



Sustainable Biofuel Production from Agricultural Residues: An Ecofriendly Approach

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ABSTRACT: *Current fossil fuel reserves are insufficient to meet escalating demand and will run out shortly. Contamination, rising temperatures, and skyrocketing oil prices have fuelled the quest for new energy sources. Macro algae have gained popularity as a viable and promising means of producing renewable biofuels. Several investigations are underway to evaluate microalgae's capacity for producing a variety of bio products such as biofuels. Biofuels are being pushed as an environmentally friendly alternative to fossil fuels due to their ability to reduce greenhouse gas (GHG) releases and the subsequent warming effect from commuting. However, there are concerns that its broad usage will have unanticipated environmental consequences. Countless life cycle assessment (LCA) projects has been conducted to investigate how biofuels influence the environment as well as other aspects of the environment. However, their conclusions are frequently contradictory, with a broad range of estimations. Thus, the goal of this work is to evaluate and analyze the most recent available research to offer a better knowledge of the environmental implications of various liquid biofuels. This study discusses on the production of biofuels from different agriculture residues. Furthermore, the current analysis focuses on cost-effective sustainable biofuel generation, as well as commercialization and scale up.*

Keywords: *Agriculture, Environment, Fuel, Greenhouse, Renewable.*

1. INTRODUCTION

The world's most of fuel sources are fast and unexpectedly depleting because of the expanding population and increasing requirements in the renewable energy sector, which is mostly related to rapid urbanization and industrialization. The major, yet non-renewable, source of energy is fossil fuels. The uncontrolled use of fossil fuels has environmental consequences, poor air quality, and global climate change, all of which contribute to ecological imbalance and health consequences. Between 2010 and 2040, it is predicted that demand for fossil fuels will increase by 40%. As a result, finding a distinctive source of sustainable energy is of utmost importance[1]. The existing strategy for building sustainable biofuel processes and supply networks is incorrect. Life cycle concepts are frequently implemented retroactively into the design process, resulting in incremental environmental improvement rather than the selection of fuel paths that minimize environmental consequences over the life cycle. Furthermore, creating sustainable biofuel supply chains necessitates considering economic, environmental, and social aspects at many geographical and temporal stages. Traditional life cycle assessment (LCA) excludes economic factors as well as the role of ecological products and services in supply chains, limiting its capacity to guide decision-making among options and frequently resulting in suboptimal solutions. Incorporating economic and environmental goals into the design and optimization of future biofuel supply chains necessitates a significant shift in mindset [2].

Transportation has witnessed the greatest growth in GHG emissions of any industry. The business is heavily reliant on fossil fuels, which accounted for 96.3% of all fuel used for transportation in 2018. Transportation is also responsible for 15% of worldwide GHG emissions including 23% of all associated with energy CO₂ emissions. Biofuels are largely recognized as feasible alternative forms of fuels capable of reducing dependency on petroleum-based fuels while combating climate change. Biofuels are being used in the automobile industry since its inception. Following World War II, bioethanol research and development came to an end as fuel made from petroleum became more affordable. Many nations showed increased interest in the

manufacture of commercial biofuels during the 1970s oil crisis, but only Brazil initiated to yield ethanol on a significant scale as part of the “National Ethanol Program”[3],[4].

It couldn't be more crucial to transform waste from agriculture into biofuels that are economical, easily available, and environmentally beneficial. Biofuels are renewable, biodegradable, inexpensive, and ecologically friendly fuels derived from waste lignocellulosic biomass. Agricultural waste conversion into biofuel does not worsen food security, helps manage waste, stops environmental deterioration, and assures energy security. To scale up commercial biofuel production from algae and be able to significantly contribute to energy needs, several obstacles must be overcome[5].



Figure 1: Displays the Common techniques for using and disposing of kitchen trash.

The three primary essential concepts for treating kitchen trash are reduction, harmlessness, and recycling. Therefore, depending on the situation in the local area, appropriate strategies should be used. Figure 1 depicts the typical disposal and usage techniques now in use. Some ways of disposing of kitchen trash, like as landfilling, incineration, and pulverization discharge, however, have negative effects on the environment, the economy, and society. Solid alcohol biofuels were made using leftover edible oil from catering businesses, and high-energy product is obtained [6]. Some studies explored the potential of using inexpensive and efficient kitchen wastes as substrates for improved biohydrogen production technology, and they suggested using nanomaterials to boost biohydrogen production's yield and make the entire process more cost-effective and sustainable. This review's goal is to explore several macroalgae-based biofuel production methods. To have a thorough understanding, the Patent of macroalgal biofuel production has also been explored. This article's conclusion discusses some of the challenges faced by macroalgal biorefineries as well as upcoming research topics that should be investigated for potential future industrial growth[7].

2. LITERATURE REVIEW

Marlon Caicedo et al. using plant biomass to reduce CO₂ emissions is a viable solution, the stay-green feature may be advantageous for the creation of dual purpose cultivars since it is connected with lower biomass losses and lodging. However, if the stay-green feature is connected with greater Stover moisture at harvest, it may be harmful to agricultural waste management; however this idea has not been adequately investigated. A review of features related to the production of dual-purpose cultivars is provided in this work. On the other side, if the stay-green feature is related with increased stover moisture at harvest, it may be deleterious to agricultural waste management, albeit this idea has not been adequately investigated. This work presents features crucial to the creation of dual purpose variety, with a focus on stover moistures because these key qualities have received less attention in the literature. From a breeding standpoint, the prospect of producing new types for joint production is considered[8].

Vivek Narisetty et al. discussed on bio refinery technique to producing bio-based fuels and chemicals has sparked substantial attention as an alternative platform for petroleum-derived processes, since these biobased processes have been shown to have favourable environmental and social implications. Municipal solid wastes, for example, can be utilised to provide substrates for the generation of economically viable gaseous and liquid fuels, as well as short-chain fatty acids and carboxylic acids. In this study, technology and procedures requiring the manufacture of value-added product are thoroughly presented in still the worth of municipal solid waste and the budget, as well as the biorefinery element[9].

Hui Wang et al. ; studied the biorefinery which uses yellow mealworm (*Tenebrio molitor* L.) to break down maize stover in the first stage, and black soldier fly (*Hermetia illucens* L.) in the second stage to use the leftovers created in the first stage. 90% of the free fatty acids in crude grease were converted into biodiesel. In maize stover, the cellulose, hemicellulose, and lignin constituents all dissolved in unison, with corresponding decreases. Additionally, changes in fat, protein, and decreasing sugar were examined. The study's analysis showed that successive co-conversion of maize stover by insects with different feeding preferences could be a desirable option for effectively using lignocellulosic resource. It also represent a potentially beneficial solution to crops residue management, the rise of the world's demand for liquid energy, and the need for animal feed[10].

3. DISCUSSION

Various biomasses have made substantial developments as possible alternatives to fossil fuels and might be potential eco-friendly base goods [11]. It is classified as 'conventional biofuels' since it recover renewable fuels using traditional methods. The trash created by this crop cultivation is mostly utilized to produce biofuels[12]. Non-consumable food such as agricultural leftovers and woody crop, which are more difficult to extract and need complex conversion equipment, are widely used. Seaweed, cyanobacteria, and marine resources are intriguing possibilities. Since macroalgae can grow in salty water, unfavorable circumstances, and other environments, it may be the most promising non-consumable biofuel source. The algal biofuel is completely sulfur-free, safe, and biodegradable. These amounts vary between species and are strongly controlled by biotics and abiotics environment growth factor including hotness and light[13]. Because of the numerous distinctions that may be made, multiple definitions for biofuel kinds are in use[14],[15].

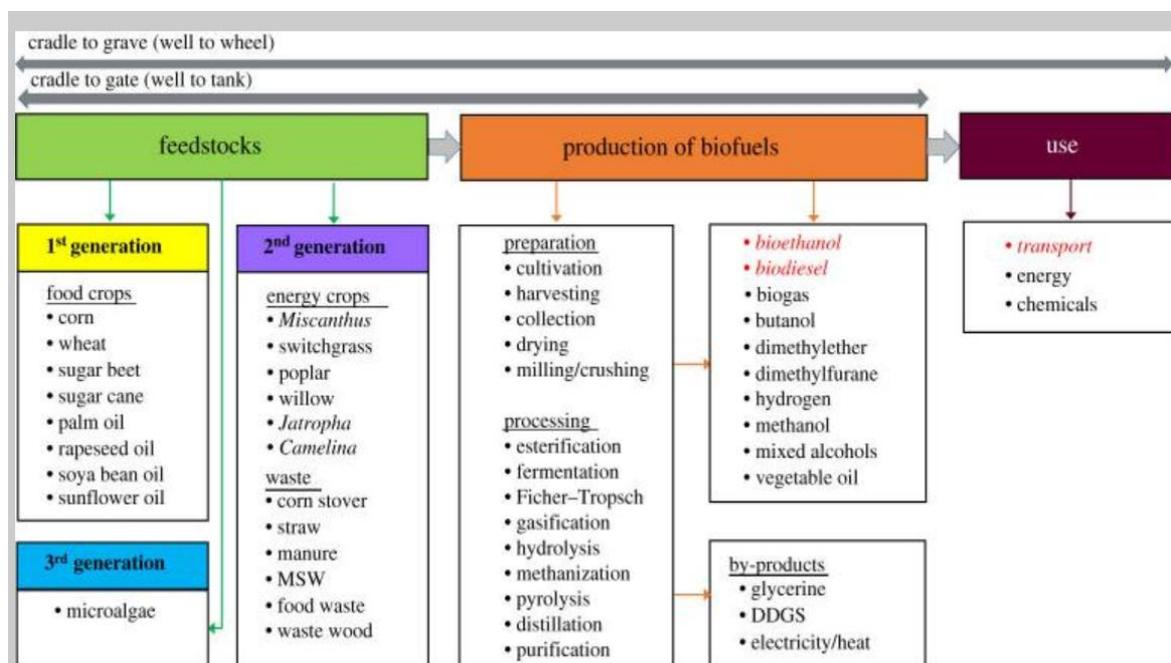


Figure 2: Shows an explanation of the raw materials and manufacturing procedures for various biofuels, together with a diagram of the fuel's life cycle from well to tank to wheel to grave.

One of the fundamental characteristics of second-generation biofuels is that they are manufactured from non-food feedstocks such as specific crops for energy production, agronomic and forest waste, and other waste products (such as UCO and municipal solid waste). Third-generation biofuel is biodiesel produced from microalgae using conventional transesterification or hydrotreatment of algal oil. Because second and third-generation biofuel production technologies or pathways are still in the phases of research and advancement, pilot, or demonstrating stages, they are frequently referred to as "advanced biofuels." Throughout this study,

the labels "first, second, and third generation" were the ones chosen and utilized consistently. Figure 2, provides a summary of several biofuel types, their feedstocks, and conversion pathways [16]. On the one hand, the key global drivers from biofuels are the corresponding decrease of GHG emissions, reliability of energy, and the growth of agriculture. On the other hand, increasing biofuel production raises concerns about food price inflation, the risk of increased GHG emissions from both immediate and long-term land-use change (LUC) compared to producing biofuel feedstocks, and the potential hazards of ecosystem degradation and degeneration of forests, agricultural land, water resources, and additional natural resources. Between the conflict against food production and concerns about exploiting cropland for the manufacture of petroleum products, the use of first-generational feedstocks, that includes maize, is now an especially contentious issue.

3.1. Macro-algae and its environmental impact:

Varied and non-phylogenetic macroscopic aquatic eukaryotes, macroalgae are members of the phyla Rhodophyta, Phaeophyta, and Phaeophyceae. In practically all forms of water, including wastewater, algae may be grown. Furthermore, macroalgae have an oil content that is around 30 times higher than that of traditional feedstocks, and their growth rate is roughly 20–30 times faster than that of fodder crop. The oil made from algae has greater quality and is fully biodegradable and sulphur-free. Furthermore, the absence of lignin makes macroalgae quicker that converts into a biofuel than land-based plant and makes it easier for bacteria to digest throughout the biorefinery process[17].

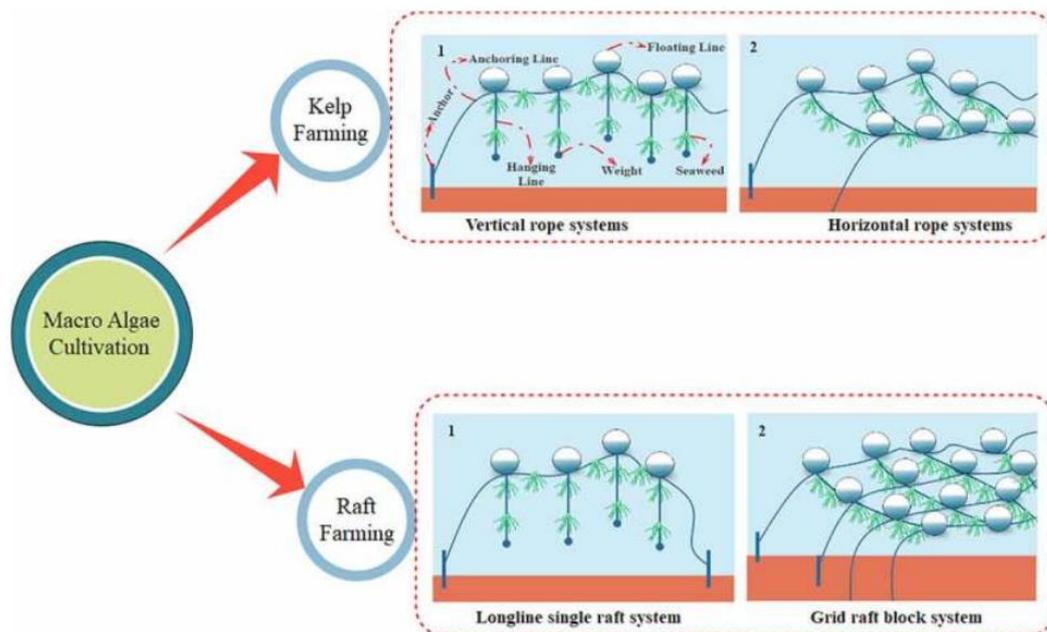


Figure 3: Shows the Various macroalgae cultivation techniques.

A multitude of approaches may be used to cultivate the macroalgal throughout both marine and offshore habitats. Figure 3 illustrates offshore farming, which consists of floating, rafting, and kelp growth. Rope or as net cultivation is reported to be a frequent cultivation approach since it is less expensive to construct and maintain. Lagoons are used to cultivate macroalgae since the nutrients originate from the ocean. Other methods for cultivating macroalgae include fixed from bottom, long lines, and rock farming. Another method of culture is transplantation, which involves allowing species seedlings to mature indoors prior they are grown in tanks and subsequently rope-transplanted into the sea. Seawater has been commonly used for culture in shoreline cultivation techniques due to its prohibitive degree of control for safety as well as substantial product production. Onshore cultivating is more environmentally conscious than offshore culture since it has no influence on aquatic organisms and provides greater flexibility for a wider range of macroalgae.

In this kind of farming, mixing is another possible component that fosters higher algal development. To efficiently mix algal cultures, proper agitation or circulation has been favored, although it is more expensive. Currently, this onshore cultivation lacks an extensive system of inventive sustainable low-cost technology. Furthermore, open farming is likely to intrude on both the abiotic and biotic parts of an ecosystem. The amount that is available of fossil fuels is finite, and they are not renewable. Multiple investigations have shown unambiguous evidence of fossil fuel depletion. According to reports, global accessible oil reserves are

diminishing at a rate of 4 billion tonnes per year. However, the current rate of depletion continues, all of these savings are likely to be depleted by 2060. If new reserves are discovered before this time, the deadline might be extended somewhat. Nonetheless, the threat exists. As a result, in order to preserve our existing way of living, we must discover alternative energy sources [18].

3.2. Biofuels derived from agricultural waste:

It is ideal if they are transformed into biofuel due to the massive waste produced by the agriculture industry and their effects on people, animals, and the environment. The only two environmentally friendly methods for converting agricultural waste into biofuels are biochemical and thermochemical procedures. The biochemical conversion approach, which merges biological and chemical processes, is a common technique for manufacturing biodiesel, biomethane, bioethanol, having biobutanol from waste from agriculture with high moisture, cellulose, having hemicellulose contents, and a C/N ratio of more than 30%. Bioethanol is a liquid, renewable biofuel produced by the process of fermentation of natural materials, most commonly plant compounds or waste from farming. Bioethanol, frequently recognized as ethanol, is the most widely utilized liquid biofuel globally. The need towards bioethanol has fueled increased output. The predicted global demand with bioethanol, which was 100.2 billion liters in 2016, is anticipated to climb to 134.5 billion liters by 2024. The use of gasoline or fuel additives accounts for more than 40% of the world's ethanol output. Even though the effects of the COVID-19 epidemic caused a reduction in worldwide output to 26 million gallons in 2020 [19].

In the last several decades, there has been discussion on most of the use of starch crops as feedstocks, such as maize, sugarcane, or sweet sorghum, has spurred discussions about food vs. fuel and ethical issues in several forums. Due to this, study has been increasingly focused on the viability of non-food feedstock options for the manufacture of bioethanol. According to economic, availability, hygienic, and environmental factors, using lignocellulosic biomass—such as wood, agricultural residue, and municipal and industrial waste—is preferred over other options. Despite the lack of a comprehensive analytical structure for grading feedstocks, the use for agricultural residues as feedstocks, which includes residues from crops, waste wood, and various other types of waste biomass, has begun to gain traction and is widely recognized. Because of improved production processes, the easy availability of locally and cheaply accessible feedstocks, alongside the continuous demand for bioethanol for a variety of applications, the share of bioethanol in biofuel production has reached over 65%. Bioethanol is made from a range of farming wastes amongst crop residues, such as baggage from sugarcane, sorghum sweetener bagasse, the straw of rice, barley straw, grain straw, maize stover, cassava peels of fruit sugar beet, wood, and others. These materials are inexpensive, easily accessible, and non-edible at a fair price. Their usage as a feedstock for the manufacture of gasoline has no negative effects on food security and is morally acceptable. Over the past few decades, there have been numerous advancements in the production of bioethanol from agricultural waste. These techniques complement the use of affordable and environmentally friendly pretreatment techniques [20].

3.3. Pathways for Emerging Biofuels:

Global climate change, variable petroleum costing, energy security concerns, and resources diminution have prompted governments to explore expanding their energy portfolios to include renewable and alternative energy sources. Transportation, together with power and energy generating, are the two main GHG producing industries in the United States. As a result, regulatory actions in the United States (U.S.) along with European regulations have been devised to reduce GHG emissions from mobility and power generation while increasing the nation's energy independence and stability. The Energy Independence and Security Act (EISA), passed by the United States Congress in 2007, calls for the production of 36 billion gallons of biofuels by the year 2022, with a portion coming from traditional, cellulosic, and biomass-based diesel, as well as advanced biofuels [21].

The most extensively manufactured and used biofuel in the United States right now is ethanol made from corn. However, the potential of maize ethanol alongside other first-generation biofuels to address climate change and reduce dependency on fossil fuels presents serious concerns. It has been suggested that both the immediate and long-term consequences of land use change may possibly offset first-generation biofuels' capacity to cut GHG emissions, potentially leading to higher life cycle GHG emissions than baseline petroleum fuels. First-generation biofuels also need changes to the present transport networks, such as modifications to vehicle engines and gasoline pipelines. The detrimental consequences of first-generation biofuel production and consumption on ecosystem services and products, such as eroding soil, air and water contamination, and

biodiversity loss, prompted the research and development of next-generation biofuels. Several substantial papers have extensively analyzed the various catalytic, biochemical, along with thermochemical conversion mechanisms for the production of biofuels using biomass feedstocks. Transesterification is a process requiring the interaction of chemicals with an alcohol, which includes methanol has traditionally been used to convert fats and oils derived from oilseed plants into biodiesel. However, as compared to diesel fuel made from petroleum, biodiesel has around 10% less energy density and poorer cold flow characteristics. It also has a higher cloud point. Acid treatments are necessary to break down cellulose and hemicellulose into sugars in lignocellulosic feedstocks including woody biomass and agricultural waste. Sugars can then be converted by microorganisms into hydrocarbons[22].

3.4. Production of biofuel from macroalgae:

Biofuel is defined as any fuel derived from organic materials in the form of solid, liquid, or gaseous. These biofuels may be employed in autos and a range of industrial applications. The kind of biomass determines the first, second, and third-generation biofuels. Figure 4, depicts several biochemical and thermochemical processes for obtaining biofuels from macroalgae. "Transesterification, liquefaction, fermentation, anaerobic digestion, and pyrolysis are the most prevalent biofuel manufacturing techniques". This has an impact on biofuel output and can be decreased by using appropriate pretreatment. Pretreatments disrupt molecular bonds and depolymerize the complex structure, improving solubilization. The solubilized sample may be conveniently employed in the conversion process that increases biofuel output. To solubilize the complex substrate in macroalgae, many pretreatment methods such as biological, chemical, mechanical, physical and combinative procedures are applied.

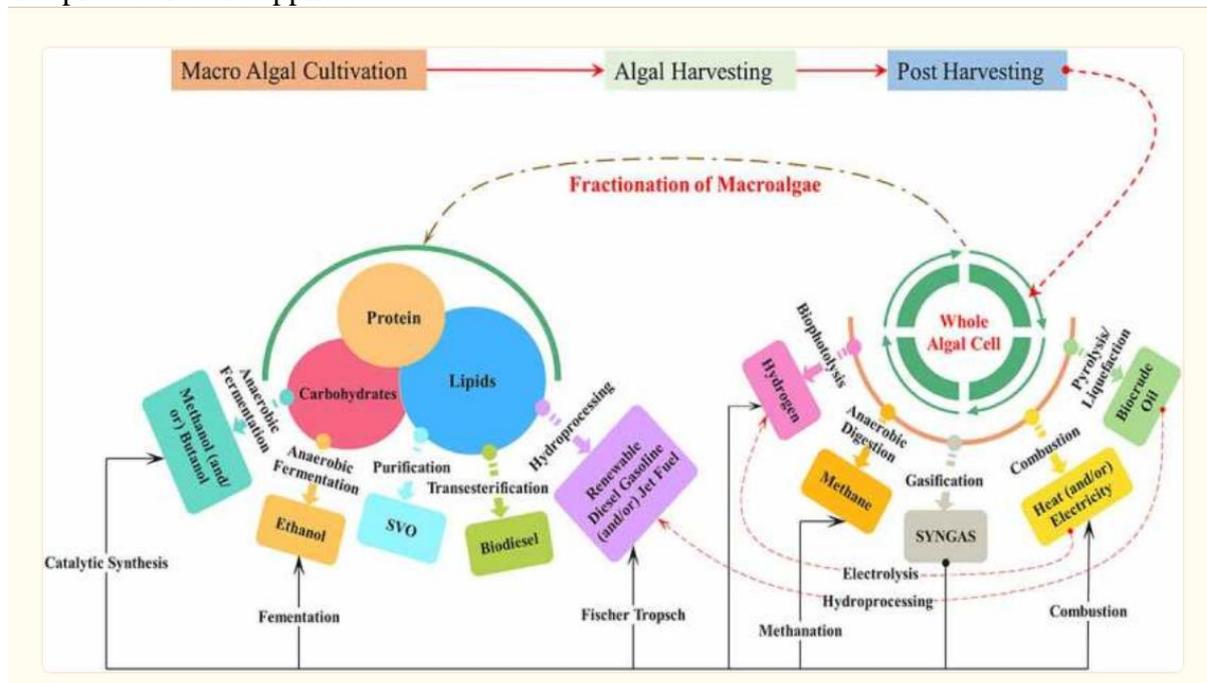


Figure 4: Demonstrates the Macroalgal Biofuel Refinery.

Despite the huge demand for biofuels, biofuels may be the most viable replacement for fossil fuels. This section will explore these difficulties from several angles. One of the difficulties of using biofuels is the environmental impact. The cultivation of agricultural areas to produce biofuel feedstock reduces soil fertility and quality, resulting in a shortage of nutrients and minerals, as well as a loss in the availability of water in the soil for plants. For generating more biomass, more pesticides and fertilizers must be used, resulting in groundwater contamination, soil deterioration, and human health harm. Biofuel production has restrictions and obstacles both in terms of output and economics. The generation of biogas is hampered by high production costs and a lack of incentives.

The natural gas grid's capacity to produce biomethane (more than 97% CH₄) limits its ability to meet demand for microgrids and transportation fuel. When biomass is utilized to make syngas, the CO, H₂, and CH₄ components required to meet the engine's gas heating value are typically missing. The method of producing biomass fuel must be cost-effective. The price and disparity between conventional fuels and biofuels remain major problems for the development and sustainability of biofuel production. Another issue in biofuel

production is the flexibility of feedstock materials used in the manufacturing of biofuels. Because of the remarkable advancement, researchers are still debating and investigating the selection and production of acceptable types of feedstock materials for manufacturing biofuels. Biofuel manufacturing is heavily reliant on feedstock supplies

4. CONCLUSION

Biofuels derived from renewable biomass have the greatest potential for CO₂-neutral generation of any sustainable energy sources. First-generation biofuels derived from corn, sugarcane, and soya perform badly in a variety of environmental contexts. Agriculture biomass utilization as an alternate energy source appears to be a realistic solution, as proved by several nations such as the United States, Canada, China, and Poland. Agriculture biomass is primarily used in the manufacture of biofuels, which may be converted to any phase of biofuel using different thermochemical, biochemical, and other chemical conversion techniques. Furthermore, it provides a sustainable source of fuel, which will most likely replace decreasing fossil fuel supplies while reducing GHG and solid waste.

Research investigations have revealed prospective biochemical processing procedures using several unique macroalgae species from all 3 taxonomic groups for the creation of biofuels, bioproducts, and high-value biochemicals. The demand for fossil fuels is gradually growing as technology advances (for example, urbanization and increased living standards), necessitating the use of additional fuels. This increased utilization of energy reserves will reduce the need for fossil fuels in the future. To improve the effectiveness and efficiency of macroalgae in the future, it is important to prioritize the discovery of novel microorganisms, the technological development of genetic transformations and metabolics engineering, and the processes development and optimization for yields enhancement. As a result, macroalgae may eventually emerge as the most promising biomass and greatly contributed to low-carbon economies.

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