaterials. In *Biomass as Renewable Raw Material to Obtain Bioproducts of High-Tech Value*; Elsevier: Amsterdam, The Netherlands, 2018; pp. 1–37.
7. International Renewable Energy Agency. *Global Bioenergy Supply and Demand Projections; A Working Paper for REmap 2030*; International Renewable Energy Agency: Abu Dhabi, UAE, 2014.
8. Saxena, R.C.; Adhikari, D.K.; Goyal, H.B. Biomass-based energy fuel through biochemical routes: A review. *Renew. Sustain. Energy Rev.* 2009, 13, 167–178. [CrossRef]
9. Rettenmaier, N.; Schorb, A.; Koppen, S. *Status of Biomass Resource Assessments*; Biomass Energy Europe, Institute for Energy and Environmental Research: Heidelberg, Germany, 2010.
10. *Key Findings: Statistical Report*; Bioenergy Europe: Brussels, Belgium, 2018.
11. Nanda, S.; Azargohar, R.; Dalai, A.K.; Kozinski, J.A. An assessment on the sustainability of lignocellulosic biomass for biorefining. *Renew. Sustain. Energy Rev.* 2015, 50, 925–941.
12. Cai, J.; He, Y.; Yu, X.; Banks, S.W.; Yang, Y.; Zhang, X.; Yu, Y.; Liu, R.; Bridgwater, A.V. Review of physicochemical properties and analytical characterization of lignocellulosic biomass. *Renew. Sustain. Energy Rev.* 2017, 76, 309–322.
13. Paul, S.; Dutta, A. Challenges and opportunities of lignocellulosic biomass for anaerobic digestion. *Resour. Conserv. Recycl.* 2018, 130, 164–174.
14. Cater, M.; Zorec, M.; Marinšek Logar, R. *Methods for Improving Anaerobic Lignocellulosic Substrates ~ Degradation for Enhanced Biogas Production*. Springer Sci. Rev. 2014, 2, 51–61.
15. Bajpai, P. *Pretreatment of Lignocellulosic Biomass for Biofuel Production*; Springer: Berlin/Heidelberg, Germany, 2016; p. 8. ISBN 978-981-10-0686-9.