

***Optimization of the Esterification Process of Crude Palm Oil (CPO) Using
Heterogeneous Natural Zeolite Catalyst with Analysis of Variance Method***

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ABSTRACT

Crude Palm Oil (CPO) is the most competitive feedstock for biodiesel production in Indonesia; however, its utilization is often hindered by a high Free Fatty Acid (FFA) content. FFA levels exceeding 2% trigger a saponification reaction when reacted with a basic catalyst during the transesterification stage, thereby reducing biodiesel yield and complicating product purification. This study aims to reduce the FFA content of CPO through an esterification process using an acid-activated natural zeolite as a heterogeneous catalyst (activated with 2M H₂SO₄), with variations in reaction time (60, 75, and 90 minutes) and catalyst concentration (1%, 3%, and 5% w/v). The study employed a Completely Randomized Design (CRD) with a 2-factor factorial arrangement and 3 replications, analyzed using ANOVA and Duncan's Multiple Range Test (DMRT). The results showed that the combination of 90 minutes reaction time and 3% catalyst concentration (A3B2) yielded the highest FFA reduction, at 67.55%, with final CPO characteristics of 2.24% FFA content, 887 kg/m³ density, 4,33 cSt kinematic viscosity, 0.15% water content, and 0.17% sediment content. Statistical analysis revealed that reaction time, catalyst concentration, and their interaction had a highly significant effect on FFA reduction, with a non-linear pattern attributed to desorption and further hydrolysis/oxidation reactions occurring at the 75-minute mark. Although the final FFA content (2.24%) did not fully meet the SNI standard (max. 2%), these findings confirm the potential of natural zeolite as an environmentally friendly and economical heterogeneous catalyst for the pretreatment of high-FFA CPO.

Keywords: free fatty acid, Crude Palm Oil, esterification, heterogeneous catalyst, natural zeolite.