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Kinetic and thermodynamic evaluations of oil extraction from immobilized *Chlorella vulgaris* using different solvents

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ABSTRACT

Investigating the effect of different solvents used for microalgae oil extraction on the determinations of kinetic values and thermodynamic parameters is a compelling novel approach for the current study. The primary concern of microalgae oil extraction is selecting a solvent system because it has a massive influence on the extraction yield, composition, and oil quality. Three different solvent systems were inspected to determine the suitable solvent for the oil extraction from immobilized *Chlorella vulgaris*: heptane, heptane:methanol, and heptane:ethanol. The research methodology begins with the immobilization of microalgae cells. The matured immobilized beads were then harvested, and dried biomass was recovered. The oil was extracted by solvent extraction method using the solvents mentioned. Finally, the extracted oil was *trans*-esterified and analyzed for fatty acid methyl ester profile. Based on the results calculated, heptane is determined to extract the most oil with 27.42 %, followed by H:M and H:E at the highest temperature and longest running time. When the polar solvent is mixed with a non-polar solvent, the mixture has the least kinetic value and immense activation energy. However, the activation energy for heptane is only 89.06 kJ/mol. Another essential objective of this research is to determine the effects of solvents on the thermodynamics parameters. The extraction process of microalgae oil using heptane alone is determined to have a ΔH value of 0.111 kJ/mol, followed by 0.201 and 0.102 kJ/mol for solvent system H:M and H:E respectively. All the values obtained are positive, thus making the extraction processes using various solvents to be endothermic. The positive values of ΔS and the negative values of ΔG indicated that the oil extraction using heptane is thermodynamically spontaneous and irreversible, thus making it economically feasible. The fatty acids methyl esters such as palmitic, stearic, oleic, linoleic, and linolenic were the prime constituents quantified in the oil extracted using heptane compared to other solvent systems. Therefore, with the larger and increasing kinetic values and lowest activation energy, it can be concluded that heptane is the most suitable solvent for the oil extraction of immobilized *Chlorella vulgaris* compared to other solvent systems employed in the current research work.

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1. Introduction

Adverse circumstances correlated with first and second-generation biofuels making microalgae as third-generation feedstocks for quality biodiesel production [1,2]. Microalgae with no competition with food production can be a promising raw material to fulfill the demand for producing biofuels [3]. *Chlorella vulgaris*, one of the many microalgae species has attracted researchers as an ace choice for the biofuel industry thanks to its high growth rate, easy cultivation in different culture mediums, less risk of contamination, and its robustness to the environment [4–7]. Despite many positive notes, major drawback in converting microalgae into biomass is separating microalgae cells from its growth medium, known as microalgae harvesting. It is still considered a long-term objective to have a separation method without consuming high energy, low cost, and producing high-value lipids [7]. Therefore, the immobilization method has been actively introduced as a suitable harvesting method to eliminate all the previous obstacles [8].

Following with separation of microalgae, another vital stage for producing algal biofuel is oil extraction. Generally, the researchers

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