STUDIES ON PRODUCTION OF ENRICHED BIOGAS USING JATROPHA AND PONGAMIA DE-OILED SEED CAKES AND ITS UTILIZATION IN I. C. ENGINES

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by

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in fulfilment of the requirements of the degree of
Doctor of Philosophy
to the

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Dedicated to .....

My Beloved Mother

CERTIFICATE

The thesis entitled "**Studies on Production of Enriched Biogas Using Jatropha and Pongamia De-oiled Seed Cakes and Its Utilization in I. C. Engines**" being submitted by ***Mr. Ram Chandra*** to the Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy**, is a record of *bona fide* research work carried out by him. He has worked under our supervision and has fulfilled the requirements for the submission of this thesis, which has attained the standard required for a Ph. D. degree of the Institute.

The results presented in this thesis have not been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

In the present investigation, the possibility of using jatropha and pongamia non-edible de-oiled seeds cakes for biogas production (through biomethanation process) has been explored in detail. Other major objectives of the research are to enrich methane content in biogas using an improved water scrubbing system and to utilize methane enriched biogas as a fuel for internal combustion engine. In order to accomplish these objectives, biomethanation of these de-oiled seed cakes, enrichment of biogas and performance testing of engine through enriched biogas has been carried out.

Characterization (proximate and ultimate analysis) of jatropha and pongamia de-oiled seed cakes establishes their suitability as alternative feed material for biogas production. This characterization analysis confirms that jatropha and pongamia de-oiled seed cakes have rich proportionate of volatile solids content, low non-volatile solids content, high hydrogen and high carbon content as compared to cattle dung. Though preliminary biomethanation study into batch mode (5.0 L glass reactors), it is established that previously developed inoculum environment inside the digester is mandatory requirement for proper digestion of these de-oiled seed cakes. This study also confirms that the addition of fresh cattle dung in newly formed substrates of jatropha and pongamia de-oiled seed cakes increases the biodegradability of substrates by providing suitable environment required for good methanogenesis phase. The second phase of biomethanation study is carried out in the digester of 300 L capacity by continuous feeding of the substrates. Phase third of biomethanation study is carried out for continuous feeding of jatropha and pongamia de-oiled seed cakes in a 20 m^3/d capacity floating drum biogas plant. The study under this phase has resulted into an average specific biogas and specific methane production potential of 0.640 m^3/kg VS and 0.422 m^3/kg VS, respectively for jatropha de-oiled seed cake and 0.738 m^3/kg VS and 0.448 m^3/kg VS, respectively for pongamia de-oiled seed cake. The study also confirms that the biogas produced from jatropha and pongamia de-oiled seed cakes contains about 15 - 20 % more methane content than biogas produced from cattle dung.

In order to study the kinetics of batch feed and continuous feed biomethanation process of jatropha and pongamia de-oiled seed cakes, first order kinetics model and Chen-Hashimoto model are applied. First order kinetics model using single linear regression equation has been found suitable for predicting the behavior of batch anaerobic digestion of these de-oiled seed cakes. It is also found that Chen-Hashimoto model is best suited for predicting the behavior of these de-oiled seed cakes in continuous mode of feeding. Furthermore, the dimensions of biogas plant digester for same biogas production capacity as that of cattle dung through jatropha and pongamia de-oiled seed cake are found to be reduced by 38.7 % and 41.9 %, respectively.

To achieve the objective of methane enrichment in biogas using water scrubbing system, installation of automation instruments in water scrubbing system is carried out. The performance of the improved system has been established in term of performance index and % methane enrichment. Furthermore, the performance of a 5.9 kW compression ignition engine converted into spark ignition mode has been evaluated in term of engine brake power output, engine speed, brake specific gas consumption, brake thermal efficiency and equivalence ratio of combustion for the tested fuels of compressed natural gas, methane enriched biogas and raw biogas produced from these de-oiled seed cakes. The engine test results on methane enriched biogas have showed that the engine performance is almost comparable to that of compressed natural gas.

The automation of water scrubbing system has resulted into steady state operation of the system and provided a consistent quality of methane enriched biogas, along with saving a significant amount of labour requirement.

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