Production Of Bioethanol From Different Leaves Waste And Performance And Emission Characteristics Of Single Cylinder CI Engine

Sreenivas Reddy Bathula (✉ jaishwa@gmail.com)

<https://orcid.org/0000-0001-5910-2819>

Vikas S. Ballary

Bapuji Institute of Engineering and Technology

S. Kumarappa

Bapuji Institute of Engineering and Technology

A.M. Guruchethan

Bapuji Institute of Engineering and Technology

Harika Mali

Adama Science and Technology University

Research

Keywords: Saccharomyces cerevisiae, Leaves waste, Fermentation, Diesel engine.

Posted Date: June 30th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-35231/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background: The need of bioethanol is being increased nowadays; hence the production of bioethanol must be increased using cheaper and eco-friendly raw materials. Based on these criteria, different leaves wastes are considered as cheaper and eco-friendly. In the present study selected tree leaves wastes such as Rain tree, Jackfruit tree, Mango tree and Singapore cherry tree leaves waste were used as raw materials to produce bioethanol by using *Saccharomyces cerevisiae* (yeast). The operating conditions are pH 6.5, temperature $27\pm 2^{\circ}\text{C}$, speed 80rpm, fermentation period 10 days. Also an attempt has been made to find out the suitability of extracted bioethanol as a fuel in CI engine.

Results: Experimental work on performance and emission characteristics of ethanol blended diesel fuel was conducted on single cylinder four stroke CI engines at operating pressure 210 bar. The results obtained from this work shows that the higher rate of ethanol can be produced through fermentation of wet Jackfruit tree leaves, which gives good percentage of ethanol as compared to other tree leaves wastes.

Conclusions: The conversion of waste into fuel, which forms an attractive solution towards both waste management and Biofuels generation. This study concludes that the Jackfruit tree leaves contain rich fermentable sugar can be converted into useful products like bioethanol that can serve as an alternative energy source.

1. Background

The rapid depletions of fossil fuel create negative impact on our environment as greenhouse gas emissions are harmful. The need of fuel is increased because of increase in the vehicles and industries. By using biofuels greenhouse gas emissions are reduced. The production of bio-fuels from plant waste gives an attractive solution towards the waste management and energy generation. The bioethanol produced from feed stocks such as fruits rind part, barley, wheat, etc. In this present study the feed stocks selected are plant wastes such as Rain tree leaves, Jackfruit leaves as possible resources by conversion of plant wastes to fuel [1].

The use of starch and sugar from cassava, corn, and sugar cane are basically human food which leads to the food crisis problem. Agro-industrial bio-fuel comprised on lignocellulose biomass is an inexpensive, renewable, abundant and obtained from the non-food resource [2].

The production of ethanol from leaves involves two stages 1) Hydrolysis of biomass 2) Ethanol fermentation. Hydrolysis of Biomass can be done by using acid or enzyme catalyst. Using acid for hydrolysis produces hazardous environmental acid wastes and also causes difficulties in recovery of sugars. Enzymatic Hydrolysis is environmental friendly and efficient way to convert lignocellulose to bioethanol. The fermentation process is achieved from *Saccharomyces cerevisiae*. *Saccharomyces cerevisiae* is widely known organism that can utilize glucose and xylose for ethanol fermentation [3]. Because of more latent heat of vaporization and oxygen content, bioethanol produced from the

fermentation process are having high octane number and it is less polluting compared to Diesel. Because of their longevity, regeneration after cut-off the leaves are considered as one of the most suitable energy crops.

Samanea saman (Rain Tree) is a species of flowering tree in the *Albizia* family. The common name for Raintree includes Saman, monkey pod, giant thibet, ingasaman, cow tamarind, East Indian walnut, soar and suar. *Artocarpus heterophyllus* (Jackfruit) trees belongs to the *Moraceae* family. The jackfruit trees grow in India, Bangladesh and other parts of Southeast Asia. Jackfruit tree leaves are rich in starch and protein. *Muntingia calabura* (Singapore cherry) trees belong to a *Muntingiaceae* family [4]. The common name includes Jamaican cherry, panama berry, Singapore cherry. These thrive in poor soil, able to tolerate acid and alkaline condition and drought. *Mangifera indica* (Mango) trees belong to *Anacardiaceae* family. These trees belong to mangifera genus. These leaves contain 3–15% of lignin and 40% of cellulose.

Hence in our present study leaves waste are considered as raw material for the production bioethanol. This bioethanol is mixed with diesel at different percentages of blends [5].

2. Results And Discussion

2.1 Essay of ethanol from both Jackfruit and Rain tree leaves

After fermentation ethanol obtained from both Jackfruit and Rain tree leaves was estimated by GC-MS method. Description of the samples and estimated ethanol percentages were given in Table 1 and 2. The two bar graphs shown in Figs. 1 and 2 represents type of samples and ethanol percentage.

Table 1
Ethanol percentage identified by GC-MS after fermentation in
Jackfruit leaves sample.

Jackfruit Leaves Sample	Ethanol Assay (%)
1)Wet Jackfruit	4.34
2)Dry Jackfruit	1.60
3)Dry Jackfruit + NaOH	2.27
4)Dry Jackfruit + NaOH + HS	2.51
5)Dry Jackfruit + Na ₂ SO ₄	3.15
6)Dry Jackfruit + Na ₂ SO ₄ + HS	3.33
7)Dry Jackfruit + NaOH + Na ₂ SO ₄	3.51
8)Dry Jackfruit + NaOH + Na ₂ SO ₄ + HS	4.23
9)Dry Jackfruit + HS	1.93

Table 2
Ethanol percentage by GC-MS after fermentation in Rain tree
leaves sample

Rain tree Leaves Sample	Ethanol Assay (%)
1)Wet Rain tree	3.52
2)Dry Rain tree	0.97
3)Dry Rain tree + NaOH	1.04
4)Dry Rain tree + NaOH + HS	1.17
5)Dry Rain tree + + Na ₂ SO ₄	1.52
6)Dry Rain tree + Na ₂ SO ₄ + HS	2.02
7)Dry Rain tree + NaOH + Na ₂ SO ₄	2.30
8)Dry Rain tree + NaOH + Na ₂ SO ₄ + HS	2.46
9)Dry Rain tree + HS	1.02

From GC-MS results we have got more percentage of ethanol in wet jackfruit after fermentation. The percentage of ethanol in Wet jackfruit sample was found to be 4.34% and in dry Jackfruit leaves percentage of ethanol was found to be 4.23%. We have selected wet Jackfruit leaves for the scale up production of bioethanol.

The results obtained by performing experiments under pure Diesel mode and Ethanol blended diesel fuel mode and results are shown in Figs. 3–10.

Table 3. Properties of fuels

Properties	Percentage of Ethanol blends with Diesel				
	0%	5%	10%	15%	100%
Flash point °C	53	51	43	37	16
Fire Point °C	59	54	48	42	18
Density Kg/m ³	840	839.4	839.1	838.9	836
Kinematic Viscosity mm ² /sec	3.15	2.87	2.71	2.57	1.3
Calorific value MJ/kg	43	42.7	42.48	42.21	19.2

2.2 Evalution of propertie for Diesel and different blends

Open cup apparatus is used to determine Flash point and Fire point. Redwood viscometer is used to determine density and kinematic viscosity. Bomb calorimeter is used to determine Calorific value [6, 7, 8].

2.3 Brake specific fuel consumption(BSFC)

The Fig. 3 illustrates the variation of BSFC with BP for Diesel, 5% blend, 10% blend, 15% blends. The BSFC decreases with increase in BP for Diesel and for different blends. As compared to Diesel the BSFC are decreased for Ethanol fuel blends due to decrease in Calorific value. At 0.58 kW BP the difference between Diesel point and 15% ethanol blend point the BSFC is decreased by 8% compared to Diesel. At 4.11 kW BP we observed that there is 13% decrease in BSFC for 15% ethanol blend point than Diesel. So as the percentage of ethanol blend increases the BSFC value decreases respectively. Thus 15% ethanol blend has lower BSFC compared to other blends and Diesel for various loads [9].

2.4 Brake thermal efficiency (BTE)

The Fig. 4 illustrates the variation of BTE with BP for Diesel and different ethanol fuels blend. The BTE increases with increase in BP for both Diesel and ethanol fuel blends [10]. Due to lower calorific value and higher latent heat of vaporization as the percentage of ethanol fuel blends increases in Diesel the BTE increases as compared to diesel fuels. At 0.58 kW BP we observed that there is 23% increase in BTE for 15% ethanol blend compared to Diesel. At 4.11 kW BP we observed that there is 14% increment in BTE for 15% ethanol fuel blend compared to Diesel. Thus for 15% ethanol blend has higher BTE compared to other ethanol blends and Diesel for different loads.

2.5 Exhaust gas temperature (EGT)

The Fig. 5 shows the variation of EGT with BP for Diesel and various percentage ethanol fuel blends. Exhaust gas temperature for ethanol fuel blends decreases as compared to Diesel because as the percentage of ethanol blend increases which increases the oxygen in the fuel blends which gives cooling effect to the engine hence reduces the exhaust gas temperature. Lower calorific value of ethanol fuel blends also decreases the exhaust gas temperature. For 0.58 kW BP there is 11% decrease in exhaust gas temperature for 15% ethanol fuel blend as compared to Diesel. At 4.11 kW 9% decrease in exhaust gas temperature for 15% ethanol fuel blends compared to Diesel. Thus for 15% ethanol fuel blend has lower exhaust gas temperature compared to other blends and Diesel for various loads.

2.6 Peak pressure rise

The Fig. 6 illustrates the variation of Peak pressure rise with BP for Diesel and various percentages of ethanol blends. Ethanol has more content of oxygen and rapid combustion will occur hence sudden peak pressure rise was achieved. As the BP increases the peak pressure rise is higher in ethanol fuel blends and lower pressure rise in diesel for various loads. Thus 15% ethanol fuel blends is having higher peak pressure rise as compared to other fuel blend and diesel for various loads.

2.7 Carbon monoxide (CO) emissions

The Fig. 7 illustrates the variations of CO emissions with BP for Diesel and various ethanol blends. It is indicated that CO emissions are decreased with increase in percentage of ethanol blend compared to Diesel. Ethanol is oxygenated fuel so ethanol blends have more content of oxygen compared to diesel and gives complete combustion and also reduces the emissions of CO. At 0.58 kW BP about 50% of CO emissions are reduced for 15% ethanol blend compared to diesel. At 4.11 kW BP about 27% of CO emissions are reduced for 15% ethanol blend compared to diesel. Thus graph shows that 15% of ethanol blend has lower CO emissions compared to other ethanol fuel blends and diesel at various loads.

2.8 Carbon Dioxide (CO₂) emissions

The Fig. 8 illustrates the variation of Carbon Dioxide (CO₂) emissions with Brake power (BP) for various ethanol fuel blends and diesel. Due to more oxygen content in ethanol fuel blends complete combustion will occur. This result in decrease in CO₂ emissions for ethanol blend compared to diesel. So as BP increase CO₂ emissions will be reduced. At 0.58 kW BP about 32% of CO₂ emissions will be reduced for 15% ethanol fuel blend compared to diesel. At 4.11 kW BP about 17% of CO₂ emissions will be reduced for 15% ethanol fuel blends compared to diesel. Thus from above graph it is concluded that for 15% ethanol blend has lower CO₂ emissions compared to other ethanol fuel blends and diesel at various loads.

2.9 Hydrocarbon (HC) emissions

The Fig. 9 illustrates the variation of HC emissions with BP for various Ethanol blends and diesel. Ethanol blends having high latent heat of vaporization and low Cetane number, which reduces the exhaust gas temperature and promote the rapid combustion hence with increase in percentage of ethanol blends

increases the Hydrocarbon emission compared to diesel. As Brake power increases hydrocarbon emissions also increases with increase in percentage of ethanol blends. At 0.58 kW BP about 38% of hydrocarbon emissions will be increased for 15% ethanol blends compared to diesel similarly at 4.11 kW BP about 19% of hydrocarbon emissions will be increased for 15% ethanol blend than diesel. Thus the above graph shows that there will be increase in HC emissions for ethanol blends compared to diesel for various loads.

2.10 NO_x Emissions

The Fig. 10 illustrates the variation of NO_x emissions with BP for various ethanol blends and diesel. The NO_x formation is highly influenced by combustion temperature. From the graphs, it was observed that the NO_x emission increases with the increase in load for diesel and various blended fuels. Moreover at all load ranges, the NO_x emission is less for all blended fuels when compared with that of diesel. The high latent heat of vaporization and lower calorific value of ethanol reduces the cylinder temperature which in turn reduces the NO_x emissions. At 0.58 kW BP about 24% of NO_x emissions were decreased for 15% ethanol blend compared to diesel. Similarly at 4.11 kW BP about 13% of NO_x emissions were decreased for 15% ethanol blend than diesel [11].

3. Conclusion

From results obtained following conclusions are made

1. In this present study, selected leaves wastes such as Rain tree leaves, Jackfruit tree leaves, Singapore cherry tree leaves, Mango tree leaves were considered as raw materials for the production of Bioethanol and the conversion of waste into fuel, which forms an attractive solution towards both waste management and Biofuels generation.
2. Due to more starch content in Jackfruit tree leaves and Rain tree leaves we have selected these leaves for the production of bioethanol. The percentage of ethanol from Gas Chromatography-Mass Spectrometry was found to be 4.34% in Wet Jackfruit tree leaves and 4.23% in Dry Jackfruit tree leaves. In Wet Rain tree leaves the percentage of ethanol was found to be 3.52% and in Dry Raintree leaves it was found to be 2.46%.
3. The extracted Bioethanol from wet Jackfruit tree leaves wastes and analysis of fuel properties, the performance and emission characteristics of single cylinder CI engine were carried out.
4. The Brake specific fuel consumption (BSFC) of ethanol blended diesel was decreased because ethanol blended diesel have lower calorific value and lower Cetane number compared to diesel. At 0.58kW BP about 8% BSFC was decreased for 15% ethanol blend compared to diesel. At 4.11kW BP about 13% decrease in BSFC for 15% ethanol blend compared to diesel.
5. The Brake thermal efficiency (BTE) of ethanol blended fuel is increased with increase in Brake power (BP) as compared to diesel. This is because the ethanol blend diesel has more oxygen content and high latent heat of vaporization as compared to diesel which promotes the combustion. At 0.58kW

BP about 23% BTE was increased and at 4.11kW BP about 14% BTE was increased compared to diesel.

6. The ethanol blend diesel has more oxygenated fuel compared to diesel and results in complete combustion. Hence CO emissions will be reduced for ethanol blend diesel compared to diesel. At 0.58kW BP about 50% of CO emissions will be reduced and at 4.11kW BP about 27% of CO emissions are reduced compared to diesel [12].
7. The ethanol blend fuel decreases the CO₂ emissions compared to diesel because of complete combustion. At 0.58kW BP about 32% of CO₂ emissions are reduced and at 4.11kW BP about 17% of CO₂ emissions are reduced compared to diesel.
8. Due to rapid combustion the hydrocarbon emissions will be more for ethanol blend diesel compared to diesel. At 0.58kW BP about 38% of HC emissions will be increased and at 4.11kW BP about 19% of HC emissions are increased compared to diesel for Jackfruit leaves ethanol [13].
9. NO_x emission increases with the increase in load for diesel and various blended fuels. Moreover at all load ranges, the NO_x emission is less for all blended fuels when compared with that of diesel. The high latent heat of vaporization and lower calorific value of ethanol reduces the cylinder temperature which in turn reduces the NO_x emissions. At 0.58kW BP about 24% of NO_x emissions were decreased for 15% ethanol blend compared to diesel. Similarly at 4.11kW BP about 13% of NO_x emissions were decreased for 15% ethanol blend than diesel.

4. Materials And Methods

4.1 Microorganism and Culture media

The media was prepared with 22.75 g of Sabouraud Dextrose Agar (SDA) in 350 ml of distilled water in a 1000 ml conical flask and mixed well thoroughly, which was plugged with cotton plug and sterilized or autoclaved for 30 min at 15psi and 121 °C. Then the media is allowed to cool to the room temperature and the medium is equally distributed petri dishes in laminar flow chamber. The SDB media was prepared by adding 65 g of Sabouraud Dextrose Broth (SDB) to 1000 ml of distilled water and mixed well thoroughly which was plugged with cotton plug and autoclaved (sterilized) for 30 minutes at 15psi and 121 °C. Sabouraud Dextrose Broth (SDB) with an organism is allowed to grow for 24hours.

4.2 Collection of raw material

Lignocellulosic dry and wet leaves such as Rain tree leaves, Jackfruit leaves, Singapore cherry leaves, Mango tree leaves were taken from agricultural rural areas [14]. All the leaves samples were dried and grounded into powder.

4.3 Iodine test to determine starch content in leaves

The iodine test is conducted to determine the starch content in the different plant leaves. The plant leaves have green parts (where the cells contains chlorophyll) and white parts (where there is no chlorophyll).

Only the parts that were green becomes blue black with iodine solution. From this test we observed that there is more starch content in Jackfruit and Rain tree leaves compared to Mango tree and Singapore cherry leaves [15]. We selected Rain tree and Jackfruit tree leaves for the production of bioethanol.

4.4 Extraction of juice from different plant wastes

About 50 g of wet leaves of Rain tree and jackfruit trees are weighed separately and which was rinsed with water and then washed and added 250 ml of distilled water. The wet leaves of rain tree and jackfruit trees were separately crushed in a mixer and stored in a conical flask. Similarly the dry leaves of the jackfruit trees and rain trees are collected and cleaned with distilled water and dried in sunlight for reduction of moisture content in the leaves [16]. About 500 g of dry leaves of both trees were weighed separately and 25 g of each plant wastes are taken in 10 different 250 ml conical flask and 100 ml of water is added.

4.5 Fermentation process

The 250 ml juice of wet leaves of both rain trees and jackfruit trees are taken in 500 ml conical flask and which were plugged with cotton plug. The content was autoclaved for 30minutes at 15psi and 121 °C. The 25 g of each dry rain tree and jackfruit tree leaves are weighed separately and were taken separately in 9 different 250 ml conical flasks and 100 ml of distilled water is added for each conical flask [17].

750 mg of sodium hydroxide is added for 2 conical flasks of each plant leaves Heat Shock treatment is given for 1 conical flask of each samples.

750 mg of sodium sulphate is added for another 2 conical flasks of each plant leaves and Heat Shock treatment is given for 1 conical flask of each samples.

750 mg of each sodium hydroxide and sodium sulphate is added for another 2 conical flasks of each plant leaves and Heat Shock treatment is given for 1 conical flask of each samples.

For remaining 3 conical flasks of each plant leaves no chemicals were added. Only control is maintained. Heat Shock (HS) is given for 1 conical flask at 10 power 5 minutes of each leaves and remaining 2 conical flasks were used for biochemical tests and were plugged with cotton plug and were autoclaved for 30 minutes at 15psi, 121 °C. Pre-treatment of lingo cellulose biomass by microwave irradiation is based on non-thermal and thermal effects of microwaves. Heating is very essential parameter in pre-treatment technology. Higher temperature accelerates the reaction rate and minimizes the chemicals requirement during pre-treatment [18].

The process was continued to find the pH values of specimens by using pH paper method. These contents were allowed to cool and 10% of *Saccharomyces cerevisiae* culture was inoculated in 9 different 250 ml conical flask of each plant leaves in laminar air flow chamber. The media was incubated for 10days at 27 ± 2 °C temperature, 80 rpm in rotary shaker incubator [19]. After 10days of incubation the media was filtered and centrifuged at 13000 rpm for 10minutes to remove cell and suspended particles.

The supernatant was collected and Gas chromatography and mass spectrometry (GC-MS) test was conducted for the estimation of ethanol content [20].

4.6 Determination of Carbohydrate by Anthrone Reagent method

The major constraint beyond the carbohydrate estimation is that carbohydrates are dehydrated with concentrated H_2SO_4 to form furfural. This furfural condenses with Anthrone reagent to form green colour which is measured by calorimeter at 670 nm. Anthrone reagent was prepared by dissolving 100 mg of Anthrone reagent in 50 ml of concentrated Sulphuric acid [21]. Standard Glucose was prepared by Adding 100 mg of Glucose or Maltose to 50 ml of distilled water.

4.7 Engine setup

The experiments were conducted on 4 Stroke, Single Cylinder Diesel engine with electrical loading is as shown in Fig. 11.

- 1. Diesel engine
- 2. Generator
- 3. Electrical load
- 4. Fuel tank
- 5. Pressure pickup
- 6. Shaft encoder
- 7. Computer
- 8. Exhaust gas analyzer
- 9. Exhaust temperature measurement meter
- 10. Data acquisition system

Table 4
Engine specifications

Company	Kirloskar
Engine type	Four Stroke Single Cylinder
Power	5.2 kW
Stroke	110 mm
Speed	1500 rpm
Compression Ratio	17.5:1
Cooling	Water Cooled
Fuel injection	Mechanical injection with injection timing 23°bTDC
Injection pressure	210 bar

4.7.1 Exhaust gas analyser

AVL DIGAS 440 gas analyser as shown in Fig. 12 is a device used to measure the emissions.

Table 5
Data showing the
measurement resolution of
emissions

Emissions	Resolutions
HC	1 ppm
CO	0.01%
CO ₂	0.01%
O ₂	0.01%
NO _x	1 ppm

Abbreviations

BSFC: Brake specific fuel consumption; BTE: Brake thermal efficiency; EGT: Exhaust gas temperature; HC: Hydrocarbon; BP: Brake power; SDA: Sabouraud Dextrose Agar; SDB: Sabouraud Dextrose Broth; HS: Heat Shock; GC-MS: Gas chromatography and mass spectrometry.

Declarations

Acknowledgements

I would like to acknowledge SAVI EASY LIFE s.r.o., and Springer Nature team for their support.

Authors' contributions

Dr. Ir. Sreenivas Reddy Bathula conducted fermentation related work including manuscript preparation; Vikas S Ballary mechanical lab work; Dr. Kumarappa engine data analysis; Guruchethan A.M. produced figures, graphs and conducted CI engine studies; Harika Mali contributed to the discussion and results analysis. All authors contributed to editing the manuscript. All authors read and approved the final manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Availability of data and material

The authors confirm that the data supporting the findings of this study are available within the reference articles and in its supplementary materials.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author details

¹Adama Science & Technology University, P.O Box 1888, Adama, Ethiopia. Email id: sreenivas.reddy@astu.edu.et ; Mobile No: +251-988683641

²Dept of Mechanical Engg, BIET Davangere, Karnataka, India.

³SAVI EASY LIFE s.r.o., Czech Republic.

References

1. Saravana C, Murugan, Rajendran S. Bioethanol Production from Agave Leaves Using *Saccharomyces cerevisiae* (MTCC 173) and *Zymomonas mobilis* (MTCC 2427). *Int J Microbiol Res.* 2013;4(1):23–6.
2. Elsa Cherian, Dharmendra Kumar M, Baskar G. Cellulosic bioethanol production by sequential fermentation using agriculture waste. *International Journal of Chem Tech Research.* 2014;6(14):5653–60.
3. Corbin KR, Byrt CS, Bauer S, DeBolt S, Chambers D, Holtum JA, Karem G, Henderson M, Lahnstein J, Beahan CT, Basic A, Fincher GB, Betts NS, Burton RA. Prospecting for Energy-Rich Renewable Raw Materials: Agave Leaf Case Study. *PLoS One.* 2015;10(8).
4. Dhurjati. **Method for the production of bioethanol from** *Muntingia calabura* **from** *Saccharomyces cerevisiae*. 2014;25:patent number. 260312.
5. Shrikant BS, Thakor NJ, Haldankar PM, Kalse SB. **A Review on Jackfruit and Its Many Functional Components as Related to Human Health.** 2012;11(6):565–576.
6. Devarajan Y, Munuswamy DB, Nagappan B. Emissions analysis on diesel engine fuelled with cashew nut shell biodiesel and pentanol blends. *Environ Sci Pollut Res Int.* 2017;24(14):13136–41.
7. Ravishankar BV, Vikas SB, Akarsh MR, Rangaswamy BE, Bathula SR. Production of Bio-ethanol from an Underexploited Fruit of *Muntingia calabura* and Studying Performance and Emission Characteristics of Single Cylinder CI Engine. *Bioprocess Eng.* 2017;1(1):1–6.

8. Sulakshana SD, Channapattana SV, Pawar AA. Experimental Evaluation of Diesel Engine Performance and Emissions Using Diesel/Biodiesel/Ethanol Blend Fuel, *International Journal of Emerging Technology and Advanced Engineering*. 2015;5(1).
9. Ashfaque Ahmed S, Prabhakar S, Binu KS, Irshad Ahmed M. Performance test for Lemon grass oil in twin cylinder diesel engine, *ARPJ Journal of Engineering and Applied Sciences*. 2013; 8(6).
10. Comparative Studies on Performance
Ragit SS, Mohapatra SK, Kundu K. Comparative Studies on Performance.
11. Characteristics of CI Engine Fuelled. with Neem Methyl Ester and Mahua Methyl.
Ester and Its Respective Blends with Diesel Fuel. *J Environ Sci Eng*. 2014;56(1):73–8.
13. Attempts to minimize nitrogen oxide emission from diesel engine by using
Rashedul HK, Kalam MA, Masjuki HH, Teoh YH, How HG, Monirul IM, Imdadul HK. Attempts to minimize nitrogen oxide emission from diesel engine by using.
14. antioxidant treated diesel-biodiesel blend. *Environ Sci Pollut Res Int*. 2017;24(10):9305–13.
15. Premnath S, Devaradjane G. Improving the performance and emission characteristics of a single cylinder diesel engine having reentrant combustion chamber using diesel and *Jatropha* methyl esters. *Ecotoxicol Environ Saf*. 2015;121:10–5.
16. Experimental investigation of homogeneous
Ganesh D, Nagarajan G, Ganesan S. Experimental investigation of homogeneous.
17. charge compression ignition combustion of biodiesel fuel with external mixture.
18. formation in. a CI engine. *Environ Sci Technol*. 2014;48(5):3039–46.
19. Budzianowska A, Budzianowski J. [Tobacco—a source of biofuels]. *Przegl Lek*. 2012;69(10):1149–52.
20. Masahide Yasuda H, Nagai K, Takeo Y, Ishii. Bio-ethanol production through simultaneous saccharification and co-fermentation (SSCF) of a low-moisture anhydrous ammonia (LMAA)-pretreated napie grass. *Springerplus*. 2014;3:333.
21. Surendra PS, Kumar S, Mishra I, Adhikari DK. Recent Advances in Production of Bioethanol from Lignocellulosic Biomass. *chemical engineering technology*. 2009;32(4):517–26.
22. Panagiotopoulos IA, Chandra RP, Saddler JN. A two-stage pretreatment approach to maximise sugar yield and enhance reactive lignin recovery from poplar wood chips. *Bioresour Technol*. 2013;130:570–7.
23. Rokeyah S, Kanokphorn S, Chompoonuch W. Conversion of leaf waste to sugar and ethanol by SHF and SSF fermentation using cellulase from *cellulomonas* sp. *International Journal of Advanced Biotechnology Research*. 2011;2(3):345–9.
24. Nyachaka CJ, Yawas DS, Pam GY. Production And Performance Evaluation Of Bioethanol Fuel From Groundnuts Shell Waste. *American Journal of Engineering Research*. 2014;2(12):303–12.
25. Martins MT, de Souza WR, da Cunha BA, Basso MF, de Oliveira NG, Vinecky F, Martins PK, de Oliveira PA, Arenque-Musa BC, de Souza AP, Buckeridge MS, Kobayashi AK, Quirino BF, Molinari HB.

Characterization of sugarcane (*Saccharum spp.*) leaf senescence: implications for biofuel production. *Biotechnol Biofuels*. 2016;9:153.

26. Jin Y, Huang T, Geng W, Yang L. Comparison of sodium carbonate pre-treatment for enzymatic hydrolysis of wheat straw stem and leaf to produce fermentable sugars. *Bioresour Technol*. 2013;137:294–301.

Supplementary Information

Supplementary information accompanies this paper

Additional file 1: Comparison of Ethanol percentage in various Jackfruit sample

Additional file 2: Comparison of ethanol percentage in Rain tree leaves sample

Additional file 3: Variation of BSFC with BP for Diesel and various blend of ethanol

Additional file 4: Variation of BTE with BP for Diesel and various blend of ethanol

Additional file 5: Variation of EGT with BP for Diesel and various blend of ethanol

Additional file 6: Variation of Peak pressure rise with BP for Diesel and various blend of ethanol

Additional file 7: Variation of CO emissions with BP for Diesel and various blend of ethanol

Additional file 8: Variation of CO₂ emissions with BP for Diesel and various blend of ethanol

Additional file 9: Variation of HC emissions with BP for Diesel and various blend of ethanol

Additional file 10: Variation of NO_x emissions with BP for Diesel and various blend of ethanol

Additional file 11: Line diagram of single cylinder, four stroke Diesel engine

Additional file 12: Exhaust gas analyser

Figures

Figure 1

Comparison of Ethanol percentage in various Jackfruit sample

Figure 2

Comparison of ethanol percentage in Rain tree leaves sample.

Figure 3

Variation of BSFC with BP for Diesel and various blend of ethanol

Figure 4

Variation of BTE with BP for Diesel and various blend of ethanol

Figure 5

Variation of EGT with BP for Diesel and various blend of ethanol

Figure 6

Variation of Peak pressure rise with BP for Diesel and various blend of ethanol

Figure 7

Variation of CO emissions with BP for Diesel and various blend of ethanol

Figure 8

Variation of CO₂ emissions with BP for Diesel and various blend of ethanol

Figure 9

Variation of HC emissions with BP for Diesel and various blend of ethanol

Figure 10

Variation of NOx emissions with BP for Diesel and various blend of ethanol

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Supportingdata.docx](#)