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A highly active clay-based catalyst for the synthesis of fatty acid methyl ester from waste cooking palm oil

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ABSTRACT

Local clay was prepared, characterized and used as catalyst for the synthesis of fatty acid methyl esters from waste cooking palm oil. Calcined raw clay at various temperatures was investigated and showed good activity for transesterification reaction when samples were treated at 830 °C for 4 h. The effects of parameters affecting the catalytic reaction, methanol to oil ratio, catalyst loading and reaction temperature in the range of 150–170 °C were investigated at fixed reaction time of 5 h. The obtained data showed that at methanol/oil ratio of 15:1, catalyst loading of 3.5 wt% and reaction temperature of 150 °C, the FAME content from the process was 96%. The catalyst is easily prepared and handled, avoiding the use of expensive rare earth metals in biodiesel production, easily separated from the reaction medium and could be reused up to three cycles.

1. Introduction

The subject of biodiesel and unearthing appropriate technology for its industrial production has dominated the global scene recently. Biodiesel is a renewable fuel obtained by the transesterification of vegetable oils using homogeneous and heterogeneous catalysts. However, associated problems with the homogeneous process (mainly in product purification and sludge generation) make the rummage for alternative become imperative. The new directed research is focused on the application of heterogeneous catalysts for biodiesel production and much effort is needed to find suitable solid catalyst with high activity at moderate reaction temperatures [1].

Several materials have been tested as heterogeneous catalysts in the transesterification of vegetable oils for biodiesel production. However, the reaction requires high temperatures to achieve good conversion to desired products and in some cases the catalysts require complex preparatory procedures, rare and expensive [2,3]. Also, high yield of FAME could be obtained at moderate reaction temperatures with other solid catalysts as have been demonstrated using ambient pressure and mild temperatures (lower than 70 °C) are able to yield methyl ester higher than 95% [4–8].

Kawashima et al. studied different metal oxides containing calcium, barium, magnesium, and lanthanum as heterogeneous base catalysts for biodiesel production. The catalysts with calcium in the mixed oxides ($CaTiO_3$, $CaMnO_3$, $Ca_2Fe_2O_5$, $CaZrO_3$ and $CaO–CeO_2$) showed high activities and the yield of methyl ester was close to 90% [9]. Leaching of active sites posed a major challenge to its further utilization [10].

In the industry, where efficiency and high productivity is required, the search for a heterogeneous catalyst developed from natural sources with high activity for biodiesel production in transesterification reaction is advantageous to the overall process. Clay is available in natural or modified forms and has several applications as catalytic material to carry out some typical industrial reactions [11,12]. Clay minerals are important constituents of the earth's crust not only because of their abundance but merely because of their chemical activity. For example, clay material is used in paper making, cement, and porcelain, sand castings, bricks, dishware, and glass industries and in the removal of heavy metals from waste water and air purification because it is an inexpensive, abundant and widely distributed raw material [13–16].

In the present work, locally sourced clay which has not been explored was used as highly active catalyst in transesterification to produce fatty acid methyl esters (FAME) from waste cooking palm oil (WCPO) and was characterized to gain insights into its chemical structure. The effects of the clay composition and structure on the final transesterification activity, effects of different parameters, reaction time, methanol/oil molar ratio, catalyst loading and

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