International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Advancement in Biofuels Technologies Towards Sustainable Energy Transition

Sunidhi Maurya[1], Puja Pal[2]

[1]Research Scholar, Lovely Professional University
[2]Professor, Lovely Professional University

Abstract

Considering the fact that greenhouse gas emissions from fossil fuels are increasing and contributing to global climate alteration, the essay examines the pressing need to switch to sustainable energy sources. Biofuels are esteemed as viable alternatives due to their renewability, lower greenhouse gas emissions relative to conventional fuels, and potential for reduced environmental impact compared to traditional fuels. Based on the sources of feedstock and the methods used in production, the development and categorization of biofuels into primary, first-generation, second-generation, and third-generation are examined. Second-generation biofuels, which use non-edible biomass but have cost-effectiveness issues, are compared with first-generation biofuels, which were originally promising but contentious owing to competition for land and worries about food security. Despite present economic constraints, third-generation biofuels, especially those derived from algae, are renowned for their high biomass production and environmental advantages. The study covers the latest developments in technology, how they integrate with the current infrastructure, how regulations support them, and if they are economically feasible for general use. Prospects for the future place a strong emphasis on technological developments and global scalability to provide sustainable energy solutions.

Keywords: Biofuels, Microalgae, Primary biofuels, Secondary biofuels, Sustainable energy, tertiary biofuels

1. Introduction

Over the past two centuries, the phenomenon of global warming has transitioned from anecdotal lore to a critical global health crisis with the potential to profoundly disrupt current socio-environmental dynamics and pose existential threats to humanity. Because of increased greenhouse gas emissions from the burning of fossil fuels, the average surface temperature of the Earth has been rising continuously. Carbon dioxide (CO_2), methane (CH_4), ozone (O_3), and nitrous oxide (NO_3) are the constituents of greenhouse gases. The collective property of these gases is their ability to absorb infrared light. A Tasmanian monitoring station at Cape Grim detected 400 parts per million of CO_2 in the atmosphere in May of 2016. In order to put this in perspective, levels were last this high over.

A Tasmanian monitoring station at Cape Grim detected 400 parts per million of CO_2 in the atmosphere in May of 2016. The last time levels were this high was more than 15 million years ago [1], to put this into perspective. Conventional fuel sources are running out extremely rapidly; at the current pace of use, they are predicted to be able to accomplish the world's energy needs for only a few more decades. As the biggest energy user in the world, the United States currently imports 60% of its oil since it has already used 80% of its oil reserves.

While civilization has significantly enhanced living standards through technological advancements facilitated by widespread fossil fuel consumption, this progress has come with inherent costs and trade-offs. Among the detrimental repercussions of prolonged fossil fuel consumption include biodiversity loss, sea level rise, glacier retreat, and climate change. Fuels, as they are economical, efficient, sustainable, renewable, and contribute less to greenhouse gas emissions. There are four categories for biofuels: primary, first, second, and third generation [2]. Based on their source feedstock, biofuels are categorized, as shown in Fig. 1. Wood and other primary biofuels don't need to be processed further before being burned to provide energy. In addition to biofuels like bioethanol and butanol, first-generation biofuels employ food source materials like seeds and recycled food oil to make bio-oil and simple sugars that may be processed to produce fatty acid methyl esters (FAME) as biodiesel and glycerol [2].

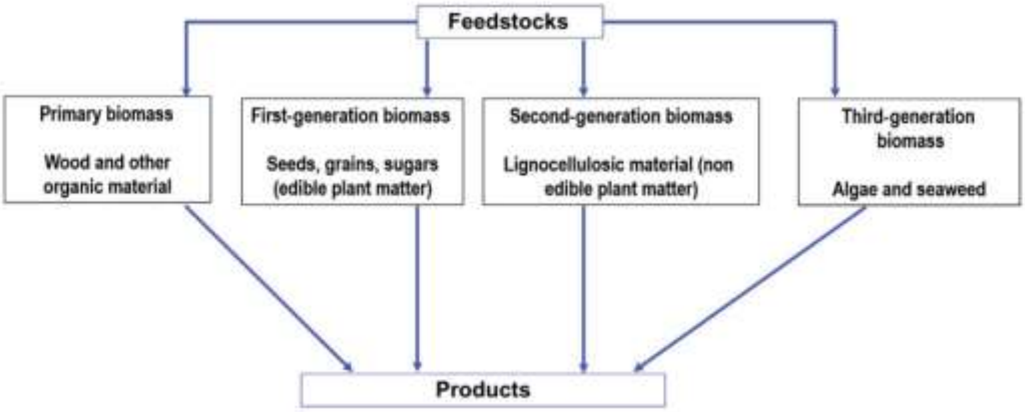

Figure 1. Biofuels production from different biomass [4]

Diesel engines employed seed oil in the early 1900s [3]. Because vegetable oil has a higher viscosity (2840 mm^2/s) than gasoline diesel (34 mm^2/s), it can no longer be used directly in car combustion chambers [5]. Engine coking is caused by this high viscosity [5]. Non-edible plant material, such wheat straw, is used in second-generation biofuel production to create FAME, biofuels, and biobased compounds [2]. Third-generation biofuels are made from algae and yield FAME, biofuels, and several biochemicals through a variety of processes [2].

Compared to liquid biofuels, primary biofuels are more energy-efficient and produce more energy per kilogram of biomass [6]. Regretfully, because solid biofuels like wood aren't purified, burning them produces a lot more pollutants [7]. Because they are awkward to replace and burn, solid fuels are also unsuitable for light vehicle transportation. Since first-generation biofuels mostly come from human food sources, long-term sustainability is not favorable impacted by this alternative [3]. Although the manufacturing processes for second-generation biofuels are still somewhat costly, they are more environmentally friendly [3].

Algae are an ideal biomass source for biofuel and biobased chemicals because they can grow orders of magnitude faster than all other plants, produce relatively large amounts of lipids, grow in variable conditions, and sequester CO_2 [8]. Third-generation biofuels require expensive, technologically advanced equipment.

In order to attain sustainable growth in the areas of energy, environment, and economy, all nations, with a particular focus on the United States, Brazil, Canada, China, Germany, India, and the United Kingdom, are making concerted efforts to promote the development of renewable energy sources and expedite the modification of their energy infrastructure [4].

This study focuses on seven nations from the Group of Twenty (G20) - the United States, Brazil, Canada, China, Germany, India, and the United Kingdom - that have been more proactive in the use of biofuels compared to other countries worldwide. The United States and Brazil are leading the way in the development of biofuels and provide significant expertise in this field. China has now emerged as the third biggest producer of gasoline ethanol globally, behind the United States and Brazil. Figure 1 illustrates the 2017 distribution of per capita gross domestic product (GDP). It shows that the United States, Canada, Germany, the United Kingdom, Brazil, China, and India have the highest to lowest per capita GDP, respectively. The United States has the greatest per capita GDP among these nations. Presently, the United States and Brazil hold the positions of the foremost and second-largest biofuel producers in the globe, respectively.

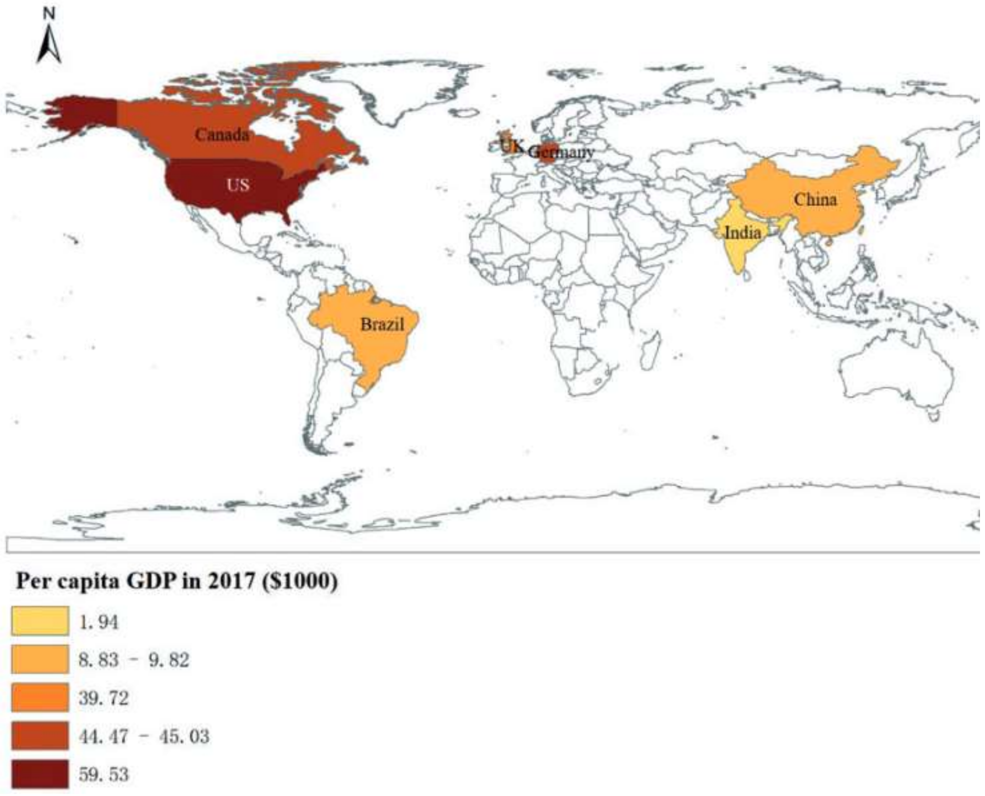

Figure 2. G20 per capita GDP

As early as 1908, the United States started using ethanol as a fuel. Ford, the renowned American automobile manufacturer, introduced a combination of ethanol and gasoline for the first occasion in a T-car. Brazil pioneered the global implementation of legal measures to mandate the promotion of gasoline ethanol. In 1975, Brazil enacted the National Ethanol Fuel Plan with the aim of actively promoting the growth of biofuels. As a result, Brazil has emerged as a leading worldwide producer and user of sugarcane ethanol.5 Based on data from BP [6] and the World Bank [7], biofuel consumption (BIO) in the United States grew from 1.38 million tonnes oil equivalent (Mtoe) in 1990 to 36.94 Mtoe in 2017.

During the same period, the country's GDP expanded from $23.95 thousand to $59.53 thousand. At the same time, the consumption of biofuels in Brazil climbed from 5.63 million tonnes of oil equivalent (Mtoe) in 1990 to 18.47 Mtoe in 2017. Additionally, the country's gross domestic product (GDP) grew from $3.09 thousand in 1990 to $9.82 thousand in 2017.

As Figure 2 depicts, the distribution of CO 2 emissions from high to low is attached to China, the United States,

India, Germany, Canada, Brazil, and the United Kingdom. China is the highest CO 2 emissions in these countries. China and India have relatively large populations, and with the continuous development of the economy, car ownership has increased year by year; thus, the demand for fuel has increased year by year. Because oil reserves in India are not abundant, to ensure the energy supply, India vigorously develops new energy such as wind energy, solar energy, and biofuels.

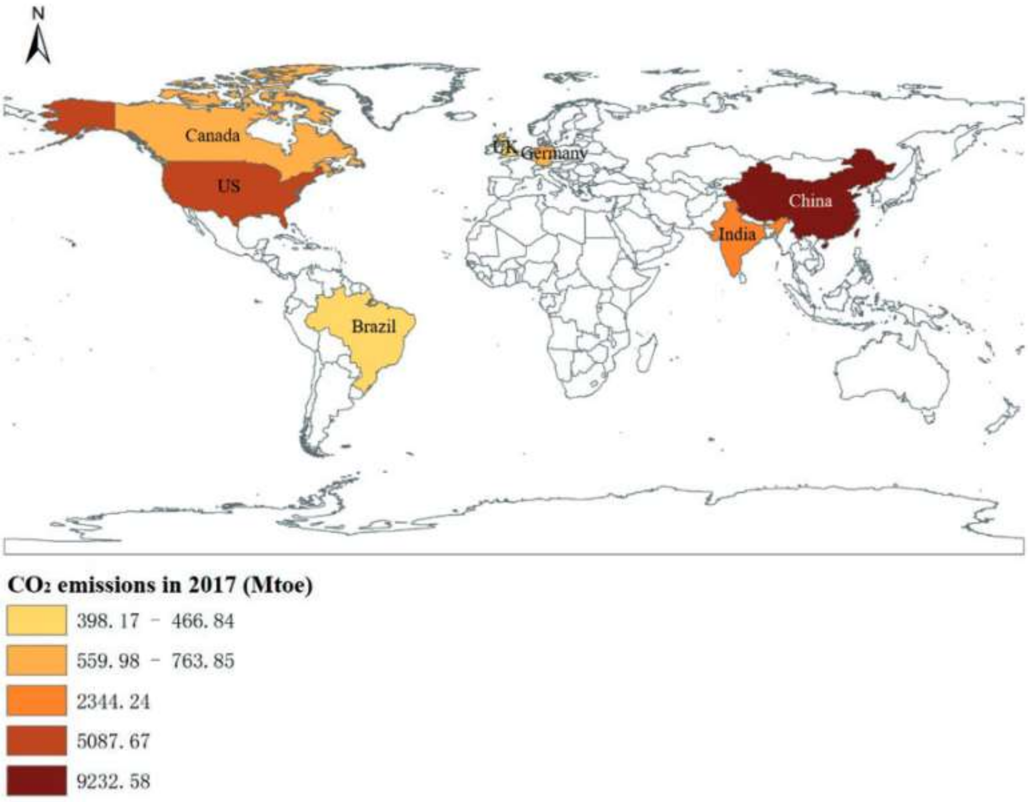

Figure 3. CO2 emission in G20

1.1.Production technologies

This section provides a more detailed discussion of some key biofuel production processes, including several technical options for getting the same ethanol from different feedstocks.

- **Anaerobic digestion process**

Anaerobic digestion (AD) is the primary technique used for the production of biogas. Compared to incineration or a mix of digestion and composting, this method is preferable in terms of both environmental and economic factors. It has a better energy balance and emits less volatile chemicals (Appels et al., 2011). The production of methane occurs via a sequence of metabolic processes involving microbes, including hydrolysis, acidogenesis, acetogenesis, and methanogenesis. These stages transform organic matter into biogas, as shown in Figure 2.

Biogas is generated through anaerobic digestion (AD) in various sources such as wastewater treatment facilities, landfills, and co-digestion facilities. The fermentation process is carefully monitored to ensure that the biogas produced contains at least 50% methane, and in some cases, the methane content can reach up to 75%.

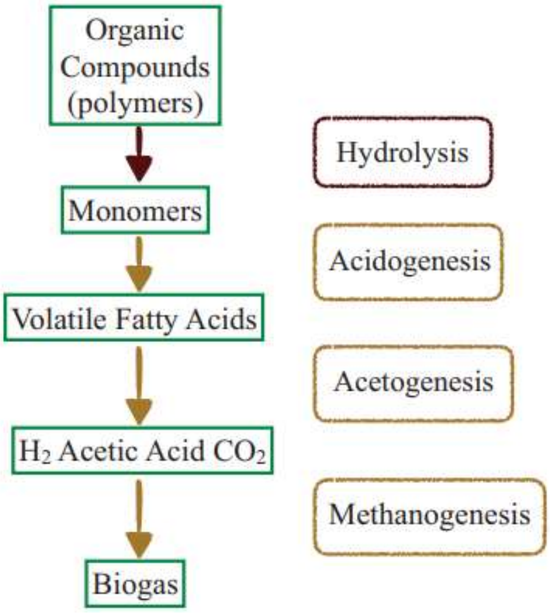

Figure 2. Methane biosynthesis

- **Syngas production**

Syngas is mostly acquired by gasification or pyrolysis procedures. These processes share a similar concept: in the former, biomass is quickly heated to high temperatures (e.g. 700–1200 degrees Celsius for lignocellulosic biomass), without combustion and with a low concentration of oxidizing agents (e.g. O2), while the latter thermally breaks down waste without any oxygen present (air). According to Capodaglio and Callegari (2018), the temperatures in the pyrolysis process might be much lower depending on the kind of energy used. Gasification is seldom used in industry at present, but pyrolysis is a technique that is gaining a wider variety of uses.

During gasification (or pyrolysis) processes of lignocellulosic biomass, three primary changes take place: dehydration, pyrolysis, and partial oxidation (Guo et al., 2015). During the first stage, biomass is subjected to a temperature of 200 degrees Celsius to eliminate moisture. Subsequently, pyrolysis occurs as the temperature gradually rises, resulting in the production of char and vapor from the biomass (Callegari & Capodaglio, 2018). The char undergoes partial oxidation, resulting in the formation of carbon monoxide (CO) and carbon dioxide (CO2). Simultaneously, the vapor is transformed into water (H2O) and carbon dioxide (CO2). The processes occur to acquire carbon monoxide (CO) and hydrogen (H2) from char and carbon dioxide (CO2), whereas carbon monoxide (CO) combines with water (H2O) to create hydrogen (H2) and carbon dioxide (CO2). Various gasifier designs are available, including traditional kinds such as fixed, fluidized, and entrained flow bed gasifiers, as well as transport reactor, catalytic, and plasma gasifiers (Mondal, Dang, & Garg, 2011). Woody biomass is more advantageous than herbaceous crops since it contains less ash and nitrogen, while herbaceous crops produce more ash and may lead to slagging in the gasifier. Following manufacturing, several alternatives exist for the use of syngas, as seen in Figure 3. While crude syngas may be combusted directly (yielding an energy recovery of around 5.3 MJ/Nm3), the prevailing approach is to purify it using methods that eliminate impurities and enhance its worth.

In these operations, the removal of particulate matter, tars, sulfur, nitrogen compounds (NH3 and HCN), and chlorine is often carried out. Various methods are commonly employed to purify crude syngas, including hot gas techniques such as cyclones, granular filters, electrostatic precipitators, thermal plasma, turbulent flow precipitators, ceramic bags, and rigid barrier filters. Cold gas purification methods typically involve the use of liquid absorbents, such as spray, wet, or dynamic scrubbers, Venturi devices, and wet electrostatic precipitators. Warm gas cleanups are also utilized. Additionally, solid sorbents like zeolite and activated carbon, as well as silver-loaded adsorbents, are widely used for this purpose (Woolcock & Brown, 2013).

Following the purification process, there are several choices for using syngas. These include the integrated gasification combined system (IGCC) with a following power generation cycle, Fischer-Tropsch processing for producing liquid hydrocarbons, synthesis of methanol, ammonia, ethanol, and other possibilities. Biochar, a byproduct derived from the gasification process, may be enhanced and used in several applications, such as serving as a catalyst for the generation of biodiesel and the removal of tar, as well as for further extraction purposes. The majority of fibers may be allowed to undergo hydrolysis, resulting in the formation of simple sugars.Utilize as an electrochemical material (You, Ok, Tsang, Kwon, & Wang, 2018).

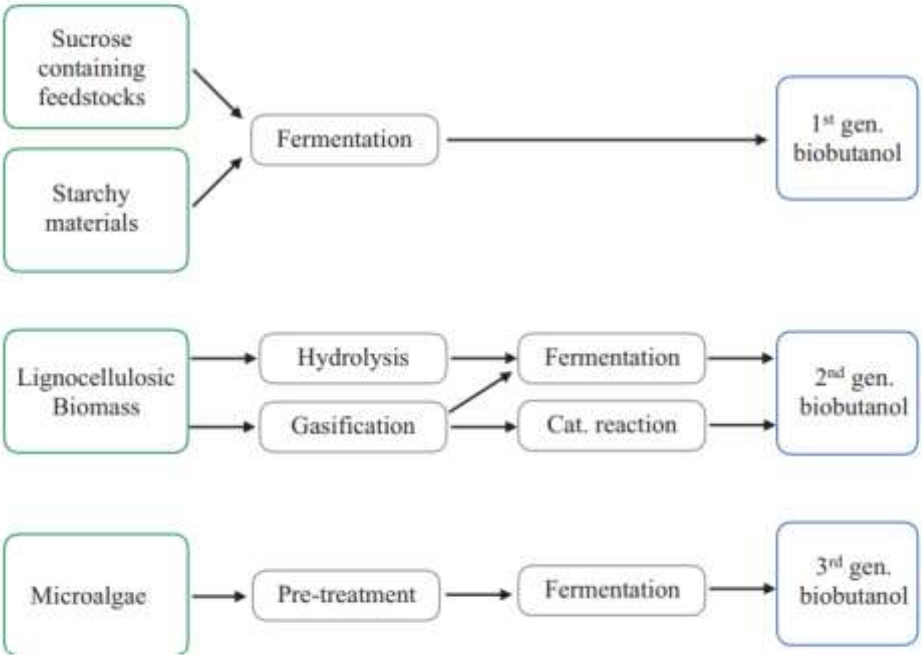

Figure 3. 1st, 2nd and 3rd generation biofuels from different processes

- **Bioethanol production**

The bioethanol manufacturing process exhibits variability depending on the sugar-containing raw feedstocks used. Typically, this process may be separated into three distinct phases (Binod et al., 2010). (Figure 4): The process involves the creation of a solution containing sugars that may be fermented into bioethanol. The bioethanol is then separated and purified, often by distillation, followed by rectification and dehydration (Vohra et al., 2014).

Additional processes may potentially be combined, depending on the type(s) of feedstock and the chosen process technology. Typically, when biomass is transported to a bioethanol production plant, it undergoes pre-processing to avoid early fermentation and/or contamination. During this conditioning process, carbohydrates undergo separation or conversion into a more readily available form. Recirculating or immobilizing yeasts enhances cell density inside the fermenter, hence enhancing their activity and boosting process productivity. The fermentation process requires temperatures ranging from 25 to 30 degrees Celsius for a duration of 6 to 72 hours. The specific time necessary depends on factors such as the content of the hydrolysate, cell density, and the kind of yeast used (Talebnia, Karakashev, & Angelidaki, 2010). The fermentation solution generally has an ethanol concentration of 8-14% (volume/volume), and distillation will produce an azeotropic mixture consisting of around 95.5% alcohol and 4.5% water, with a constant boiling point. The substance referred to as hydrous ethanol is later transformed into anhydrous ethanol by the removal of water, resulting in a composition of about 99.6% alcohol and 0.4% water. The residuals generated during the distillation process, known as vinasse or stillage, may be evaporated to produce various by-products such as steam, power, animal feed products, fertilizers, or other useful goods (Pandey, 2008).

Corn can undergo two distinct processing procedures, resulting in distinct byproducts: wet milling and dry milling. Dry mills have a limited capacity and are specifically built to only create ethanol. On the other hand, wet mills, sometimes called corn refineries, produce other valuable by-products such as glucose, dextrose, and high-fructose corn syrup (HFCS).

Wet mills first separate maize into corn oil, corn gluten meal (CGM), and corn gluten feed (CGF) to extract residual value as food or animal feed. Subsequently, starch is hydrolyzed into sugars for ethanol production. During the procedure, maize kernels are divided into hulls, germs, and endosperms before undergoing fermentation. The main outputs of the primary process are starch and its derivatives (such as HFCS and ethanol), as well as corn oil and gluten. These are produced via a series of several processes. Shelled corn is subjected to mechanical cleaning to remove undesired material. It is then placed in steeping tanks and soaked in dilute sulfuric acid at a temperature of 52 degrees Celsius for a period of 1 to 2 days. This process tenderizes the kernels by breaking down the proteins that keep the starches together, and it also eliminates other soluble components. The process water, which originates from the first steep tank and is abundant in protein, is sent to evaporators. In this stage, the water is concentrated to a range of 30-55% solids. The resultant concentrated liquid is often marketed as animal feed. Germs are extracted from the soaked corn in de-germinating mills, where kernels are fractured to separate the germ from the residual starch and gluten. The starch is separated from the mixture using wet cyclones, then it is cleaned, dewatered, dried, and processed to obtain corn oil. The hulls that have been thrown away are dehydrated to be used as animal feed. The end product will include ethanol with a concentration of 8-10% by volume, as stated by M. Guldi in 2007.

- **Biobutanol production**

In addition to the commonly used sucrose-based feedstock such as sugar and starch, various forms of biomass such as barley, straw, bagasse, maize cores, and lignocellulosic biomass may be used for the production of biobutanol. Figure 5 provides a summary of the distinct industrial biobutanol production processes for each feedstock. For the synthesis of butanol from lignocellulosic biomass, the initial material is subjected to pretreatment and detoxification to eliminate inhibitors. Subsequently, fermentation takes place, such as in the synthesis of biobutanol from sugar feedstock, using an ABE (acetone, butanol, ethanol) method (Bharathiraja et al., 2017). Ultimately, the product is retrieved and refined by the process of distillation, which involves separating acetone, ethanol, and butanol based on their distinct boiling points (56 degrees Celsius, 78 degrees Celsius, and 118 degrees Celsius, respectively). Irrespective of the bacterial consortium participating in the ABE process, acetone, butanol, and ethanol are generated in a consistent 3:6:1 ratio. The limitations of the ABE process can be identified in its poor performance in producing butanol, resulting in high recovery costs and increased process water consumption. Additionally, it has a low butanol production yield, leading to an increase in feedstock use and costs. Furthermore, the process exhibits a low specific productivity of solvents, which further contributes to increased costs. Distillation of butanol is both energetically and economically costly, and is associated with a larger water footprint compared to ethanol. Specifically, it generates 10.7 liters of stillage every liter of ethanol generated, but it produces 87 liters of stillage each liter of butanol produced (Tashiro, Yoshida, Noguchi, & Sonomoto, 2013).

- **Biodiesel**

In addition to the selection of feedstock, the extraction technique is a crucial stage in the biodiesel manufacturing process. The extraction process involves retrieving the oil from the kernel or seed (second generation feedstocks) or from algal cells (third generation). Seed preparation is a necessary step before extracting oil. This process entails the removal of the outer layers of the substance in order to reveal the kernels or seeds. Subsequently, the kernels or seeds are subjected to drying at temperatures ranging from 50 to 70 degrees Celsius until they attain the necessary moisture content. There are two distinct techniques utilized for seed cracking: stompers or mallets (Jahirul et al., 2013). There are three primary methods for extracting oil: mechanical, chemical or solvent-based, and enzymatic. Additional often used methods include accelerated solvent extraction (ASE), supercritical fluid extraction (SFE), and microwave-assisted extraction (MAE) (Karmakar, Karmakar, & Mukherjee, 2010).

The mechanical press method is the most established technique for oil extraction. This technique employs either a manual ram press or an engine-driven screw press. Ram presses have a maximum extraction yield of 60-65%, but an engine powered screw press may extract 68-80% of the available oil (Atabani et al., 2013). Nevertheless, oil that is produced mechanically by pressing requires further processing through the combination of filtration and degumming.

Solvent extraction, often known as leaching, is the method by which a component is separated from a solid substance using a liquid solvent. The use of n-hexane for chemical extraction generates the maximum amount of oil, making it the most often employed technique. The extraction rates are influenced by many factors, including the particle size, the nature of the extracting liquid, the temperature, and the level of agitation of the solvent. Solvent extraction is a cost-effective method for large-scale manufacturing, especially for quantities above 50 tons of biodiesel per day, despite its time-consuming nature. Furthermore, some techniques, such as n-hexane extraction, have adverse environmental consequences stemming from the substandard quality of the resulting process water, elevated energy demands, emissions of volatile organic compounds (VOCs), and potential health hazards associated with dangerous and combustible chemicals. Accelerated or pressurized solvent extraction (ASE/PSE) are contemporary methods of extraction that include the use of organic and/or water-based solvents at elevated temperature and pressure. These techniques effectively decrease the duration of the extraction process and minimize the amount of solvent required. Increased temperatures expedite the speed at which substances are extracted, but elevated pressures prevent the solvent from reaching its boiling point (Khattab & Zeitoun, 2013).

After the extraction of oil from the feedstock, it becomes essential to use a biodiesel conversion technique. The direct use of extracted vegetable oils in traditional diesel engines is inadequate and might lead to engine issues and damage owing to their high viscosity, low volatility, and polyunsaturated content. This can potentially result in the formation of carbon deposits (Singh & Singh, 2010). A variety of processes and techniques, including pyrolysis, dilution, microemulsification, and transesterification, have been used to create biodiesel from non-edible feedstocks, waste materials, and algae (Leung, Wu, & Leung, 2010). Pyrolysis is the process of thermally converting organic substances in the absence of oxygen, with the aid of a catalyst. Vegetable oil pyrolysis may provide products with high cetane number, low viscosity, water content, and sediments, along with mild corrosion values. This approach has many benefits, including simplicity, little waste creation, environmental friendliness, and cost-effectiveness when compared to other procedures.

The incorporation of 20-25% vegetable oil into diesel fuel, known as dilution or blending, has been shown to be effective for diesel engines without the need for any extra chemical processes. Micro-emulsification, also known as co-solvency, involves the combination of vegetable oils with esters and dispersants, or with liquids that do not mix well (such as ethanol, butanol, methanol, hexanol). This method offers a possible solution to the issue of high viscosity in these oils (Namasivayam et al., 2010). Currently, transesterification, which is the process of reacting fats and oils with alcohols, is the most widely used method for producing biodiesel. This is because it is cost-effective, highly efficient in converting the materials, and very simple to carry out. The process comprises a series of sequential, reversible reactions, which are shown in Figure 6.

The transesterification process involves the reaction of an alcohol with vegetal/algal (bio)oil in the presence of a catalyst. Ethyl or methyl alcohol is used for the production of ethyl or methyl esters. After the reaction has finished, two distinct layers, one consisting of ethyl or methyl ester and the other of glycerin, become visible and may be isolated. When vegetable oil combines with methanol (along with a catalyst), it produces raw biodiesel and glycerin. Prior to additional applications, the glycerin undergoes a process of refinement. Biodiesel in its raw form undergoes a refining process to separate it from alcohol, which may then be reused in the manufacturing cycle (Shahid & Jamal, 2011). The rate of transesterification is significantly affected by temperature, with higher temperatures resulting in faster reaction rates (and shorter reaction times). Typically, the reaction is carried out under gentle heating conditions (50–60 degrees Celsius), which is below the boiling temperatures of the alcohols used (about 60–78 degrees Celsius for methanol and ethanol, respectively). Typically, there are two distinct methods to do transesterification. The primary decision is in the selection between using catalysts or abstaining from their usage.

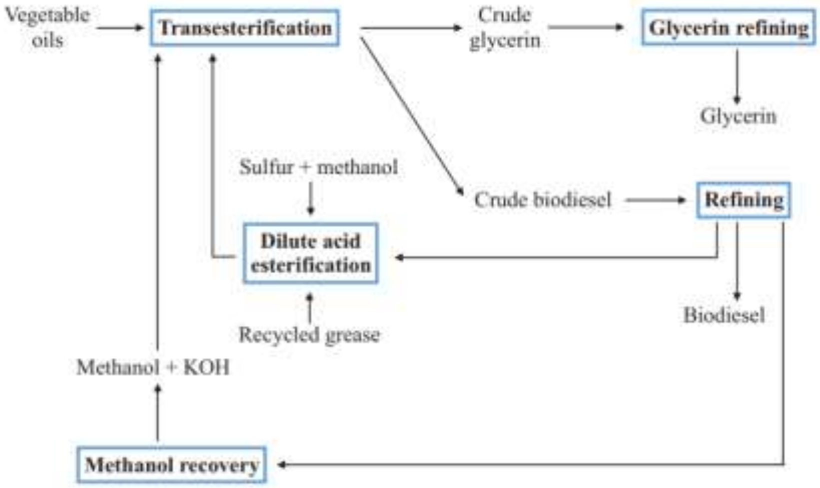

Figure 4. Transesterification to generate biofuels

1.2.Different generation of biofuels

- **First generation:**

Initially, it appeared that first-generation biofuels made from edible biomass, such as starch from potatoes, wheat, barley, and corn, or sugars from sugarcane and sugar beet, could reduce the amount of fossil fuels burned and the amount of CO_2 in the atmosphere that crops absorb during growth [9]. However, issues with employing edible crops as feedstocks and its effects on croplands, biodiversity, and the availability of food emerged.

First-generation biofuels, such as biodiesel (bio-esters), bioethanol, and bio-gas, are being generated commercially at a rate of around 50 billion liters per year. Bio-gas, which comes from the anaerobic digestion of manure and other biomass sources, has not been widely used in the transportation industry, in contrast to the other two forms of biofuels [10]. The fuels are assessed based on their suitability for use in alternative vehicle technologies like natural gas or flexible fuel cars, or on their capacity to be combined with petroleum-based fuel for use in internal combustion engines.

When evaluating edible biomass for biofuel production, there are a few things to take into interpretation. This may include: (a) the chemical composition of biomass; (b) energy balance; (c) croplands' availability and the impact on biodiversity and cropland value losses; (d) competition with food needs; (e) cultivation practices; (f) emission of pollutant gases; (g) the impact of mineral absorption on water resources and soil; (h) the use of pesticides; (i) the cost of the biomass and its transportation and storage; (j) soil erosion; (k) economic evaluation taking into account both the coproducts and feedstocks; (l) the creation or maintenance of employment; and (m) the availability of resources like water [11].

- **Second generation biofuels:**

Biodiesel may be produced from a variety of second-generation feedstocks, including wood residual waste, energy crops, and agricultural residues. Jatropha, Aleurites Moluccan, salmon oil, rubber tree Madhuca longifolia, tobacco seed, sea mango, and jojoba oil are the most often used energy crops for this purpose. Furthermore, feedstocks for biodiesel may be made from waste cooking oil waste, non-edible oil crops, restaurant grease, cow tallow, animal fats, and swine lard [12].

Animal fats provide advantages over first-generation feedstocks, including greater octane numbers, sustainability, non-corrosiveness, and absence of waste. The primary disadvantage of this feedstock generation, nevertheless, is the absence of viable technology for the industrial utilization of the waste produced during the synthesis of biodiesel. Moreover, the transesterification complexity is increased by the high quantity of saturated fatty acids seen in the majority of animal fats [12]. The primary drawback of biodiesel is that it performs very poorly in cold climates, making it unable to completely replace petroleum-based transport fuels [13]. Moreover, tainted animal feedstocks may give rise to biosafety concerns [13].

- **Third generation biofuels:**

The third generation of biofuels uses a variety of microorganisms as feedstocks [14]. The most prevalent kind of algae for biodiesel generation are promising microalgae. Based on their size and appearance, algae are divided into two primary categories: macroalgae and microalgae. Kelp is a marine macro-alga that is widely utilized. It is composed of numerous cells that resemble the roots, stem, and leaves of higher plants. On the other hand, fresh and sea water include microalgae, which are categorized as autotrophic, heterotrophic, and mixotrophic microscopic organisms [15].

Because they can photosynthesize, microalgae organisms have a great potential to manufacture unique compounds and nutritious goods [16]. The sources of the carbon that autotrophic and heterotrophic microalgae eat are different; autotrophs use inorganic carbon, whereas heterotrophs require organic carbon sources [17]. In order to exploit both inorganic and organic carbon substrates, mixotrophic algae can concurrently drive heterotrophy and autophototrophy [18]. This increases microalgae production and improves their capacity to thrive in wastewaters.

This kind of algae has the potential to overcome problems related to autotrophic algae development, such as light limitation at high cell densities and wastewaters with dark colors [19]. With a 61.5% decrease in CO_2 release, Chlorella protothecoides' mixotrophic growth may give lipids that are 69% greater than those of its heterotrophic yield on glucose [20].

Mixotrophic algae culture is not economically advantageous due to the high cost of glucose, which accounts for about 80% of the growth medium charge penalty, despite the excellent biomass and lipid productivities [20]. However, the production of mixotrophic algae shows great potential when using low-cost carbon sources. Examples of carbon sources include cane molasses, cellulosic materials, crude glycerol from the biodiesel sector, and sugars from agricultural and industrial waste [20].

1.3.Properties of microalgae:

Among its many noteworthy characteristics are their high oil content, low space requirements, adaptability to both natural and artificial surroundings, and environmental friendliness [21]. Their capacity to produce hydrogen and engage in oxygenic photosynthesis gives them a distinct edge. Furthermore, the only things they need for growth are light, carbon dioxide, and other inorganic nutrients [22].

Microalgae also help lower the amount of CO2 in the atmosphere since they require around 1.8 kg of CO_2 to produce 1 kilogram of algal biomass [23]. Historically, the first people to study microalgae anaerobic digestion were Oswald and Golueke of California in the 1950s. They gathered the biomass for the purpose of producing biogas using various forms of microalgal biomass, such as those found in high-rate ponds.

The microalgae biomass's oil content varies greatly. Oil makes up more than 80% of the dry weight of some forms of algae, but it only makes up 15% to 40% of other varieties. When compared to other crops, palm kernel, copra, and sunflower have 50–60% more oil. Among different plants, microalgae are generally thought to be the finest oil generator. While the capacity of palm, coconut, castor, and sunflower oil production ranges from 1000 to 6000 l/hectare/year, that of microalgae oil production can reach 100,000 l/hectare/year [24].

Several biofuels, such as bioethanol and biodiesel, as well as CH4 and H2, may be produced from microalgae by various methods. Microalgae-derived biofuels can be used in current gasoline engines without the requirement for any modification [25]. Biodiesel fuels derived from microalgae have characteristics with petroleum-based biofuels, including viscosity, density, heating value, flash point, cold filter plugging point, and solidifying point. As a result, they comply with the International Biodiesel Standard for Vehicles [26] as well as the American Society for Testing and Materials (ASTM) regulations.

1.4.Microalgae based biofuels:

Comparing microalgae-based bio-oil to fossil-based oil made from quick pyrolysis of wood, the latter has a low density, low viscosity, and a high heating value [27]. Because it is of higher quality than oil derived from lignocellulose, it is also preferred. A schematic diagram of the manufacture of third-generation biofuel is shown in Figure 2. The benefits of microalgae include their capacity to remove inorganic nutrients from wastewater and their inclination to absorb nitrogen and phosphorus in their tissues, which allows them to produce larger amounts of green biomass.

Thus, combining wastewater treatment with microalgal culture is a viable approach to improve the economic and production efficiency of microalgal-based biofuels [28, 29]. This approach has a number of benefits over other feedstocks, including: (a) lower costs because it only requires solar energy; (b) the capacity to effectively lower CO_2 concentrations; (c) no additional organic carbon sources are needed, unlike in the case of biological nitrification and denitrification; (d) fewer sludge handling problems; and (e) a propensity to raise the dissolved oxygen level (also known as O_2 concentration) in water bodies [30]. However, there are significant drawbacks to this type of biomass, including its high cost and the fact that biofuel made from algae is less stable than ethanol made from other sources. This is a result of the extremely unsaturated nature of the oil produced by algae, which makes it more prone to degradation and more volatile, particularly at high temperatures.

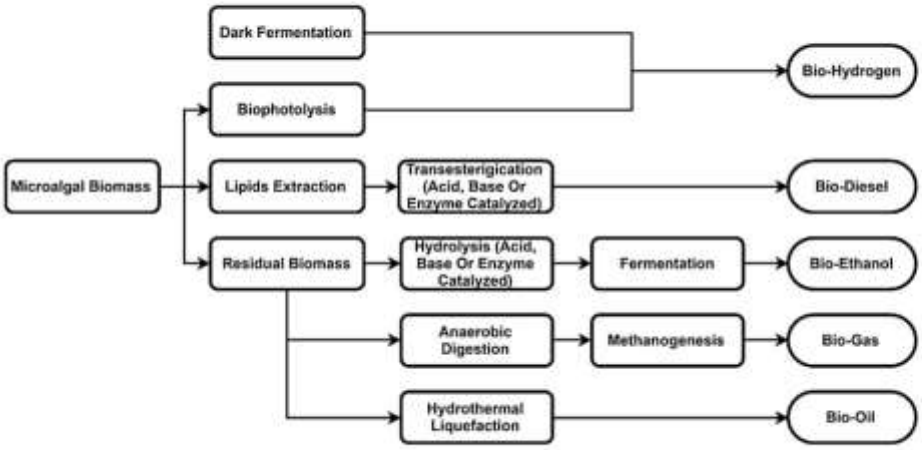

Figure 5. Microalgae biomass fuel production

2. Discussion

The use of biofuels in place of conventional fossil fuels is essential for reducing the harmful consequences of global warming. Increased greenhouse gas emissions from the burning of fossil fuels have caused the Earth's average surface temperature to rise steadily, which has serious socio-environmental repercussions such as biodiversity loss, sea level rise, and climate change. In May 2016, 400 parts per million (ppm) of CO2 were measured in the atmosphere by the Tasmanian monitoring station at Cape Grim, a level not seen in more than 15 million years. The whole community is increasingly looking to biofuels as a sustainable option as conventional fuel sources rapidly exhaust.

Based on the source feedstock, biofuels are divided into four generations: primary, first, second, and third. First-generation biofuels are made from food sources like seeds and recycled food oil, whereas primary biofuels, like wood, don't need to be processed before use. Third-generation biofuels are made from algae and create fatty acid methyl esters (FAME), biofuels, and other biochemicals. Second-generation biofuels use inedible plant material. Every generation has benefits and drawbacks. Despite being more energy-efficient, primary biofuels emit more pollutants. First-generation biofuels are not long-term sustainable since they come from human dietary sources. Despite being more ecologically friendly, second-generation biofuels are more expensive to produce. Third-generation biofuels show promise because of their high lipid synthesis and quick development, especially those derived from algaae [31].

There is a noticeable global push toward changing the energy infrastructure and promoting renewable energy, particularly among G20 countries including the US, Brazil, China, Germany, India, and the UK. China is becoming a major participant in the biofuel industry, with the United States and Brazil taking the lead. According to history, the United States started utilizing ethanol as fuel in 1908 when Ford introduced a combination of ethanol and gasoline. Brazil became a major producer and consumer of sugarcane ethanol in 1975 after enacting the National Ethanol Fuel Plan, which greatly increased biofuel production and consumption. Alongside significant GDP development, the United States' biofuel consumption increased from 1.38 million tonnes oil equivalent (Mtoe) to 36.94 Mtoe between 1990 and 2017. Brazil's economic success and biofuel usage both increased throughout this time.

The development of alternative energy sources, including biofuels, has been fueled by the rising automobile ownership and fuel consumption in China and India, two countries with sizable populations and expanding economies. The CO2 emissions distribution among these nations puts China first, followed by the United States, India, Germany, Canada, Brazil, and the United Kingdom.

The methods used to produce biofuels differ. The main method for producing biogas is anaerobic digestion (AD), which is chosen over incineration due to its superior energy balance and reduced emissions. Acidogenesis, acetogenesis, methanogenesis, and hydrolysis are all involved in AD. By thermally breaking down biomass through gasification or pyrolysis, syngas production produces pure syngas that may be used in Fischer-Tropsch processing, integrated gasification combined systems (IGCC), or the synthesis of methanol, ammonia, and ethanol. Preparation, fermentation, and distillation are the steps in the manufacturing of bioethanol, and they differ based on the basic feedstocks. The ABE (acetone, butanol, ethanol) process, which produces biobutanol from different biomass types, has problems with yield and recovery costs. Oil is extracted from feedstock and converted via pyrolysis, dilution, microemulsification, and transesterification—transesterification being the most economical and successful process—to produce biodiesel.

In conclusion, the necessity for sustainable energy options to mitigate climate change is what is driving the worldwide move towards biofuels. Comparative studies draw attention to the many methods and technologies used in the production of biofuels, highlighting the necessity of ongoing innovation and global collaboration to improve energy security and sustainability.

While in the studies given by Leung et al., 2010 showed A low-emission fuel replacement for diesel, biodiesel is produced from waste lipid and renewable resources. Transesterification—particularly alkali-catalyzed transesterification—is the most widely used process for producing biodiesel. The alkali catalyst will react with the free fatty acids in the raw materials (oils or fats) to generate soaps when there is a large percentage of water or free fatty acids. Triglycerides can be hydrolyzed by water to produce diglycerides and additional free fatty acids. The yield of the biodiesel product is decreased by the two unfavorable reactions mentioned above. In order to prevent the saponification reaction in this case, the acidic materials have to be pre-treated.

This study examines the many methods used by the industry to refine crude biodiesel and lower the amount of free fatty acids in raw oil. The amount of alcohol, reaction duration, reaction temperature, and catalyst concentration—the primary determinants of biodiesel yield—are examined. This report also discussed several novel biodiesel manufacturing techniques. For example, the Biox co-solvent technique creates a one-phase oil-rich system by using inert co-solvents to convert triglycerides to esters. Although it demands high pressure and temperature, the non-catalytic supercritical methanol method has the benefit of having a faster reaction time and fewer purification stages.

In order to transesterify the oils in the oilseeds for the in situ biodiesel process, the oilseeds are treated directly with methanol in which the catalyst has been carefully dissolved at room temperature and pressure. However, animal fats and leftover cooking oils cannot be processed by this method [32].

3. Conclusion

Examining the processes used in the manufacturing of biofuels reveals a wide range of creative approaches meant to improve productivity and solve environmental issues. Crude syngas, which is produced by gasifying biomass, must be purified by going through a series of rigorous steps including chilling, scrubbing, and catalytic conversion in order to get rid of particles and tars. Modern catalysts and membrane technologies are essential for increasing the effectiveness of purification while using less energy. Important biofuels produced from biomass fermentation, such as bioethanol and biobutanol, are prime examples of continuous progress. The manufacture of bioethanol, which is often derived from lignocellulosic materials such as maize or sugarcane, has improved ethanol output through enzymatic hydrolysis and fermentation conditions. Thanks to creative fermentation methods and genetic engineering of microorganisms, biobutanol—which has a greater energy density—benefits from increased productivity and process efficiency.

References

1. 30th 2016 PD, 29th 2016 PD, 28th 2016 PD, 27th 2016 PD, 23rd 2016 PD, 21st 2016 PD. 2016: News: Climate Central. Climate Central. http://www.climatecentral.org/news/ archive/2016; 2016.
2. Wu H, Miao X. Biodiesel quality and biochemical changes of microalgae Chlorella pyrenoidosa and Scenedesmus obliquus in response to nitrate levels. Bioresour Technol 2014;170:421 7. Available from: https://doi.org/10.1016/j.biortech.2014.08.017.
3. Environmental history/biofuels. Revolutions in Communication. http://www.environmentalhistory.org/billkovarik/about-bk/research/cabi/; 2015.
4. Nigam PS, Singh A. Production of liquid biofuels from renewable resources. Progress in Energy and Combustion Science 2011; 37:5268. http://dx.doi.org/ 10.1016/j.pecs.2010.01.003.
5. Knothe G. Introduction. The biodiesel aandbook:1 3. https://do.i.org/10.1016/b978-1- 893997-62-2.50006-1; 2010.
6. 2016 National algal biofuels technology review. Department of Energy. https:// www.energy.gov/eere/bioenergy/downloads/2016-national-algal-biofuels-technologyreview; 2016.
7. Aldaya M, Allan J, Hoekstra A. Strategic importance of green water in international crop trade. Ecol Econ 2010;69:887 94. Available from: https://doi.org/10.1016/j. ecolecon.2009.11.001
8. Sharara MA, Clausen EC, Carrier DJ. An overview of biorefinery technology. Biorefinery Co-Products:1 18. https://doi.org/10.1002/9780470976692.ch1; 2012.
9. M. Rodionova, R. Poudyal, I. Tiwari, R. Voloshin, S. Zharmukhamedov, H. Nam, B. Zayadan, B. Bruce, H. Hou, S. Allakhverdiev, Int. J. Hydrogen Energy 42 (2017) 8450–8461.
10. S.N. Naik, V.V. Goud, P.K. Rout, A.K. Dalai, Renew. Sustainable Energy Rev. 14 (2010) 578–597.
11. Singh, S.I. Olsen, D. Pant, Importance of life cycle assessment of renewable energy sources, in: Life Cycle Assessment of Renewable Energy Sources, Springer, 20131–11.
12. S.H. Shah, I.A. Raja, M. Rizwan, N. Rashid, Q. Mahmood, F.A. Shah, A. Pervez, Renew. Sustainable Energy Rev. 81 (2018) 76–92.

13. H. Mahmudul, F. Hagos, R. Mamat, A.A. Adam, W. Ishak, R. Alenezi, Renew. Sustainable Energy Rev. 72 (2017) 497–509.
14. W.-H. Leong, J.-W. Lim, M.-K. Lam, Y. Uemura, Y.-C. Ho, Renew. Sustainable Energy Rev. 91 (2018) 950–961.
15. X.R. Zhang, Z.Y. Jiang, L. Chen, A.H. Chou, H. Yan, Y.Y. Zuo, X.X. Zhang, Bioresour. Technol. 139 (2013) 209–213.
16. N. Uduman, Y. Qi, M.K. Danquah, A.F. Hoadley, Chem. Eng. J. 162 (2010) 935– 940.
17. S.H. Shah, I.A. Raja, Q. Mahmood, A. Pervez, Bioresour. Technol. 214 (2016) 199– 209.
18. Bhatnagar, S. Chinnasamy, M. Singh, K. Das, Appl. Energy 88 (2011) 3425– 3431.
19. D. Hoh, S. Watson, E. Kan, Chem. Eng. J. 287 (2016) 466–473.
20. Bhatnagar, S. Chinnasamy, M. Singh, K. Das, Appl. Energy 88 (2011) 3425– 3431.
21. Yi-Feng, Q. Wu, Production of biodiesel from algal biomass: current perspectives and future, in: Biofuels, Elsevier, 2011399–413.
22. E. Daneshvar, C. Santhosh, E. Antikainen, A. Bhatnagar, J. Environ. Chem. Eng. 6 (2018) 1848–1854.
23. W.G. Zhou, P. Chen, M. Min, X.C. Ma, J.H. Wang, R. Griffith, F. Hussain, P. Peng, Q.L. Xie, Y. Li, J. Shi, J.Z. Meng, R. Ruan, Renew. Sustainable Energy Rev. 36 (2014) 256–269.
24. Y.F. Chen, Q.Y. Wu, Production of Biodiesel from Algal Biomass: Current Perspectives and Future, 2011.
25. N. Pragya, K.K. Pandey, P. Sahoo, Renew. Sustainable Energy Rev. 24 (2013) 159– 171.
26. H. Wu, X. Miao, Bioresour. Technol. 170 (2014) 421–427.
27. C.M. Silva, A.F. Ferreira, A.P. Dias, M. Costa, J. Clean. Prod. 130 (2016) 58–67.
28. B. Bharathiraja, M. Chakravarthy, R.R. Kumar, D. Yogendran, D. Yuvaraj, J. Jayamuthunagai, R.P. Kumar, S. Palani, Renew. Sustainable Energy Rev. 47 (2015) 634–653.
29. R. Katiyar, B.R. Gurjar, S. Biswas, V. Pruthi, N. Kumar, P. Kumar, Renew. Sustainable Energy Rev. 72 (2017) 1083–1093.
30. L. Granada, N. Sousa, S. Lopes, M.F. Lemos, Rev. Aquac. 8 (2016) 283–300.
31. Hoekman SK. Biofuels in the US–challenges and opportunities. Renewable energy. 2009 Jan 1;34(1):14-22.
32. Leung DY, Wu X, Leung MK. A review on biodiesel production using catalyzed transesterification. Applied energy. 2010 Apr 1;87(4):1083-95.