Abstract

Owing to the ongoing advancement in technology, escalating population sizes and urbanization rate, fossil fuels (coal, petroleum oil and natural gas) remain attractive as an energy source to run most of the daily operations. Consequent to heavy consumption of fossil fuels, the world faces detrimental challenges such as future energy security and environmental concerns. Combustion of fossil fuels results in emission of greenhouse gases such as CO_2 and SO_2 thereby contributing to global warming and acid rain problems. These alarming challenges drive the need for exploration of alternative energy sources to reduce dependence on fossil fuels.

Presented in this dissertation is a study of biodiesel, a biodegradable, non-toxic and environmentally benign energy source as an alternative to petroleum-based fuels. Chemically known as fatty acid alkyl ester (FAAE), biodiesel is commonly produced from vegetable oils or animal fats in addition to methanol by a catalysed transesterification reaction. Currently, biodiesel is more expensive than petroleum diesel due to high operation costs incurred during the production process. Despite the high prices, biodiesel production continues to grow on an industrial scale across the world as supported by policy measures and biofuel targets.
Researchers have identified two main factors that contribute to high costs of biodiesel production; 1) type of feedstock and 2) type of catalyst used in the production process. Conventional methods of production use edible oils as feedstock. This becomes unjustified due to the potential price hikes in the food market owing to the prospective competition between fuel and food industries. As a result, numerous researchers reported on the use of cheap and non- edible feedstock oils such as waste cooking oil and animal fat.

However, the challenge with the use of non-edible oils is their high content of free fatty acids (FFA) which is unattractive for a smooth transesterification process, more especially when homogeneous base catalysts are used. Homogeneous base catalysts are widely used in current industrial biodiesel production methods because they yield faster transesterification processes due to increased reaction rates. However, these types of catalysts are much sensitive to FFA, so when high FFA content feedstock is used, a saponification reaction occurs which consequently reduces the yield of biodiesel. An additional process unit is required to reduce the FFA content via esterification process prior to the main transesterification reaction.

Furthermore, since the reaction mixture is homogeneously combined with the product, an additional process unit for product separation is required to recover the resulting biodiesel from the mixture, translating into additional production costs.

Researchers are currently exploring the use of heterogeneous catalysts, which tend to avoid the saponification reaction and reduce the need for an esterification reaction used as oil pre-treatment step to reduce FFA content. This dissertation is therefore dedicated to attaining a economic and environmentally attractive process for biodiesel production using cheap non-edible beef tallow oil (BTO) and a heterogeneous hydroxy sodalite (H-SOD) catalyst.
Some industrial operations such as zeolite manufacturing processes produce a low grade H-SOD as by products, which is in turn disposed as chemical waste and therefore induces ground water contamination concerns. Exploration on the use of H-SOD as catalyst can largely contribute to the environmental protective measures as a waste management process among other benefits. The use of H-SOD is extensively reported in current research development on membrane separation; limited research reports on the use of H-SOD material to catalyse chemical processes are present in literature. For the first time in open literature, H-SOD is reported as the solid catalyst for biodiesel production in this dissertation.

The investigative study commenced with a preliminary study to gauge the feasibility of using H-SOD as a catalyst where a batch transesterification of waste cooking oil (WCO) was studied. The reaction was conducted at 60 ^{o}C for 12 h at a methanol-to-WCO ratio of 7.5:1 using 3 wt. % H-SOD catalyst with a particle size of just below 300 Å, the stirring intensity was kept at 1000 rpm to ensure uniform mixing throughout the reaction. The product obtained after the reaction was analysed using a pre-calibrated Chromatography-Mass Spectrometer (GC-MS) described in Chapter 5, and the results demonstrated the possibility of catalysing a transesterification reaction using solid H-SOD.

Under the same reaction conditions, the study was then extended to an investigation on the use of H-SOD to catalyze transesterification of BTO (4.53 % FFA) to FAME. The results showed that FAME was produced, at a yield of 39.6% and a conversion of 68.4%. Seeing that the yield and conversion obtained is relatively small compared to literature findings, the effect of some process conditions on the conversion and biodiesel yield were studied. The transesterification reaction was conducted with variations in the mixing intensity (700 – 1250 rpm), catalyst particle size (200 – 300 Å), reaction time (6 – 24 h) and reaction temperature (40-60 °C). The

maximum performance of H-SOD catalyst for a transesterification of BTO was achieved with a conversion of 78.3% and biodiesel yield of 62.9% obtained at optimum conditions: a stirrer speed of 1000 rpm, with the smallest catalyst particle size of 200 Å at maximum temperature of 60 °C and 24 h reaction time. The values of activation energy, reaction constants and frequency factor obtained from the kinetic study were 0.0011 min^{-1}, 5.52 $x10^{8}$ min^{-1} and 79.20 kJ/mol, respectively, and are within the range of the results reported in literature. As a result, solid H-SOD is recommended as a catalyst for the batch transesterification of BTO in a biodiesel production process.