ABSTRACT

Fossil fuel based energy sources are not sustainable because of environmental impacts, economic dependence and energy security issues. Thus, it is important to find an alternative energy source that is renewable, sustainable and environment friendly. This pushes the attention in areas such as biomass, hydrogen, fuel cells and solar cells. Carbon neutral renewable liquid fuels are needed to replace the petroleum derived transport fuels. Among all the renewable biofuel sources, biodiesel from renewable feedstocks including edible, non-edible oils, animal fats and micro algae seems more promising as an alternative sustainable as they are biodegradable and non-toxic.

Currently, feedstock alone represents more than 75% of the overall biodiesel production cost. Therefore, selecting the best feedstock is vital to ensure low production cost. It has also been found that the continuity in transesterification process is another choice to minimize the production cost. Biodiesel is currently not economically feasible and more research and technological development are needed. Thus, it is important to promote biodiesel research and make their prices competitive with other conventional sources of energy. Exploring ways to reduce the high cost of biodiesel is of much interest in recent biodiesel research. So the use of cheap and non-edible vegetable oils, animal fats and waste oils as raw feedstocks for biodiesel production is an effective way to reduce the cost of biodiesel.
The present work was undertaken to identify and investigate new, potential and cheap feedstock for biodiesel production compared with refined and edible grade vegetable oils. An attempt has been made to produce and characterize biodiesel from three different non-edible seed *Sterculia foetida* (*S. foetida*), *Ceiba pentandra* (*C. pentandra*) and *Persea americana* (*P. americana*). The process requirement and properties of biodiesel depend on the nature of the vegetable oil to be used for preparation of biodiesel.

*S. foetida* oil is one of the non-edible oil that has not been fully investigated, as a raw material for the production of biodiesel. The oil content of the seed was 57 wt%. The extraction was established for finding solvent selection, seed to solvent ratio, kinetic parameters, thermodynamic parameters and activation energy. The oil extraction follows first-order kinetics and the yield was maximum at 1:12 seed to hexane weight ratio. Activation energy and activation thermodynamic parameters were determined as $E_a (466.85 \text{ kJ mol}^{-1})$, $\Delta H^\circ (446.51 \text{ kJ mol}^{-1})$, $\Delta S^\circ (-234.79 \text{ J mol}^{-1} \text{K}^{-1})$ and $\Delta G^\circ (545.87 \text{ kJ mol}^{-1})$. Complete physical and chemical properties of oil were analyzed using standard methods. The low acid value of 0.42 mg KOH g$^{-1}$ for fresh oil enables alkali catalytic transesterification. The different biodiesel production parameters like methanol to oil molar ratio, catalyst concentration and reaction temperature were examined. An optimum yield of 95.4 wt% with a conversion of 98.91% was achieved at 6:1, 0.9 wt% and 65°C respectively.

*C. Pentandra* is generally drought-resistant tree and its seeds were reported to have low feeding value due to its high fiber content and presence of tannins. At
present this oil has only limited application and the natural production of seeds remain under utilized. The oil yield of the seed was found to contain a mean value of 26.4%. The extraction process was optimized to select appropriate solvent, seed to solvent, quantity and temperature. The extraction process was observed with regard to the percent oil yield versus time, and the reaction order was found to be first-order kinetics by the differential method. The activation energy for the oil extraction kinetics of *C. pentandra* seed with hexane was $E_a = 9.18 \text{ kJ mol}^{-1}$, and the activation thermodynamic parameters at 60°C were $\Delta H^\ddagger (6.41 \text{ kJ mol}^{-1})$, $\Delta S^\ddagger (-261.76 \text{ J mol}^{-1} \text{K}^{-1})$ and $\Delta G^\ddagger (93.56 \text{ kJ mol}^{-1})$. *C. Pentandra* oil shows a high FFA content 28.71 mg KOH g$^{-1}$. This requires two-step acid base catalyzed transesterification. The acid catalyzed esterification is a pretreatment process employed to decrease the acid value of the feedstock below 2 mg KOH g$^{-1}$. Followed by alkali catalyzed transesterification to produce biodiesel. The influence of the major reaction parameters such as catalyst concentration, methanol to oil molar ratio, reaction temperature and time have been studied. The conversion of biodiesel was found to be 99.5% under the optimized conditions of 1.0 wt% KOH and 6:1 methanol oil molar ratio at 65°C for a reaction time of 45 min.

*P. americana* seeds are waste from fruit processing industries, the have no economic value and considered as a solid waste. Oil extracted by Soxhlet method is 9.4 wt%. This low oil content facilitates the production of biodiesel through direct transesterification of *P. americana* seed. Its low level of Free Fatty Acids (FFA) favors alkali to catalyze the reaction. The method included solvent assisted *in situ* alkali-catalyzed transesterification. Experiments were conducted to determine the
selection of appropriate solvent, effects of catalyst, methanol weight, temperature, time, stirring rate and co-solvent amount. This process yields biodiesel of 94.4 wt% with respect to weight of total oil content in the seed. The optimum parameters were of 0.05 wt% catalyst, 1.5 g methanol, 65°C reaction temperature, 600 rpm stirring rate, 50 min reaction time and 30 g of Tetra Hydro Furan (THF) for 10 g of \textit{P. americana} seed.

The product biodiesel produced from these sources was washed, dried and properly stored in an air tight brown glass container for characterization studies. Biodiesel fuel properties were determined by ASTM test methods and compared with ASTM D6751 standards. It was found that the fuel properties complied with the limits as prescribed in the standards.