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A REVIEW ON THE SCALING AND SCOPING OF 2G ETHANOL BLENDED WITH CONVENTIONAL FUELS IN INDIA.

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Abstract : The use of cellulose in the manufacturing of ethanol prevents the waste of non-edible components of agricultural plants like corn and sugar cane. As opposed to bioethanol made from sugar and starch, they can be utilized to make bioethanol, which increases agricultural productivity and reduces the carbon footprint of crops by up to 85% (1G ethanol) Cellulosic ethanol reduces GHG emissions by 88% to 108% when compared to gasoline, depending on the feedstock used. Because of this, 2G ethanol is a sustainable fuel choice that helps cut air pollution. This review study discusses various methods for producing 2G ethanol, with a particular emphasis on pretreatment methods and 2G ethanol's energy efficiency. The findings help better decision-making in the development and design of biorefineries by illuminating the optimum process alternatives that can result in increased sustainable ethanol output.

Index Terms: Fuels, 2G Ethanol, lignocellulosic materials, biorefinery, Pretreatment, Dilute Acid Pretreatment, energy efficiency, Bagasse stillage.

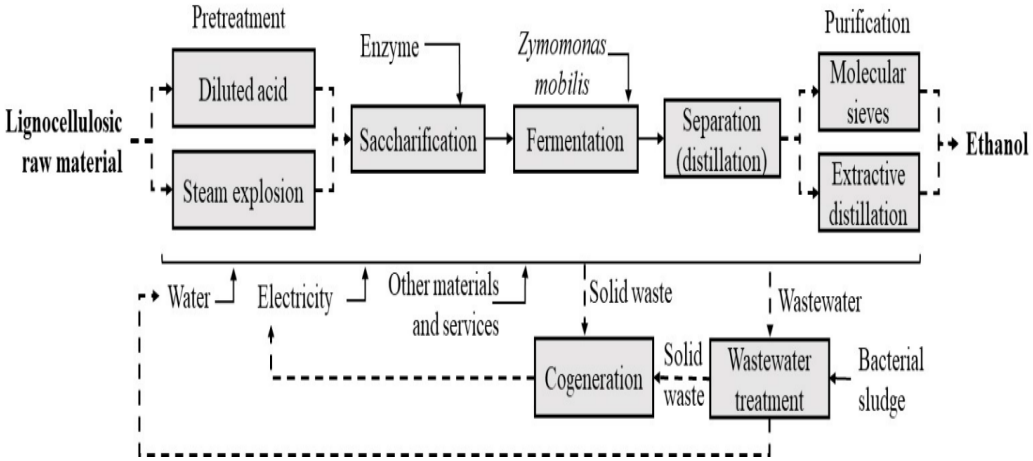
I. INTRODUCTION:

The main motivation for oil-importing nations like India is to lessen their reliance on fossil fuels. With limited access to crude oil resources, nations like India can produce crops for energy use and attain some economic independence. Biofuels can be combined with gasoline and are clean fuels with little Sulphur in them. They can be made on an industrial scale using the sugar fermentation method, and depending on where the sugars come from, they can be either first generation (1G) or second generation (2G). When it comes to feedstock, lignocellulosic materials like wheat straw, corn, wood, agricultural byproducts, or municipal solid waste are commonly employed as a source of bioethanol in 2G technology. Crop leftovers, a waste that would otherwise be worthless, are used in 2G technologies as opposed to 1G technology, which uses grain as feedstock. This study summarizes the contents of several periodicals, focusing on the current situation in the nation and the need to switch to 2g ethanol.

Gonzalez-Contreras *et al*. (2017) proposed a methodology to evaluate alternatives for the synthesis of 2G bioethanol from agro-industrial wastes, with the incorporation of different processing technologies. The conceptual design of the 2G ethanol biorefinery consists of five main sections : Pretreatment, Saccharification, Fermentation, Separation, and Purification.[1] The author has chosen Dilute Acid Pretreatment (DAP) and Steam Explosion Pretreatment (SEP) methods for pretreatment study **Fig 1.**

Pretreatment processes of lignocellulosic biomass play a key role in the productivity and performance of saccharification and fermentation, while dehydration of ethanol determines the quality of the final product to be used as a fuel. Two ethanol dehydration processes have been selected: Adsorption with molecular sieves (AMS) and extractive distillation with solvents (EDS). By taking four combinations of pretreatment and dehydration processes the author concluded that the best pretreatment would be DAP and there was no distinction between the AMS and EDS separation processes. SuperPro Designer is used to evaluate mass and energy balances, and the Pinch method for heat integration is used to reduce input of external energy and operating costs. [2-3]

Fig 1: Conceptual design for the production process of 2G bioethanol.



Pre-treatment, in general, is the process of removing the lignin-carbohydrate barrier that naturally blocks enzyme access to cellulose and hemicelluloses and reduces their accessibility. In order to effectively break down lignocellulosic biomass for the generation of 2G ethanol, protonic ionic liquids are viable pretreatment agents.[4] One of the key elements of lignocellulosic biomass is lignin, which makes it harder for enzymes to reach the biomass. An ideal pretreatment selectively removes, solubilizes the lignin, and preserves the carbohydrates such as cellulose and hemicelluloses in the remaining pulp, which may then be further converted into sugar monomers by enzyme cocktails.

Aprotic ILs have demonstrated promising results in terms of biomass fractionation, but their excessive cost poses a significant economic hurdle on process development. Protic ionic liquids (PILs) have been recently studied for biomass fractionation and have shown promising features, especially in terms of lignin solubilization.[4] PILs can be used as pretreatment agents to selectively solubilize lignin and hemicelluloses to produce pulps high in cellulose. The performance of a protic ionic liquid, 2-hydroxyethanol ammonium acetate or monoethanolammonium acetate, [MEA][OAc], was tested under various conditions in bench scale reactors (0.5 L). A combination of [MEA][OAc] and water was added to the reactors along with around 10.7 g of unground, air-dried sugarcane bagasse.[6]

The author has detailed the statistical analysis and the overall parameter investigation progress was given in the following table. On choosing the best condition, where parameters would increase process efficiency rather than maximize carbohydrate conversion, practical factors were considered.[4] pretreatment effectiveness of [MEA][OAc] found that higher temperatures promoted higher cellulose yields by increasing the temperature from 75 °C to 150 ° C, there was a 3-fold increase in cellulose yield.

Sun *et al*. evaluated the pretreatment performance of switchgrass with [MEA][OAc] and found that the cellulose and hemicellulose yield (reported as xylose yield only) increased by 20% and 18%, respectively, when the temperature was raised from 140° C to 160°C. In this study, from 120 °C to 150 °C with 150 min of pretreatment time, there was an increase of 30% and 15% in the cellulose and hemicellulose yields, respectively.[5] As a result, the author concluded that protic ionic liquids (PILs) are potential pretreatment agents that effectively break down lignocellulosic biomass for 2G ethanol production.

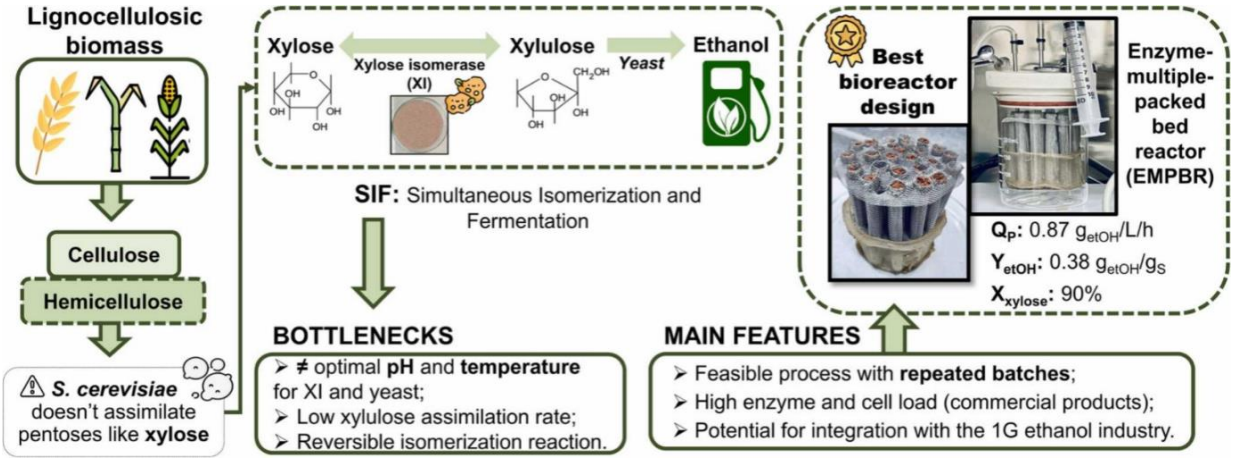
Second-generation (2G) processes, which involve the use of lignocellulosic biomass sugars, have been widely studied to increase ethanol production. xylose is the second-largest carbon source available, but it is more challenging to process compared to hexoses due to the difficulty of converting them into valuable products. Saccharomyces cerevisiae, the most used yeast in the sugar-energy industry, does not metabolize xylose, which is a major hindrance to biofuel production based on this sugar. Xylose assimilation for ethanol production requires either in-vivo routes present in natural pentose-fermenting strains and genetically modified microorganisms (GMO) or ex-vivo, in which native/industrial strains are associated with extracellular enzymes that allow xylose conversion.[5]

The most studied in-vivo route is the use of recombinant S. cerevisiae strains, capable of directly assimilating xylose. Yeast strains, such as Kluyveromyces marxianus, Candida shehatae, and Scheffersomyces stipitis, are an alternative, but they have low ethanol productivities and yield. Ex-vivo routes involve the use of the native strain, which can be converted into xylulose through a reversible isomerization reaction catalyzed by the enzyme xylose isomerase (XI).[7] The process conducted in the presence of XI and microorganisms is denominated Simultaneous Isomerization and Fermentation (SIF), consisting of the isomerization of xylose by the enzyme XI, and the simultaneous assimilation of xylulose by the yeast. With this approach, the process of reversible isomerization (1 xylulose:5 xylose) is shifted in favor of xylulose .[9]

Continuous SIF were carried out in a fixed bed reactor filled with XI immobilized in chitosan and co-immobilized with *S. cerevisiae* as a biocatalyst. The continuous culture was run for 7 days and high values of ethanol yield and productivity were obtained (0.37 g_{EtOH}/g_S and 1.9 $g_{EtOH}/L/h$).[8] For the purpose of performing SIF in repeated batches, this design was proposed which combines a commercially available immobilized enzyme with an appropriate industrial yeast maintained as a free cell suspension culture. Thus, 2g ethanol is produced from xylose using industrial *S. cerevisiae* and commercial xylose isomerase.[8-11]

Fig 2.

Fig 2: Bioreactor design for 2G ethanol production from xylose using industrial *S. cerevisiae* and commercial xylose isomerase.

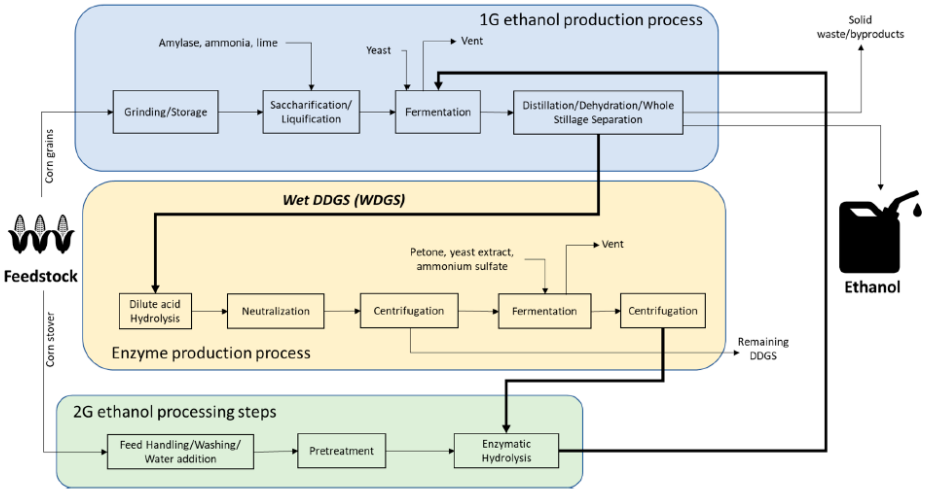


The author has combined 1G and 2G bioethanol production by using Distillers' Dried Grains with Solubles (DDGS) as the feedstock to produce lignocellulolytic enzymes.[13] The important nutrients and high fiber content of DDGS can be used to create lignocellulolytic enzymes like cellulases and hemicellulases for the synthesis of 2G bioethanol. The ideal circumstances for the development of these enzymes can subsequently be done using media optimization and fermentation process optimization methodologies.

DDGS can be used as an on-site enzyme feedstock for making second-generation bioethanol in first-generation ethanol plants, thus bridging the two processes for efficient production of bioethanol. **Fig 3** For the manufacture of 2G biofuel, biological pretreatment, particularly enzymatic pretreatment, has been suggested in numerous research studies.[12]

An ideal microbe for producing such enzymes is one that can manufacture all the enzymes required for a certain type of lignocellulosic biomass. Four fungi species are known to secrete cellulolytic enzymes: Trichoderma, Aspergillus, Humicola, and Penicillium. These fungi are known for their capacity to degrade wood.

Fig 3: The integration of 1G and 2G ethanol via the production of lignocellulolytic enzymes using DDGS



The main benefit of having on-site enzyme synthesis is that it saves money on shipping, stabilizers, and concentration costs. **Table1** Nitrogen source addition, such as yeast extract, peptone, and ammonium sulphate, is used to achieve medium optimization.[14] Another study adjusted the culture parameters for A. Niger by optimizing the inoculum size (6.5%), aeration (1.4 vvm), and agitation (310 rpm) (NRRL 330). The use of microparticles, genetic manipulation, and methods for improving fungi strains are a few examples of such procedures.[14-16]

Table1: Studies conducted to analyse the potential of on-site enzyme production for 2G ethanol.

Research Aspect	Feedstock	Main Results
Screening for fungal strains	Wet oxidized wheat straw and filter cake straw	Twenty-five out of sixty-four fungal strains were selected for their cellulolytic activities.
Enzyme activities on the substrate and glucose yield	Steam-pre-treated sugarcane bagasse	Cellulase activity (1.93 FPU/mL) and β-glucosidase activity (0.37 BGU/mL) were obtained. Glucose yield was 80%.
Extent of enzyme production	Microwave alkali-pre-treated rice straw	Cellulase activity (24 FPU/gds), xylanase activity (258 IU/gds) and β-glucosidase activity (3.8 IU/gds) were obtained.
Extent of enzyme production	Spent fibre sludge hydrolysates	Cellulase activity of 2700 to 2900 nkat/mL was obtained
Production cost and energy analysis of 2G ethanol	Sugarcane bagasse	Cellulase activity of 2700 to 2900 nkat/mL was obtained
Greenhouse gas emissions reductions	N/A	On-site enzyme production further decreases the greenhouse gas emissions.
Extent of enzyme production and hydrolysis	Wheat bran and cellulose	The produced cellulase hydrolysed alkali pre-treated sorghum stover which was fermented to ethanol with approximately 80% efficiency.
Extent of enzyme production and hydrolysis	Sugar cane bagasse	The fermentation efficiency to ethanol of 78% was achieved with the on-site enzyme blends.
Technoeconomic analysis	Same as 2G ethanol	Production cost of 2G ethanol decreased by 19% with on-site enzyme production scenario.
Technoeconomic analysis	Corn stover	The product value (PV) of 2G ethanol was estimated to be 1.42 USD/LGE.

Archana Mishra *et al*. aimed to explained why India should go for 2G bioethanol. To avoid conflict between food production and fuel production, first generation bioethanol production must be switched to second generation (from lignocellulosic biomass). [11]The production of 2G ethanol and its use become more prevalent when considering India's biomass potential and its reliance on foreign energy sources [12].

The Ministry of Agriculture (India) and several agricultural extension agencies, as well as energy statistics, served as the sources of the calculation data for this study (India).[17] **Fig 4** The goal of this study was to evaluate the energy efficiency of wheat straw as a viable lignocellulosic feedstock and its conversion to cellulosic ethanol in an Indian context. **Fig 6** Energy efficiency was calculated using the Net Energy Ratio (NER), which is the ratio of the input and output energy required to produce ethanol[17-19].

When analyzing the effects of lignocellulosic feedstocks on the environment, NER and carbon balance are two significant elements to consider. An alternative to fossil fuels needs to be less harmful to the environment.[17-18] NER An indicator of net energy gain during the entire production process is > 1, indicating that the energy output is higher than energy input, whereas NER 1 suggests that a production process is not sustainable. Finally, author concluded that India should improve wheat straw-based second-generation bioethanol and Research and development studies on exploration of lignocellulosic feedstocks should be improved to decrease the total production cost.

Fig 4: Trend of category wise energy consumption from 2005- 06 to 2014-15.

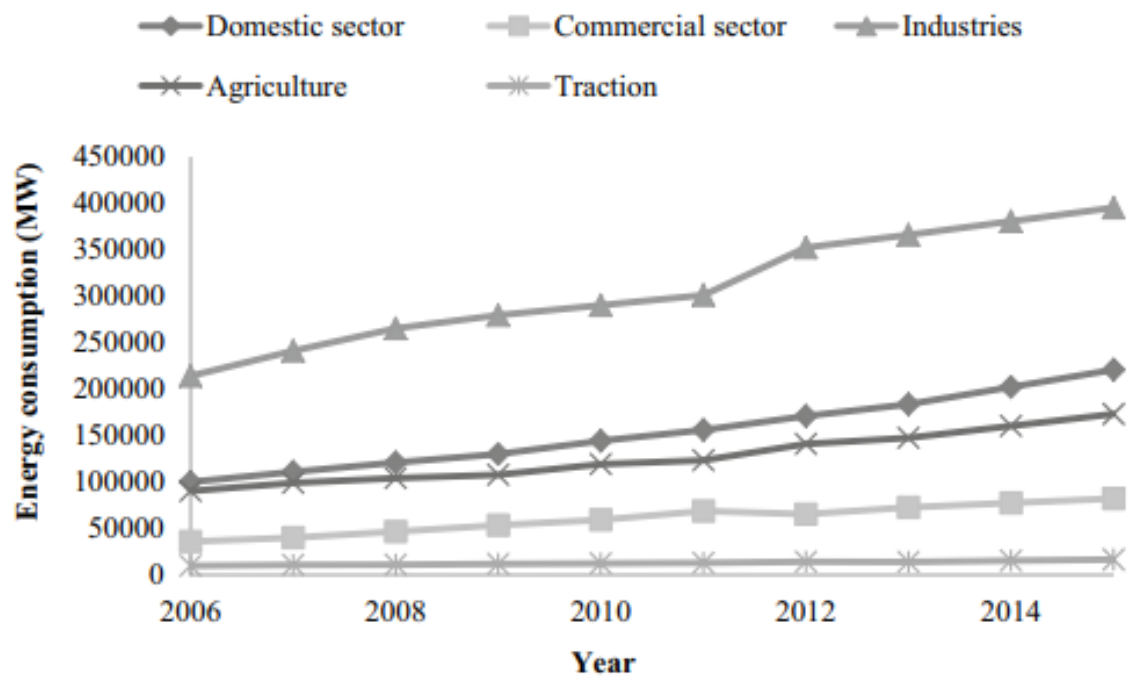


Fig 5: Source wise installed capacities of renewable powers in India as on 31.03.2013 and 31.03.2014.

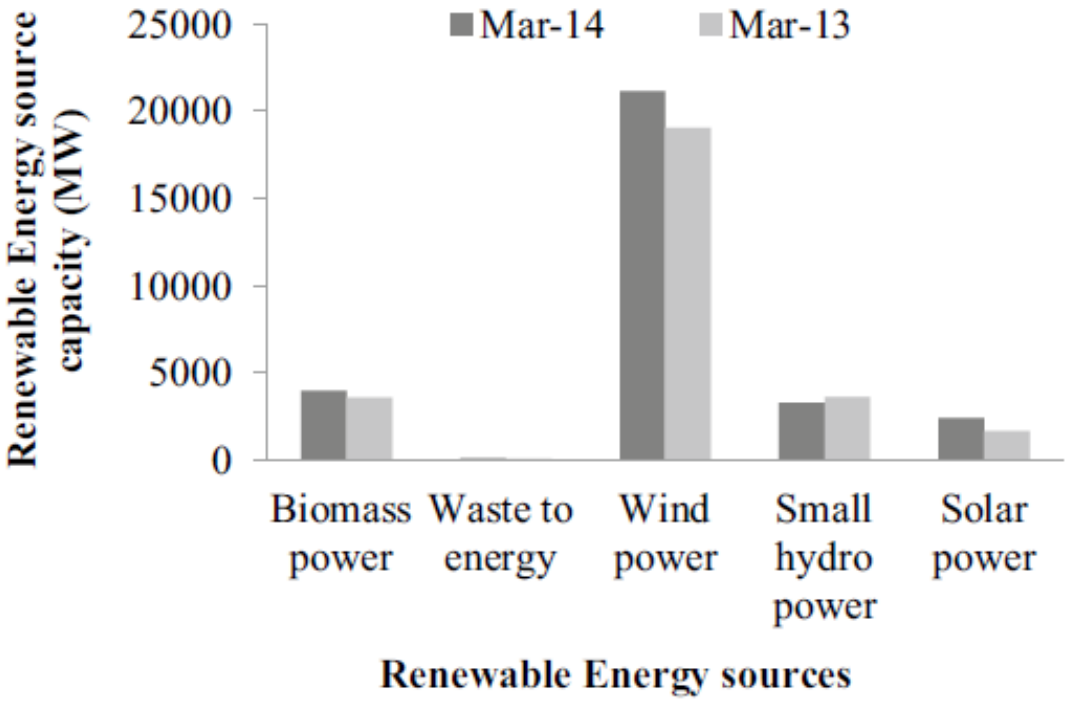
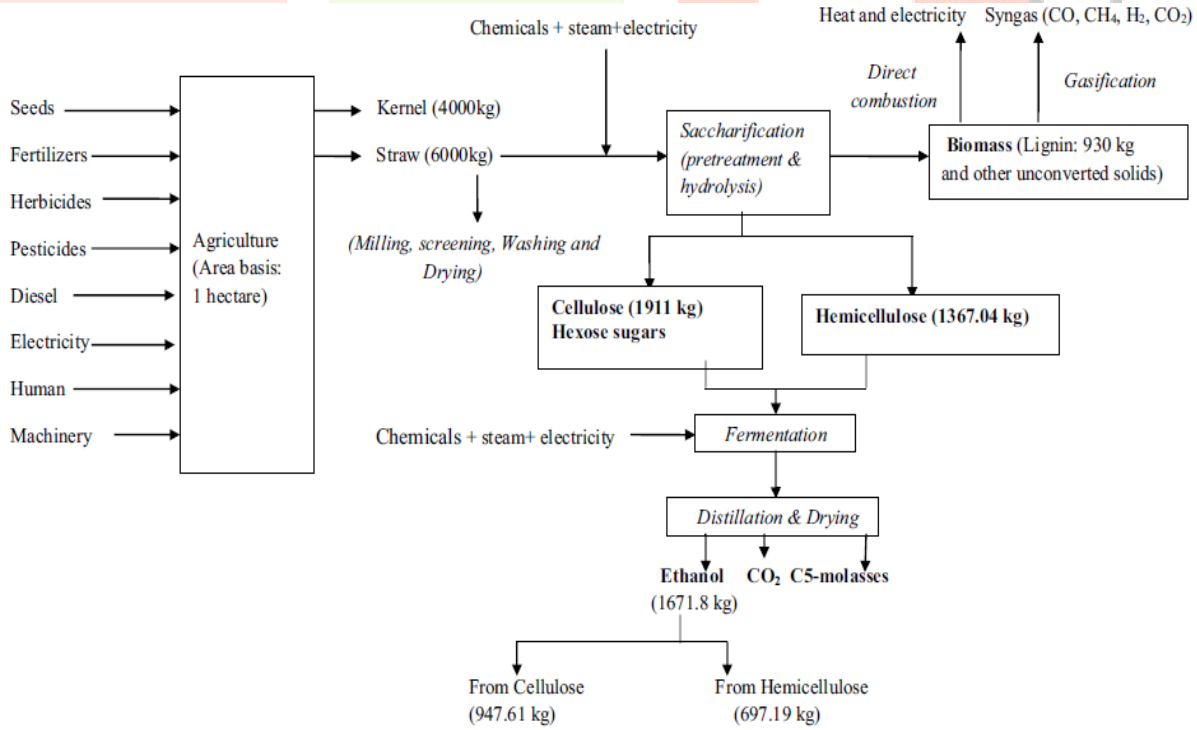


Fig 6: Main processes involved in analysis of energy generation and consumption during bioethanol production from wheat straw in Indian scenario.



A promising new sustainable fuel source made from lignocellulosic materials is second generation (2G) ethanol. An estimated 1.5 billion t/year of dry lignocellulosic biomass produced by the agriculture sector can be used to make 442 billion L/year of bioethanol. However, second generation (2G) ethanol produces more stillage than first generation (1G) ethanol, causing worries for the environment and the economy. If released into the environment untreated, 2 G stillage's chemical oxygen demand (COD) is high (>100 g/L) and will result in considerable environmental damage [20]. To increase the effectiveness and profitability of 2G ethanol production, a low-cost valorization method is needed.

A promising approach for producing bio-based products from wet biomass, such as stillage, is hydrothermal liquefaction (HTL). **Fig 7** HTL produces higher-quality bio-oil than other thermochemical processes due to its reduced oxygen concentration, although needing high pressures (100–300 bar) and moderate temperatures (250–350 °C).[21] **Fig 9** Pilot-scale 2G ethanol cellulosic stillage was evaluated for its potential to yield high-value monomers and platform chemicals, such as phenolic monomers and organic acids, using hydrothermal liquefaction.

Fig 7: Diagram representing 2G ethanol cellulosic stillage to value-added chemicals

Bagasse stillage outperformed eucalyptus stillage in terms of oil and phenolic monomer yield, despite the latter's higher organic acid yield**.** HTL and catalytic hydrodeoxygenation (HDO) of eucalyptus-derived 2G ethanol stillage were contrasted by Hita *et al*. Whereas the HTL process [21] (305 °C) produced a greater oil yield of 53.2% but had a lower alkylphenol monomer content (10%), the HDO process (Ru/C catalyst at 450 °C and 100 bar H2 pressure) produced an oil yield of 30.7% (total monomer yield: 25.2%, where 50% was alkyl phenolics). **Fig 8** Thus, the author has clarified Cellulosic stillage from a pilot plant that contains 2G ethanol is converted to compounds with added value using hydrothermal liquification technique [22].

Fig 8: Block diagram of the bagasse ethanol and stillage HTL process.

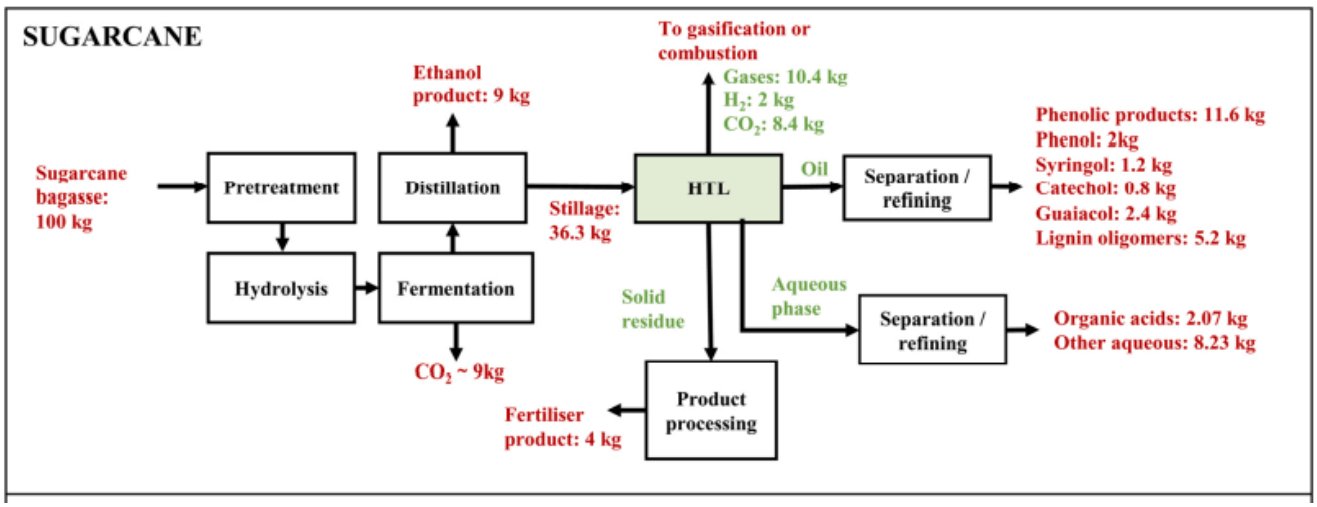
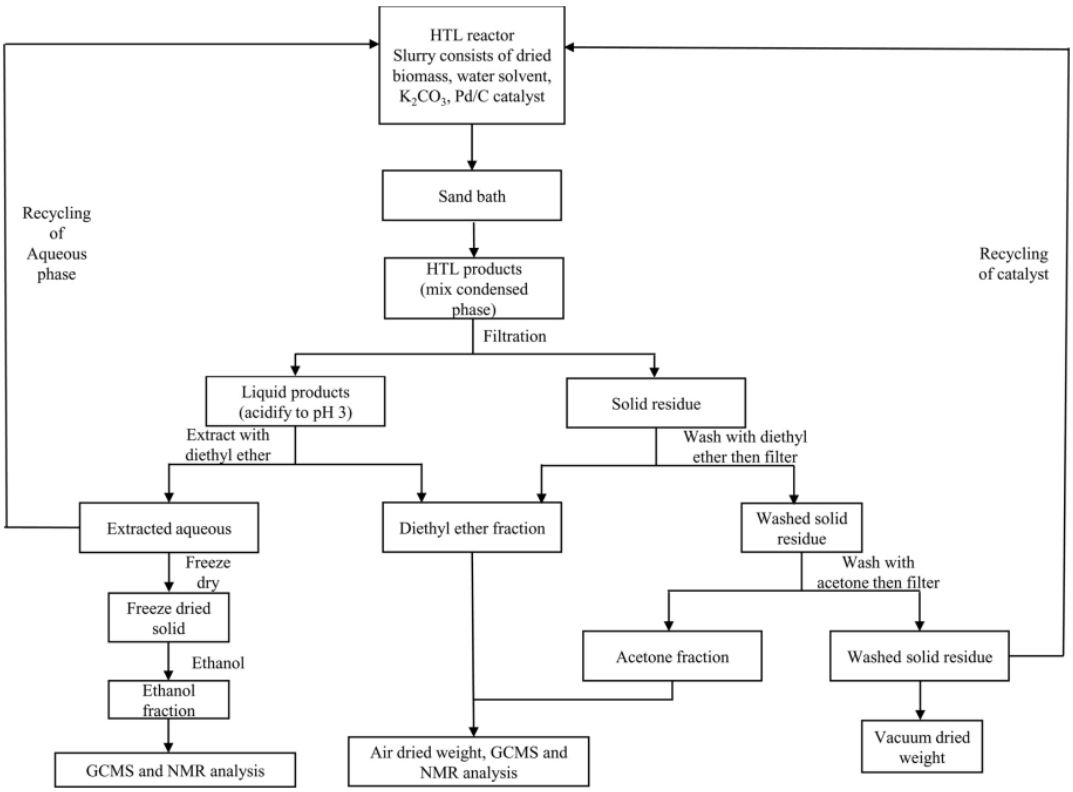


Fig 9: Schematic diagram of product separation after HTL.



II. Conclusion:

By substituting fossil fuels with renewable resources, which are more evenly distributed and raise fewer environmental and social concerns, it is possible to successfully change the current state of global warming and all problems resulting from the usage of fossil fuels. Biomass from plants is used to make biofuels, which are sources of renewable energy. Using this feedstock would decrease the use of fossil fuels and the resulting harm to the environment. Yeast fermentation from a variety of feedstocks is the major method used to create bioethanol, a substitute for fossil fuels. It is clear from the supplied data that bioethanol can be a different approach to the current fuel problem.

In recent decades, substantial advancements have been made in the pretreatment of renewable biomass, the synthesis of cellulase, the co-fermentation of pentose and hexose, as well as the separation and purification of bioethanol; however, bioethanol is still not cost-competitive with fossil fuels. The major issue still is how to make bioethanol cheaper to produce. In order to more fully utilize renewable feedstocks and produce additional value-added byproducts (such as bio-based components from lignin), which would lower the cost of bioethanol production, the biorefinery idea is required and research should be done in improvement of bioethanol production . As a result, bioethanol will be more economically viable than fossil fuels.

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