International Journal of
Electrical and Computer System Design
ISSN: 2582-8134 www.ijecsd.com

Revolutionary Exploration: Unleashing the Power of Rice Bran Oil Biodiesel in Compression Ignition Diesel Engines

Arul Raj Kumaravel*[1], Narmatha Deenadayalan[2], Sundar Vettum Perumal[3], Andrew.H Sadallah[4]

[*1,3,4,5] St. Joseph University in Tanzania, Mbezi, Dar Es Salaam, Tanzania, pkarulraj@yahoo.co.uk

[2]Einstein College of Engineering, Tirunelveli, Tamilnadu, India, niranjnarmi@gmail.com

Abstract: Research has been conducted on the extraction of oil from rice bran seeds, resulting in the development of rice bran oil, an edible oil. As part of the investigation into alternative fuel solutions, a biofuel has been synthesized by esterifying rice bran oil with methanol and potassium hydroxide. Esterification is a crucial process in biofuel production as it facilitates the extraction of free fatty acids (FFA) present in vegetable oils. The biofuel obtained from this process undergoes further purification to eliminate glycerol content. The resulting biofuel is then blended with diesel in different proportions (B5, B10, B20, and B30) and evaluated using a single cylinder diesel engine. To assess the performance of the biofuel blends, a comparison was made against pure diesel (D100). The aim was to determine the blend that would exhibit optimal performance by improving mechanical efficiency and reducing fuel consumption. After careful evaluation, B10 was selected as the most promising blend, demonstrating performance on par with diesel fuel. The findings indicate that rice bran blends have the potential to serve as viable substitute fuels for diesel engines. In addition to the experimental data, an artificial neural network was developed to predict engine performance. The results obtained from this analysis displayed a strong correlation with the experimental findings, as evident from the high correlation coefficient value approaching unity. This suggests that the artificial neural network model is a reliable tool for estimating engine performance when using rice bran oil blends as fuel.

Keywords: Methanol, Blending, Transesterification, Mechanical efficiency, Brake Power.

1. Introduction

Biofuels, derived from organic matter and plant-based materials, offer a viable alternative to conventional petro-diesel. Plants play a vital role in this process by absorbing atmospheric CO2 through photosynthesis and converting it into polysaccharides, specifically cellulose and hemicellulose. These plant polysaccharides, when utilized for biofuel production, ensure that the carbon dioxide released upon combustion remains within acceptable limits, leading to a carbon-neutral cycle. The research undertaken in this study provides valuable insights into the utilization of rice bran oil as a renewable and sustainable energy source. The successful synthesis of biofuel from rice bran oil, along with the optimization of the blend ratio, offers a promising avenue for reducing dependence on traditional diesel fuels and mitigating environmental impact [1-5]. The development and implementation of advanced technologies in biofuel production, such as enzymatic hydrolysis and fermentation, further enhance the efficiency and environmental viability of biofuels.

The utilization of biofuels presents a straightforward and secure approach to addressing the global challenge of climate change by effectively reducing CO2 emissions. Non-food dependent biomass, including materials like rice straw, forest thinning residues, and corn Stover, serve as valuable resources for the production of biofuels. The use of these non-food biomass materials for biofuel preparation offers multiple advantages. Firstly, it helps alleviate concerns related to food security by utilizing biomass sources that are not intended for human consumption. This ensures that biofuel production does not compete with the production of essential food crops, mitigating any potential negative impacts on the global food supply. Secondly, the utilization of non-food biomass for biofuel production supports sustainable land management practices. By utilizing agricultural residues and forest thinning residues, biofuel production becomes an integral part of overall land management strategies, promoting ecosystem health and reducing the risk of wildfires [6-8].

Two distinct methods are employed for the processing of biofuels derived from non-food materials.

The first method involves the efficient modification of pentose sugars, while the second method focuses on alleviating the inhibition of fermentation caused by organic compounds such as aromatics, organic acids, and furans. The proficient modification of pentose sugars is a crucial approach in biofuel production from non-food materials. Pentose sugars, such as xylose, are abundant in lignocellulose biomass and serve as a potential source for biofuel synthesis. Through advanced enzymatic and microbial engineering techniques, the efficient conversion of pentose sugars into biofuels, such as ethanol, is achieved. This method enables the utilization of a broader range of feedstocks and maximizes the energy potential derived from non-food materials. The alleviation of fermentation inhibition caused by organic compounds represents another significant aspect of biofuel processing. Aromatics, organic acids, and furans, which are commonly present in non-food biomass, can hinder the fermentation process and reduce biofuel yields. To overcome this challenge, various strategies are employed, including genetic modifications of microorganisms, detoxification processes, and optimization of fermentation conditions. By mitigating the inhibitory effects of these compounds, the efficiency and productivity of biofuel production from non-food materials are improved [9-12].

The presence of both pentose sugars and hexose sugars in biomass-derived polysaccharides poses a challenge in biofuel production. While microorganisms are commonly employed in biofuel manufacturing, they are unable to effectively utilize pentose sugars, leading to reduced biofuel production. This limitation hinders the overall efficiency of the process. To overcome this hurdle, an essential step in the enzymatic saccharification of biomass is required. During the thermochemical process of non-food biomass, inhibiting mixtures are generated, which can impede the enzymatic conversion of sugars into biofuels. These inhibiting mixtures are known to negatively impact the enzymatic activity, leading to decreased efficiency and lower biofuel yields [13-17].

Petro-diesel fuel composition consists of approximately 87 percent carbon, making it a significant contributor to carbon emissions. When combusted, vehicles powered by petro-diesel emit harmful pollutants, including carbon monoxide and nitrogen oxides (NOx), which are known to pose serious health risks. In an effort to mitigate these detrimental effects, the production of alternative fuels for petrol and diesel aims to minimize toxic emissions [18]. Rather than directly adding blended diesel, an alternative approach involves trans esterifying the obtained fuel to extract fatty acids from gasoline. This process can have a significant impact on the overall fuel composition. In addition to methyl esters and diesel, the inclusion of linseed oil and rice bran can further enhance the fuel mixture. The combination of linseed oil, rice bran, methyl esters, and diesel in the transesterification process allows for a tailored fuel composition that meets specific performance and environmental requirements. The resulting blend can exhibit improved lubricity, reduced emissions, and enhanced fuel efficiency compared to conventional diesel fuels. [19].By decreasing the carbon percentage in the fuel composition, it becomes possible to mitigate various detrimental effects. One significant advantage is the reduction in knocking, which refers to the undesirable phenomenon of uncontrolled combustion leading to engine damage and decreased efficiency. A lower carbon content in the fuel helps minimize the occurrence of knocking, thereby improving the overall fatigue performance of the engine. Furthermore, by reducing the carbon content, the potential for corrosion within the engine system can be diminished. Corrosion can lead to degradation of engine components, impacting their durability and performance. Through the optimization of fuel composition and carbon reduction, the risk of corrosion can be effectively mitigated, ensuring prolonged engine life and reliable operation [20].

The biofuel blends are not directly injected into the CI engine for operation; instead, various proportions, such as B5, B10, B20, B30, and B40, are utilized and evaluated to ensure compliance with the required parameters [21]. Among the different biofuel blends, the combination of both oils is considered one of the most promising alternatives for diesel engines.

Artificial neural network (ANN) models have gained widespread adoption as a technique to predict engine performance due to their low complexity and high computational speed [22]. ANN demonstrates the capability to identify and capture the intricate relationships between input and output parameters, making it suitable for solving complex problems [23]. Moreover, ANN exhibits the ability to handle incomplete data values and process them using nonlinearity .The versatility of ANN extends beyond engine performance prediction and has also found application in modelling biofuel production [24]. By leveraging its powerful computational capabilities, ANN can effectively analyse and model the intricate processes involved in biofuel production [25].

The research undertaken in this study provides valuable insights into the utilization of rice bran oil as a renewable and sustainable energy source. The successful synthesis of biofuel from rice bran oil, along with the optimization of the blend ratio, offers a promising avenue for reducing dependence on traditional diesel fuels and mitigating environmental impact.

2. Materials and Methods

2.1. Oil Extraction Technique and Trans-esterification process

In recent years, significant research efforts have been dedicated to exploring oil extraction techniques for non-conventional feedstocks, with a particular focus on the cold press method as illustrated in Fig 1. For the preparation of biodiesel, a process called esterification is employed using vegetable oils, waste cooking oils, or animal fats as the starting materials. During this process, glycerides present in the oils react with alcohol (methanol or ethanol) in the presence of a catalyst, resulting in the formation of fatty acid alkyl esters and alcohol. This transesterification process is reversible and involves the interaction of fatty acids, catalysts, and alcohol. Catalysts such as solid bases or high acid substances (e.g., KOH) are commonly used, with sodium being an alternative catalyst used in the industry. The primary product of this transesterification process is raw biodiesel, along with glycerol as a by-product. Glycerol finds applications as a base material in anaerobic digestion processes.

Fig 1 Cold Press Process

The advancements in oil extraction techniques have paved the way for the utilization of unconventional feedstocks, leading to improved methods for biodiesel production through the esterification process. The catalysts employed play a crucial role in facilitating the reaction, and substances like KOH or sodium have proven effective in this regard. The transesterification process involves intricate interactions between the reactants, ultimately yielding raw biodiesel and glycerol as valuable outputs. The glycerol obtained from this process finds significant utility in anaerobic digestion, highlighting its potential as a valuable resource in the overall biodiesel production cycle. Efforts to optimize the esterification process and explore alternative catalysts are ongoing, aiming to enhance the efficiency and sustainability of biodiesel production.

2.2. Biodiesel extraction Procedure

The procedure outlines the sequential steps followed during the experimental investigation of biodiesel extraction from rice bran oil as displayed in Fig 2. It ensures the systematic execution of the research methodology, allowing for accurate analysis and comparison of the performance of various blended fuels in Compression Ignition engines.

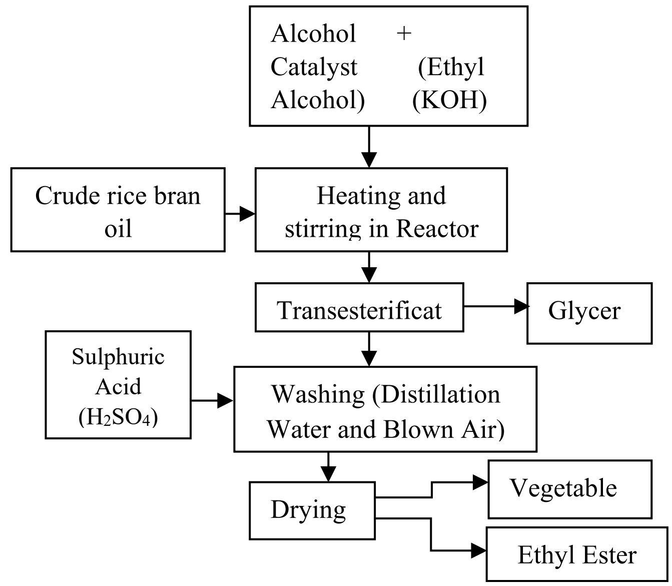

Fig 2. Procedural flow chart

The experimental procedure for biodiesel extraction is outlined below in a step-by-step manner.

2.3 Materials and Equipment

- Rice bran oil (200 mL)
- Methanol (50 mL)
- KOH beads (5 grams)
- Glass measuring utensil
- Magnetic stirring equipment
- CI engine test rig
- VI package module

1. Measurement and Preparation:
   - Measure 200 mL of rice bran oil, 50 mL of methanol, and 5 grams of KOH beads using a glass measuring utensil.
2. Transesterification:
   - Heat the solution using Magnetic Stirring equipment to maintain a temperature of 60 degrees Celsius as in Fig 3.
   - Stir the solution for 3 hours while closely monitoring the process.
   - Insert a magnetic stirrer into the solution to ensure thorough mixing of rice bran oil, methanol, and KOH beads.
   - Allow the solution to continue heating to eliminate water vapours.

Fig 3 Magnetic Stirrer Heating set up

3. Separation and Settling:

- Transfer the trans-esterified oil to a separating funnel as in Fig 4.
- Let the solution settle for 24 to 36 hours to separate Free Fatty Acids and other impurities, which settle at the bottom of the funnel.
- Open the lid of the separating funnel and collect the fatty acids in a small container by slowly turning the handle counterclockwise.

Fig 4. Pouring oil in Funnel

4. Washing and Impurity Removal:

- Heat water to 45-50 degrees Celsius and pour it into the separating funnel.
- Allow the mixture to stand for 5 to 8 minutes for impurities to settle down as shown in Fig 5.
- Remove water by venting the lid of the separating funnel.

Fig 5. Oil settled down for resting

5. Biodiesel Collection and Repetition:

- Collect the biofuel from the separating funnel and store it in a bottle.
- Repeat the entire experiment 4 to 5 times to ensure consistency and reliability.
- Fig 6 indicates the impurities removal and Fig 7 shows the hot water bath of biofuel.

Fig 6. Impurities removal

Fig 7 Hot water bath

6. Water Vapor Removal:

- Prior to blending, heat the trans-esterified oil at 60-70 degrees Celsius to remove any remaining water vapor as in Fig 8.

Fig 8: Water vapor removal

Fig 9: Esterified Oil

7. Blending:

- Mix the trans-esterified oil obtained in Fig 9 with diesel in desired proportions, such as blend5, blend10, blend20, blend30 as in Fig 10 where the number indicates the percentage of biofuel oil in the blend (e.g., blend5 implies 5% biofuel oil and 95% diesel).

Fig 10: RBO Blends

8. Engine Performance Testing:

- Utilize the CI engine test rig as in Fig 11 and VI package module for performance testing.
- Record parameters such as brake power and other engine characteristics to calculate the mechanical efficiency of the blended fuels.

Fig 11: C.I engine test rig

9. Comparative Analysis:

- Compare the mechanical efficiency of the different blended fuels derived from rice bran oil.
- Identify the optimal blend for diesel substitution based on the performance results.

3. Neural Network Model

The network model for this study was designed using the MATLAB Neural Network toolbox. A feed-forward backpropagation network was developed, employing the Levenberg-Marquardt learning algorithm and tangent-sigmoid transfer function. The architecture of the network model consisted of an input layer, a single hidden layer, and an output layer. To train and test the neural networks, input and target datasets were created based on experimental values. During the testing procedure, the network was presented with the training and target data, and the weights were adjusted iteratively to minimize the error between the predicted and actual values. Upon completing the training process, the trained network was used for predicting new data.

The input parameters utilized in the network model were torque, speed, air rate, fuel rate, and water flow. These parameters were fed into the network to predict the corresponding output parameters, which included brake power, brake specific fuel consumption, volumetric efficiency, and brake thermal efficiency. By employing the MATLAB Neural Network toolbox and following the described procedure, the network model was effectively trained and tested using experimental data. The network's ability to accurately predict the output parameters based on the input parameters demonstrates the potential for utilizing artificial neural networks in analyzing and optimizing engine performance. Further analysis and evaluation were conducted based on the predicted results to gain insights into the relationships and dependencies between the input and output parameters.

4. Results and Discussions

The experimental results obtained from the performance analysis of different fuel blends (D100, B5, B10, B20, and B30) are presented and discussed in this study. By comparing the graphs of these blends as in Fig 12, it can be observed that D100, B5, and B10 have similar properties in terms of various performance parameters.

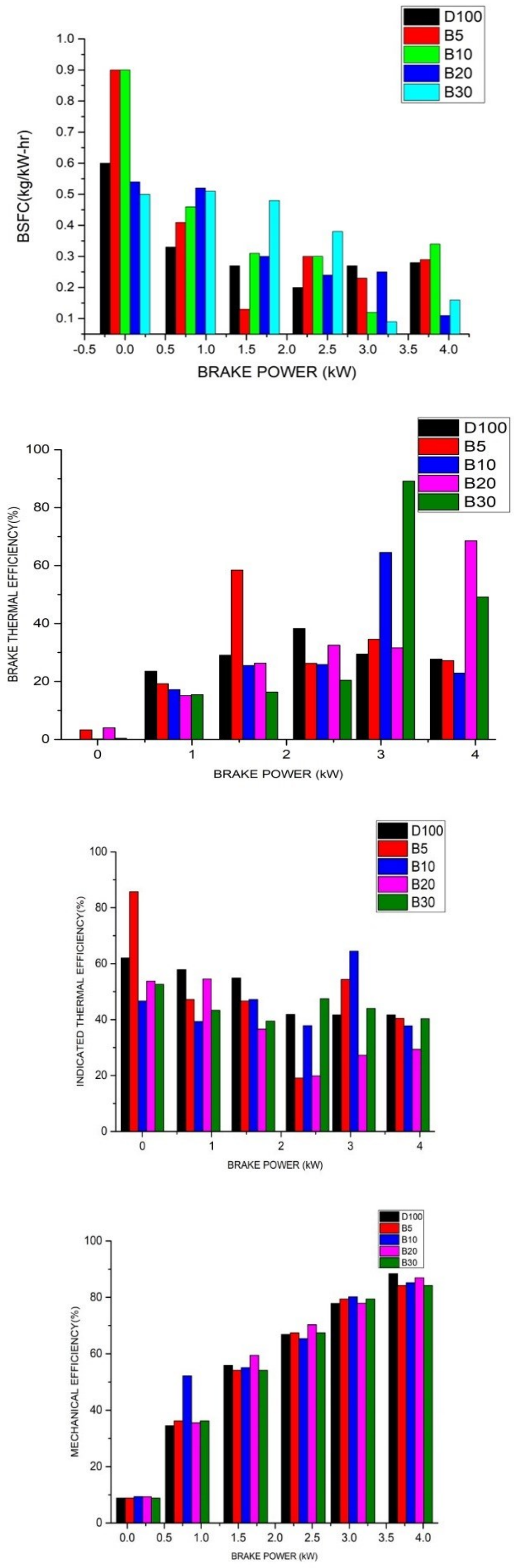

Fig12- Performance Parameter comparison of various blends

Firstly, the mechanical efficiency of the engine was found to be approximately 53% for all three blends, indicating their comparable effectiveness in converting the brake power to useful work. Similarly, the volumetric efficiency, which represents the engine's ability to intake and exhaust gases, was observed to range between 72% to 73% for D100, B5, and B10. This suggests that these blends have similar volumetric efficiency characteristics. Furthermore, the indicated thermal efficiency, which measures the ratio of useful work output to the fuel energy input, exhibited comparable values for D100, B5, and B10 blends. This indicates that these blends have similar combustion characteristics and are able to convert a similar portion of the fuel's energy into useful work.

Regarding the mechanical efficiency, it was found that B10 blend can be considered as a substitute for D100, as they both demonstrated similar mechanical efficiency values. This implies that B10, which consists of a 10% biodiesel blend, can provide comparable engine performance to pure diesel fuel (D100) while incorporating a renewable and environmentally friendly component. Moving on to the analysis of B5 blend, it was observed that the maximum brake thermal efficiency attained was 32.6%, and the volumetric efficiency readings ranged between 71% to 75%. The mechanical efficiency of the B5 blend averaged at 53.8%. It was also noted that the fuel consumption rate increased at low brake power, while the indicated specific fuel consumption steadily increased with the increase of brake power. At a certain stage, the brake specific fuel consumption and indicated specific fuel consumption followed a similar trend.

In the case of B20 blend, the indicated power and frictional power were found to be almost the same, except for a gradual reduction in frictional power at 1.25 kW of brake power. The mechanical efficiency achieved for B20 was 54%, and the volumetric efficiency ranged from 71% to 72.6%. The brake thermal efficiency increased with the rise in brake power, similar to the trend observed for mechanical efficiency. For B30 blend, it was observed that the engine faced several combustion problems as the brake specific fuel consumption rate increased. To overcome these challenges, a higher compression ratio of 16.5 or above was required for this blend. At peak loads, the efficiency readings were found to be very high, indicating improved engine performance. The mechanical efficiency for B30 was measured at 56.9%, while the volumetric efficiency ranged between 70% to 71%.

The experimental results and analysis of the different fuel blends revealed that B10 can be considered as a viable substitute for D100 in terms of mechanical efficiency. B5 showed good brake thermal efficiency and volumetric efficiency characteristics. B20 exhibited comparable power and frictional power, as well as a steady fuel consumption rate. B30 demonstrated higher efficiencies at peak loads but required careful consideration of combustion issues. These findings provide valuable insights into the performance characteristics of various biodiesel blends, aiding in the development of sustainable and efficient engine technologies.

4. Artificial Neural Network Results

The performance of the network in predicting engine performance using the entire dataset is illustrated in Fig 13. The network model employed a random division of the input and target data, allocating 70% of the data for training and the remaining portion for testing and validation. This approach ensured a comprehensive assessment of the network's predictive capabilities. The correlation coefficient between the actual values and the predicted values, based on the experimental data for the performance characteristics, was calculated to be 0.98394. This high correlation coefficient indicates that the predicted values obtained from the artificial neural network (ANN) closely align with the experimental values, with minimal deviations. Consequently, the ANN exhibits a strong ability to accurately predict engine performance metrics.

Further analysis and comparisons between the predicted and experimental values were performed to assess the ANN's overall performance and identify any potential areas for improvement. The close agreement between the predicted and experimental values further supports the utilization of ANN as a reliable tool for predicting engine performance metrics.

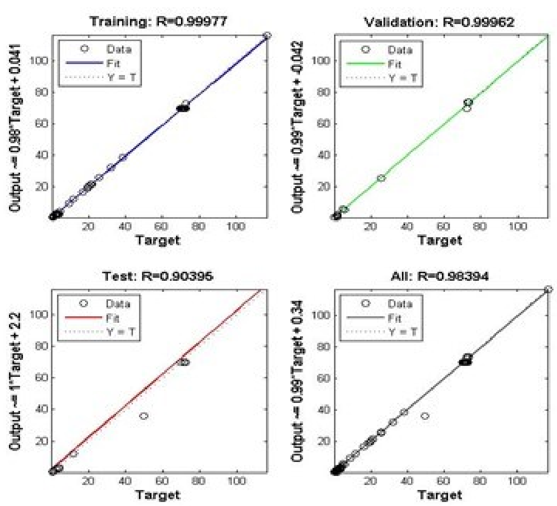

Fig13. Correlations between actual value and predicted value

5. Conclusion

The analysis conducted indicates that the performance of the engine using rice bran oil as a fuel was comparatively lower compared to other types of biofuels. The brake thermal energy utilization was higher, while the thermal efficiency of the engine was lower when using rice bran oil compared to the base reference fuel. The analysis also revealed lower levels of nitrogen oxide emissions compared to diesel fuel. However, the emissions of carbon monoxide and unburned hydrocarbons were higher with higher blend ratios of rice bran oil compared to diesel fuel throughout the experimental range. Despite these findings, the analysis suggests that rice bran oil has the potential to serve as a viable alternative fuel for diesel engines, as its performance and emission characteristics were found to be comparable to diesel fuel. Among the different biofuel blends tested, the B10 blend demonstrated favourable results in terms of air-fuel ratio. Both the B10 and B20 blends exhibited similar outcomes in terms of mechanical efficiency and volumetric efficiency. Furthermore, an artificial neural network (ANN) model with a 5-5-4 pattern was developed to predict engine performance parameters such as brake power, volumetric efficiency, brake thermal efficiency, and brake specific fuel consumption. The ANN model demonstrated strong learning capabilities and optimized the experimental data to estimate engine performance. The correlation coefficient value for the ANN model was determined to be 0.98394, indicating a good relationship with the experimental data. The mean square error was found to be 0.00154, further validating the accuracy of the ANN model.

References:

1. K. S. Reddy, P. Revanth, M. Yatheendar, J. S. V. M. Teja and P. R. Reddy, “Experimental investigation on performance of compression ignition engine fuelled with mahua oil methyl esters,” International Journal of Mechanical Engineering and Technology, vol. 8, no. 11, pp. 147-155, 2017.
2. P. Sivakumar, V. Nagaraju, S. Subhankarghosh, R. Rajeevraushan and GSS Anuroop, “Experimental investigation of 4-stroke single cylinder diesel engine using alternative fuels,” International Journal of Mechanical Engineering and Technology, vol. 8, no. 5, pp. 409-419, 2017.
3. S. R. Kunduru , G. S. Gopal , C. R. Kishore , P. Dileep and M. H. Vardhan , “Design, optimization and thermal analysis of a compression ignition engine cylinder using nano materials,” International Journal of Mechanical

Engineering and Technology, vol. 8, no. 5, pp. 124-134, 2017.
4. A.H.K Theja and R.Subbarao,“Investigations on the performance of various bio-fuels along with low thermal conductivity piston crown in a diesel engine,” Lecture Notes in Mechanical Engineering., vol., no., pp., 2017.
5. K.S Reddy , T.T Sandeep and Y.V.H Rao,“Study on the performance analysis of four stroke single cylinder diesel engine fuelled with tobacco seed methyl esters and castor seed methyl esters,” International Journal of Mechanical Engineering and Technology., vol., no., pp., 2017.
6. N. Satyanarayana, B. R. Bundel, Y. V. H. Rao and C. N. Kumar, “Experimental investigation on diesel engine using jatropha bio diesel blends with air pre-heating,” International Journal of Mechanical Engineering and Technology, vol. 8, no. 10, pp. 265-273, 2017.
7. V. Nagaraju, P. Sivakumar, K. Sreekanth, A. SaiHarsha, P. Venkatesh and K. Hanu Kumar, “Experimental investigation on four stroke single cylinder diesel engine by using linseed oil,” International Journal of Mechanical Engineering and Technology, vol. 8, no. 5, pp. 380-388, 2017.
8. S.A Raghavendra Prasad., “A Review on CNSL Biodiesel as an Alternative fuel for Diesel Engine,” International Journal of Science and Research , vol. 3, no. 7, pp. 2028–2038., 2014.
9. K. Srinivasa Reddy, P. Revanth, M. Yatheendar, J.S.V.M Teja and P.Rajavardhan Reddy,“Study on performance of diesel engine by using cotton seed methyl esters along with additive as alternative fuel,” International Journal of Mechanical Engineering and Technology., vol.9,no.4 , pp.275-283 ,2018.
10. B.Koteswararao,KVN Rao and TV Rao,“Cotton stalks as alternative fuel source for rural areas,” International Journal of Mechanical and Production Engineering Research and Development., vol., no., pp., 2018.
11. Venkateswarlu Kavati Ramakrishna and Konijeti, “Effect of turbulence and multiple injection strategies on homogeneous charge compression ignition (HCCI) diesel engines-a review,” International Journal Of Ambient Energy.
12. G.V. More and Y.V. Hanumantha Rao, “Biodiesel production with the help of different additives on the basis of standards – A review,” Journal of Advanced Research in Dynamical and Control Systems, vol. 10, no. 9, pp. 2050-2064, 2018.
13. G. Jamuna Rani, Y.V. Hanumantha Rao, and B. Balakrishna, “Investigation of fuel injection pressure impact on ci engine performance and emissions using biodiesel blend with alumina nano additives,” International Journal of Mechanical Engineering and Technology, vol. 9, no. 6, pp. 922-928, 2018.
14. K. Venkatesan and J. Rahul Rao,“Diesel engine performance and emission analysis using mosambi peelpyro oil with nano additive particles,” International Journal of Mechanical and Production Engineering Research and Development, vol. 8, no. 6, pp. 311-316, 2018.
15. N.D. Kamitkar et al., “Performance investigation and exhaust analysis of C.I engine fuelled by diesel mixed with jamun seed powder and jack fruit seed powder,” International Journal of Mechanical and Production Engineering Research and Development, vol. 8, no. 3, pp. 339-350, 2018.
16. S. Kumar, N.D. Kamitkar, and A.N. Basavaraju, “Effect of exhaust gas recirculation on performance and emissions of lhr diesel engine using jatropha biodiesel,” International Journal of Mechanical and Production Engineering Research and Development, vol. 9, Special Issue, pp. 118-125, 2019.
17. S.R. Koli and Y.V. Hanumantha Rao, “Acetylene an potential alternative fuel for stationary diesel engine,” International Journal of Recent Technology and Engineering, vol. 8, no. 2, pp. 5013-5016, 2019.
18. K.S. Reddy et al., “Experimental investigation on performance of a compression ignition engine fuelled with linseed (flax) methyl esters,” International Journal of Mechanical Engineering and Technology, vol. 10, no. 1, pp. 142-151.
19. S. Khadharbasha, Satishkumar, and N.D. Kamitkar, “The performance evaluation and emission study of compression ignition engine operating with blends of animal fat and palm oil based biodiesels,” International Journal of Mechanical and Production Engineering Research and Development, vol. 9, no. 4, pp. 199-206, 2019.
20. K.V. Narasimha Rao, S.N. Meeravali, and N.D. Kamitka, “Effect of cooled egr technique on performance and emissions of crdi engine operated with biodiesel blends,” International Journal of Mechanical and Production Engineering Research and Development, vol. 9, no. 4, pp. 241-252, 2019.
21. N. Indrareddy, K. Venkateswarlu, and R. Konijeti, “Experimental investigation of algae biofuel-diesel blends on performance of a CRDI

diesel engine," International Journal of Ambient Energy, pp. 1-17, 2020.
22. D.Vinay Kumar, P.Ravi Kumar, and M.Santhosha Kumari,"Prediction of Performance and emissions of a Biodiesel Fueled Lanthanum Zirconate Coated Direct injection Diesel Engine using Artificial Neural Network," Procedia Engineering, vol. 64, pp. 1418-1427, 2013.
23. J.O.Olajide,J.C.Igbeka,T.J.Afolabi,and O.A.Emiola,"Prediction of oil yield from groundnut kernels in an hydraulic press using artificial neural network(ANN)," Journal of Food Engineering, vol. 80,no.3 pp.972-978 ,2007.
24. Machavaram Rajendra ,Prakash Chandra Jena and Hifjur Raheman,"Prediction of optimized pretreatment process parameters for biodiesel profuction using ANN and GA," Fuel ,vol .88,no .11 ,pp .2199-2206 ,2009.
25. M. Rajendra, P.C. Jena, and H. Raheman, "Prediction of optimized pretreatment process parameters for biodiesel profuction using ANN and GA," Fuel, 2009, doi: 10.1016/j.fuel.2008.12.008.