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Conversion of Lignocellulosic Biomass to Ethanol and Used as Liquid Transportation Fuel: A Review

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Abstract: Ethanol production from lignocellulosic biomass is a replacement of transportation fuel. Due to high demand of transportation fuels and shortage of commercial fuel, lignocellulosic ethanol is recognized as a viable and unique liquid transportation fuel with environmental friendly option. Agricultural and forestry residue, grasses, corn straw and fast growing woods are used as raw material for lignocellulosic ethanol production. All these are renewable source which gives the edge over fossil fuels and crude oil, particularly in reducing greenhouse gas emission. In this paper, we critically reviewed the biochemical conversion of lignocellulosic biomass to ethanol.

Index Terms **- Biomass, Cellulosic, Ethanol, Fuel, Lignocellulosic, Straw.**

I. INTRODUCTION

Lignocellulosic biomass is the most abounded waste material in the world, it is the structural portion of plants and includes agricultural and forestry residues, major fractions of municipal solid waste, herbaceous and woody crops grown as energy resources, for example corn stover which is all of the above ground portion of the corn plant, excluding the grain, sawdust, waste paper and yard waste, switch-grass, poplar respectively. These all materials comprise maximum 45–55% cellulose and 20–30% hemicellulose, and small amounts of lignin and other compounds sugars, oils, and minerals. Cellulose is a defined as polymer of glucose sugar molecules which are physically linked together in a crystalline structure which gives structural support for plants. In addition, hemicellulose is complex, amorphous, branched structure material present in plants. Lignin is a phenyl-propene compound that can be viewed as a low-sulfur, immature coal.

Fig.1- Lignocellulosic biomass- corn straw and switch grass

The world's current economy is totally dependent on various types of fossil energy sources of oil, coal and natural gas. These are being used for the production of fuel, electricity and other goods [17]. Highly consumption of fossil fuels, especially in urban areas, caused generation of high levels of pollution in very short decades. The level of greenhouse gasses in the earth's atmosphere has drastically increased [1]. Increase with human population and industrialization, global energy consumption also has increased gradually. Import of transport fuel is affected by limited reserves of fossil fuel. Annual global oil production will begin to decline within the near future [2]. In this scenario, renewable sources might serve as an alternative. Energy from fossil fuels has played a very important role in our lives, but such an important role has been clouded out due to the environment hazard caused from fossil emission. The fossil fuel and the crude oil products are the non-renewable source. Petroleum covers more energy worldwide than any other source of energy, approximately for about 35% of total energy produced, and unstable regions of the world hold the bulk of all known reserves of these fuels. In addition, due to half of the petroleum based fuel is used for a transportation related sector that is almost totally dependent on petroleum, developing alternative sources of liquid transportation fuels is important to alleviating this perilous dependence [16]. This has led to the new dimension in energy utilization known as renewable energy fuels to fully support this type of energy from biological mass, adequate biomass source must be harnessed. The lignocellulosic biomass, the most abundant and low cost biomass world over are the raw material for the production of fuel ethanol [4].

II. BENEFIT OF LIGNOCELLULOSIC ETHANOL

Lignolcellulosic ethanol is believed that it gives environmental advantages over petroleum fuels, particularly in reducing greenhouse gas emission from vehicles. Ethanol has higher octane content than regular or premium gasoline. This property, coupled with a higher heat of vaporization, allows operation with a higher compression ratio when ethanol is used as operational fuel. The result can be considerably good efficiency when compared to gasoline in account of miles powered per unit energy content of the fuel, compensating to some degree for the somewhat lower energy content of ethanol as compared to the gasoline. Thus, ethanol must sell for about 60–70% of the price of gasoline to provide equivalent and relatively same cost per distance traveled. However, a maximum portion of ethanol is used as blends with gasoline, and all automobile manufacturers warrant their vehicles for this use and employ appropriate materials in fuel lines to accommodate the somewhat greater corrosivity of blended ethanol which gives edge over any other transportation fuel. Although pure ethanol has low evaporative losses that can cause smog, low level blends with gasoline increase evaporation somewhat, potentially negating some of the benefits for reducing tailpipe emissions. In addition to the powerful strategic and economic attributes of lignocellulosic ethanol, the use of lignin to power the lignocellulosic ethanol production facility and the low fossil fuel inputs required to plant, grow, harvest, and transport lignocellulosic biomass and to transport ethanol to its destination result in very favorable energy balances for lignocellulosic ethanol. As a result, less than 10% of the ethanol energy produced has required fossil energy inputs [3].

III. MATERIALS AND METHODS

Agricultural and forestry residue, grasses, corn straw, rice straw, wheat straw, bagasse and fast growing woods are used as raw material for lignocellulosic ethanol production.

Table.1- Quantities of agricultural waste (million tons) reportedly available for bioethanol production [6].

Agro-waste	Europe	Asia	America	Africa	Oceania
Wheat straw	132.59	145.20	62.64	5.34	8.57
Bagasse	0.01	74.88	87.62	11.73	6.49
Corn straw	28.61	33.90	140.86	0.00	0.24
Rice straw	3.9	667.6	37.2	20.9	1.7

A. Pretreatment

The most important process in the ethanol production is pretreatment of the biomass. Lignocellulosic biomass is composed of three different constituents namely hemicellulose, lignin and cellulose. In pretreatment stage the solubilization and separation of one or more of these components of biomass carried out. The lignocellulosic complex is made up of a matrix of cellulose and lignin bound by hemicellulose chains. The pretreatment is done to break the matrix in order to reduce the degree of crystallinity of the cellulose and increase the fraction of amorphous cellulose, the most suitable form for enzymatic attack [13]. Pretreatment is undertaken to carry out changes in the macroscopic and microscopic size and structure of biomass. It makes the lignocellulosic biomass susceptible to quick hydrolysis with increased yields of monomeric sugars.

Goals of an effective pretreatment process are

(i) formation of sugars by hydrolysis process

(ii) to avoid loss

(iii) degradation of sugars formed

(iv) to limit formation of inhibitory products

(v) to reduce energy demands and to minimize costs.

B. Saccharification

Saccharification is the process of breaking down complex carbohydrates sugar cane into monosaccharide components. The optimum conditions for cellulase have been reported as temperature of 40-50 ^{o}C and pH 4-5 [9]. In this step, proprietary enzymes and water are added to the pretreated store. This critical step in the process helps to release sugar in lignocellulose which is much more difficult to break own than corn or grain. Enzyme called glucoamylases, are like tiny soldiers who fight to degrade fiber in this process.

C. Fermentation

The fermentation stage of ethanol production is similar to the process of producing wine or beer. A de-crystallized cellulosic mixture of acid and sugar reacts in the presence of water to complete individual sugar molecules. Microorganisms are added to mixture to convert or ferment the sugar into alcohol. The proprietary micro-organisms are added to the cooling hydrolysate to enable the conversion of sugar to ethanol on an industrial scale. After fermentation the beer is pumped to the distillation unit where it will be distilled to create liquid ethanol. The saccharified biomass is used for fermentation by using several different kinds of microorganisms. But the industrial utilization of lignocelluloses for bioethanol production is hindered by the lack of ideal microorganisms which can efficiently ferment both pentose and hexose sugars [15]. A portion of pretreated biomass can be used to feed a fungus or other organism that produces cellulase that can then be added to the bulk of the pretreated solids to release glucose from cellulose. In addition, the enzymes must be capable of releasing sugars contained in hemicellulose if the pretreatment step does not fully accomplish this. Then, an organism is added to ferment all of the sugars to ethanol. Although conventional yeasts ferment glucose and other sugars containing six carbon atoms efficiently, they do not use the five-carbon sugars arabinose and xylose well, and bacteria and yeasts have been genetically modified to accomplish this task.

D. Distillation

After fermentation completion, the broth sends to a distillation column for recovery of ethanol. In distillation column the concentration of the ethanol carried out. The beer is heated to release ethanol in the form of vapors. Then the vapors are condensed reforming the liquid ethanol. After a final drying and purification process the fuel grade ethanol is send to storage tanks where it will be stored for further use. It will be denatured before being loaded onto rail car sand ship to be blended into gasoline. The co-product is formed during the production of liquid ethanol also having more potential value.

E. Residue Processing

After the ethanol is removed during the distillation stage, the remaining mixture is called whole stillage. This contains lignin a valuable source of energy. The lignin and other remaining portions which not converted into ethanol used to generate heat, power and electricity, with excess power left to export to homes and businesses. The sugars released during pretreatment of hemicellulose and cellulose could be converted into other products and could be employed to produce various materials such as fillers and adhesives. This lignin co-product and remaining constitutes can be used in biomass boiler to produce steam, heat and energy. It may also be sold to coal burning companies to offset the use of fossil fuel.

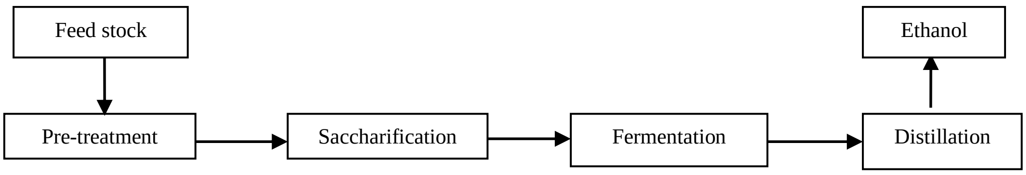

Fig.2- Important stages in the biochemical conversion of lignocellulosic biomass to ethanol.

IV. LITERATURE REVIEW

Feroz Kabir Kazi et.al. made study on techno-economic comparison of process technologies for biochemical ethanol production from corn stover examines the short-term commercial viability of biochemical ethanol production. The raw material for the process is corn stover remaining after harvesting. The process is carried out in seven stages- four pretreatment technologies (dilute acid, 2-stage dilute acid, hot water and ammonia fiber explosion); and three downstream process variations (pervaporation, separate 5-carbonand 6-carbon sugars fermentations and on site enzyme production). Followed by these stages we can obtain the ethanol used as transportation fuel [5].

J. N. Nwakaire et.al. in their study, adopted the production of cellulosic ethanol from wood sawdust. Materials used included 18 m (78% concentration) of sulfuric acid, 6 m of sodium hydroxide for hydrolysis and fermentation process. The hydrolysis process compresses the extraction step of fermentable sugar from a cellulosic biomass. The sawdust of sulfuric acid mixture was allowed to sit for 48 hours then the distilled water was used to dilute in order to bring up its pH between 5.0-6.0. 10 kg of sawdust gave 500cm^3 of ethanol using Beer-Lambert plot of ethanol water mixture. The success of the extraction of ethanol shows there are possibilities for improvements [11].

Chen Guang Liu. et.al. made study on cellulosic ethanol production: progress, challenges and strategies for solutions. In their research, they critically studied updated progress, and highly challenges and strategies for solutions. Different types of lignocellulosic biomass such as cellulose, hemicellulose and lignin were explained in their research. Followed by pretreatment, enzymatic hydrolysis of the cellulosic component and distillation/dehydration stages we get the cellulosic bioethanol [7].

A research made by P. V. Neves on the production of cellulosic ethanol from sugarcane bagasse by steam explosion: Effect of extractives content, acid catalysis and different fermentation technologies. The sugarcane bagasse with 50 weight% moisture content was obtained from Nova America were used for their studies. In their research they adopted following stages- extraction of sugarcane bagasse with ethanol 95%, sugarcane bagasse pretreatment and fermentation of enzymatic hydrolysates and steam exploded substrates. Extraction of cane bagasse with ethanol 95% removed 80% of its organic solvent extraction materials [10].

V. CONCLUSION

This paper has given a review that lignocellulosic ethanol is best alternative for fossil fuel and crude oil. The production of ethanol from comparatively low-cost and abundant lignocellulosic biomass gives a unique route to feasible production of liquid transportation fuels that our society uses so pervasively and offers tremendous economic and environmental benefits. The lignocellulosic ethanol is termed as a future of transportation fuel with environmental friendly option. The above study discusses the biochemical conversion of biomasses to ethanol. The lignocellulosic ethanol creates 90% less greenhouse gas emission and also the wide range of feed stocks that can be used as raw material. It has been noted that the price that's associated with the production lignocellulosic ethanol is one of the concern and also the process is too complex. Thus for future progress in the production of lignocellulosic ethanol, more work will need to be done.

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