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Biodiesel From Microalgae: Recent Progress And Key Challenges

Venktesh Kumar

Assistant Professor, Gopal Narayan Singh University, Jamuhar, Sasaram, Bihar, India

Corresponding author: venkteshkumar2@gmail.com

ABSTRACT

Microalgae biodiesel (BD), which has a substantial amount of lipids and a powerful ability to compensate for CO2, is a potential environmentally friendly fuel. However, the first generation of BD development's intricate and energy-intensive culture, pretreatment procedures, and BD conversion approaches have hindered the commercialization of BD from being accomplished. By meticulously analysing recent technological advancements in the microalgae BD production process, this work resolved the problems and provided encouraging suggestions for future research. Base-catalyzed transesterifications, which were developed from the first generation of BD technologies, are extensively employed in the the microalgal BD synthesis methods nowadays in use. However, the base-catalyzed suffers from the procedure of saponification and a low yield of production since microalgae have a high water content and free fatty acid content. Due to the high yield of microalgae BD synthesis, this technique is not financially viable since it requires substantial pretreatments such drying, esterification to result of fatty acids that are free, and filtration. In an effort to create novel transesterification platforms, new methods that can tolerate contaminants have been suggested, such as dynamically produced non-catalytic transesterifications. Within a minute of a response at 350 °C, thermally induced reactions enable the in situ conversion of microalgae lipid into BD (95 wt%). This technique is robust to the presence of water and free fatty acids and does not require a lipid extraction procedure. It was hypothesised that lowering the reaction temperature for thermally induced transesterifications might improve the efficiency of this approach. A pilot study, thorough life cycle assessment, and economic analysis were also recommended in order to explore the economic viability and environmental effects.

Keywords: biodiesel, microalgae, environment, economic, biofuels, emission

INTRODUCTION

Since the onset of industrialization, the world we live in has placed a significant reliance on fossil fuels (coal, petroleum, and natural gas) to meet its needs for carbon [1]. The practical use of fossil fuels has the potential to raise the living standard index, but an excessive dependence on them has led to significant environmental issues (such global warming) [2]. Years of scientific and technical research [3,4] have shown that the use of fossil fuels results in significant amounts of carbon dioxide

(CO_2) emissions, which are a key contributor to the development of global warming. In order to decrease the catastrophic effects of global warming, it is crucial to implement carbon-free or carbon-neutral energy sources. Because of their inherent carbon neutrality, biofuels including biodiesel, bioethanol, biogas, and biohydrogen have attracted a lot of attention [5,6]. Particularly, the ability of BD/BE to be combined with petrol and diesel produced from petrochemicals has made their use as transportation fuels both financially and practically viable [7,8]. Since they effortlessly leverage the established distribution networks, BD/BE uses have been successfully put into practise [9,10]. BE is created using the yeast fermentation process. According to this fact, yeast respiration and carbon synthesis inside yeast cells induce carbon loss throughout the biological BE conversion process, which cannot be prevented [11]. More than 50% of the carbon in the sugary molecule is lost during the BE conversion process [12]. Through catalytic trans-esterification, BD is now chemically transformed, and a lipid feedstock's carbon content may be kept to a level of more than 90% [13]. In order to keep carbon from a raw material, manufacturing BD is preferable than producing BE. First generation, second generation, and third generation are the divisions of BD based on its feedstocks. A homogeneous alkaline catalyst (KOH or NaOH) is used to produce first-generation BD from edible fat, such as soybean, palm, rapeseed, or maize oil [14,15]. However, the use of edible fat in the manufacture of BD has led to a variety of problems, such as an increase in food costs and deforestation [16,17]. In an effort to address the problems with the manufacture of first-generation BD, fat from non-edible resources has been sought to generate BD of the second generation [18]. The primary feedstocks for second-generation BD are biomass from plants produced on non-arable land or waste products such used cooking oil, animal fats, and manures [19,20]. Although these basic components are commercially accessible, BD conversion is difficult due to their relative impureness. These competitively cost raw materials, however, are quite impure, making it challenging to convert BD using a catalytic trans-esterification process. Microalgae are yet another resource that has been touted as a possible supply of raw materials for third-generation BD synthesis [21]. In comparison to terrestrial biomass, microalgal biomass generates 10-800 times more lipid [22,23]. Microalgae can absorb CO_2 because they can fix carbon better than terrestrial plants. Microalgae are 10–50 times more efficient in photosynthesis than terrestrial algae [24]. Because it doesn't require pesticides or arable land, growing microalgae is also good for the environment [25]. Every year, more study is conducted globally on BD manufactured from microalgae. The biggest contributions were made by Tsinghua University, the Chinese Academy of Sciences (CAS), and the Korea Advanced Institute of Science and Technology (KAIST) in terms of total publications [26]. BD manufacture from microalgae is made possible by the two primary processes, upstream and downstream activities (Fig. 1). The upstream process involves choosing the species and cultivating the microalgae. The process continues with drying, lipid extraction, and BD conversion after harvesting. Microalgae offer a lot of potential as a source of raw materials for BD, but it is currently difficult to determine if they are economically viable. In order to produce BD from microalgae, it is thus strongly encouraged to seek for a technical innovation by examining the existing status of each unit operation. The evaluation is intended to give current information on all microalgae BD production unit operations in order to meet these aspirational targets. The conclusion of the literature reviews for the upstream process was motivated by this goal. Selecting the appropriate microalgae species and modifying the culture for lipid formation were given particular emphasis in this review. Each unit activity in the downstream process, such as harvesting, drying, lipid extraction, and BD conversion, must be defined in terms of its technical advantages and drawbacks. the repercussions of the repercussions of the repercussions (TEA). Every need for the mass production of microalgae BD was also addressed. Finally, methods for evading the economical and environmental constraints on microalgae BE were explored.

Section snippets

Production of biodiesel's upstream process

The culture of microalgae and species selection that occur upstream are described. Figure depicts the general layout of the whole upstream process as described by the figure.

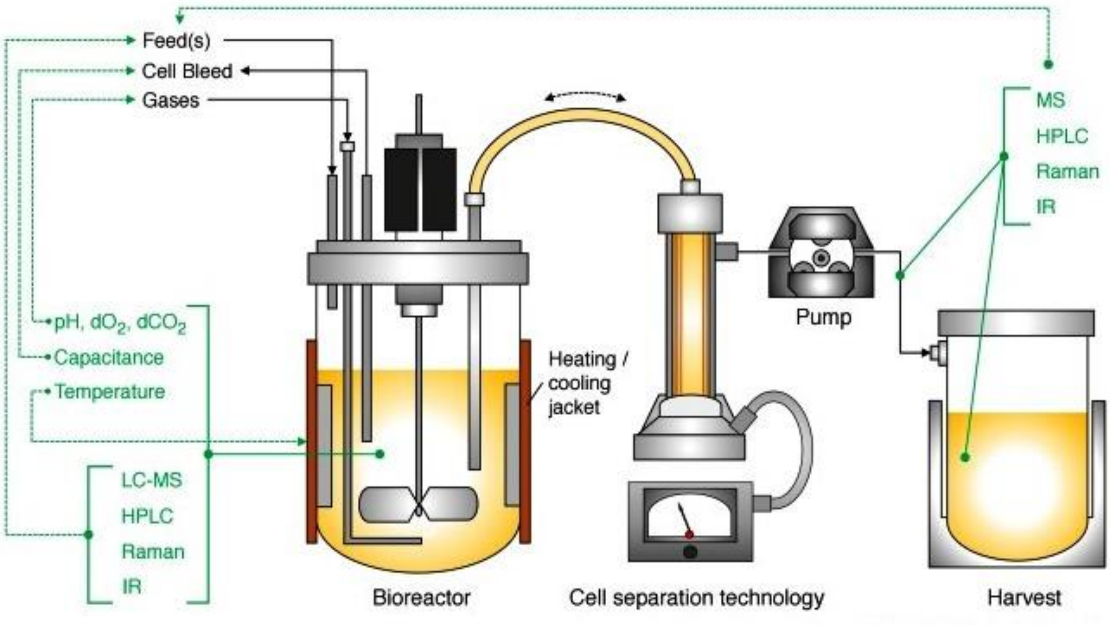

Fig - 1

Downstream technique to produce biodiesel

The synthesis of BD from nurtured microalgae necessitates a number of pretreatment measures before the lipid substance in the microalgae is transesterified. Microalgae from regions of growth must initially be collected, dried, and stripped of their lipids to serve as a raw material for BD manufacturing. The downstream processes of BD manufacture are schematically shown in figure. The subsections that follow provide a thorough explanation of each approach.

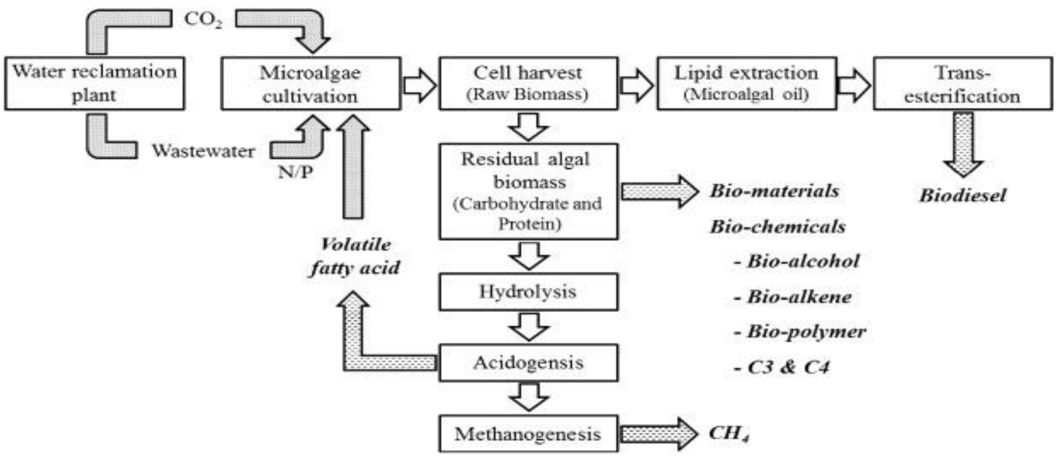

Fig-2

Life cycle analysis (LCA) of microalgae-based BD production

Compared to the the production of petrol, diesel, and first- and second-generation Bio diesel, the production of Bio diesel from microalgae may offer more environmental benefits. For the past 20 years, several research teams have mostly conducted life cycle assessment (LCA) studies to determine the advantages of biodiesel made from microalgae. Both upstream and downstream procedures that are being used today, such culture, harvesting, drying, lipid extraction, and transesterification, were employed to create microalgae-based biodiesel.

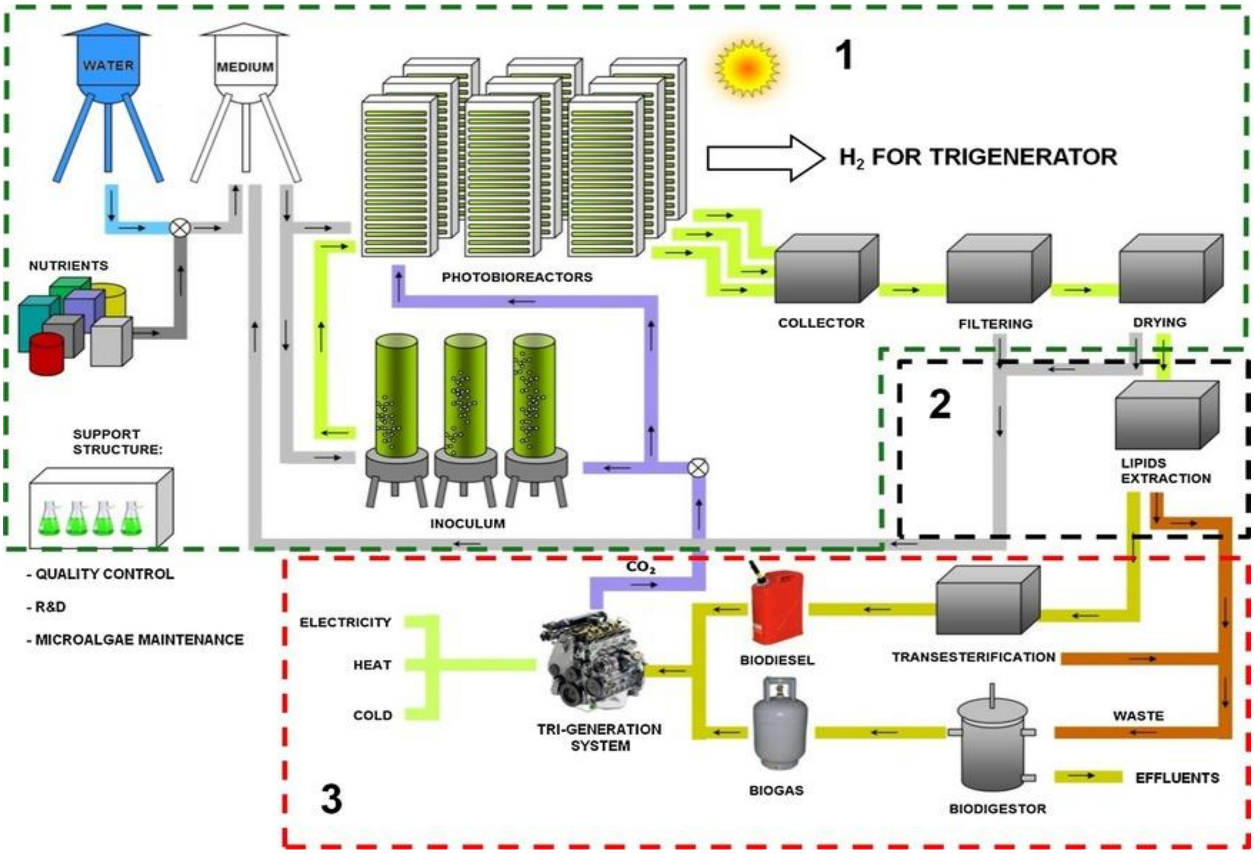

Fig - 3

Development of microalgae-based biodiesel: A Techno-Economic Analysis

Numerous research conducted techno-economic analysis to figure out how much it would cost to produce BD from microalgae. When 500 tonnes of lipid were generated yearly from Chlorella vulgaris, phototrophic (autotrophic) cultivation was 65 times greater in cost to maintain than phototrophic farming. utilising the phototrophic technique of Chlorella vulgaris production, one kilogramme of lipid cost $480 to generate as opposed to $7.5 when utilising the heterotrophic approach.

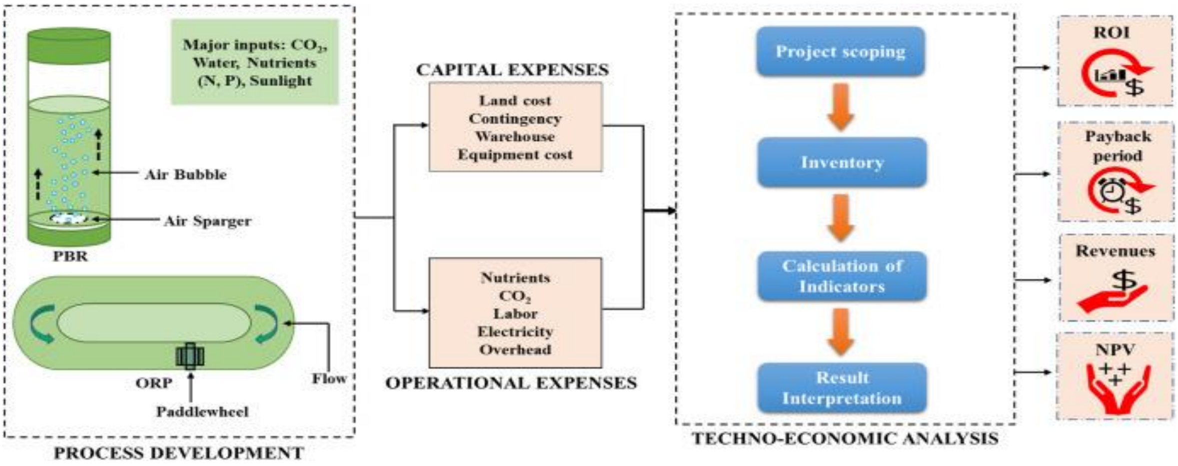

Fig-4

Large scale microalgae production

Large-scale cultivation of microalgae and their transformation into BD must be accomplished in order to efficiently employ microalgae as feedstocks (i.e., lipids) for commercial BD. Since there are so many factors impacting growth that might change, such as the level of light, oxygen in solution concentration, stirring speed, etc., scaling up microalgae production can be a daunting process. The production of microalgae and lipids is also significantly influenced by the geological circumstances of the expanding system.

Integrated methods for appraising microalgae

Lipid from microalgae has been employed as a feedstock for the generation of biodiesel. As shown in Table 2, the lipid concentration of several microalgae ranges from 6 to 63 wt%. In addition to their metabolisms, microalgae also include lipids, proteins, and other compounds. In order to make microalgae more appealing as feedstocks for biorefineries, it will be necessary to transform all of their organic compartments into value-added products.

For biodiesel

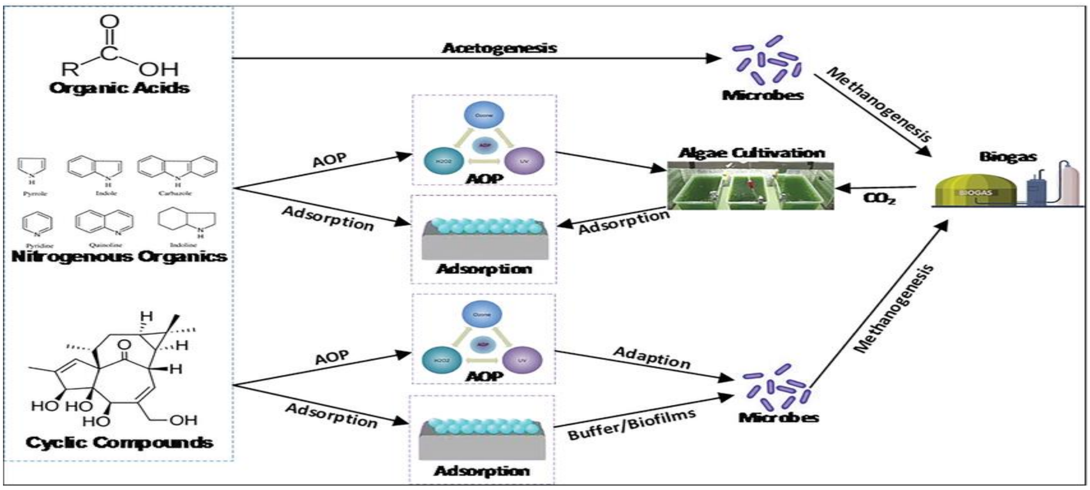

Fig - 5

Challenges and future prospects

The extraction of BD from microalgae may have more effectively environmental effects than BD produced from rapeseed and palm oil in regards to GWP, acidification as well as at cultivation sites, and human exposure [287,288]. Additionally, compared to first generation BD production, the quantity of arable land needed for a comparable amount of BD production may be reduced by 90% when employing microalgae [287,288]. But given current technological advancements, growing microalgae is relatively costly.

CONCLUSION

In this investigation, the prospective use of phytoplankton as a biodiesel (BD) feedstock was emphasised, and recommendations for commercialising microalgae BD were suggested. The heavy on energy and expensive pretreatment in order interprets of microalgae cultivation, dewatering, and drying, separating lipids from lipid, and eliminating free fatty acids and organic pollutants are one of the major technical obstacles in the production of microalgae BD, given the current scenario.

Conflict of Interest Disclosure

There are no conflicts of interest.

Recognition

Mister Jee Young Kim at the moment, Jee Young Kim is a Ph.D. candidate researching under Prof. Yoon-E Choi at Korea University's Biomass Utilisation Laboratory in Seoul, Korea. His study concentrates on the consumption of metabolites and biomass from microalgae.

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