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Technical Note

Evaluation and composition of lignin content to enable the production of lignocellulosic biomass pretreatment into sustainable biofuel: A review

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ABSTRACT

Biomass wastes have a significant deal of promise for usage as a non-depleting source of renewable energy and for the creation of goods with benefit. The world's attempts to valorize surplus lignocellulose biomass wastes depend on the pretreatment procedure to remove the lignocellulose material's refractory barrier for access to valuable substrates. Finding an appropriate unit operation for the conversion of biomass into value-added goods. There are many different pretreatment methods available, and research into more affordable, efficient, and ecologically friendly procedures is ongoing. Various studies have shown that a good pretreatment method can reduce the network of strong chemical linkages between the cellulose, hemicellulose, and lignin in the biomass. Using high heat and pressure to dissolve the structure, hydrothermal pretreatment is emphasized as a valuable technique in the recovery of lignin. The need for a flexible strategy to meet rising global energy demands has led many academics to concentrate on renewable biofuel made from sustainable resources. There are many challenges that need to be resolved before lignocellulose biomass can be transformed into commercially viable biofuels and bio products. This study also emphasizes the significance of bioethanol production in light of worries about climate change, technical advances, and prospects for the future.

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INTRODUCTION

The world's largest and cheapest non-depleting energy source, biomass is frequently regarded as holding great potential for a future continuous and sustainable energy source, particularly in the form of biofuels and other value-added products. How to safeguard and preserve the environment on Earth has recently become a concern for humanity [1]. We need to focus more on sustainable resource recovery and reuse if we want to overcome these challenges. And the first step has already been taken because biofuels have the potential to eventually replace nonrenewable fossil fuels thanks to numerous studies and real-world uses. Biofuel is a type of fuel made mostly from bio-based sources like bacteria, algae, and plants [2]. Direct burning of wood, animal waste, forest, and crop leftovers produces primary biofuels. Agricultural residues (like cotton straw, sugarcane bagasse, cotton straw, maize straw, wheat straw, potato husk, rice straw, and other plant leftovers), forestry residues (like wood), industrial residues (like waste from pulp and paper production), and energy crops are also examples of biomass (switch grass) [3]. Broadly speaking, straw biomass is one of the agricultural waste products that is plentiful, affordable, clean, safe, renewable, and sustainable. It may also resolve the conflict between the use of energy and food, making it the ideal option to replace traditional fossil fuels [4]. Most of the biomass from straw may be converted into a variety of high-value compounds that can help the economy and society thrive sustainably while reducing environmental problems [5]. Cellulose, hemicellulose, and lignin make up the majority of lignocellulose biomass, and hydrolyzing the sugar components yields fermentable sugars [6]. However, there are many obstacles to effective application since different straw biomass has complicated compositions that are intimately related. Cost-effective bioethanol is made by converting depolymerized sugars, starches, and lignocellulose materials [7]. Biomass resources plant biomass permits the production of biofuels, which has drawn the attention of experts across the globe. It is made up of polysaccharides, an aromatic kind of biopolymer, cellulose, and hemicellulose [8]. In the form of biofuels and other value-added products, biomass is commonly seen as holding great potential for a continuous and sustainable energy source in the future. Additionally, it is the most abundant and affordable non-depleting energy source in the planet [9]. There is an enormous amount of lignocellulose biomass that can be used right now on a worldwide scale. However, the majority of countries have not yet utilized and extracted all of the available biomass waste resources for energy, chemicals, and materials. For instance, in Malaysia, key industries like forestry or "wood products," the manufacture of rubber, cocoa, sugar cane. Contribute significantly to the nation's output of biomass wastes, both directly and indirectly [10]. With an annual production of 7 million tons of crude palm oil, Malaysia is currently the second-largest producer of palm oil in the world. About 20 tons of biomass leftovers are produced annually from this sector in the nation [11]. Typically, lignocellulose biomass has 15–25% lignin, 30–60% cellulose, and 20–40% hemicellulose. Polysaccharides (cellulose and hemicelluloses) and aromatic polymer (lignin) make up the majority of lignocellulose biomass [12]. However, depending on the source and physical characteristics of the biomass, the precise lignocellulose components of lignocellulose biomass may change. Some typical lignocellulose biomass compositions that have been described in a variety of literature are included in Table 1. It is crucial to valorize rather than discard these biomass wastes since they can be turned into a variety of value-added products like bio-derived fine chemicals and biofuels as well as substitute feedstock for dwindling fossil fuels. However, their main function is to provide as readily available energy sources for [13] the production of enzymes required for bacterial fermentation. As a result of their inexpensive price and renewable nature, lignocellulose biomass has recently attracted the attention of numerous academics. The biggest barrier to the utilization of lignocellulose biomass, however, is the resistance of plant cell walls to biochemical and biological disintegration, which is facilitated by the heterogeneous polyphenolic structure of lignin [14]. Thus, pretreatment of these materials is introduced to encourage the use of biomass waste and to release the contained potential in lignocellulose biomass.

Table 1. Specific lignocellulose biomass wastes composition [15].

Lignocellulose materials	Cellulose %	Hemicellulose %	Lignin %	References
Wheat husk	37	28	15	32
Rice husk	28-36	23-28	12-14	32
Neem tree bark(NTB)	35-50	12-18	13-16	20
Babul tree bark(BTB)	40-60	15-20	15-18	32
Walnut shell (WNS)	25.6-30	22.1-28	50-55	14
Almond shell(AS)	40-50.7	20-28.9	18-20.4	32
Banana tree	28	23	12	32
Corn straw	44.5	20.7	8.7	20
Coffee	20	16	51	13

VALORIZATION OF LIGNIN

Both Plants and Biofuels

Plants use the process of photosynthesis to draw out and transform the energy stored in their cell walls. The production of biofuels and other bio products from renewable plant biomass, including the lignocellulose found in plant cell walls, has long been considered a sustainable feedstock, and it is anticipated that widespread adoption of this technology will significantly reduce CO_2 emissions in the transportation sector. Lignocellulose biomass surpasses starch and sugar crops in a number of critical areas as a carbon source for biofuels and bio products [16].

Lignin

Nineteen years prior to A Botanist A. Payer made the discovery of cellulose in 1838. Lignin in plants was first discovered by P. de Candolle. De Candolle gave lignin the Latin term lignum, which translates to "wood," in 1842. Because of its fibrous qualities and insoluble nature in both water and alcohol. Because it provides mechanical support, impermeability, disease and insect resistance, as well as the movement of water and nutrients, lignin is crucial for the health and growth of plants. After cellulose, It takes about 20–30% of the dry biomass and is the second-most common biopolymer on the planet [18]. The majority of lignin is composed of phenylpropanoid monolinguals, although minor amounts of other monolinguals, comprising acylated monolignols, dihydrohydroxycinnamyl alcohol, hydroxybenzaldehydes, flavonoid tricin, and caffeoyl alcohol, may also be found. The amino acid phenylalanine serves as the precursor for monolignol's production in the cytosol. A glucose molecule is then attached to the monolingual, making it water-soluble and enabling it to pass through the plant's cell wall. Varied plants and genotypes have different S: G: H ratios, which results in a variety of lignin forms [19]. For instance, whereas G and S units are equally common in hardwood, G units are more common than H units in softwood. Another characteristic of this intricate biopolymer is the multitude of linkages that emerge as lignin polymerizes. In 50% of softwood and 60% of hardwood, lignin largely consists of the -O-4 aryl ether bond [20]. Additionally, it offers low CO_2 emission biochemical and biofuels [21]. Furthermore, experts are rethinking cutting-edge techniques in response to the global demand for biomass energy. These new techniques for processing put a focus on biotechnology and plants, working along with process improvement and fuel selectivity [22]. How can this immensely complex chemical be transformed into valuable bio products and biofuels. The three primary stages are: I selecting and cultivating bioenergy crops; (ii) transforming those crops into specific intermediates, like sugars, monomers, and oligomers of lignin; (iii) utilizing microorganisms to transform those intermediates into biofuels and other bio products [23].

Lignocellulose Biomass

Because it affects all necessary downstream conversion processes, bioenergy crop selection is crucial. Numerous bioenergy crops, including switch grass and sorghum, have been researched. Each species of plants has a unique lignin structure and composition [24]. Engineering the plant's lignin biosynthesis to produce less recalcitrant biomass by changing the lignin's composition and content is one way to lower downstream expenses. The selection of the bioenergy crop is crucial as it influences all crucial downstream conversion processes [25]. Reduced lignin can cause issues like lowered biomass content, altered energy to generate, and decreased plant viability. This method is time-consuming because the results are unpredictable. However, other strategies that modify the lignin's composition rather than its content have been devised with more promising results to boost the cell wall degradability [26]. It is possible to alter the composition of S:G:H , which indicates how this alters the characteristics of biomass digestibility. For instance, a high S-lignin content can speed up the enzymatic hydrolysis of the biomass because it has a lower degree of polymerization or a higher number of monolingual units in the lignin macromolecule [27].

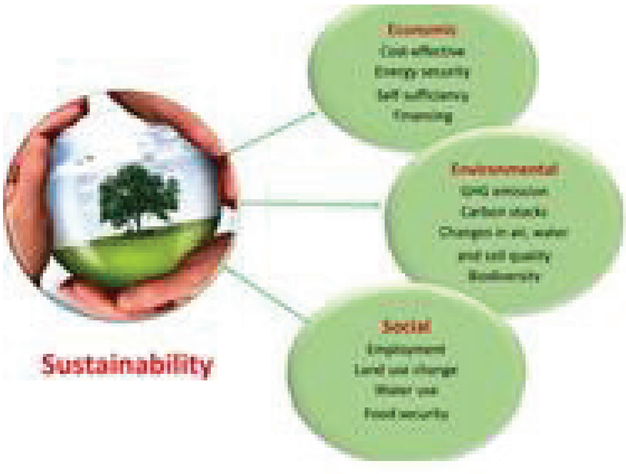

Figure 1. The social and economic benefits of biofuel [28].

TRADITIONAL METHODS FOR PRETREATING LIGNOCELLULOSIC BIOMASS

The fundamental obstacle to using the simple substrates trapped within lignocellulose biomass is thought to be the resistance of plant cell walls to biochemical and biological degradation, provided by the heterogeneous polyphenolic structure of lignin. To ensure the recovery of cellulosic content from these lignin-based biomasses, pretreatment of lignocellulose biomass is essential [29]. As a result, during the pretreatment procedure to extract the cellulose, the lignin barrier in lignocellulose biomass is broken down and destroyed. Cellulose is also changed, and both its degree of

Table 2. Comparison of the various pretreatment techniques [37].

Pretreatment methods	Solvent used	Advantages	Disadvantages	Reference
Physical preparation milling	------	biomass pore volume and high surface contact	demand for high energy	20
Chemical First Aid Pretreatment with concentrated acid	p-Toluenesulfonic acid with sulfuric acid	increase cellulose and hemicellulose enzymatic hydrolysis	Toxic effects	13
Pretreatment with alkaline	Ammonia, Calcium hydroxide, Sodium hydroxide, Potassium hydroxide	decreased crystallinity	long occupancy from hours to days	20
Pretreatment with organosolv	Methanol, Glycol, Glycerol, Formic acid, Acetic acid, Acetone, Phenol, Dioxane, Formic acid, and Acetic acid	Lignin acquired as added-value byproducts from the pretreatment	High cost and energy demand	14
Physicochemical Pretreatment	Ethanol, sodium hydroxide, potassium hydroxide, toluene	low investment costs	Minimal impact on the environment	20

polymerization and crystallinity are reduced [30]. Through a combination of chemical and structural changes to the lignin and carbohydrates, the compact structure of lignocellulose is disrupted during the pretreatment process to overcome the resistance, exposing the cellulose fibers and facilitating the hydrolysis reaction [31].

Physical Pretreatment

Mechanical processing is necessary to reduce the size of lignocellulose biomass. There are various types of physical pretreatment, including milling, microwave, extrusion, and ultrasound. Physical pretreatment's primary goal is to minimize and reduce particle size. This consequently leads to an increase in surface area, a decrease in polymerization level, and a decrease in crystallinity. Additionally, the processes can be carried out properly and efficiently [32].

Prior Chemical Treatment

In order to dissolve lignin and break down the refractory structure of the lignocellulose materials, chemical treatment involves the employment of organic or inorganic substances that interact with the interpolymer linkages of cellulose, hemicellulose, and lignin. Acid pretreatment, alkaline pretreatment, organosolv pretreatment, and ozonolysis are the four basic types of chemical pretreatment for lignocellulose biomass [33].

Alkaline Pretreatment

The general working concept of alkaline pretreatment is the solubilization of lignin in alkali solution. Studies show that sodium hydroxide carries out the pretreatment process. The pretreatment phase of the process is when alkaline reagents, such as potassium hydroxide, calcium hydroxide, and ammonium hydroxide, work best. Because of the saponification process, the connections between hemicelluloses and lignin in this pretreatment method are divided and separated. The enzymatic hydrolysis of cellulose was further accelerated by the solubilization of lignin and hemicellulose[34].

Organosolv Pretreatment

Generally speaking, organosolv pretreatment refers to the pre-treating of certain lignocellulosic biomass using organic solvents. The bonds that bind lignin and hemicellulose together can be broken down by using organic solvents such ethylene glycol, methanol, ethanol, acetone, organic acid, and organic peracid. By removing the lignin and solubilizing the hemicellulose, the surface area and pore volume of the cellulose are increased, making it more susceptible to enzymatic hydrolysis. Lowering the pretreatment temperature and accelerating the delignification process are two common effects of adding mineral acids, bases, and other salts that act as catalysts [35].

Physicochemical Pretreatment

Both the physical and chemical properties as well as their chemical bonding (bond cleavage) and intermolecular interactions are affected by the hybrid pretreatment method known as physicochemistry. Steam explosion, ammonia fiber explosion, carbon dioxide (CO_2) explosion, and liquid hot water pretreatment are the four main forms of physicochemical preparation [36].

CONCLUSION

In order to get the enzyme-accessible substrates, the refractory structure of the lignocellulose biomass must be disrupted. Lignin biomass is a naturally occurring resource that can serve as an alternate application with regard to economic importance. However, using chemical methods while keeping environmental concerns in mind; high lignin growth is still under-processed. The nature and composition of lignin need not be changed. In order to find potential answers to the problems associated with conventional chemical pretreatments, we have compared research with traditional and environmentally friendly pretreatment techniques. In this review, paper, alkali, treatment and acid treatment is a superior methods for feedstock. Physical pretreatments need more energy. The lignin-derived bio products reduce our dependency on petrol. The review continues by examining the benefits and drawbacks of various pretreatment techniques as well as biofuel industry can grow that meet such as agreement on sustainable, political goals, environmental, sustainable.

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AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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