ABSTRACT

The aim of this study was to obtain biodiesel from crude mahua (*Madhuca indica*) oil (CMO) and to conduct its engine performance and emissions tests vis-à-vis high speed diesel (HSD). A biodiesel processor consisting of a 5 l capacity main reactor, heater, temperature controller, pump and a separating funnel was designed and fabricated to obtain biodiesel from CMO having 19% FFA content by a two step 'acid-base' process; acid-pretreatment followed by main base-transesterification reaction. The pretreatment process was optimized for reducing the FFA content of oil to less than 1% by using response surface methodology (RSM) and a central composite rotatable design (CCRD). The optimized parameters for pretreatment were found to be 0.32 v/v methanol-to-oil ratio, 1.24% v/v H_2SO_4 concentration, 1.26h reaction time and 60°C reaction temperature. After the reaction, the mixture was allowed to settle for 2h in a separating funnel. Two layers were formed, methanol-water mixture at the top and the pretreated oil at the bottom, which were then separated. The product separated at the bottom was used for the main transesterification using 0.25 v/v methanol, 0.7% w/v KOH, 0.5h reaction time and 60°C reaction temperature. The reaction mixture was allowed to settle for about eight hours before separating mahua biodiesel (MBD) and glycerine layers. This process gave more than 98% yield of MBD. The fuel properties namely, density, kinematic viscosity, calorific value, acid value, flash point, pour point, water content, ash content, and carbon residue of MBD, HSD and their blends (B0, B20, B40, B60 and B80) along with CMO were determined according to the standard ASTM procedures and were found to comply with the requirements of both the latest American (ASTM D 6751-02) and European (DIN EN 14214) standards for biodiesel.

The "constant speed (1500rpm) variable load (0, 25, 50, 75 and 100%)" tests were carried out in a Ricardo E6 engine using HSD, MBD and their blends at three different compression ratios (CR 18, 19 and 20) and three injection timings (IT 35, 40 and 45° before TDC) following a randomized complete block design. The engine performance and emissions were measured in terms of brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), exhaust gas temperature (EGT) and smoke, carbon monoxide (CO) and nitrous oxides (NOx), respectively. The BSFC and EGT increased, whereas BTE decreased with increase in the proportion of MBD in the blends. However, a reverse trend was observed with increase in the CR and advancement of IT for all fuels tested. The BSFC of mahua biodiesel and its blends with HSD reduced, whereas BTE and EGT increased with the increase in engine load. The smoke and CO reduced, whereas NOx increased with increase in percentage of MBD in the blends as well as with increase in CR and advancement of IT. However, the level of emissions increased with increase in engine load for all fuels tested. MBD could be safely blended with HSD up to 20% at any of the compression ratio and injection timing tested and up to 60% at 'CR20IT40' and with some sacrifices on fuel consumption, even the pure MBD could be used to replace the conventional HSD without significantly affecting the engine performance and emissions.

Keywords: mahua, biodiesel, performance, emissions, pretreatment, transesterification.