# CHAPTER VIII

# CONCLUSIONS AND RECOMMENDATIONS

## 8.1 Conclusions

In this work, the heterogeneous catalysts, KOH/NaY, KOH/mordenite and KOH/bentonite, were capable of being used as solid base catalysts for biodiesel production via transesterification in batch and packed-bed reactors. The condition parameters studied were reaction time, percentage of potassium loading, methanol to oil molar ratio, amount of catalyst, reaction temperature, and stirrer speed or flow rate. It has demonstrated that obtained biodiesel yield over 90% was effectively taken place over these heterogeneous catalysts under reaction temperature below 65 °C.

The performance of a series of KOH loading on solid support for the transesterification was evaluated. It was found that the uncalcined catalyst showed higher catalytic activity compared to the calcined catalysts because physical structure and chemical composition of the catalysts were not destroyed by high temperature. In addition, the catalytic activities of KOH on solid support associated with the basic properties of the catalyst. Increasing potassium can generate the strong basic site between potassium and solid support; however, excess potassium results in coverage of basic site that cause to decrease the biodiesel yield.

The reusability of the catalyst was also investigated in order to observe leaching of the active species from the catalyst. The zeolite and clay supported by KOH exhibited low leaching of active species, higher rate and better stability due to the presence of strong basic site in the framework. However, the biodiesel still dropped gradually which could be due to glycerol blockages on the active sites which were indicated by a decrease in the basicity of spent catalyst. Although the spent catalyst was washed with methanol, and glycerol was removed, the activity of spent catalyst still dropped because of ability of methanol which resolves the active site. Then, the spent catalysts, washed with acetone or methanol, were not being able to restore their catalytic activity. When the spent catalysts treated with KOH solution could revive their catalytic activity almost the same as a fresh catalyst.

The comparison between the two different types of reactor for biodiesel production using KOH loaded on the NaY, mordenite, and bentonite was found that the batch experiment took a reaction time less than 5 h, while the packed-bed reactor required reaction time approximate 6 to 10 h to receive methyl ester over 90 %. Although satisfactory production time of these catalysts in the batch reactor had been achieved, the packed-bed reactor system appeared to have a slightly higher biodiesel yield during successive runs, corresponding to the results from XRF that the amount of potassium leaching of the catalyst in the packed-bed reactor was lower than that in the batch reactor. Therefore, the catalyst operated in packed-bed reactor exhibited suitable performance to product biodiesel.

The KOH/bentonite was studied in continuous reactor. The reaction was carried out under laminar flow (Re < 2300) condition. Without external and internal mass transfer limitation, the rate of reaction was calculated and activation energy of this catalyst was obtained of 45.24 kJ/mol. Moreover, the continuous reactor had operated for up to 144 h with almost no loss in productivity, implying that this process could provide a promising solution for the biodiesel production at the industrial scale.

## 8.2 Recommendation

Although the series of KOH loading on a solid support created an excellent activity, the preferred reaction time for packed-bed reactor is very long when compared to a commercial biodiesel. These catalysts are not sensitive to vegetable oil which had amount of free fatty acid less than 0.5 wt%; however they are not performed well when oil has fatty acid higher than 1 wt%. A bi-functional catalyst, which can accelerate both esterification and transesterification, is interesting to improve more efficiency of solid catalyst for the industrial biodiesel, for example, $La_2O_3/ZnO$, $La_2O_3/Al_2O_3$, $La_{0.1}Ca_{0.9}MnO_3$, $La_2O_3/ZnO/ZrO_2$, and active carbon supported Ru catalyst.