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Biofuels from Microalgae, A Promising Alternative

L Pérez*

Chemical Engineering Department, EEI, University of Vigo, 36310 Vigo, Spain

Serious environmental problems have been caused by excessive use of fossil fuels, especially in the automotive sector. Climate change, deterioration of the ozone layer and acid rain are some of the consequences thereof. Given the need to seek new sources of energy more respectful with the environment, scientists have focused their attention on biofuels. Among them, biodiesel produced from microalgae has emerged as a promising alternative. High growth rate, high capacity for lipid accumulation, CO_2 absorption capacity and ease of cultivation both outdoor tanks (raceway) as in closed reactors (photobioreactor) are some of the advantages exhibited by microalgae [1].

However, despite the excellent properties exhibited by microalgae, the price of algal biodiesel is not yet sufficiently competitive. Several consecutive stages such as culture, harvesting, dewatering, oil extraction and transesterification are necessary for obtaining this biofuel. The optimization of these stages is being investigated by researchers with the aim of achieving large-scale biodiesel production at a reasonable price. High costs are derived from biomass harvesting stage, around 20-30% of overall production costs of biodiesel [2]. Different microalgae harvesting technologies have been studied by several authors: flocculation, gravity sedimentation, flotation, filtration or pH induced. At present, the most promising method is pH induced flocculation. Barros et al. showed in their investigation that biomass recovery efficiency above 90% of *Dunaliella tertiolecta* microalgae was reached when the pH was brought to values of 10.5 by adding of NaOH. It can be due to neutralization of the charges present at the microalgae surface with consequent formation of large aggregates and subsequent sedimentation [3]. Furthermore, this low cost harvesting method allows reuse the culture medium by pH neutralization. After that, dehydration of microalgae is necessary. Centrifugation is postulated as one of the most efficient dewatering technique of algal biomass. By other hand, different algae oil extraction techniques can be applied to the dewatered biomass: Soxhlet, microwave (MW) or ultrasound (US) are the most prominent. The efficiency of these techniques depends largely on the solvent or solvent mixture used. Acetone, hexane, chloroform, methanol and a mixture of chloroform-methanol are most often used. Similar oil extraction yields can be obtained by microwave and ultrasound methods. Times much higher (about 8 hours) are required by the conventional Soxhlet to achieve similar yields than those obtained by MW or US in only 30 min^{-1} h.

Finally, biodiesel is obtained by transesterification and the process can be performed in 2 ways: the extracted algal oil is transesterified or dehydrated algal biomass is directly transesterified, avoiding the previous stage oil extraction. In both cases, a solvent or solvent mixture and a catalyst are needed. A complete study of Koberg et al. for *Nannochloropsis* microalgae showed that 37.1% biodiesel (% biodiesel yield based on dry biomass) was obtained by MW direct transesterification of algal biomass [4]. However, if the transesterification was performed in two steps by extraction and transesterification both MW, the yield decreased to 32.8%. If US was applied instead of MW, 20.9% of biodiesel was obtained for direct transesterification and 18.9% for the transesterification in 2 steps. A time of 5 min was employed for both direct and transesterification in 2 steps and a time of 2 min was used for oil extraction. A mixture of methanol-chloroform 1:2 v/v was employed in all cases studied and SrO was used as catalyst.

Based on published data, it can be concluded that MW could be the most effective technique for biodiesel production and the mixture of solvents chloroform-methanol is the most suitable to perform both oil extraction and transesterification.

As an added value to biodiesel production, algal waste generated in the process can be used as feedstock for pellets manufacturing, an appreciated fuel for biomass boilers. Thus, 2 valuable biofuels can be obtained from microalgae: biodiesel and pellet. With the advances being made today, the biodiesel use of large scale will be achieved in a short period of time.

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***Corresponding author:** L Pérez, Chemical Engineering Department, EEI, University of Vigo, 36310 Vigo, Spain, Tel: +34986812000; E-mail: leticiaperezrial@gmail.com

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