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BIODIESEL PRODUCTION FROM MICROALGAE

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Abstract: *Biofuels production have received much attention due to the increasing global climate changes. Recently, research interest has focused on the microalga, due to the fact that has shown high potential for lipids accumulation. Based on the preliminary results obtained, a technology for the production of biodiesel from Nannochloropsis oculata microalgae was identified taken into account the lipids extraction and the algae oil transesterification. The biodiesel obtained followed the requirements of the SR EN 14214:2010 standard.*

Keywords*: biofuels, microalgae, biomass, lipids, cyanobacteria, transesterification, oil extraction*

1. Introduction

The production of biofuels has recently received much attention worldwide due to the widespread use of fossil fuels such as petroleum, coal and natural gas that cause several environmental consequences [1,2].
The most common biofuels are biodiesel and bio-ethanol, which can replace diesel and gasoline, respectively, and they are mainly produced from biomass or renewable energy sources [3].
First generation of biofuel have the potential to increase the cost of food crops making biodiesel production more expensive. Second generation biofuels do not affect food security and have significant advantages over first generation oil crops. Third generation biofuels source, microalgal oil represents a viable alternative, in terms of social and economic acceptability and can potentially be employed for the production of biofuels at rates high enough to replace a substantial fraction of the fossil fuels usage [4,5].
Microalgae are prokaryotic as Cyanobacteria (*Cyanophyceae)* or eukaryotic photosynthetic microorganisms, for example green algae (*Chlorophyta*) and diatoms (*Bacillariophyta*) that can grow rapidly and live in harsh conditions due to their unicellular or simple multicellular structure [3,6]. Among other feedstocks available for biodiesel production, microalgae have advantages as, high growth rates, higher photosynthetic efficiency, higher biomass production, high lipid contents. Moreover, according to biodiesel standard published by the American Society for Testing Materials (ASTM), biodiesel from microalgal oil is similar in properties to the standard biodiesel, and is also more stable according to their flash point values [2]. Several microalgae have shown potential for biofuels production including *Chlorella* sp*., Scenedesmus* sp., *Nannochloropsis* sp., *Botryococcus braunii*, Chlamydomonas reinhardtii due to their relatively higher lipid content [7,8].
Biodiesel production involves solvent extraction of the lipids from algal biomass and a chemical reaction called transesterification in which triglycerides react with methanol or ethanol in the presence of a catalyst to yield fatty acid methyl esters (FAME). Transesterification process lowers the viscosity of the oil and enhances its volatility [8,9].
The aim of this study is to give an overview of microalgae as a potential source for biodiesel production.

2. Microalgae lipid content for biodiesel production

Many microalgae species can accumulate substantial quantities of lipids, thus contributing to a high oil yield. The average lipid content varies between 1 and 70% but under certain conditions some species can reach 90% of dry weight. Table 1 presents lipid content of different microalgae species [3]. Also Cyanobacteria, have been studied for biodiesel production. Anahas and

Muralitharan reported that, among the eleven heterocystous cyanobacterial strains tested, surprisingly, the top biomass producer was *Calothrix sp*. MBDU 013, while its lipid content was lower than *A. sphaerica* MBDU 105, which stand second in terms of lipid productivity. On the other hand, *Nostoc sp*. MBDU 013, *Anabaena* sp. MBDU 006 and *Nostoc sp*. MBDU 007 showed a lower lipid content. Similar results were reported by Da Ros for filamentous heterocystous cyanobacterium, *Trichormus sp*. CENA77 with maximum lipid productivity for the unicellular cyanobacterium, *Synechococcus sp*. PCC7942. Therefore, biomass productivity may be considered as an adequate criterion for biodiesel production only when associated with lipid productivity [10]. In case of using the *Microcystis aeruginosa*, by a two-stage process, such as coagulation followed by flocculation, 90.1% of lipids were converted to biodiesel [11]. By comparing two freshwater cyanobacteria, *Oscillatoria* sp. 50A and *Synechocystis sp*. NN, the findings clearly suggest that the *Synechocystis sp*. NN can be used as a suitable feedstock that is amenable for cultivation using wastes as nutrient source [9]. Singh et al., sustain that based on the recent advances in designing more efficient metabolic pathways in cyanobacteria, it is hoped that cleaner and safer energies are produced in the future to meet market demands at competitive prices [12].

TABLE 1: Lipid content

Microalgae species	**Lipid content (% dry weight biomass)**
Ankistrodesmus sp.	24-31
Chlorella sp.	10-48
Chlorococcum sp.	19.3
Dunaliella sp	17.5-67.0
Ellipsoidion sp.	27.4
Isochrysis sp.	7.1-33
Isochrysis sp.	7-33
Nannochloris sp.	20-56
Nannochloropsis sp.	12-53
Nitzschia sp.	16-47
Scenedesmus sp.	19.6-21.1
Skeletonema sp.	13.3-31.8
Tetraselmis sp.	12.6-14.7

3. Microalgae biodiesel value chain stages

All existing processes for biodiesel production from microalgae include a production unit where cells are grown, followed by the separation of the cells from the growing media and subsequent lipids extraction.

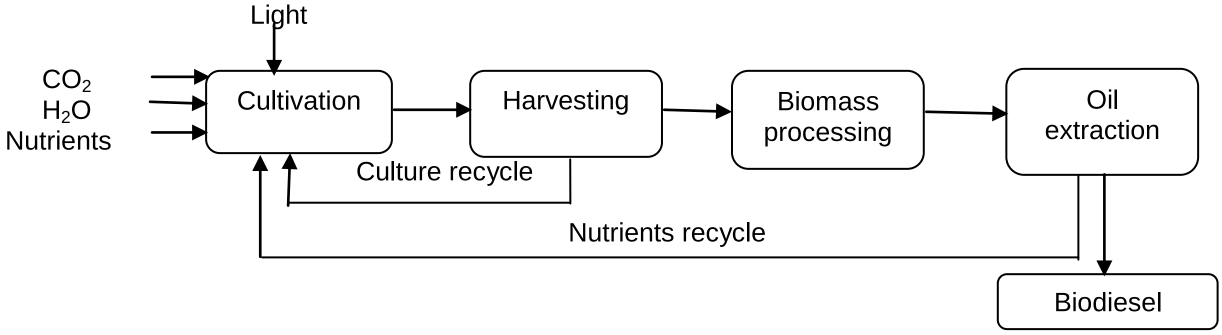

Fig. 1. Schematic representation of the algal biodiesel value chain stages

Fig. 1 shows a schematic representation of the algal biodiesel value chain stages, starting with the cultivation system for microalgae growth, biomass harvesting; then, it follows the processing and oil extraction to supply the biodiesel production unit [3].

4. Transesterification technologies in the production of biodiesel

In the process of transesterification, alcohols such as, methanol, ethanol, propanol, butanol, and amyl alcohol are key substrates. Methanol is applied more widely because of its low-cost and physical advantages. Several techniques, such as alkali, acid, or enzyme catalysed processes may be applied in transesterification. The advantages and disadvantages of these methods are presented in Table 2. It was found that alkali catalysts have higher reaction rate and conversion than acid catalysts for the transesterification of triglyceride. In the process, the free fatty acid (FFA), may react with the alkali catalyst to form soap and water. In order to prevent the loss of alkali catalysts in the process of reaction, additional catalysts must be added to compensate for the catalyst loss to soap [2].

TABLE 2: Transesterification technologies [2]

Type of transesterification	Advantages	Disadvantages
Chemical catalysis	The reaction conditions can be controlled Large scale production The methanol produced can be recycled The cost of the production process is cheap High conversion of the production	The reaction temperature is relative high and the process is complex The process need much energy The later disposal process is complex An installation for methanol recycle is required
Enzymatic catalysis	Moderate reaction condition are necessary Small amount of methanol is required No pollution to natural environment	Limitation of enzyme in the conversion of short chain of fatty acids The chemicals are poisonous to enzyme
Supercritical fluid techniques	Easy to be controlled It is safe and fast It is friendly to the environment	High temperature and pressure in the reaction condition leads to high cost of production and waste energy

5. Preliminary results

In the NUCLEU project a lab technology was realized for the production of the 3rd generation of biodiesel from algae. The technology presents the following stages: oil extraction from *Nannochloropsis oculata* microalgae with hexane, using dynamic extraction (Soxhlet extraction) followed by the algae oil transesterification, using a transesterification process in two stages: a pretreatment stage with acid for free fatty acids transmethylation, followed by alkaline catalysis for the conversion of triglycerides into methyl ester. The experiments for algae oil extraction with hexane were carried out with the following objectives: mass ratio hexane: algae and extraction time (extraction efficiency) [13].

The experiments for the algae oil transesterification with methanol were carried out taken into account the following parameters: molar ratio: methanol: oil, KOH quantity as catalyst, reaction temperature, agitation speed, reaction time, in order to determine the reaction transesterification efficiency. Also, the material balance, for the algae oil transesterification reaction with methanol in alkaline catalysis and in the pretreatment stage with acid was carried out [13].

The analysis of the biodiesel obtained with the realized technology showed that the quality requirements of the SR EN 14214:2010 standard were obeyed, except for iodine index, which reflect the degree of unsaturation of the feedstock. In order to remove the problems of biodiesel stability in time, the biodiesel obtained should be subjected to a hydrogenation step to decrease the level of unsaturation and thus it increases the oxidation stability [13].

6. Conclusions

The findings clearly suggest that the biofuels obtained from algae has the potential to revolutionize the energy industry playing a leading role in the fight against greenhouse gas emissions.
The preliminary studies showed that the *Nannochloropsis oculata* microalgae are a potential feedstock for biodiesel production.
The analysis of the biodiesel obtained from the microalgae oil showed that the quality requirements followed the SR EN 14214:2010 standard.

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