Green Fuel - A Sustainable Fuel For The Future

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Abstract

As alternatives to petroleum-based transportation fuels, biofuels are gaining popularity because they hold the long-term promise of fuel source renderability and minimal climatic impact. The development of these alternative fuels and gasoline additives, their compatibility with the current fuel delivery system, engine performance, the rivalry between the production of biofuel and food are the main topics of contemporary discussions. The discussion covers the importance of green fuels- bioethanol and biodiesel as fossil sources are depleting drastically. The first generation, second and third generation of fuels are discussed. The different innovative sources of raw organic materials like energy crops, forest biomass, Agriculture residues, Industrial waste, municipal solid waste, plant cell wall engineering, algae. from which we can extract the green fuel. Further, a clear picture of manufacturing of bioethanol is mentioned with various illustrations are mentioned (i.e., grinding, cooking and liquefaction, fermentation, distillation increase of ethanol concentration, and additionally the production of biodiesel through photobioreactor). Then, the current trends in the application and upgradation of biofuels are explained with its numerous applications in different industries. Finally, the future potentials and challenges are discussed with conclusion

Keyword: Algae; Biofuel

Feedstock ; Plant cell wall engineering ; Photobioreactor

Abbreviation

OFMSWs- Organic Fraction of Municipal Solid Waste

CDS- condensed solubles

DDGS- Distillers dried grains with solubles

SSF-Simultaneous Saccharification and Fermentation

HWE-Hot water extraction

FAO-Food and Agriculture Organization

UN- United Nations

GREEN FUEL

1.0 **Introduction**

Henry Ford had quoted ethyl alcohol, ethanol, as "the fuel of the future." He furthermore stated, "The fuel of the future is going to come from apples, weeds, sawdust – almost anything. There is fuel in every bit of vegetable matter that can be fermented." Today Henry Ford's futuristic vision worth can be easily unspoken (Geyer et al., 2007).

The number of inhabitants and number of automobiles are going to be almost equal in the near future. The emissions emitted by automobiles contribute a major percentage to the greenhouse effect. There was always a call for alternative and sustainable fuels. Thus, green fuel is the future because it converts the carbon dioxide in the air. Biofuel from various sources is considered carbon. (Demirbas, 2008)

The consumption of fossil-derived fuels in the transport sector poses an important environmental test since it is currently responsible for 24% of direct CO_2 emissions at the global level (8.2 Gt in 2019)(Duque et al., 2021). Road vehicles—cars, trucks, and buses—account for nearly 75% of total CO_2 emissions in transport. The magnitude of this impact, which has been getting worse in recent decades, makes the use of renewable and sustainable sources for the production of alternative biofuels imperative, among which biomass plays a crucial role. The intense work involving research, government, and industry sectors has turned biomass-based liquid fuels, mostly bioethanol and biodiesel, into an actual alternative to the use of conventional fuels (gasoline and diesel) today. These liquid biofuels are considered vital elements to progress in energy safety in terms of supply, improve climate change, and support rural development at the international level.(Tye et al., 2011)

Fuel, power, and other fuel sources, among others, are very important to the world economy. Someone else's garbage might be someone else's treasure, as the old saying goes. Numerous recyclable wastes and raw materials can be used as bioethanol production substrates. Examples include organic and oil-based residues, specified agricultural products, and lignocellulosic material.(Millati et al., 2019)

Eighty-four percent of the world's bioethanol production is produced in the United States and Brazil. In 2019, the European Union produced 5443 million liters, or 5% of the world's production, ranking it third. Presently, food-related crops which includes sugarcane, corn, wheat, and barley are mainly utilized for producing fuel ethanol. First-generation (1G) bioethanol is what has been produced, and the technology is widely used at the industrial level. 94% of the nation's total bioethanol production in 2019 was based on maize starch. Brazil, on the other hand, primarily obtains bioethanol from sugarcane (99% of total production). In the EU, a variety of feedstocks, including wheat (18.7%), maize (19.6%), sugar beet (57.9%), barley (1.9%), and rye (1.9%), are used to make bioethanol.((Duque et al., 2021)Energy sources and their utilization regulate the economic status and growth of developing countries all over the world. The Statistical Assessment of World Energy estimated in 2013, the principal sources of energy consisted of petroleum at 32.9%, coal at 30.0%, and natural gas at 23.7%, amounting to an 87.0% stake for fossil fuels in primary energy consumption in the world. In the year 2003, the world consumed 9943.8 million metric tons of primary oil equivalent primary as energy; this value improved by 7.8%, 20.2%, and 28.0% in 2005, 2010, and 2013, respectively. Today's society is based on the use of fossil resources for transportation fuels and petrochemicals. World energy consumption by many fuel types It is evident that the consumption of oil, coal, and natural gas greatly surpasses the consumption of renewable energy and hydroelectricity. The result of unlimited consumption of fossil energy due to its low cost and ready availability is a severe exhaustion of the natural reserves.(Asif & Muneer, 2007). However, the use of fossil fuels also leads to environmental damage. The burning of every ton of fossil fuel adds 180 kg of sulfur oxides to the atmosphere, causing irritation to the respiratory system and contributing to the formation of acid rain. In addition, the burning of fossil fuels produces around 21.3 gigatons of carbon dioxide (CO_2) per year; nevertheless, it is estimated that natural processes can only absorb about half of that amount, so there is a net increase of 10.7 billion tons of atmospheric carbon dioxide per year (one ton of atmospheric carbon is equivalent to 44/12 or 3.7 tons of carbon dioxide). Dropping fossil reserves and an increasing call for energy, together with environmental concerns, have led to focused research on the development of alternative fuels that are eco-friendly, biodegradable, and economical. (Reshmy et al., 2023) The use of renewable resources to produce liquid biofuels offers attractive solutions to reducing greenhouse gas emissions, decreasing reliance on foreign oils, addressing energy security concerns, establishing rural and agricultural economies, and increasing the sustainability of the world transportation system.

Every region has its own locally generated biomass feed stocks from agriculture, forest, and urban sources. A wide variety of biomass feed stocks are available and biomass can be produced anywhere the plants or animals can live. Furthermore, most feed stocks can be made into liquid fuels, heat, electric power, and biobased products. This makes biomass a flexible and widespread resource that can be adapted locally to meet local requirements and purposes. Some of the most common and most promising biomass feed stocks are:(Johnson, 1996)

1)Grains and starch crops – corn, sugarcane, wheat, sugar beets, industrial sweet potatoes,

2) Agricultural residues – Corn stover, wheat straw, rice straw, orchard pruning’s, switchgrass

3) Food waste community waste produce, food processing waste

4) Forestry Biomass: Logging residues, forest thinning

5) Animal by-products: tallow, fish oil, manure

6) Energy crops: switchgrass, miscanthus, hybrid poplar, willow, algae

7) Urban and suburban wastes: municipal solid wastes (MSW), lawn wastes, wastewater treatment sludge, urban wood wastes, disaster debris, trap grease, yellow grease, waste cooking oil, etc.

First Generation biofuels

"Conventional" biofuels are first-generation biofuels. Ethanol and biodiesel are the two primary first-generation biofuels utilized in transportation. In ordinary automotive engines, ethanol replaces gasoline and can be used either in blends or straight up for modified engines. It is produced through the fermentation of plants like sugarcane that contain a lot of sugar or starch. The majority of the time, biodiesel is blended with diesel and utilized in trucks or other commercial transport vehicles. Animal or vegetable fats, including soy or palm oil, are used to make it the majority of the time. Using current technology, it is relatively simple to extract the sugars and vegetable oils. Due to the massive scale required to supply present demand, sustainability concerns are connected to food competitiveness, resource usage, and land usage.(Nanda et al., 2018)

Second generation biofuels—also known as "advanced" biofuels—are produced using a variety of biomasses. This can include woody plants, agricultural waste, lignocellulosic biomass, as well as animal fats. To extract the necessary fuel, chemical and physical processes are needed, which calls for more sophisticated technical systems to create transport fuels. Although there is less direct competition with food production, second-generation biofuels still require the utilization of agricultural resources and land.(Okolie et al., 2021)

The "advanced" biofuels known as third generation biofuels are also made from algae. Different types of fuel can be produced depending on the conversion method employed. This kind of biofuel is currently produced on a small scale. Expectations are high because, in contrast to first- and second-generation biofuels, algae fuel would only need a small amount of land and would not compete with or interfere with other uses of biomass resources.(Alam et al., 2015)

2.0. Advanced Resources for Progressive Bioethanol Production

One of the most promising substrates for the generation of sustainable biofuels is lignocellulosic biomass. Economically speaking, lignocellulose is easily accessible and can be manufactured locally for a reasonable price. .

The organic portion of municipal and industrial trash, as well as energy crops. These resources are plentiful on Earth and frequently have no commercial value. Aside from that, there is no conflict with the food sector because this form of biomass cannot be used as a resource for food. Because of this, lignocellulosic bioethanol is one of the most promising and sustainable substitutes for first-generation bioethanol made from biomass from food crops.(Ramesh et al., 2022)

Cellulose, hemicellulose, and lignin make up the majority of the components of lignocellulosic biomass. The linear polymer known as cellulose is made up of -d-glucose units connected by β -1-4-glycosidic linkages. By cross-linking many hydroxyl groups, hydrogen bonds and Van der Waal forces help to arrange cellulose into microfibrils within lignocellulosic biomass. This creates a rigid structure and makes up a large portion of the plant cell walls. Pentoses (xylose and arabinose) and hexoses (glucose, galactose, and mannose), sugars of 50–200 units each, make up the heteropolysaccharide known as hemicellulose. Hemicelluloses are highly branched, contain acetyl groups, and contain only trace amounts of glucuronic acid, although the composition varies depending on the biomass.(Maki-Arvela et al., 2011)

The raw material or substrate is key to the production of biofuels; few sources are abundantly available and few are not. There is further processing for them to use as a substrate. Different raw materials have different levels of production and grade, which are further classified as the first, second, and third generations of fuel. In the list below, a few are more economically feasible than others.

2.1 Energy Crops:

Energy crops are those whose entire or partial production is used as the raw material to produce functional energy. In general, these crops yield a lot of biomass per square foot and time. Rapid growth, a short growing season, and the ability to thrive in unfavorable soil and weather circumstances (where other crops would provide low and unpredictable yields) are the primary criteria for choosing energy crops.

Energy crops are mostly divided into two types: herbaceous and woody energy crops. Herbaceous energy crops mostly belong to perennial grasses, including switchgrass (Panicum virgatum), miscanthus (Miscanthus spp.), and giant reed (Arundo donax) as well as others. (Varnero et al., 2018) On the other hand, with a relatively fast growth, short rotation woody crops included poplar and eucalyptus.

The two main categories of energy crops are herbaceous and woody energy crops. Perennial grasses like switchgrass (Panicum virgatum), miscanthus (*Miscanthus* spp.), giant reed (Arundo donax), and others are for herbaceous energy crops. On the other side, short rotation woody crops with a rather quick growth rate included poplar and eucalyptus.

The lignocellulosic energy crops that have received the most research is switchgrass and Miscanthus species. Switchgrass was converted after being pretreated with NaOH, NH3(aq), H2SO4, and CH3OH. Methanol proved to be the most efficient pretreatment procedure, resulting in a final yield of 0.32 g of ethanol/g of glucose and 97% conversion yields. (Duque et al., 2021).

2.2. Forest Biomass

Forest biomass, chiefly woody materials such as branches, leaves, and lops, has been used as feedstock for bioethanol production. Wood can be classified into softwood (gymnosperms) or hardwood (angiosperms). Main differences between softwoods and hardwoods include growth rates and densities. Hardwoods typically exhibit slower growth and are consequently denser than softwoods.

This group is crucial for the preservation of marginal land and the reduction of CO_2 levels in the atmosphere. When compared to other raw materials, one of the main benefits of employing forest biomass as feedstock is its flexibility in terms of harvesting time because these materials are not seasonal. Eucalyptus bark is a byproduct typically obtained during the production of eucalyptus trees in the pulping industry as an example of forestry resources. For every 100 tons of pulp product, 20 tons of bark might be produced throughout this procedure. With pretreatment technology and simultaneous saccharification and fermentation (SSF) as a process strategy, this residue was employed as an alternative source to produce 252 L of bioethanol per ton of biomass.

Boards, such as fiberboard, chipboard, and block board, which are inevitably created from reeds, wood chips, and branches, are more interesting forest-derived leftovers. Following use, these panels are typically set on fire. However, as these materials primarily include lignocellulose which makes up more than 85% of its composition, they can be used instead to produce bioethanol. The Northeastern United States' ability to produce decarbonization-supporting ethanol from forest biomass depends largely on the energy sources selected to power the biorefinery and the specifications of the intended conversion process. Under two processing energy scenarios (biomass, natural gas), the fermentation of sugars obtained from hot water extraction (HWE) of forest biomass. The energy source was a major factor in the benefits of ethanol production for combating climate change. The lifecycle greenhouse gas emissions of ethanol fuel were 78% lower for the biomass scenario compared to petroleum gasoline, whereas the natural gas scenario led to a 2% rise in GHG emissions.

Monte Carlo study showed that the biomass scenario was always in compliance with the 60% GHG reduction criterion for cellulosic ethanol when the input variable parameters allowed to vary by 20% from their baseline value. When ethanol fuels are generated under the natural gas scenario, steps to increase the energy efficiency of the biorefinery per unit of ethanol produced (i.e., increase ethanol yield or decrease energy consumption) may result in ethanol fuels with GHG emissions that are equivalent to or lower than those of petroleum gasoline. The Northeastern United States' capacity to produce ethanol from forest biomass is strongly reliant on the energy sources selected to power the biorefinery and the specifications of the intended conversion process.

2.3. Agricultural Residues

Food and Agriculture Organization (FAO) of the United Nations (UN), agricultural residues are defined as “a crop lost during the year at all stages amongst the farm and the household level during handling, storage, and transport. This covers both field and processing leftovers and includes things like straw, husks, seeds, and bagasse. By 2030, there will be 240 million dry t/year of agricultural residues accessible only in the United States for the generation of bioenergy. Rice straw is the most prevalent agricultural residue in the world, and a significant share of agricultural residues come from rice, wheat, corn, and sugarcane. 205 billion L/year of bioethanol may be produced from rice straw, 104 billion L/year from wheat straw, 58.6 billion L/year from corn straw, and 51.3 billion L/year from sugarcane bagasse, according to assessments of the feedstocks' bioethanol potential.(Abbas & Ansumali, 2010)

All nations on the planet started thinking about alternatives to fossil fuels as a result of these considerations, along with several more. As a viable source of renewable energy, bioenergy inspires both high hopes and challenges. Bioenergy supports regional improvement, rural diversification by generating jobs and income typically in underdeveloped rural areas, and most importantly, it reduces CO2 emissions while preserving non-renewable resources to improve energy security. By replacing the energy from fossil fuels with green energy, bioenergy and biofuels have been filling the gap more quickly. The United States and Brazil are pioneers in the use of conventional methods to produce first-generation fuel based on starch from food crop sugars.

The energy efficiency of biofuels varies significantly depending on the type of plant used as a feedstock, the local climate, and the method of production. According to a life cycle analysis, bioethanol produced from sugar cane in Brazil produces 8 units of bioenergy for every unit of fossil fuel used in the production process. While bio-ethanol made from US maize only has an efficiency of 1:2.5, biodiesel made from rapeseed in the EU has a ratio of 1:2.(Gold & Seuring, 2011)

2.4. Industrial Wastes

All by-product streams from currently operating industrial bio-based industries, such as the food industry, the pulp and paper industry, the textile industry, as well as processes connected to 1G biodiesel and bioethanol, are included in the category of industrial wastes. By lowering net CO2 emissions, reducing our reliance on petroleum-based resources, and boosting the processes' economic efficiency by giving value to what is unquestionably discarded as waste, the use of this type of biomass helps to lessen the environmental impact of these industrial processes. Brewers' consumed grains make up about 85% of the total amount of by-products produced by the brewing sector inside the food-derived wastes. This residue could contain a sizable amount of fermentable sugars, depending on the technology used in each brewery and the type of crop.

Wastes resulting from the pulp and paper industry are another valued source for the producing bioethanol and other value-added products. Tons of paper and paperboard and million tons of virgin pulp were produced. It is important to highlight that hardwood-derived SSL contains higher proportion of pentoses than softwood-derived SSL. Hence, pentose-fermenting microorganisms such as *Scheffersomyces stipitis* (formerly *Pichia stipitis*) primarily be considered for the conversion of hardwood SSL into bioethanol. Whereas, PPMS is a solid waste material by a high glucan content that can be converted into various value-added products. SHF process).

Fiber crops like cotton-derived materials, jute (Corchorus sp.) and Mesta (Hibiscus spp.) biomass have also been discovered for bioethanol manufacture. The use of these feedstocks contributes to reducing the amount of waste caused in the textile trade. Currently, jute biomass has been considered as a promising feedstock for bioethanol manufacture.

2.5. Municipal Solid Wastes

The average quantity of municipal solid waste (MSW) that one person produces in Europe is about 475 kg per year. This number is incessantly increasing due to the exponential growth of the total population, which is directly connected to wide consumption of energy and natural resources. MSW comprises of household waste from households, biodegradable garden waste, offices, restaurants, caterers, and trade, and similar waste from food processing Industries. Furthermore, OFMSWs frequently present variable contents of inert materials such as plastic, glass, and textiles, whose concentrations very much depend on the collection method. The occurrence of a high number of inert materials can aggravate different technical problems and decrease the effectiveness of the valorization process.lant Cell Wall EngineeringGenetic engineering of lignocellulosic feedstocks signifies a fascinating approach to simplify the accessibility of carbohydrates during conversion processes. The intricate chemical composition and structure of secondary cell walls are physical barrier difficult to breakdown. Targeting to reduce this biomass resistance, different substitutions have been planned to genetically modify lignocellulosic feedstocks and development conversion efficiencies. Additionally, this plan allows transferring of the tuned properties to upcoming generations and makes the process more real along the years. Nevertheless, the genetic changes offered in these organisms my affect the plant cell growth and/or its developmental procedures, which may harmfully impact biomass yields. In short, genetic engineering of plant cell walls offers great potentials for improving the efficiency of lignocellulose conversion processes within a bio-based economy viewpoint, though further research is needed to understand the full potential of these strategies and decrease the negative impact of such modifications

.Figure 1: Feed stock of bioethanol from va sources

2.7 Algae is photosynthetic organism which are consider very potential form of raw material as to their capacity to lessen nearly all the drawbacks of first- and second-generation biofuels, third-generation biofuels derived from algae are now regarded as excellent biofuel substitutes. As a result, despite their short-term economic inefficiencies, the global commercial production and consumption of third-generation liquid, solid, and gaseous biofuels keep growing. The global market for third-generation biofuels is growing at a rapid rate, creating significant growth potential

3. Manufacturing of Green fuel

As we have seen, there are many raw materials that we can use for the manufacturing of banol and. Now, we understand that any organic waste has the potential to produce biofuel. So, we will look into the way it is produced, taking corn as one example. Corn can be transformed into fuel ethanol by three viable processes: wet milling, dry milling, and dry grind processing. Over the decades, many new fuel ethanol plants have been built and substantial innovations have happened throughout the industry vis-à-vis production developments used and final products formed, as well as raw materials, water, and energy usage. Many of these innovations have arisen with the advent of dry grind processing. Owing to many advantages, with lower capital and operating costs, and energy inputs most new ethanol plants are dry grind facilities as different to the traditional style mills. For instance, in 2002, 50% of U.S. ethanol plants remained dry grind; in 2004 that number had risen to 67%; in 2006 dry grind plants constituted 79% of all facilities; and in 2009 the fraction had grown to over 80%.(*Overview of Corn-Based Fuel Ethanol Coproducts: Production and Use | IntechOpen*, n.d.)

Dry milling is a method wherein corn is ground into flour and fermented in ethanol, which includes by-products of distillers' grains and carbon dioxide.{Citation} The wet mill largely produces corn sweeteners, as well as ethanol and many other by-products such as corn oil and starch. Wet mill split up the starch, protein and fiber from the corn before treating with additives into commodities including ethanol. The dry grind process involves many important steps, which includes grain receiving, distribution, storage, cleaning, grinding, distillation, cooking, liquefaction, fermentation and saccharification, ethanol storage and loadout. Centrifugation, coproduct drying and coproduct storage as well as loadout. Extra systems that play significant roles includes energy and heat recovery, waste organization, grain aeration, CO_2 scrubbing and removal, dust control, facility cleanliness, instrumentation and controls, and sampling and regular inspection.

Grinding, cooking, and liquefying helps convert the corn starch into glucose, which is disbursed during the fermentation process by yeast (*Sacchharomyces cerevisiae*). After fermentation is done, the ethanol is separated from the water and nonfermentable residues -which contains the corn kernel proteins, fibers, oils, and minerals by distillation process.

Several processes involved in Downstream processes are dewatering, separation, evaporation, mixing, and drying are at that time used to remove water from the solid residues to produce a varieties of coproducts streams -known as distillers' grains: wet or dry, with or without the addition of condensed solubles: CDS and. DDGS -Distillers dried grains with solubles ,and is often dried to approximately 10% moisture content, to confirm an extended shelf life and good flowability, and then wholesaled to local livestock producers or shipped by truck to various destinations throughout the nation. DDGS is increasingly being exported to international markets as well. Distillers' wet grains (or DWG) has been gaining acceptance with livestock producers near ethanol plants in recent time. It is estimated there will be constant rise.

Dry grind ethanol manufacturing results in three main products: ethanol, the primary end product; residual nonfermentable corn kernel components, which are sold as distillers' grains; and carbon dioxide. A common rule of thumb is that for each 1 kg of corn processed, approximately 1/3 kg of each of the constituent streams will be produced. Another rule of thumb states that each bushel of corn (~ 56 lb; 25.4 kg) will yield up to 2.9 gal (11.0 L) of ethanol, approximately 18 lb (8.2 kg) of distiller's grains, and nearly 18 lb. (8.2 kg) of carbon dioxide. Of course, these will differ to some degree over time due to production patterns, equipment state, concentrations, maintenance lists, equipment state, environmental conditions, the quality of the raw corn. The location where the corn was grown, as well as the growing period that produced the corn.(*Overview of Corn-Based Fuel Ethanol Coproducts: Production and Use | IntechOpen*, n.d.)

3.1. Grinding

Grinding of corn is done by hammermill or roller mill is used to do the grinding. As shown in the figure of a hammermill with corn being put through it. The hammers are attached to rods that turn on a rotor. The rotor turns the corn and is hammered against the wall. At the bottom particles are collected that are small enough to leave the unit and keep in the larger particles to continue to be hammered till all the material is in the correct size. The grinding helps to break the rough outer coatings of the corn kernel, which will increase the surface area of the starch. the After the corn is broken down, it is mixed with heated water to form a mash or slurry.

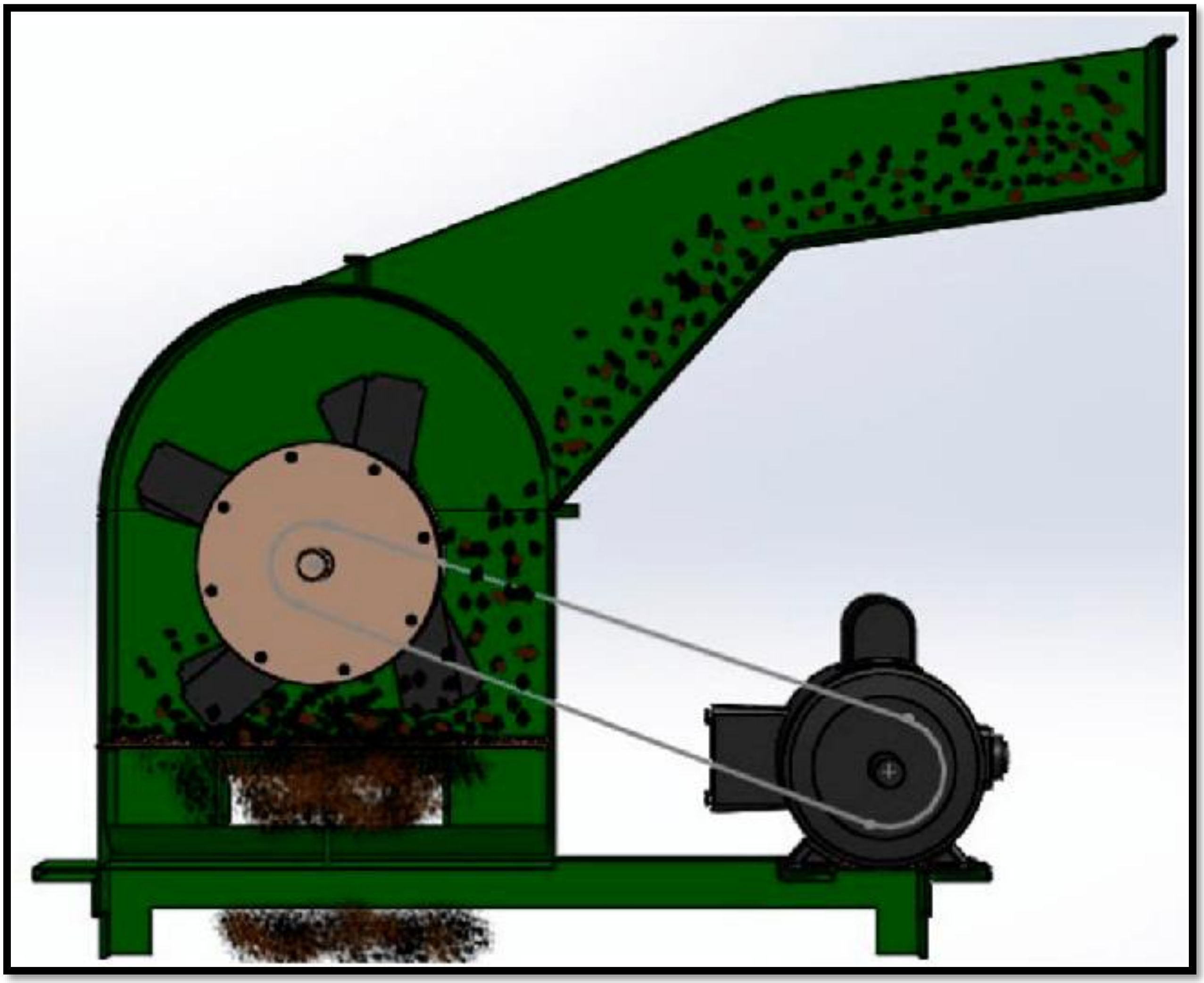


Figure -2 Hammer mill machine - adopted from research gate (*Figure 3*, n.d.)

3.2 Cooking and Liquefaction

Once the corn slurry is completed, it goes for further process of cooking and liquefaction. The cooking stage is also known as gelatinization. Water interacts with the starch granules in the corn, and when the temperature is greater than 60°C it forms a viscous suspension. The process of liquefaction involves partial hydrolysis, which reduces viscosity. It breaks the larger chains of starch into smaller chains. Dextrose equivalents (DE), which are a measure of the proportion of reducing sugars to glucose contained in a sugar product and are given as a percentage on a dry basis, can be used to determine this. The number of bonds that were broken in comparison to the initial number of bonds is known as the dextrose equivalent. Dextrose is also referred to as glucose.

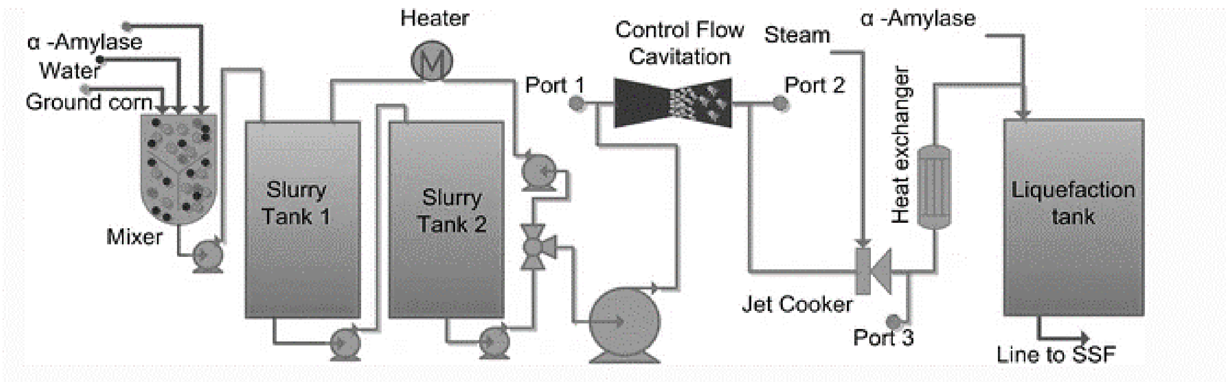


Figure 3:Biofuel production flow (*Fig. adopted from Flow Sheet for Conventional Biodiesel Production*, n.d.)

The medium was autoclaved at 137.9 kPa for 20 minutes tsterilize it. 10 g of yeast extract, 20 g of peptone, 50 g of dextrose, and 1,000 mL of sterilized DDI water were combined to create YP medium with 5% glucose. The medium was sterilized and filtered. By combining 192 g of anhydrous citric acid with 1,000 mL of DDI water and titrating the mixture with a solution of 10 mol/L of sodium hydroxide to a pH of 4.3, citrate buffer (1 mol/L, pH 4.5) was created. The solution was autoclaved at 137.9 kPa for 20 minutes to sterilize it.(Ramirez-Cadavid et al., 2014)

Some enzymes are added such as- The α-amylase for liquefaction acts on the internal α (1,4) glycosidic bonds which helps to yield dextrins and maltose. one type of α-amylase exists in the saliva of humans; a different α-amylase is utilized by the pancreas. The subsequent step in the process of production ethanol is saccharification. Saccharification is the development of further hydrolysis to glucose monomers. Different enzyme is used, called a glucoamylase it is also known by amyloglucosidase.

3.3 Fermentation

Fermentation is the last chemical process in the ethanol production process using starch. 1 mole of glucose results in the chemical process of fermentation, which produces 2 moles of ethanol and 2 moles of carbon dioxide. Equation below illustrates the reaction.

$C_6H_{12}O_6 \rightarrow 2C_2H_6OH + 2\ CO_2C_6H_{12}O_6 \rightarrow 2C_2H_6OH + 2\ CO_2$

Fermentation to take place by adding yeast. The yeast used is saccharomyces cerevisiae, which is a unicellular fungus. The reactions take place at 30-32°C for 2-3 days in a batch process. Supplemental nitrogen is added as ammonium sulfate or urea. A protease can be used to convert proteins to amino acids to add as an additional yeast nutrient. Antibody like Virginiamycin and penicillin are often used to prevent bacterial contamination. Then carbon dioxide produced also lowers pH, which can reduce the contamination risk. Nearly 90-95% of the glucose is converted to ethanol.

It is possible to do saccharification and fermentation in single step. It is known as Simultaneous Saccharification and Fermentation (SSF), and there is addition of glucoamylase and yeast. It is done at a lower temperature than saccharification at-32-35°C, which slows the hydrolysis into glucose. As glucose is formed, it is fermented, which reduces enzyme product inhibition. It lowers initial glucose concentrations, lessens contamination risk, reduces energy requirements, and produces higher yields of ethanol. Because SSF is done in one unit, it can improve capital costs and save residence time.

3..4 Distillation and Increase of Ethanol Concentration

The final phase of ethanol manufacturing is the processing of ethanol to increase the ethanol concentration. Downstream from the fermenters, the ethanol concentration is 12-15% ethanol in water that is you have 85-88% water in your solution. Distillation is performed in case of crude oil and it must be distilled into various boiling fractions to separate the oil into functioning products. Distillation is a process to separate components using heat and particularly designed towers to keep the liquid flowing downward and the vapors being generated to flow upwards. Water boils at 100°C, while ethanol boils at 78°C. Though, because water and ethanol evaporate at a lower temperature than their boiling points, and because they both have OH functional groups which gets attracted to each other, ethanol and water molecules are bound strongly to each other and form an azeotrope. which means that you cannot completely separate ethanol from water – the ethanol fraction will contain about 5% water and 95% ethanol in the final step.

3.5 Biodiesel from Microalgae through photobioreactor

A photobioreactor means that it employs light. When do we need light? - whenever an organism needs light. And something that requires light is called a photosynthetic organism. Photosynthetic organisms, when you use them, you need to use something called a photobioreactor.

It is a third-generation biofuel and as discussed earlier this is it covers less capital and land space. Furthermore, it can be used in very efficient as fuel and have potential to be used in lager applications also. Microalgae for the production of bio-diesel? Microalgae happen to be photosynthetic organisms. They convert the carbon dioxide in the air to bio-fuel and that is why, it is also considered a carbon neutral kind of a situation. That is, it does not take any carbon from the earth. It just takes the carbon from the air, converts it into bio-fuel and even if it gets back into air, it is still a neutral kind of a situation, there is no addition of carbon dioxide from the earth into the atmosphere. So, when a microalga is grown to produce bio-oil, you use something called a photobioreactor. The process is rather straightforward and simple. Everything is known about the process. This is the vessel here that contains the broth, and this vessel has an outlet, which leads to this photo section. I think the next picture would show the photo section a little better. You know this is the photo section lit up.

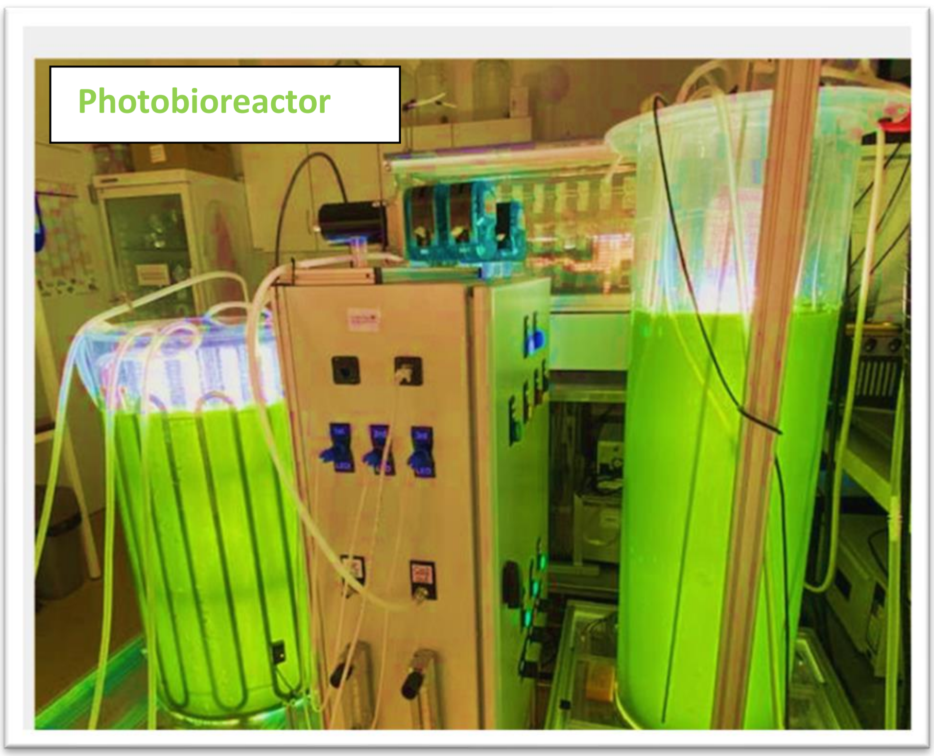
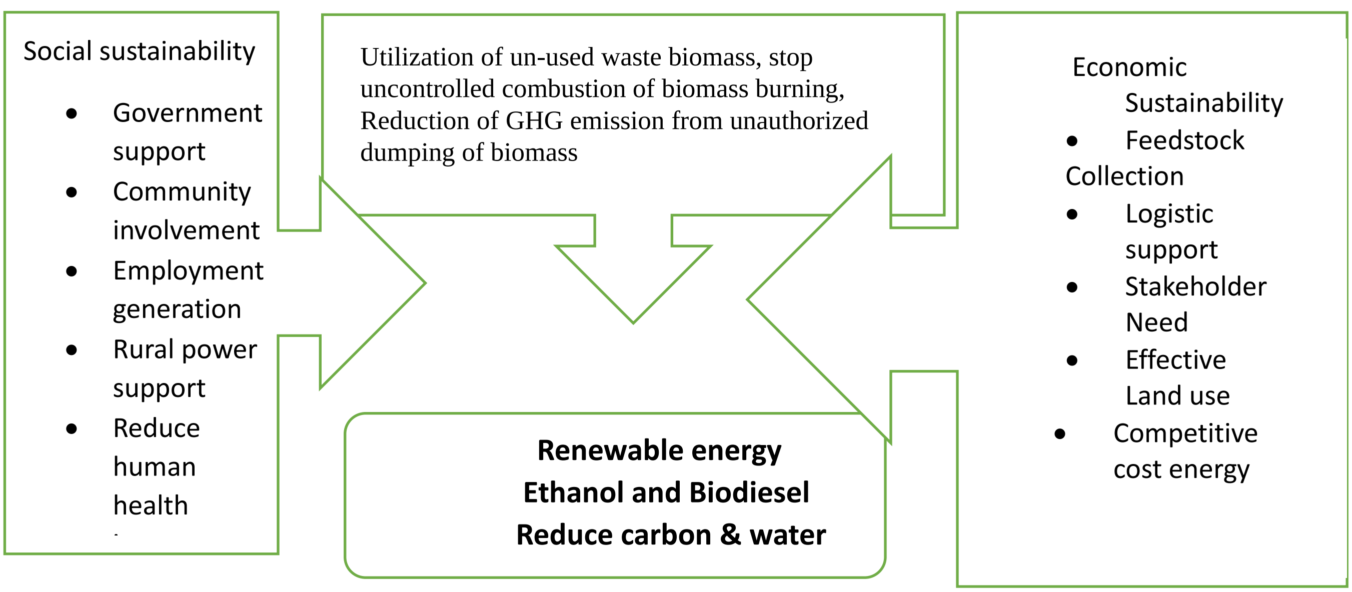


Figure 4 : Biofuel production by algae(Adopted form feednavigator.com, 2018)

The organisms receive light here when they are in the photo section which are made up of glass tubes and then they return to the vessel and that happens continuously. So, this is a photobioreactor. Coming back to the process of bio-diesel or bio-oil production using microalgae, the process is rather simple. You grow microalgae. The microalgae convert the carbon dioxide in the air and in that process, they collect lipids or bio-oil. The lipids can be gotten out of the microalgae after production by just pressing them using a press. The oil flows out and then you can use the oil for whatever you need. The process i**4.0 Developments-application and upgradation of biofuel**

Tabel 4.1 sustainable approach to biofuel



Cutting-edge innovation in bioethanol offers several advantages compared to traditional bioethanol production processes in terms of sustainability conditions. This includes, for instance, the use of nonfood crops or residual biomass as raw material and a higher potential for reducing greenhouse gas emissions. The major focuses on the recent progress related to the production of advanced bioethanol,

Created from organic matter (biomass), they can be easily replenished, while the low emissions associated with their combustion means they are an attractive prospect for eco-conscious business owners and private citizens. But what exactly are they used for? Here are five of the most common applications of biofuels being practiced today:

4.2 Various applications of biofuels in different industries.

Heating

Primary biofuels – or materials that are still in their raw state, without processing or treatment – are a common form of heating homes in developing countries where no alternative fuel source is available. While the environmental profile of these types of biofuels is not as desirable as it could be, secondary biofuels that have been processed in a refinery can serve as an efficient and eco-friendly alternative to the natural gas used to heat many homes in the western world, too.

Transportation

Biofuels such as bioethanol and biodiesel can be used as a substitute or as an additive to traditional sources of fuel for vehicles like cars and buses. Not only do these alternatives boost fuel efficiency, but they reduce emissions, as well. However, not all vehicles in the UK are equipped to handle biofuels on their own, while analysing them to determine concentrations of sulphur, chlorine and other impurities is another key consideration for the biofuels used in road transport.

Aviation

Air travel is another major contributor to the harmful emissions that cause pollution and contribute to climate change. For that reason, many airlines have been researching how biofuels can be used in jet engines to enhance their environmental credentials. However, it should be noted that its unique properties make biodiesel unsuitable for use in the aviation industry. The article Analysing Jet fuel for Biofuel contaminants - safety first carries more information on this topic for interested parties.

Lubrication

Regardless of the industry or sector in which it is employed, a piece of machinery must be maintained and lubricated to ensure it runs smoothly and enjoys as long a lifespan as possible. This role has historically been fuelled by diesel-based and oil-based lubricants, which obviously entail the same damaging consequences for the environment as all other applications of fossil fuels. Biofuels can provide a more sustainable alternative which is also more cost-effective.

Oil clean-up operations

Oil spillages are a sad but inevitable occurrence which happen periodically in the world of oil extraction, distribution and storage. When they do take place, they can cause devastating harm to the ecosystems which they contaminate and the animals that call them home. Thankfully, biofuels have been demonstrated to effectively address this problem, since the methyl esters contained in the fuel source is a powerful solvent that can serve as a washing agent for contaminated shorelines.(Chen et al., 2020)

Highlighting current results from using novel biomass sources such as the organic fraction of municipal solid waste and certain industrial residues (e.gresidues from the paper, food, and beverage industries); describing new developments in pretreatment technologies for the fractionation and conversion of lignocellulosic biomass, such as the bio-extrusion process or the use of novel ionic liquids; catalogue of the use of new enzyme catalysts and microbial strains during saccharification and fermentation processes. Furthermore, the most promising biorefinery methods that will contribute to the cost-competitiveness of advanced bioethanol production processes are also debated, focusing on innovative technologies and applications that can contribute to achieve a more sustainable and actual utilization of all biomass fractions. Special attention is given to unified strategies such as lignocellulose-based biorefineries for the simultaneous production of bioethanol and other high added value bioproducts.(Hendriks & Zeeman, 2009)

As the world attempts to slow the negative effects of climate change, there has been a conscious shift towards renewable sources of energy for powering our daily lives. With alternative energy sources like biofuel being explored, it is crucial we fully understand how this game-changing fuel type is sourced and utilized.The benefits of introducing these techniques are recognized, extensive research is still needed to scientifically and economically justify the further research and applications of bioethanol. There is a need for tentative economic assessment, with production costs not only depending on the extent of applying process improvements, but also on the raw material used in the process.(Timilsina & Mevel, 2013)

5.0 Future Potential

Ethanol has potential as a valuable replacement of gasoline in the transport fuel market. Every region represents a potential supply, production, and demand region. In the first step of the value chain, the harvested agricultural residues are baled to facilitate storage and transportation. At the biorefinery, the feedstock is converted in several process steps to bioethanol and the by-products electricity and biomethane.(Menon & Rao, 2012)

One of the major tasks in developing technology for bioethanol production from rice straw is selection of an appropriate pretreatment technique. The optimal choice of pretreatment methods plays an important role is to increase the efficiency of enzymatic saccharification and making the process economical.(Abbas & Ansumali, 2010)

The condition is important to optimize all factors involved so that the different steps, with different optimal conditions, can be carried out at their optimums. Drawbacks cited in SSF processes are

(a) the disparity in suitable temperatures being 50 °C for enzymatic hydrolysis but 30 °C for yeast fermentation (described above),

(b) ethanol being an inhibitor for common xylanases in processes where both hexoses and pentoses are to be fermented

(c) LPMOs causing competition of available oxygen between LPMOs and yeast. Strategies such as the use of thermotolerant microorganisms, the discovery of new xylanolytic enzymes, and/or the use of H_2O_2 as an oxidizing agent have been studied to overcome these challenges. Thermotolerance of the fermenting microorganism is a trait commonly searched for as previously described. New xylanases obtained from *Emerciella nidulans* or marine bacteria Acinetobacter johnsonii are being developed that not only show lower inhibition to ethanol, but a higher activity in its presence. Recent studies suggest that using H_2O_2 as an oxidizing agent instead of oxygen in anaerobic SSF processes could work as a solution for LPMO competition with microorganisms, as long as the peroxide concentration is low enough so that the microorganism does not suffer inhibition.(Zhang et al., 2013)

To sum up, recent research on enzymatic hydrolysis and fermentation improvements for a robust bioethanol production will be crucial for improving productivity and thus reducing operational costs, especially in the case of hydrolysis which is known to be the most cost-intensive step in current processes. The use of surfactants as additives for cellulases along with supplementation of other enzymes such as xylanases or LPMOs has been proven to be an effective way of increasing the digestibility of structural carbohydrates. Genetic modification of

S. cerevisiae, as well as of other notable microorganisms, results in enhanced fermentations, granting them the capability to aptly ferment other abundant monomers such as xylose and resist higher temperatures more suitable for SSF processes. These improvements combined will aid sustainable ethanol production from lignocellulose in a more efficient manner, along with other aspects gathered throughout this review.

The trends of both carbon dioxide concentration in the atmosphere and global surface temperature call for actions to mitigate the potential effects of climate change. Low carbon or net negative GHG emissions biofuels (such as bioethanol, renewable diesel, and sustainable aviation fuel) hold an important key to unlock the transition toward net-zero emissions economy in the future by displacing fossil fuels in hard-to-decarbonize sectors, such as medium and heavy-duty vehicles, aviation, and marine transportation.

Great opportunity exists to look for feasible alternative processing routes to produce high-added value bioproducts and biofuels from lignin in the so-called lignin valorization platform within the LB concept. On the other hand, lignin can be isolated and recovered throughout the pretreatment process by specific techniques to obtain a high-purity component for further valorization, as in the case of residual lignin from the lignocellulose-based industry. Lately, it has reviewed a series of potential bio-based products that could be generated in the lignin platform from the point of view of both its use as macromolecule with multiple functions and its depolymerization into low-molecular weight aromatics (including phenol, guaiacol, syringol, catechol, and cresol) for further conversion to fuels and chemicals. The exhaustive list of potential products such as phenols, carbon fibers and materials, phenol formaldehyde resins, oleo-gels, and polymer blends have a large variety of applications in cosmetics, plastics, pharmaceuticals, or the fuel industry. More specifically, Liao et al. [169] propose an integrated biorefinery strategy to valorize birch wood for phenol, propylene, oligomers, and pulp production through a process that is able to convert 78% (weight basis) of initial birch biomass into those high-value bioproducts.(Duque et al., 2021)

Starch, the principal accumulated algal biomass constituent, makes algae a potential feedstock source for biological energy conversion processes, i.e., ethanol, methane, etc. Previous studies suggest no lignin content in algal biomass, while other reports claim 2–3% of lignin in the algal cell walls. The lignin content of the biomass is also low, which adds to the advantage because it is a significant barrier to a cost-efficient application of feedstock to biofuels. The lignin is hard to break, and its concomitant properties with biomass still need to be clarified due to the recalcitrant nature of this polymer. (Bhushan et al., 2023)

Algae accumulate a high quantity of stored polysaccharides, mainly starch, in complex, multi-layered cell walls. This bears a strong structural and functional resemblance to higher plant storage starch. Overall, the economics of the biomass-to-ethanol process is primarily determined by the efficiency of biomass hydrolysis. For the optimal recovery of biofuel precursors, pretreatment is necessary. Many hurdles are associated with the pretreatment of first- and second-generation feedstocks. The challenges associated with the pretreatment of these feedstocks include low biodegradability, high levels of lignin and hemicellulose, and low sugar yields. Mainly the pretreatment modules were classified as physical, chemical, and biochemical. Drawbacks associated with physical and chemical methods of pretreatment include energy-intensive, high cost, and use of hazardous chemicals. However, biological methods are advantageous by being eco-friendly, non-toxic, and easy to handle. Anaerobic digestion of the algal biomass produced biomethane containing 10–15% hydrogen, 30–40% carbon dioxide, and 50–55% methane. Biological pretreatment of the algal biomass enhanced biomethane production.

Among all of these, lignocellulosic biomass valorization is a potential resource for production of second-generation ethanol, which can significantly reduce greenhouse gas emissions and offer positive environmental impacts.(Velvizhi et al., 2022) In general, second-generation liquid biofuels (ethanol, biodiesel and liquid alkanes) are considered as important renewable fuels able to at least partly replace petroleum-based ones. The production of ethanol has gained industrial maturity and is considered as a future alternative to gasoline for transport, as it has the appropriate characteristics such as high-octane number, the high heat of vaporization and low cetane number. It is also less toxic to the environment considering the reduction in GHG emissions and other pollutant emissions Chemical or toxic challenges.(Balat et al., 2008)

Agricultural wastes are cost effective, renewable and abundant. Bioethanol from agricultural waste could be a promising technology though the process has several challenges and limitations such as biomass transport and handling, and efficient pretreatment methods for total delignification of lignocellulosics. Proper pretreatment methods can increase concentrations of fermentable sugars after enzymatic saccharification, thereby improving the efficiency of the whole process. Conversion of glucose as well as xylose to ethanol needs some new fermentation technologies, to make the whole process cost effective.(Gupta & Verma, 2015)

2. Making it less expensive - To reduce the ethanol production cost it is necessary to reach high ethanol yields, as well as a high ethanol concentration during fermentation, to be able to decrease the energy required for distillation and other downstream process steps. Improved pretreatment methods, enhanced enzymatic hydrolysis with cheaper and more effective enzymes, as well as improved fermentation systems present major research challenges if we are to make lignocellulose-based ethanol production competitive with sugar- and starch-based ethanol.

Process integration, either internally or externally with other types of plants, e.g. heat and power plants, also offers a way of reducing the final ethanol production cost.

3. specific to rice straw - Rice straw is an attractive lignocellulosic material for bioethanol production since it is one of the most abundant renewable resources. It has several characteristics, such as high cellulose and hemicelluloses content that can be readily hydrolyzed into fermentable sugars. But there occur several challenges and limitations in the process of converting rice straw to ethanol. The presence of high ash and silica content in rice straw makes it an inferior feedstock for ethanol production. One of the major challenges in developing technology for bioethanol production from rice straw is selection of an appropriate pretreatment technique. The choice of pretreatment methods plays an important role to increase the efficiency of enzymatic saccharification thereby making the whole process economically viable.(Gupta & Verma, 2015)

4. For the optimal recovery of biofuel precursors, pretreatment is necessary. Many hurdles are associated with the pretreatment of first- and second-generation feedstocks. The challenges associated with the pretreatment of these feedstocks include low biodegradability, high levels of lignin and hemmanicellulose, and low sugar yields. Mainly the pretreatment modules were classified as physical, chemical, and biochemical. Drawbacks associated with physical and chemical methods of pretreatment include energy-intensive, high cost, and use of hazardous chemicals. (Hendriks & Zeeman, 2009). However, biological methods are advantageous by being eco-friendly, non-toxic, and easy to handle. Anaerobic digestion of the algal biomass produced biomethane containing 10–15% hydrogen, 30–40% carbon dioxide, and 50–55% methane. Biological pretreatment of the algal biomass enhanced biomethane production.(Hendriks & Zeeman, 2009)

The environmental impacts of bioethanol production are totally dependent on feedstock availability and conversion technology. The biochemical conversion route must overcome several technological and economical challenges such as pre-treatment, fermentation, hydrolysis process and separation. A completely mature technology is still to be developed and must adapted to the nature of the feedstock. (Vohra et al., 2014)

This approach is particularly relevant for the C5 sugars from hemicellulose generated in the cellulosic conversion process, whose conversion to ethanol by fermentative yeasts in an LB still poses challenges related to strain robustness and tolerance to toxic metabolites, in spite of a large research effort to overcome them in recent decades. As in the case of lignin-derived products, the intense R&D work has permitted several companies to get involved in the production of several bioproducts at different plant stages that can be considered the basis or intermediate chemicals for generating commodities

The bioeconomic potential takes into account a large array of accessibility limitations, such as technical limitations, sustainable removal rates to sustain soil organic carbon, and privileged local biomass demands by applications such as animal bedding, it therefore can be considered as conservative scenario. (Wietschel et al., 2021)

In general, all these works reach similar conclusions: the search for alternative fermenting microorganisms can be fruitful not only for their potential use as industrial strains themselves, but also for the introduction of their favorable traits into the traditional S. cerevisiae through metabolic engineering for a more robust bioethanol production.

Wastes derived from the pulp and paper industry are another valuable source for the production of bioethanol and other high value-added products. In 2015, 400 million tons of paper and paperboard and 188 million tons of virgin pulp were produced. Spent sulfite liquor (SSL) and pulp and paper mill sludge (PPMS) are major wastes derived from papermakers (Singh et al., 2022) with potential for bioethanol production. It is important to highlight that hardwood-derived SSL contains higher proportion of pentoses than softwood-derived SSL. Hence, pentose-fermenting microorganisms such as Scheffersomyces stipitis (formerly Pichia stipitis) must be considered for the conversion of hardwood SSL into bioethanol

6.0 Conclusions

This chapter discussed about green fuel for its environmental advantages. With various raw material as a potential feedstock for first, second and third generation biofuels. Staring from resources to manufacturing and three generation of fuels. Utilizing lignocellulosic biomass for the production of bioethanol requires a production method that is both economical and environmentally responsible. One method of lowering both the consumption of crude oil and environmental pollution is the production of bioethanol from biomass. The usage of bioethanol-blend fuel in cars can greatly cut down on the consumption of petroleum and greenhouse gas emissions from exhaust. Due to its plentiful availability and alluring composition, rice straw seems to be a promising and potent candidate for the manufacture of bioethanol given the development and need for second-generation biofuels. Now, the world is turning to the third generation of biofuel production from algae to meet rising fuel demand without compromising the environmental sustainability and nutrition requirements of the population. Biomass pretreatment is an essential step for the optimal recovery of biofuel precursors, which is leading to higher biofuel yield.

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Fig. 13.6 Flow sheet for conventional biodiesel production. (n.d.). ResearchGate. Retrieved July 31, 2023, from https://www.researchgate.net/figure/Flow-sheet-for-conventional-biodiesel-production_fig3_278655010

Figure 3: Proposed hammermill with flat screen. (n.d.). ResearchGate. Retrieved August 2, 2023, from https://www.researchgate.net/figure/Proposed-hammermill-with-flat-screen_fig3_326490185

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