

ABSTRACT

Biodiesel is a promising alternative fuel for diesel engines that often requires no modifications for use. This study began by evaluating five different biodiesels: Sea Mango Methyl Ester (SMME), Borassus Flabellifer Methyl Ester (BFME), Prosopis Juliflora Methyl Ester (PJME), Used Cooking Oil Methyl Ester (UCME), and Albizia Amara Methyl Ester (AAME). The primary focus was on their thermal efficiency and emission reduction capabilities. Among these, BFME showed thermal efficiency similar to diesel and significant reductions in CO and HC emissions, though it had higher NO_x emissions.

BFME was selected for further investigation due to its lower viscosity, higher calorific value, and superior cetane number, confirming its potential as a diesel alternative. Various blends of BFME with diesel (20%, 40%, 60%, 80%, 100%) were prepared and compared to pure diesel. Performance, combustion, and emissions were tested on a single-cylinder diesel engine, and the B20 blend was identified as the optimal mix.

To enhance engine efficiency, the piston bowl geometry was modified from the standard shape to shallow combustion bowl (SCB), hemispherical combustion bowl (HCB), and toroidal combustion bowl (TCB). The combustion chamber was also coated with zirconium for thermal insulation, and various design modifications were implemented. The toroidal combustion bowl exhibited superior performance, reducing HC and CO emissions and enhancing thermal efficiency, despite increased NO_x emissions, making it the preferred chamber shape for the CI engine.

To address the higher NO_x emissions, nanoparticles were introduced to the BFME20 blend. Charcoal Cashew Shell Nanoparticles (CCSNP) were

chosen as the additive, in concentrations ranging from 25 to 75 ppm. The BFME20 nanoadditive blend was tested, showing significant reductions in NO_x emissions and moderate decreases in CO, HC, and smoke emissions. Improvements in brake thermal efficiency (BTE) and brake-specific fuel consumption (BSFC) were also observed with the addition of nanoparticles and low heat rejection (LHR) technology. The BFME20 blend with 50 ppm CCSNP demonstrated the best performance.

In the final phase, exhaust gas recirculation (EGR) was employed with the BFME20 nanoadditive blend. By mixing exhaust gases with intake air, cylinder and combustion temperatures were reduced, thereby lowering NO_x emissions. The effects of BFME20+CCSNP50ppm with 10%, 20%, and 30% EGR on engine performance were analyzed. The BTE results for BFME20+CCSNP50ppm at 0%, 10%, 20%, and 30% EGR flow rates were 31.7%, 31.2%, 30.8%, and 30.5%, respectively, compared to 31.1% for diesel. The study concluded that the direct injection of a CI engine with BFME20+CCSNP50ppm, using a toroidal combustion shape and LHR mode, results in improved combustion, reduced emissions, and enhanced performance.