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Current Innovations In The Productions Of Biofuels From Lignocellulose Biomass As A Source Of Renewable Energy

Abdul Khayum[1], Amzad Basha Kolar[2], D.A. Shahira Banu[3] and Mary Kensa V[4]

[1]Department of Botany, Al-Ameeen Arts, Science and Commerce College, Affiliated to Bangalore Central University, Bangalore-560 027, Karnataka, India.
E-mail: abdulkhayum.q@gmail.com
[2]PG Department of Botany, The New College (Autonomous), Affiliated to University of Madras, Chennai-600 014, Tamil Nadu, India.
E-mail: amzadbashakolar@thenewcollege.edu.in
[3]Department of Botany, Justice Basheer Ahmed Sayeed College for Women (Autonomous), Affiliated to University of Madras, Chennai- 600 018, Tamil Nadu, India.
E-mail: shahirabanu.da@jbascollege.edu.in
[4]PG and Research Centre of Botany, S.T.Hindu College, Affiliated to Manonmaniam Sundaranar University, Nagercoil-629 002, Tamil Nadu, India.
E-mail: surejkensa@gmail.com

ABSTRACT

Biofuel is non-fossil fuel derived from renewable organic biomass like plant, animal, microbial, and human waste. Biofuel generates bioenergy. While energy demand rises, fossil fuel availability is finite and falling. To alleviate this shortfall, people must move from fossil fuels to biofuels, which efficiently fulfil present and future demand. This research focuses on second-generation lignocellulosic biofuels using non-edible plant biomass to reduce environmental impact (i.e., cellulose, lignin, hemicelluloses, non-food material). It's crucial to convert lignocellulosic feedstock before producing ethanol. However, it's crucial to remember that the generation of biofuel is currently not cost-effective due to a number of technological limitations, necessitating an upgrade in the techniques used. The cost-effectiveness of the process and the limits of the different technologies used are still issues with producing biofuel. Due to this, there is a critical need for continued, improved research and development to guarantee that lignocellulosic biofuel is available on the market.

Keywords: biomass; second-generation biofuel; bioenergy; bioethanol; biodiesel; non-fossil fuel

INTRODUCTION

Biorefineries turn biobased materials, such as agricultural waste, into food, feed, fuel, chemicals, and energy [1, 2]. Biomass processing, like petroleum refineries, turns biomass into fuels like gasoline, diesel, and kerosene and chemical precursors like butanol. The renewable energy policy network said that in 2011, 78% of world energy came from fossil

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fuels, 3% from nuclear energy, and 19% from renewable energy [3,4]. (wind, sun, geothermal, hydrothermal, biomass). 13% of the world's renewable energy comes from biomass combustion or thermochemical conversion. Sugar or starch from edible grains is used to make most biofuels. Yeast ferments both sources' carbohydrates into ethanol [5].

All of the world's energy comes from 85 million barrels of crude oil. Expect 116 million barrels of crude oil by 2030 [6]. Since this might deplete world crude oil inventories, other energy sources must be considered [7]. Biofuels and biochemicals made from non-edible feedstock like lignocellulosic biomass are renewable and sustainable, help fix carbon dioxide, a greenhouse gas (GHG) that causes global warming, stimulate local economies, and reduce air pollution from biomass burning in fields and rotting. Technological improvement and maturity have reduced processing costs, but as crude oil supplies decline, prices are increasing. Current estimations show that biofuels from lignocellulosic biomass cost more than crude oil. Technology will reduce expenses[8].

First generation

First-generation biofuel comes from food-producing plants (i.e., grains and oilseeds). Sugar, carbohydrates, vegetable oil, and fats are fuels. Biodiesel, ethanol, gasoline with biofuel, biogas, etc. are the most common first-generation biofuels [9,10]. First-generation biofuels are made from agricultural feedstock like sugarcane, maize, and sugar beets (biodiesel and bioethanol). A better approach is needed to boost biofuel production and make it profitable. Biofuel manufacturing from crops like oilseeds is not economically viable. Oil-based biodiesel production needs further investigation [11,12].

Second generation

Second-generation biofuel is derived from non-food biomass. Lignocellulosic (second-generation) biofuel is generated from inedible plant debris or fragments. It is generally recognised that non-edible lignocellulosic biomass is plentiful in the natural environment and may thus be utilised as a feedstock for the manufacture of biofuels. Examples of this biomass include vegetable grasses, forest wastes, agricultural waste, and more. Lignocellulosic ethanol, butanol, mixed alcohols, and other substances are examples of second-generation biofuels [13,14,15].

Third generation

The source of third-generation biofuel is photosynthetic bacteria like microalgae. From autotrophic organisms they descended. Here, feedstock (biomass) is created by combining carbon dioxide, light, and other nutritional sources [16,17,18]. This feedstock produces biofuel. Third-generation biofuels, such as microalgae-based ones, may be better energy replacements than prior generations [19]. Algae are utilised to produce first- and second-generation biofuels because of their quick development and faster rate of photosynthesis than

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terrestrial plants. Recently, researchers from all around the globe have paid increased attention to photosynthetic microorganisms (like algae/microalgae) because of their utility in the generation of biofuels [20].

Fourth generation

Since a few years ago, fourth-generation biofuel has been in the early stages of research and is uncommon. Here, genetically modified photosynthetic microorganisms are employed as feedstock, including cyanobacteria, algae, and fungus. Microbes that can synthesise photosynthetically can turn ambient CO2 into biofuel. According to certain research, some crops actively capture carbon, which they then store in their leaves, stems, and other parts of the plant before being further turned into fuel via second-generation procedures [21]. According to Alalwan et al., genetically engineered microbes are employed in fourth-generation biofuels to increase carbon (HC) output and decrease carbon emissions.

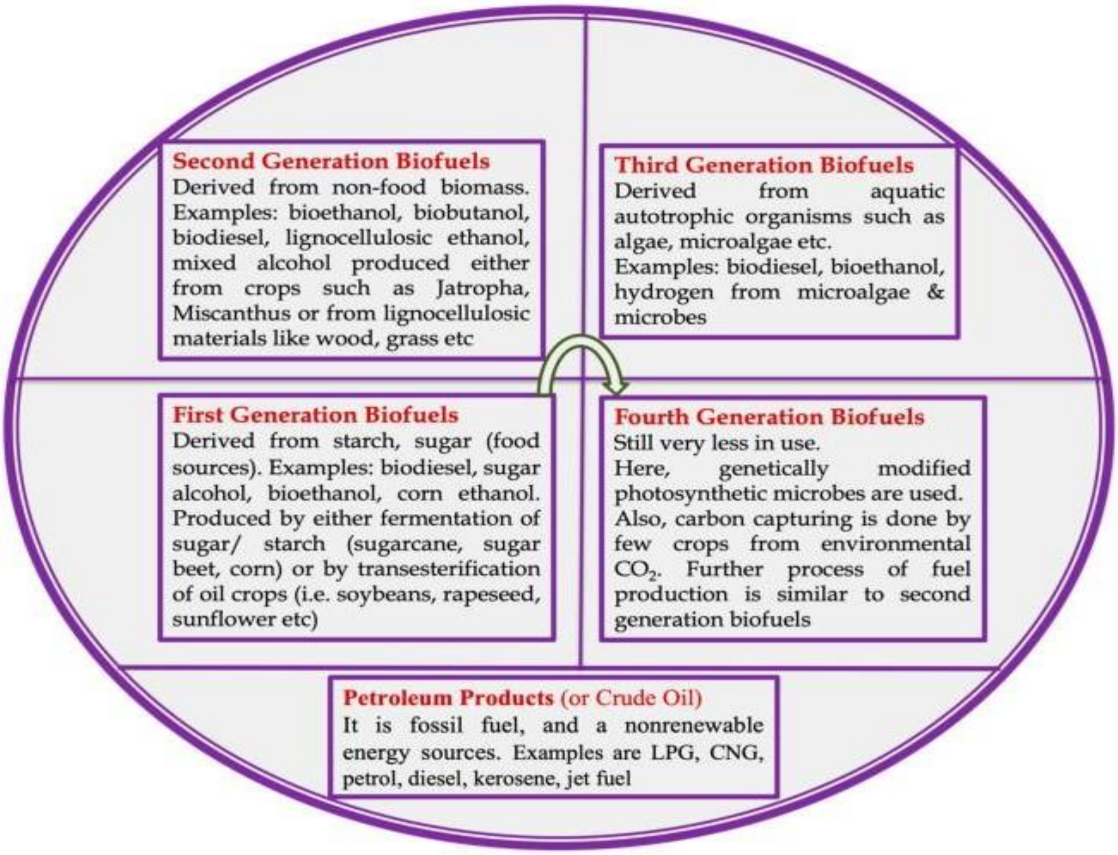

Fig:1 Comparison between petroleum fuel with first second third and fourth-generation biofuels

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Bioenergy Supply

Angiosperms include herbaceous species like corn, wheat, and rice, perennial grasses like switchgrass, miscanthus, sorghum, and bamboo, flowering plants like alfalfa, soybean tobacco, and hardwoods like poplar, willow, and black locust, and gymnosperms include soft woods like pine, spruce, fir, and cedar [22]. Cellulose, hemicellulose, lignin, and ash vary with plant species [23]. Most dicot and monocot cellulose microfibrils have few arabinoxylan connections. Most monocots have hydrogen-bound glucuronoarabinoxylans as cross-linked glycans. Lignin, an aromatic polymer comprised of syringyl (S), guaiacyl (G), and p-hydroxyphenyl (H), varies by plant species. Gymnosperms—G and H units—have the most lignin. Hard woods have few H units and mostly G and S units. Monocot grasses have more H-units than G and S units than woody plant species. Ultrastructure and compositional changes in plant cell walls affect pretreatment and biomass sugar conversion. Ammonia fibre expansion (AFEX) works well on monocot grasses and herbaceous plants but not on dicots like poplar and black locust. Additionally, biomass from the same field in future years will fluctuate in composition (due to environmental conditions). This fluctuation makes processing parameters difficult to change and immediately affects biofuel output [24].

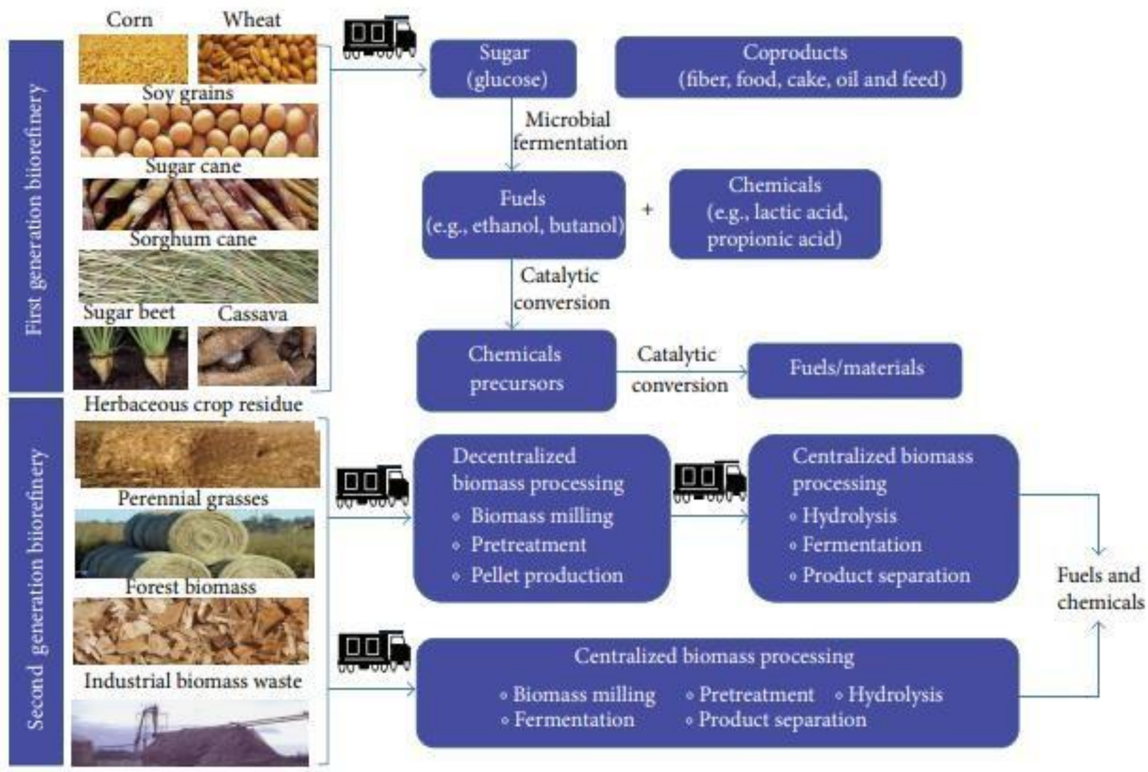

Fig. 2 Illustrates the feed stocks used in first- and second-generation biorefineries to produce biofuels, biochemicals, food, and feed.

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Biofuel Production Environmental Impacts

Environmental variables affect biofuel production since they directly affect crop and microorganism growth. Environmental conditions and biofuel have been extensively studied [25]. Hosseinzadeh-Bandbafha et al. examined biodiesel's environmental impact. Life cycle assessment was used to examine biodiesel additive environmental impacts. Biofuel technology for sustainable environmental management is gaining attention. They detailed biofuel sustainability issues [26]. Limited production and availability of raw material prohibit first-generation biofuel from achieving oil product substitution needs. First-generation biofuel comes from sugar beet, cereals, oil, and seeds, which has downsides. Second-generation lignocellulosic biofuel is made from non-edible biomass, making it more suitable for future usage. This project will focus on second-generation lignocellulosic biofuels (Figure 3)

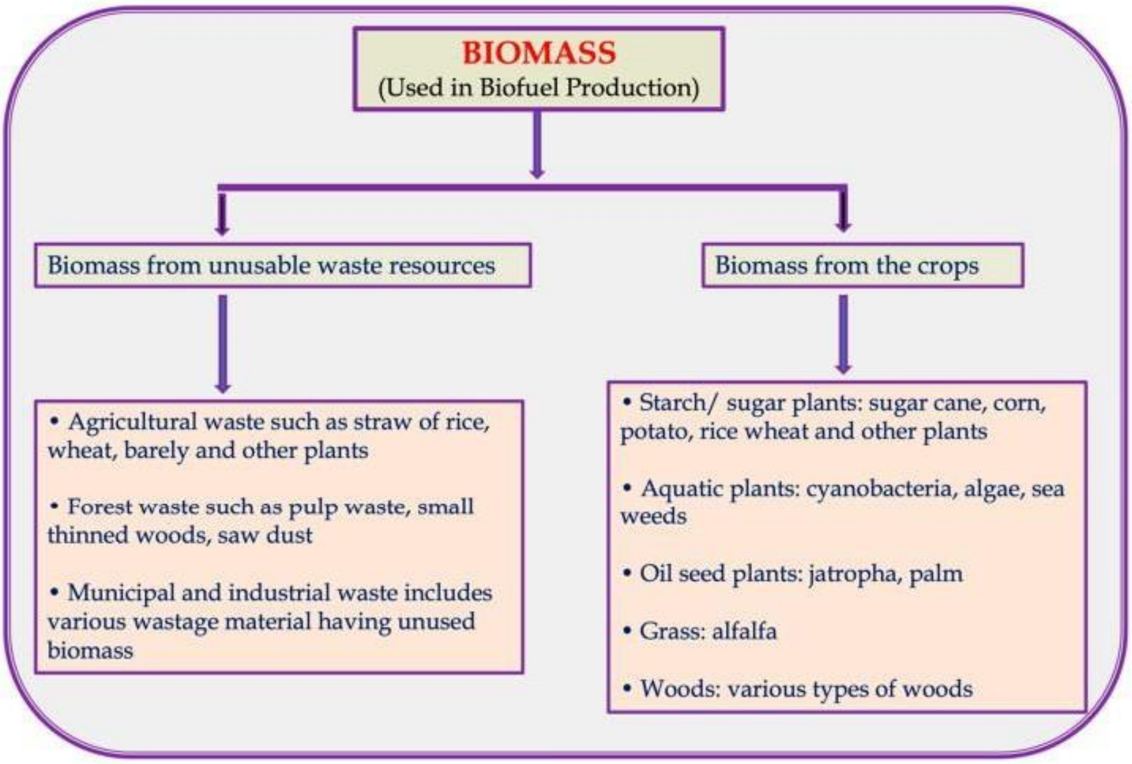

Fig. 3: Biomass is a renewable resource that is utilized to produce biofuel.

Feedstocks Linoleic Acid-based

Photosynthesis generates around 100 billion tonnes of lignocellulosic biomass per year. Humans consume just a small percentage of it, wasting resources. China has 800 million tonnes of lignocellulosic biomass, whereas the US has 1.3 billion [27]. Although fossil fuels have helped human civilization expand, they have also caused environmental degradation and an energy problem. Nations are speeding up the conversion and use of lignocellulose, a renewable resource, to solve energy shortages, environmental deterioration, and sustainable

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development [28]. Thermochemical and biological processes convert lignocellulosic feedstock's cellulose and hemicellulose, which make up two thirds of a plant's dry mass, into sugars. Herbaceous and woody energy crops, agricultural wastes, and forest residues are lignocellulosic feedstocks. Sugar from cell wall cellulose may be converted into ethanol [29] or biodiesel or butanol. The plant's cell walls' morphology prevents cellulosic ethanol production. To synthesise increased basic materials like carbohydrates, bioenergy crops should be grown on marginal land utilising modern genetics and breeding methods (which are then converted into biofuel). Marginal land bioenergy crops will provide sustainable biofuels. The following sections discuss biofuels made from various agricultural feedstocks with distinct structural and chemical compositions [30].

Pretreated lignocellulosic biomass

Biofuel production begins with raw material pretreatment. It produces ethanol and bioenergy. Physical, chemical, and biological preparation dominates. I During biofuel production, physical and chemical pretreatment improves substrate quality for subsequent digestion. Chemical pretreatment uses oxidation, ozonization, acid, or base treatments, whereas physical pretreatment uses heat, pressure, steam, hot water, ultrasonics, etc. These methods usually work best together. (ii) Biological pretreatment dissolves lignin coatings and structurally alters cellulose to make it more digestible by enzymes or microbes. In biological treatments, microorganisms produce useful byproducts [31]. Scholars worldwide have stressed the importance of biofuel preparation [32, 33]. Wagner et al. addressed biogas-boosting pretreatment methods using lignocellulosic biomass. Galbe and Wallberg also reviewed typical, successful lignocellulosic feedstock pretreatment. Sivamani et al. studied acid pretreatment for bioethanol production. Ab Rasid et al. demonstrated lignocellulosic biomass pretreatment. They focused on green biomass pretreatment methods such ionic liquids, ozonolysis, deep eutectic solvents, etc. Afolalu and Beig also examined the numerous challenges of pretreating lignocellulosic biomass. Afolalu et al. described chemical, physical, and biological preparation [34].

Dionsio et aldiluted .'s sulfuric acid pretreatment solubilized 89.5% of hemicellulose [35]. Lima et al. pretreated sugarcane with ozone to generate ethanol and biogas [36]. Morales-Martinez et al. chemically processed coffee husk waste into ethanol. Mund et al. investigated leaf waste enzymatic hydrolysis and pretreatment for biofuel (Figure 4).

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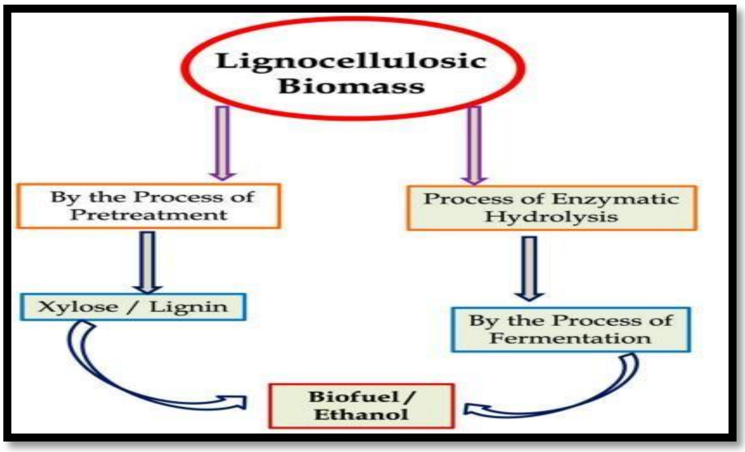

Fig. 4: Conversion of lignocellulosic biomass. (Adapted and modified from Approaches for Enhanced Biofuel Production)

The generation of biofuel could be enhanced by altering the cell walls' makeup. By using contemporary molecular biology techniques coupled with synthetic and systemic biology to increase the digestibility of plant cell walls, this might result in an improvement in the generation of biofuel from lignocellulosic biomass [37,38]. System biology and synthetic biology, The significant advancement of synthetic and systems biology technologies in recent years has given researchers studying lignocellulose biorefinery new insights and resources. Recent developments in metagenomic, transcriptome, and metagenomics technologies enable direct genome, transcriptome, and proteome reading without the need for microbial pure breeding. Fermentation cellulase genes were identified using original environment microbial population data 2022,. Enzyme expression and mechanism study led to innovative cellulase gene extraction, heterologous protein production, purification, and degradation approaches [39,40]. Several research organisations, including the US Department of Energy, retrieved whole DNA and total RNA from termite guts to construct a metagene library. Sequencing has revealed a large variety of genes involved in cellulose and hemicellulose hydrolysis, expanding our understanding of cellulase [41, 42].

Microbial Community Methods

Systems biology and synthetic biology give genome, metabolome, flux group, and computer simulation methods for microbial community analysis [43]. Screening microbial communities that degrade cellulose effectively in nature, identifying their community structure, studying fermentation kinetics, analysing the mechanism of their efficient degradation and transformation, and then simulating the construction of similar systems or strengthening their functions through transformation can generate new ideas for cellulose degradation systems [44,45].

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 11,S Iss 3, Dec 2022

Metabolic Engineering

Because sugar intake and stress resistance include many genes, proteins, regulatory factors, and stress behaviours, genetic or metabolic engineering is difficult [46]. Adaptive evolutionary engineering based on metabolic engineering may quickly produce large phenotypes in microorganisms, but confusing gene targeting and detrimental mutation interference are downsides. Multi-omics technology has revitalized evolutionary engineering and established reverse metabolic engineering [47].

Nano techniques

Nanotechnology has several biofuel production uses. Nanotechnology and nanomaterials can help produce biofuels more cheaply and efficiently [48]. Nanotechnology in biofuel production has been published and discussed by many researchers worldwide. Nizami and Rehan discussed how nanotechnology may establish a viable biofuel industry. Sekoai et al. suggested using nanoparticles to boost biofuel production (biogas, biodiesel, and bioethanol) yields.

Obstacles to Overcome

Biofuel manufacturing must overcome cost and environmental challenges (such as the loss of soil and land area). This scenario is complicated. The first major impediment is bioethanol's high production cost and economic feasibility compared to crude oil [49]. Mizik et al. recently went into great length on the numerous restrictions, particularly with regard to the financial side. The authors identified a number of issues with the development of biofuels and claimed that higher generation biofuels cannot compete on price because of their high production costs and technological restrictions [50]. In order to produce second-generation biofuels that are affordable and acceptable for commercial use, technology-based restrictions must be overcome. The development of new procedures is proving to be a difficult undertaking, particularly when it comes to tackling the financial constraints associated with the production of biofuels [51,52]. Another challenge may be funding biofuel research and development to commercialise it. Targeted and enhanced support for energy crop yields, sustainable biomass production, supply chain cost reduction, and conversion process improvement [53].

CONCLUSIONS

We discussed concepts, issues, and second-generation lignocellulosic biofuels in this study. First-generation biofuels, which directly influence agricultural products and food prices, have been the focus until now. Since biofuels are more expensive, poorer countries oppose them. Second-generation lignocellulosic biofuels, which are affordable and environmentally friendly, are being researched worldwide. In the short run, second-generation biofuel made from agricultural waste residues and lignocellulosic feedstock would be better for food

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supply than first-generation biofuel. Since first-generation biofuels have production and consumption issues, transitioning to next-generation lignocellulosic biofuel may be more economically viable [54]. Alternative fuels are still produced using existing processes. Lignocellulose derivative bio-refining facilities are expected to use more organic raw materials. Operational approach and catalytic design may be used to increase biofuel production efficiency. Bio-refineries use biomass mixes to make a variety of products. Organic chemistry requires the merging of technology and chemical and biological alteration of materials due to biological products and bioprospecting systems [55].

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