ABSTRACT

There has been an increase in research activities on biofuel in recent times due to urgent requirement for a viable alternative to conventional petroleum fuel. There are several important research issues related to biodiesel which are varied in forms amongst the different countries. In some countries, like India, identification of new feedstock addressing food-fuel conflict has been a major area of emphasis. Government of India has formulated policy for growth of biodiesel from non-edible feedstocks. Search for such new feedstock is also an important area of National Bio-Fuel Policy of the government. With the limited available land resources, forest based tree species could be one of the sustainable sources for biodiesel feedstock in India. However, target oriented research is required to ascertain such possibility.

Objectives of the present study are (i) to identify some oil bearing tree seeds of Northeast India having potential for biodiesel production, (ii) to investigate the fuel properties of biodiesel produced from oils of selected species, (iii) to study the oxidation and storage stability of biodiesel obtained from oils of selected species and investigation of efficacy of some phenolic antioxidants and (iv) to investigate the engine performance and emission characteristics of CI engine fueled with biodiesel obtained from the oils of selected species.

Two forest origin oilseeds of Terminalia belerica R. and Sapindus mukorossi G. trees are selected for this study. Oil content (w/w% of kernels) of Terminalia belerica and Sapindus mukorossi are found as 43% and 39%, respectively. Terminalia belerica oil composes of 39.5% saturated fatty acid and 60.5% unsaturated fatty acid. Palmitic (32.8%), oleic (31.3%) and linoleic (28.8%) acids are dominant in Terminalia belerica oil. On the other hand, Sapindus mukorossi oil composes of 16.5% saturated and 83.5% unsaturated fatty acids. Oleic (58.4%), linolenic (17.1%) and arachidic (7.5%) acids are the major constituents of Sapindus mukorossi oil. Overall, fatty acid profiles of both the oils are found as suitable feedstock for biodiesel production.
Oil samples of both the oils are also characterized as per the standard procedure. Acid value of *Terminalia belerica* oil is found as 8.01 mgKOH/g, which is less than the acid value of *Sapindus mukorossi* (15.6 mgKOH/g) oil. There are also differences in characteristics of these two oils which are expected to reflect in varying fuel properties of the resultant biodiesel. Moreover, the transesterification requirement would also vary between *Terminalia belerica* and *Sapindus mukorossi*, as they have varying level of acid values. However, overall results of vegetable oil characterization show both of these seed oils as prospective feedstock for biodiesel production.

Alkaline catalytic transesterification process is chosen for production of biodiesel from *Terminalia belerica* oil. A Molar ratio of 10:1 (alcohol: oil) and 1 wt% catalyst (NaOCH₃) concentration results 93% yield for *Terminalia belerica*. Two step transesterification is followed for *Sapindus mukorossi* oil as its acid value is higher. Conversion yield of 92.5% is obtained with 8:1 (alcohol: oil) and 1 wt% catalyst (NaOCH₃) concentration for *Sapindus mukorossi* oil. ¹H NMR and ¹³C NMR spectral analyses are conducted to ensure production of biodiesel.

Standard experimental procedures are followed to investigate the fuel quality parameters (viz., density, viscosity, calorific value, acid value, flash point, cloud point, pour point, ash content, carbon residue, copper strip corrosion, IBP/FBP, water content, sulphur content, cetane number, lubricity and oxidation stability) of biodiesels obtained from both the seed oils. Moreover, elemental analysis for determination of carbon, hydrogen and oxygen for both the biodiesel samples are also carried out. Overall, almost all the above fuel quality parameters for both the biodiesels are found to confirm the existing biodiesel norms except sulphur content and oxidation stability.

Induction period (IP) is considered as an index for evaluation of oxidation stability of biodiesel in the present investigation. Efficacy of six phenolic antioxidants viz., vitamin E (α-tocopherol), butylated hydroxyanisole (BHA), pyrogallol (PY), propyl gallate (PG), tert-butylhydroxytoluene (BHT) and tert-butylhydroxyquinone (TBHQ) and their concentrations (viz., 100 ppm, 500 ppm, 1000 ppm, and 1500 ppm) are investigated for freshly prepared samples of biodiesel on the basis of IP. Overall, the efficacy of
Antioxidants are summarized as, PG>PY>TBHQ>BHA>α-tocopherol for *Terminalia belerica* biodiesel and PG>PY>BHT>TBHQ>BHA>α-tocopherol for *Sapindus mukorossi* biodiesel. Oxidation stability of biodiesel (B100) and its different blends (B5, B10, B20 and B30) are also assessed with and without antioxidant additives up to a storage period of 12 weeks considering three specific antioxidants viz., PG, TBHQ and BHT, with a concentration of 1000 ppm. For freshly prepared biodiesel blends, the activities of antioxidants are in the order of, PG>BHT>TBHQ for both the biodiesels.

The blended biodiesel (B5, B10 and B20) of both the types are tested in a 39 kW CI type test engine. Results of blended biodiesel are compared with the performance results of petro-diesel. Brake power, brake thermal efficiency and specific fuel consumptions are determined at some arbitrarily varying load conditions. Overall, acceptable performances are observed for both the types of biodiesel (*Terminalia belerica* and *Sapindus mukorossi*) up to 20% blending. Experiments are also performed to assess the engine exhaust emission of CO, NO<sub>x</sub> and HC during engine operation fueled with blended biodiesel of both the types. It is found that with increase in biodiesel percentage in blends, the emission of CO and HC decreases for both the cases. However, increase in NO<sub>x</sub> emission with biodiesel fuel is observed compared with diesel fuel.

Both the non-edible oil seeds are suitable feedstock for biodiesel production. The outcomes of this study would be useful to stimulate the growth of biodiesel based on the forest resources which otherwise remain unused. Entrepreneurial activities at nearby forest areas could be enhanced and this is important for the economically backward regions like North-Eastern India. Economic analysis and long term engine testing could not incorporate in the present study and suggested for future work.