

**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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INDIAN INSTITUTE OF TECHNOLOGY, DELHI**

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ITS UTILIZATION IN I. C. ENGINES**

by

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Centre for Rural Development & Technology

Submitted

**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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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 m³/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 m³/kg VS and 0.422 m³/kg VS, respectively for jatropha de-oiled seed cake and 0.738 m³/kg VS and 0.448 m³/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.

CONTENTS

| Sl. No. | Title | Page No. |
|--------------------|---|-------------------|
| | Certificate | i |
| | Acknowledgments | iii |
| | Abstract | v |
| | Contents | vii |
| | List of Figures | xiv |
| | List of Tables | xix |
| | Symbols and Abbreviations | xxii |
| Chapter - 1 | Introduction | 1.1 - 1.18 |
| 1.1 | General | 1.1 |
| 1.2 | Indian Energy Scenario | 1.2 |
| 1.3 | Indian Renewable Energy Scenario | 1.7 |
| 1.4 | Scenario of Bio-diesel Production and Potential of Non-Edible De-oiled Seed Cakes for Biogas Production | 1.10 |
| 1.5 | Biogas: Renewable Fuel and Need of Its Purification | 1.12 |
| 1.6 | Motivation for the Present Research Work | 1.14 |
| 1.7 | Aim of Present Research Work | 1.15 |
| 1.8 | Objectives | 1.16 |
| 1.9 | Organization of the Thesis | 1.17 |
| Chapter - 2 | Literature Review | 2.1 - 2.37 |
| 2.1 | The Biomethanation Process | 2.1 |
| 2.2 | Parameters Affecting the Process of Biomethanation | 2.5 |
| 2.2.1 | Effect of hydraulic retention time (HRT) | 2.5 |
| 2.2.2 | Effect of operating temperature | 2.6 |
| 2.2.3 | Effect of pH | 2.13 |
| 2.2.4 | Effect of substrate composition and consistency of feed material | 2.14 |
| 2.2.5 | Effect of total solids and volatile solids concentration (OLR) | 2.16 |

| Sl. No. | Title | Page No. |
|--------------------|--|-------------------|
| 2.2.6 | Effect of C/N ratio | 2.19 |
| 2.2.7 | Effect of inhibition due to free fatty acid | 2.20 |
| 2.3 | Studies on Jatropha and Pongamia De-oiled Seed Cakes as Alternative Feed Material for Biomethanation | 2.21 |
| 2.4 | Kinetics of Biomethanation Process | 2.23 |
| 2.5 | Methane Enrichment in Biogas Using Water Scrubbing System | 2.27 |
| 2.6 | Utilization of Biogas and Methane Enriched Biogas in I C Engines | 2.31 |
| 2.7 | Research Gaps | 2.35 |
| Chapter - 3 | Characterization of Jatropha and Pongamia De-oiled Seed Cakes and Development of Inoculum | 3.1 - 3.33 |
| 3.1 | Jatropha and Pongamia Tree, Seed, Oil and De-oiled Seed Cake | 3.1 |
| 3.2 | Proximate and Ultimate Analysis of Feed Materials | 3.6 |
| 3.2.1 | Proximate analysis | 3.6 |
| | 3.2.1.1 Moisture content | 3.6 |
| | 3.2.1.2 Oil content | 3.7 |
| | 3.2.1.3 Total solids content | 3.8 |
| | 3.2.1.4 Volatile solids content | 3.9 |
| | 3.2.1.5 Non-volatile solid content | 3.9 |
| 3.2.2 | Ultimate analysis | 3.10 |
| | 3.2.2.1 Carbon, hydrogen and nitrogen contents | 3.10 |
| | 3.2.2.2 Phosphorus content | 3.11 |
| | 3.2.2.3 Potassium content | 3.12 |
| | 3.2.2.4 Calorific value (higher heating value) of feed materials | 3.13 |
| 3.3 | Results of Proximate and Ultimate Analysis of De-oiled Seed Cakes and Cattle dung | 3.14 |
| 3.3.1 | Proximate analysis | 3.15 |
| 3.3.2 | Ultimate analysis | 3.16 |
| 3.4 | Preliminary Biomethanation Study on Batch Treatments | 3.18 |
| 3.4.1 | Dilution ratio and total solids concentration in substrates | 3.19 |
| 3.4.2 | Preparation of substrates and their properties | 3.20 |
| 3.4.3 | Experimental setup for batch biomethanation study | 3.23 |
| 3.4.4 | Parameters of biomethanation process and measurement methods | 3.25 |

| Sl. No. | Title | Page No. |
|--------------------|--|-------------------|
| 3.5 | Results of Preliminary Biomethanation Study | 3.28 |
| 3.6 | Need for Development of Inoculum | 3.30 |
| 3.6.1 | Development of special inoculum | 3.30 |
| Chapter - 4 | Biomethanation of Jatropha and Pongamia De-oiled Seed Cakes and Study of Kinetics | 4.1 - 4.81 |
| 4.1 | Experimental Phases of Biomethanation Process | 4.1 |
| 4.2 | Parameters of Biomethanation Study | 4.2 |
| 4.3 | Methodology adopted for determination of various parameters of biomethanation process | 4.4 |
| 4.3.1 | Ambient, substrate and biogas temperature | 4.4 |
| 4.3.2 | pH | 4.4 |
| 4.3.3 | Volume of biogas production | 4.4 |
| 4.3.3.1 | Estimation of dry biogas volume at STP | 4.5 |
| 4.3.4 | Measurement of CH ₄ and CO ₂ contents in biogas | 4.8 |
| 4.3.5 | Measurement of daily production of CH ₄ and CO ₂ | 4.9 |
| 4.3.6 | Measurement of cumulative production of biogas, CH ₄ and CO ₂ | 4.9 |
| 4.3.7 | Specific biogas production | 4.9 |
| 4.3.8 | Specific methane production | 4.10 |
| 4.3.9 | Total volatile solids mass removed | 4.10 |
| 4.3.9.1 | Estimation of total volatile solids mass removal efficiency | 4.11 |
| 4.4 | Phase I - Thorough Experimentation on Selected Batch Treatments | 4.12 |
| 4.4.1 | Experimental setup and parameters investigated | 4.12 |
| 4.4.2 | Selection and preparation of substrates | 4.13 |
| 4.4.3 | Inoculation of the substrates | 4.14 |
| 4.4.4 | Results of selected batch biomethanation process (Phase I) | 4.14 |
| 4.4.4.1 | Ambient and substrate temperature | 4.15 |
| 4.4.4.2 | pH of influent substrate and effluent slurry | 4.15 |
| 4.4.4.3 | Daily biogas production rate | 4.17 |
| 4.4.4.4 | Cumulative biogas production yield | 4.19 |
| 4.4.4.5 | Specific biogas production yield | 4.20 |

| Sl. No. | Title | Page No. |
|----------------|--|-----------------|
| | 4.4.4.6 Methane concentration in produced biogas | 4.25 |
| | 4.4.4.7 Total volatile solids mass removal efficiency | 4.27 |
| 4.4.5 | Conclusions | 4.29 |
| 4.5 | Phase II - Continuous Feeding Experimental Investigation on Selected Treatments in Digester of 300 Litre Capacity | 4.30 |
| 4.5.1 | Experimental setup and parameters investigated | 4.30 |
| 4.5.2 | Selection and preparation of substrates | 4.31 |
| 4.5.3 | Startup of the digester | 4.32 |
| 4.5.4 | Results of continuous feed biomethanation process (Phase II) | 4.32 |
| | 4.5.4.1 Ambient and substrate temperature | 4.32 |
| | 4.5.4.2 pH of influent substrate and effluent slurry | 4.33 |
| | 4.5.4.3 Daily biogas production rate | 4.34 |
| | 4.5.4.4 Variation of CH ₄ and CO ₂ contents in biogas | 4.36 |
| | 4.5.4.5 Cumulative biogas, CH ₄ and CO ₂ production yields | 4.37 |
| | 4.5.4.6 Specific biogas production yield | 4.38 |
| | 4.5.4.7 Specific methane production yield | 4.41 |
| | 4.5.4.8 Total volatile solids mass removal efficiency | 4.45 |
| 4.5.5 | Conclusions | 4.47 |
| 4.6 | Phase III - Continuous Feeding Experimental Investigation in Floating Drum Biogas Plant of 20 m ³ /d Capacity | 4.48 |
| 4.6.1 | Experimental setup and parameters investigated | 4.48 |
| 4.6.2 | Selection and preparation of substrates | 4.48 |
| 4.6.3 | Startup of the digester | 4.51 |
| 4.6.4 | Results of continuous feed biomethanation process (Phase III) | 4.51 |
| | 4.6.4.1 Ambient and substrate temperature | 4.51 |
| | 4.6.4.2 pH of influent substrate and effluent slurry | 4.52 |
| | 4.6.4.3 Daily biogas production rate | 4.52 |
| | 4.6.4.4 Methane and carbon dioxide contents in produced biogas | 4.54 |
| | 4.6.4.5 Cumulative production of biogas, CH ₄ and CO ₂ yields | 4.56 |
| | 4.6.4.6 Specific biogas production yield | 4.57 |
| | 4.6.4.7 Specific methane production yield | 4.59 |

| Sl. No. | Title | Page No. |
|--------------------|---|-------------------|
| | 4.6.4.8 Total volatile solids mass removal efficiency | 4.61 |
| 4.6.5 | Conclusions | 4.63 |
| 4.7 | Analysis of Biogas Plant Spent Slurry | 4.64 |
| 4.8 | Kinetic of Batch and Continuous Feed Biomethanation Processes | 4.65 |
| 4.8.1 | Kinetic of batch feed biomethanation process | 4.65 |
| | 4.8.1.1 Applied kinetics model | 4.65 |
| | 4.8.1.2 Results of batch biomethanation kinetics | 4.67 |
| 4.8.2 | Kinetics of continuous feed biomethanation process | 4.72 |
| | 4.8.2.1 Applied kinetic model | 4.72 |
| | 4.8.2.2 Results of continuous feed biomethanation kinetics | 4.73 |
| 4.8.3 | Conclusions | 4.75 |
| 4.9 | Biogas Plant for Biogas Production from De-oiled Seed Cake Substrates | 4.76 |
| 4.9.1 | Recommendations for use of existing biogas plant on de-oiled seed cakes | 4.76 |
| 4.9.2 | Dimensions of digester for dedicated biogas plant | 4.79 |
| Chapter - 5 | Biogas Enrichment Using Water Scrubbing System | 5.1 - 5.19 |
| 5.1 | General | 5.1 |
| 5.2 | Water Scrubbing System for Biogas Enrichment | 5.3 |
| 5.2.1 | Biogas enrichment unit | 5.3 |
| | 5.2.1.1 Scrubber | 5.3 |
| | 5.2.1.2 Water supply system | 5.5 |
| | 5.2.1.3 Gas supply system | 5.5 |
| 5.3 | Need for Modification in Biogas Enrichment Unit | 5.8 |
| 5.4 | Modified Water Scrubbing System (Biogas Enrichment Unit) | 5.8 |
| 5.4.1 | Automatic pressure controller at inlet of scrubber | 5.10 |
| 5.4.2 | Automatic water level controller | 5.10 |
| 5.4.3 | Automatic pressure controller at outlet of purified gas line | 5.11 |
| 5.5 | Working of the Modified Biogas Enrichment System | 5.12 |
| 5.6 | Performance of Modified Biogas Enrichment System | 5.13 |

| Sl. No. | Title | Page No. |
|--------------------|--|-------------------|
| 5.6.1 | Performance index of biogas enrichment system at selected pressure | 5.14 |
| 5.7 | Conclusions | 5.19 |
| Chapter - 6 | Utilization of Enriched Biogas in Internal Combustion Engines | 6.1 - 6.24 |
| 6.1 | Introduction | 6.1 |
| 6.2 | Engine, Test Rig and Parameters of Measurement | 6.2 |
| 6.2.1 | Engine test rig | 6.3 |
| | 6.2.1.1 Spark ignition engine | 6.3 |
| | 6.2.1.2 Dynamometer | 6.3 |
| | 6.2.1.3 Air consumption measurement | 6.4 |
| | 6.2.1.4 Engine speed measurement | 6.5 |
| | 6.2.1.5 Load board | 6.5 |
| | 6.2.1.6 Voltmeter and ammeter | 6.5 |
| | 6.2.1.7 Gas flow meter | 6.5 |
| 6.2.2 | Engine test parameters | 6.6 |
| | 6.2.2.1 Brake power (kW) | 6.7 |
| | 6.2.2.2 Brake specific gas consumption (g/kW-h) | 6.8 |
| | 6.2.2.3 Brake thermal efficiency (%) | 6.8 |
| | 6.2.2.4 Equivalence ratio, ϕ | 6.9 |
| 6.3 | Results and Discussion | 6.9 |
| 6.3.1 | Brake power developed | 6.10 |
| 6.3.2 | Engine speed | 6.12 |
| 6.3.3 | Brake specific gas consumption | 6.14 |
| 6.3.4 | Brake thermal efficiency | 6.16 |
| 6.3.5 | Equivalence ratio (ϕ) | 6.18 |
| 6.4 | Conclusions | 6.21 |
| Chapter - 7 | Conclusions and Scope for Future Work | 7.1 - 7.6 |
| 7.1 | Conclusions | 7.1 |
| 7.2 | Recommendations for Future Scope of Work | 7.6 |

References

R.1-R.10

Appendices

A.1-A.10