Optimization of Biodiesel production from waste cooking oil using a membrane reactor

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A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering

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DECLARATION

I declare that this report is my own unaided work, unless otherwise stated. It is being submitted to the Degree of Master of Science to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

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Abstract

In view of the growing concerns over depleting energy resources, alternative renewable fuels such as biodiesel have been identified as a possible means of addressing the short fall in energy supply. The source of feedstock for biodiesel production has been an ongoing debate and waste cooking oil is seen as an ideal feedstock as it can be sourced from restaurants, schools, industry and homes unlike vegetable oils which are part of the food chain. The process of biodiesel production has been vastly studied and the use of membrane reactors has been identified as a viable option. The need to obtain biodiesel of high quality at minimal cost has driven the idea of using membrane reactors, which have the advantage of combining reaction and separation simultaneously.

In this work, design and optimization studies were conducted to the efficiency of the membrane reactor for commercial small scale production of biodiesel from waste cooking oil. A process was developed to simultaneously overcome the shortcomings of waste cooking oil and the use of homogenous catalysts with the aid of membrane technology and heterogeneous catalysts. Tax laws in South Africa encourage small batch scale production of biodiesel. Therefore, the aim of this study is to apply and optimize biodiesel production from waste cooking oil, on a small-scale production level using a membrane reactor and heterogeneous catalyst coupled with a pretreatment stage.

The pretreatment of waste cooking oil was effective in reducing the free fatty acid content to desired levels so as to avoid the saponification side reaction which hinders the effectiveness of the desired trans-esterification reaction. The yield of biodiesel upon reusing the catalyst was high and satisfactory. It is suggested to investigate the reusability of the catalyst further as only two runs did not show a significant change in the yield of biodiesel.

The central composite method of response surface methodology was utilized to investigate the effect of reaction temperature, catalyst concentration and circulation flow rate on biodiesel yield and also obtain the optimal operating conditions. A micro porous membrane packed with KOH catalyst adsorbed on activated carbon was used for the transesterification reaction. The reaction was allowed to continue for a fixed time of 60 minutes and a methanol to oil molar ratio of 23:1. Upon optimization, a biodiesel yield of 94.03 mol % was obtained at a temperature of 58.5 ℃, circulation flow rate of 18.78 ml/min and catalyst concentration of 1.24 wt %.