International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 1|| January 2018 || PP.66-77

Combustion Performance andExhaust Emission Analysis of Thurayi and Cuban Royal Palm Seed Biodiesel Blends onCI Engines

M Suresh[1], R. Hari Prakash[2],B. Durga Prasad[3]
[1]*Asso. Prof.& HOD, Dept. of ME, Gokula Krishna College of Engineering, Sullurpet*
[2]*Pincipal, Brahmaiah College of Engineering, Nellore*
[3]*Professor & Head, Dept. of ME, JNTUA College of Engineering, Ananthapuramu*
Corresponding Author:M Suresh

Abstract: *Increasing demand for fossil fuels due to the luxurious lifestyle, significant growth of population, transportation and the basic industry sectors are causing serious environmental problems. Moreover, a rapid decline in the fossil fuels has led scientists and researchers to look for new alternatives. In this regard, alternative fuels such as biofuels are becoming important increasingly due to environmental and energy concerns. Biofuels are commonly referred to as first generations, which are produced primarily from food crops. However, the use of edible oil to produce biodiesel in many countries is not feasible in view of a big gap in the demand and supply of such oils for dietary consumption. This paper is concerned about the extraction and usage of two biofuel and its blends on a Kirloskar TV-1, single cylinder, four-stroke, water cooled DI diesel engine with a displacement of 661cc. The rated power of the engine is 5.2 kW at 1500 rpm with constant speed. The fuels are extracted from Thurayi (Delonix Regia) and Cuban Royal Palm (Roystonea Regia) seeds which are nonedible. Then prepared their methyl esters through transesterification process to produce biodiesel. Different blends with diesel are also considered and the combustion and emission performance is analysed.*
Keywords: *Biofuels, Thurayi Seed, Delonix Regia, Cuban Royal Palm Seed, Roystonea Regia*

Date Date of Submission: 19-01-2018 Date of acceptance: 05-02-2018

I. Introduction

A biofuel is defined as any fuel whose energy is obtained through a process of biological carbon fixation. That definition serves to make our understanding of biofuels as clear as mud, so let's unpack it a bit. Carbon fixation is a process that takes inorganic carbon (in the form of things like CO_2) and converts it into organic compounds. In other words, any process that converts carbon dioxide into a molecule that would be found in a living organism is carbon fixation. If this process occurs in a living organism, it is referred to as 'biological carbon fixation'. The next part of the definition of a biofuel involves fuel. A fuel is nothing more than something from which we humans can get energy. Carbon fixation can lead to a number of different compounds, like proteins, fats, and alcohols (just to name a few). If any of those molecules can be used to provide energy in a mechanical setting, we call it a fuel [1][2].

A biofuel is a hydrocarbon that is made by or from a living organism that we humans can use to power something. This definition of a biofuel is rather formal. In practical consideration, any hydrocarbon fuel that is produced from organic matter (living or once living material) in a short period of time (days, weeks, or even months) is considered a biofuel [3]. This contrasts with fossil fuels, which take millions of years to form and with other types of fuel which are not based on hydrocarbons (nuclear fission, for instance). What makes biofuels tricky to understand is that they need not be made by a living organism, though they can be. Biofuels can also be made through chemical reactions, carried out in a laboratory or industrial setting, that use organic matter (called biomass) to make fuel.

The only real requirements for a biofuel are that the starting material must be CO_2 that was fixed (turned into another molecule) by a living organism and the final fuel product must be produced quickly and not over millions of years. Biomass is simply organic matter. In others words, it is dead material that was once living. Kernels of corn, mats of algae, and stalks of sugar cane are all biomass. This leads to one of the major separating factors between a biofuel and a fossil fuel – renewability [4].

II. Potential of Delonix Regia and Roystonea Regia Oil

2.1 Delonix Regia (Thurayi)

Delonix regiais a legume and belongs to the family of Fabaceae and sub-family Caesalpiniaceae. The plant grows widely and native of Nigeria either it is cultivated as an ornamental tree in gardens and by the road sides. It is also used as an agroforestry tree, planted as a shade tree in plantations, as live fence posts or grown on eroded sites for erosion control and for soil rehabilitation and improvement through atmospheric nitrogen fixation. It is a beautiful, semi-deciduous tree known as flame of forest in Nigeria and grows to heights of about 18 metres. It can be easily propagated from seeds but take a long time to germinate. Leaflets are less than 12 mm long with very numerous flowers with long stalks. Leaflets are opposite and flowers are conspicuous and scarlet. The fruits are long pods, which dangle from the branches and are green and flaccid when young and later turn dark brown and hard when matured [6][7][8].

It produces large quantities of seed pods and seeds during the fruiting season, which at present are not utilized [9]. A matured pod can contain as many as forty seeds. There has not been any documented tonnage of seeds produced annually possibly because there has not been any reported commercial value. On ripening, the mature fruit splits open into two halves revealing the elongated hard seeds. The Thirayi tree, fruit and seeds are shown in Fig. 1.

Figure 1. Thurayi Tree (Left), Thurayi Fruits (Center) andThurayi seeds (Right)

2.2Roystonea Regia (Cuban Royal Palm Nut)

Roystonea regiais a large majestic palm that is native to south Florida and Cuba it belongs to the family of Arecaceae and sub-family Arecoideae [10][11]. A large and attractive palm, it has been planted throughout the tropics and subtropics as an ornamental tree. This species quickly grows to heights of 50–70 ft., with a spread of 20–25 ft., and has a smooth light grey trunk up to 2 ft. It is ideal for landscaping streets, parks, and commercial properties, but becomes too large for typical residential landscapes [12]. The Cuban Royal Palm trees, fruits and seeds are shown in Fig. 2.

Figure 2. Cuban Royal Palm Trees (Left), Fruits (Center) and Seeds (Right)

III. Methodology

The Thurayi (delonix regia) and Cuban Royal Palm (roystonea regia) seed non-edible oils were selected for this study. Extraction of biodiesel from delonix regia and roystonea regia seed oil was done and the process is shown in Fig.3. The ornamental trees seed such as delonix regia and roystonea regia were collected from their fruits. The both seed of raw oil was extracted from their seed through cold press processes. For many generations cold press oils have been extracted from high-fat oil seeds, and have been used for preparing biodiesel for IC engines. Since several years, in fact of incresing ecological damage and of limited minerals oil resources, these oils are also used in the fields of technology [13][14]. In the technical range there is a growing market in the field of lubricants (chain saw oil, gear oil, motor oil), hydraulic oils and special applications. The energetic use of pure plant oil in motors (co-generations, diesel car engines) is an option to replace fossil fuels. Nowadays the technique is tested and well established. Pure plant oil fuel has the advantages of low sulphur content and safer handling. Using cold pressed plant oil instead of fossil diesel, there is a reduction in production of the greenhouse gas CO_2 [15]. Fig.4 shows the overview of cold pressing process for the production of raw oil. The well dried 100 kg of delonix and roystonea regia seed were taken into the oil expeller. The seeds were crushed by the expeller and separated into raw oil and oil cake. The oil yield for both delonix regia and roystonea regia is same. The yield of oil is 30 to 35% and remaining is converted into oil cake.

Transesterification is the process of conversion of the triglyceride (oil/fat) with an alcohol in the presence of a catalyst to form esters and glycerol. Vegetable oil is subjected to chemical reactions with alcohol like methanol or ethanol in the presence of a catalyst. Since the reaction is reversible, excess methanol is required to reduce the activation energy, thereby shifting the equilibrium to the product side. The triglyceride present in the vegetable oil is converted into alkyl esters (biodiesel). Among the alcohols used for the transesterification reaction are methanol, ethanol, propanol and butanol [16][17]. However, when methanol is processed, methyl esters are formed, whereas ethanol produces ethyl esters. Both these compounds are biodiesel fuels in different chemical combinations.

The procedure adopted for biodiesel extraction of both delonix regia and roystonea regia is given below. In a container 1000 ml of delonix regia seed oil is taken for extraction of biodiesel. 12 grams of potassium hydroxide alkaline catalyst (KOH) is weighed. 200 ml of methanol is taken in a beaker. KOH is mixed with the alcohol and it is stirred until they are properly dissolved. Delonix regia seed oil is taken in a container and stirred with a mechanical stirrer, simultaneously heated with the help of a heating coil. The stirrer should be operated at minimum speed, when the temperature of the raw oil reaches 60 °C the KOH-alcohol solution is poured into the raw oil container and the container is closed with an air-tight lid [18]. Now the solution is stirred with the maximum speed.

The temperature should be maintained at a level not exceeding 60 °C as ethanol evaporates at temperatures higher than 60 °C. Also the KOH-alcohol solution is mixed with the delonix regia seed oil at 60 °C because heat is generated when KOH and alcohol are mixed together. When the mixing is done the temperature of the raw oil should be more than this to ensure proper reactions. After stirring the delonix regia seed oil-KOH-alcohol solution at 60 °C for half-an-hour the solution is transferred to a glass separator. Now separation takes place and biodiesel gets collected in the upper portion of the glass separator, whereas glycerine will settle down at the bottom portion [19][20]. This glycerine is removed from the glass separator. The biodiesel is washed with water, again glycerine gets separated from the biodiesel and is removed. The biodiesel is washed with water repeatedly until no trace of glycerine is seen in the biodiesel. Now this biodiesel is heated to 100°C to vaporize the water content in it. The resulting product is the biodiesel which is ready for use [21].

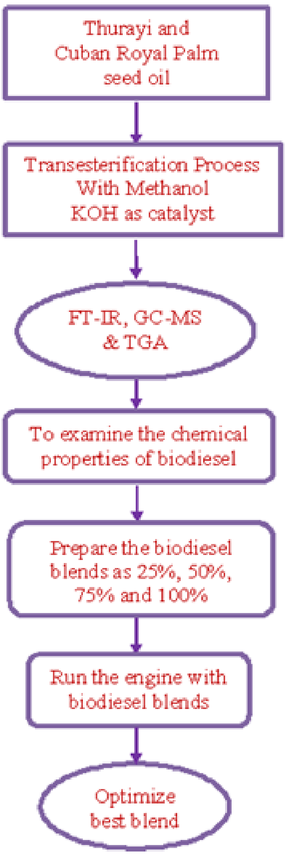

Figure 3. Methodology followed in preparing Alternate Fuels

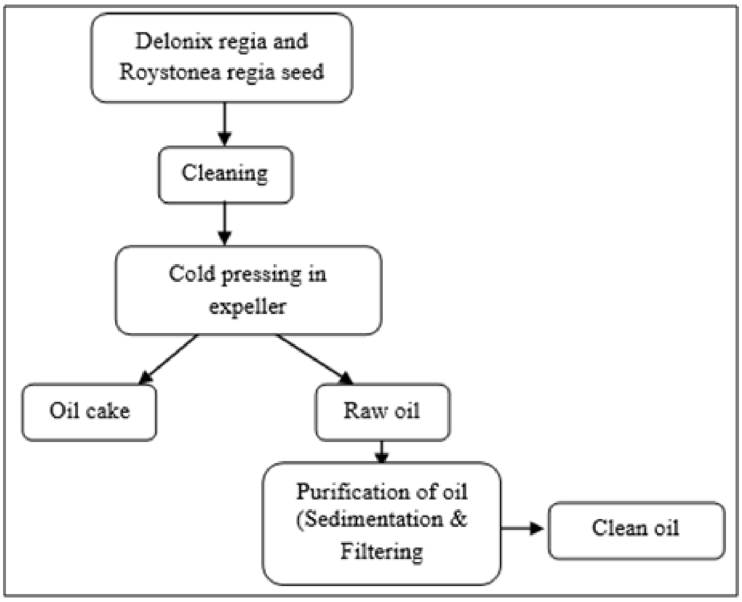

Figure 4. Overview of cold press process

The above procedure was followed to convert biodiesel for the roysotnea regia seed raw oil. From this process delonix regia gives maximum conversion of biodiesel when compare to roystonea regia [22][23]. The properties of Raw delonix regia and Roystonea regia seed oil in comparison with that of diesel are given in TABLE 1.

Table 1: Properties of diesel and raw seed oil

Properties	**Measurement Standards**	**Diesel**	**Delonix Regia Raw seed oil**	**Roystonea Regia Raw seed oil**
Kinematic viscosity at 40°C (CSt)	ASTM D445	2.6	35.44	37.21
Specific gravity @15° C	ASTM D1298	0.835	0.9211	0.9433
Flash Point (°C)	ASTM D92	74	295	300
Fire Point (°C)	ASTM D93	84	308	315
Pour point (°C)	ASTM D97	-23	-4	-5
Gross calorific value (kJ/kg)	ASTM D240	44,600	41352	40254
Density at15°C (g/cc)	ASTM D1298	0.8072	0.8220	0.8325

IV. Preparation of Biodiesel Blends

The alternate fuel of delonix and roystonea regia seed biodiesel in diesel engine is extracted through transesterification process [24]-[27]. The extracted both seed biodiesel were analyzed and its properties such as specific gravity, kinematic viscosity, calorific value, pour point, flash point and fire point. The properties of biodiesel blends are shown in TABLE 2 and 3. The biodiesel blends were prepared on volume basis. The blend B25 represents 25% biodiesel and 75% diesel fuel, B50 represents 50% biodiesel 50% diesel fuel, B75 represents 75% biodiesel and 25% diesel fuel and B100 represents 100% biodiesel.

Table 2. Properties of Diesel And Delonix Regia (DR) Seed Biodiesel Blends

Property	**Measurement Standards**	**Diesel**	**DR25**	**DR50**	**DR75**	**DR100**
Kinematic viscosity at 40°C (CSt)	ASTM D445	2.6	3.60	4.21	4.34	4.42
Specific gravity @15° C	ASTM D1298	0.835	0.8523	0.8578	0.8626	0.8821
Flash Point (°C)	ASTM D93	74	85	88	94	159
Fire Point (°C)	ASTM D92	84	89	92	98	171
Pour point (°C)	ASTM D97	-23	-10	-10	-8	-6
Gross calorific value (kJ/kg)	ASTM D240	44,600	43,875	42,655	42,548	42,425
Density at15°C (g/cc)	ASTM D1298	0.8072	0.8135	0.8496	0.8565	0.8822

Table 3. Properties of diesel and Roystonea Regia (RR) seed biodiesel blends

Property	**Measurement Standards**	**Diesel**	**RR25**	**RR50**	**RR75**	**RR100**
Kinematic viscosity at 40°C (CSt)	ASTM D445	2.6	3.75	4.32	4.38	4.46
Specific gravity @15° C	ASTM D1298	0.835	0.8566	0.8632	0.8711	0.8933
Flash Point (°C)	ASTM D93	74	87	89	96	163
Fire Point (°C)	ASTM D92	84	92	96	99	182
Pour point (°C)	ASTM D97	-23	-11	-10	-9	-6
Gross calorific value (kJ/kg)	ASTM D240	44,600	43,220	42,031	41,856	41,204
Density at15°C (g/cc)	ASTM D1298	0.8072	0.8233	0.8522	0.8638	0.8874

V. Performance of Thurayi Seed Oil Blends

The experiment was conducted on Kirloskar TV-1, single cylinder, four-stroke, water cooled DI diesel engine with a displacement of 661cc. The rated power of the engine is 5.2 kW at 1500 rpm with constant speed. The engine had a hemispherical bowl piston, 3 holes injector. The inline mechanical fuel pump was operated at a standard injection pressure of 220 kg/cm^2 and the recommended injection timing of 23° bTDC. The governor was used to control the speed of the engine. Cooling of the engine was accomplished by supplying water through the jackets in the engine block and cylinder head.In this section, investigations were carried out by standard piston with sole fuel and various blends of Thurayi (delonix regia) and Cuban royal palm (roystonea regia) seed biodiesel. The operation of the diesel engine was found to be very smooth throughout all load conditions, without any operational problems for the different biodiesel and their blends derived from transesterification process. It is observed that the performance is optimistic in this stage with blend DR25 (Thurayi blend). Fig.5 shows the Brake thermal efficiency with different blends of Thurayi. From the Figure it is evident that the performance is optimum in DR25 case. Similarly, Specific Fuel consumption, Smoke emission, CO emission, HC emission, NOx emissions, cyclic pressure and Heat release rate are shown in Figures 6 to 12.

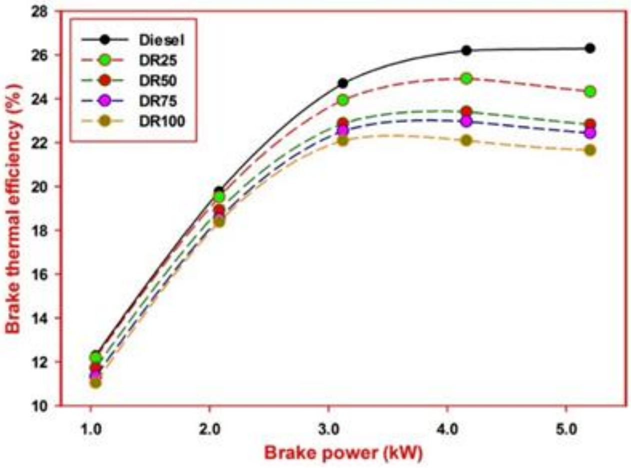

Figure 5. Brake thermal efficiency against brake power with different blends of Thurayi biodiesel.

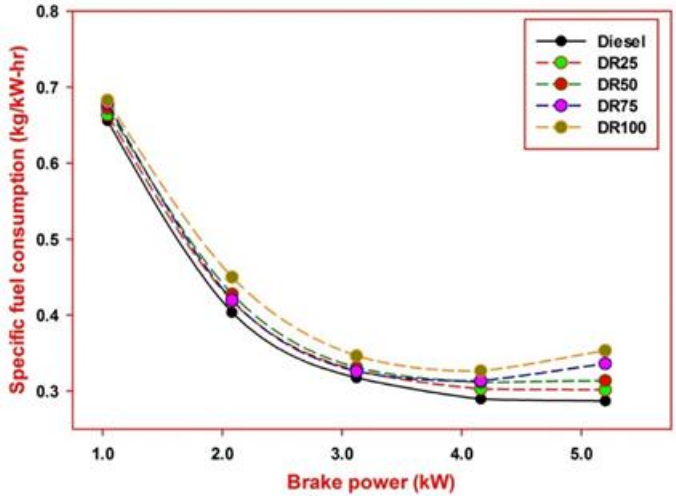

Figure 6. SFC against brake power with different blends of Thurayi biodiesel

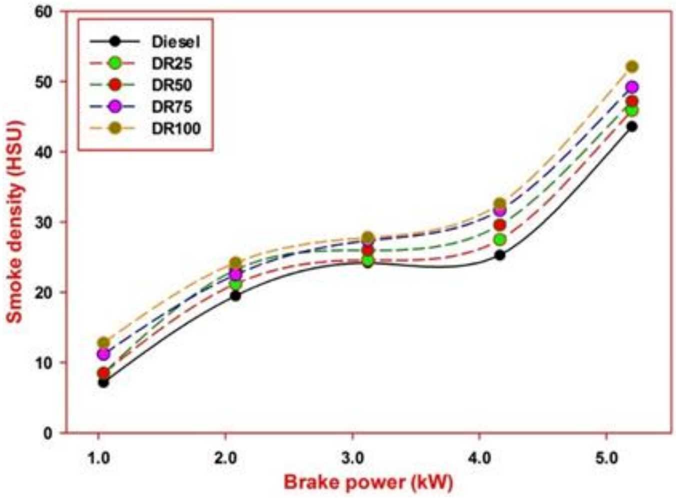

Figure 7. Smoke density against brake power with different blends of Thurayi biodiesel

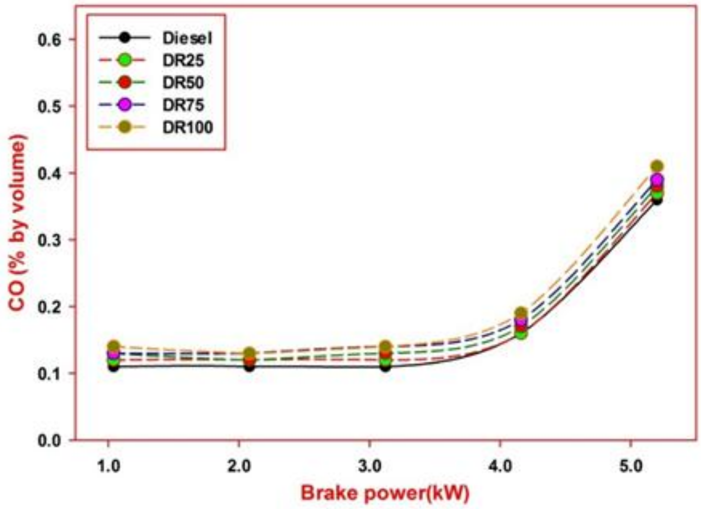

Figure 8. CO emissions against brake power with different blends of Thurayi biodiesel

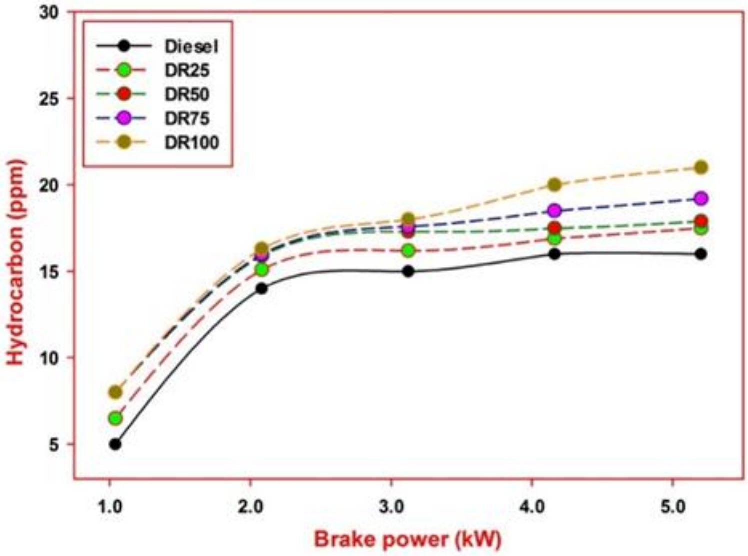

Figure 9. HC emissions against brake power with different blends of Thurayi biodiesel

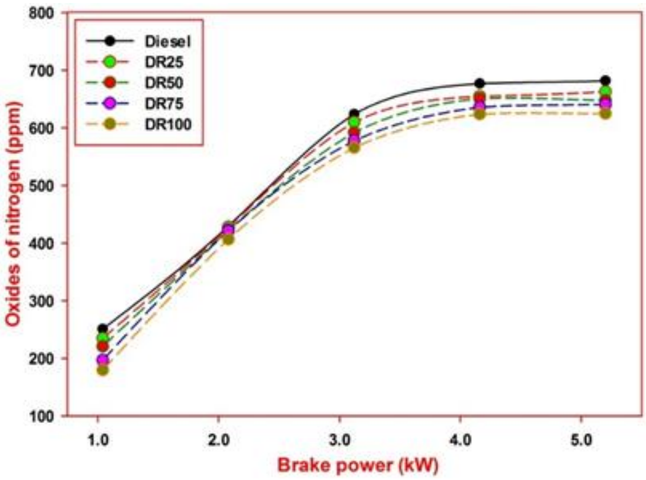

Figure 10. Oxides of Nitrogen against brake power with different blends of Thurayi biodiesel

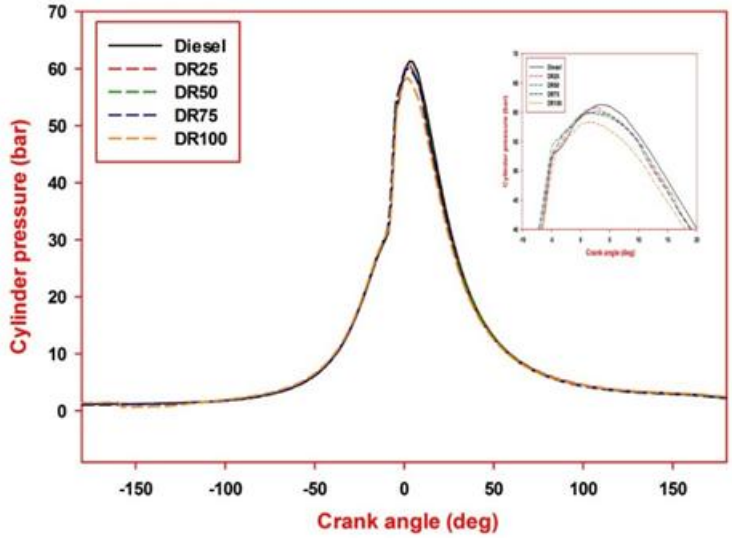

Figure 11. Cylinder pressure against Crank angle with different blends of Thurayi biodiesel

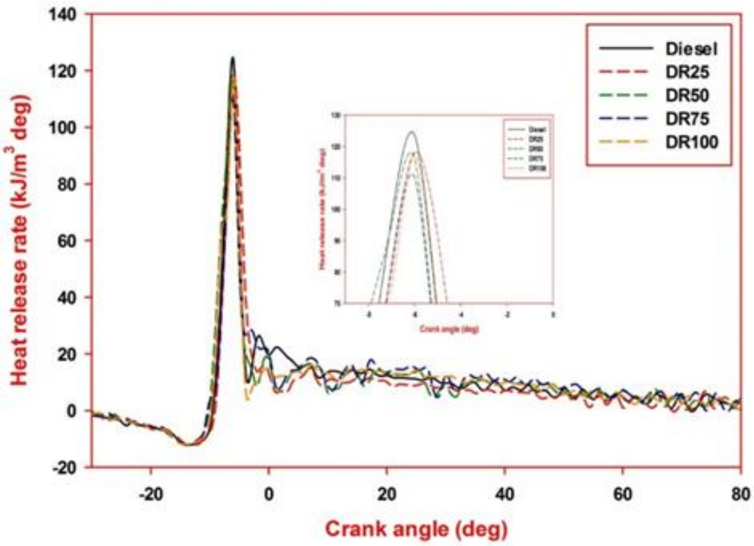

Figure 12. Heat release against Crank angle with different blends of Thurayi biodiesel

The Brake thermal efficiency, Specific Fuel consumption, Smoke emission, CO emission, HC emission, NOx emissions, cyclic pressure and Heat release rate for Cuban royal palm and blends are shown in Figures 17 to 24.

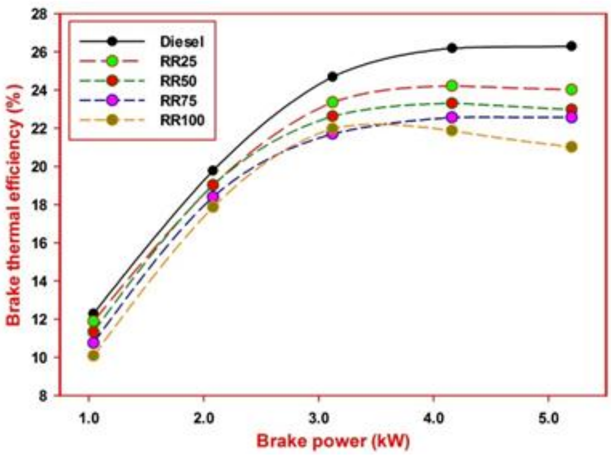

Figure 13. Brake thermal efficiency against brake power for roystonea regia biodiesel blends

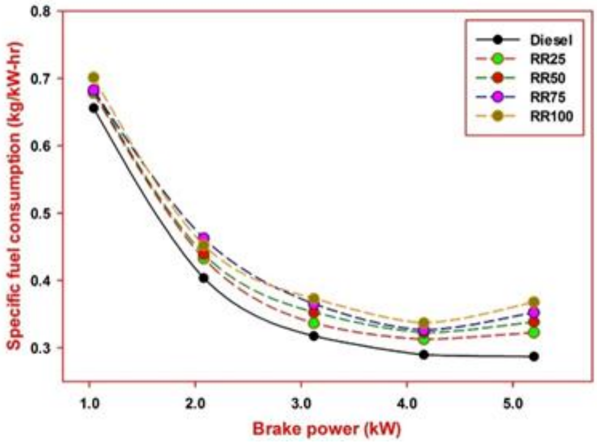

Figure 14. SFC against brake power for roystonea regia biodiesel blends

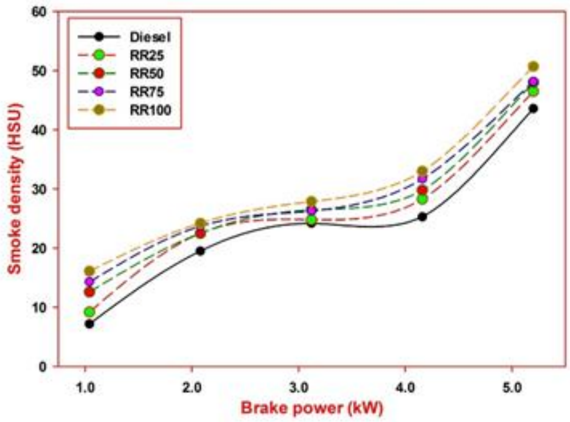

Figure 15. Smoke density against brake power for roystonea regia biodiesel blends

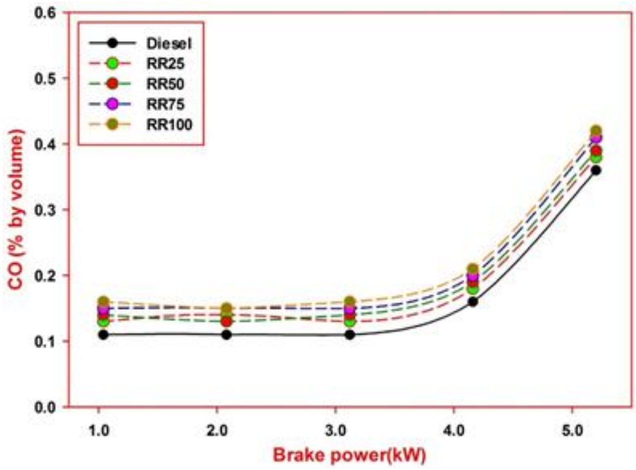

Figure 16. CO emissions against brake power for roystonea regia biodiesel blends

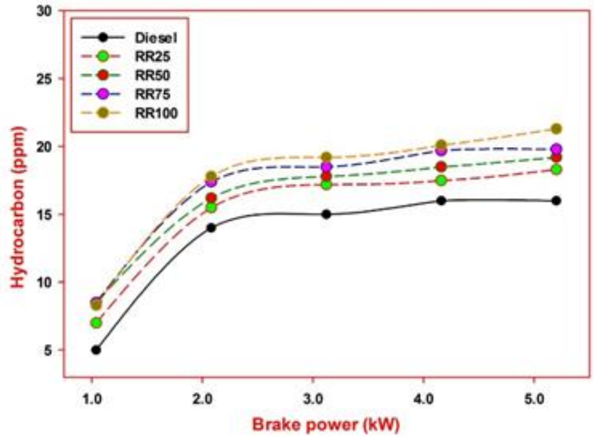

Figure 17. HC emissions against brake power for roystonea regia biodiesel blends

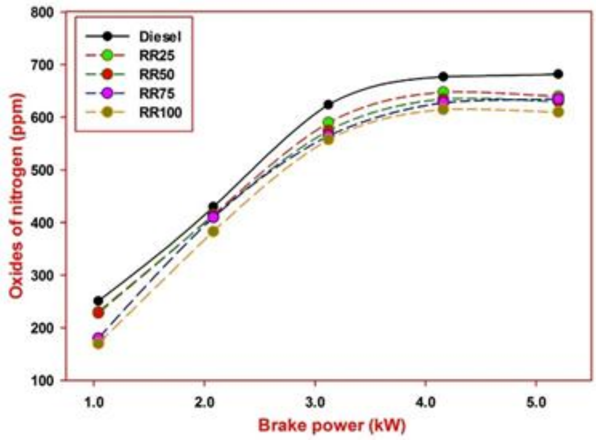

Figure 18. NOx emissions against brake power for roystonea regia biodiesel

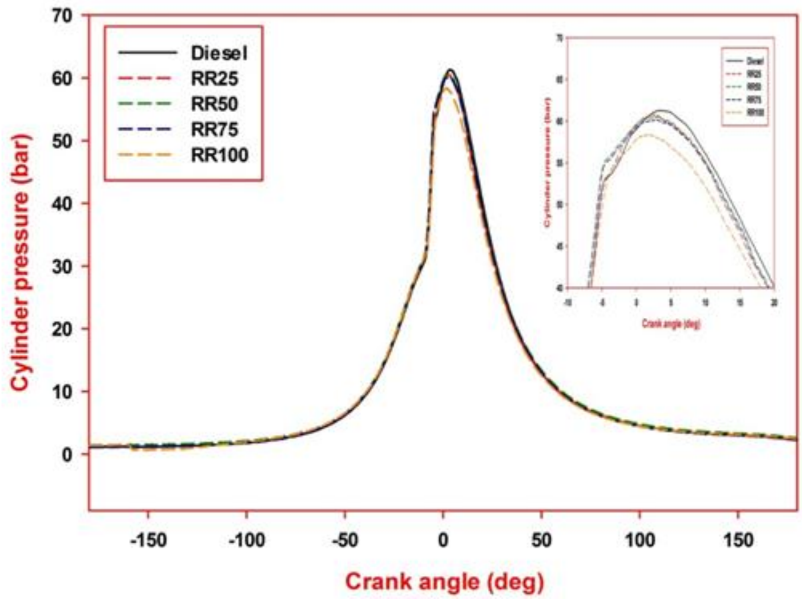

Figure 19. Cylinder pressure against crank angle for roystonea regia biodiesel blends

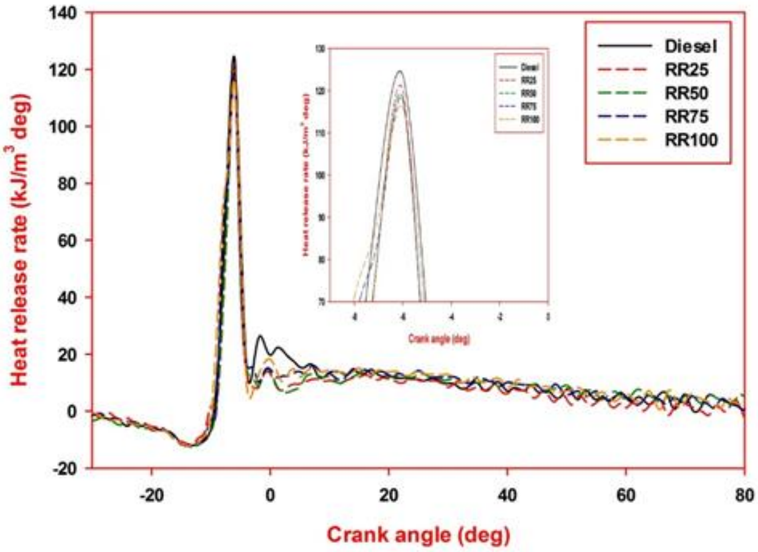

Figure 20. Heat release rate against crank angle for roystonea regia biodiesel blends

VI. Conclusions

In this paper, the fuel extraction process and preparation of biodiesel of the Thurayi and Cuban royal palm Seed Oils are presented. Blends each with 25%, 50%, 75% and 100% are prepared for both. These fuels are tested on a Kirloskar TV-1, single cylinder, four-stroke, water cooled DI diesel engine. Brake thermal efficiency, Specific Fuel consumption, Smoke density, CO emissions, HC emissions, NOx emissions, in-cylinder pressure and Heat release rate are calculated. It is experimentally verified that the blend DR25 outperforms when compared with the remaining cases.

References

[1]. MScott Curran, Zhiming Gao and Jim Szybist, Robert Wagner, Fuel Effects on RCCI Combustion: Performance and Drive Cycle Considerations, 2014 Coordinating Research Council Advanced Fuel and Engine Efficiency Workshop, Baltimore, Maryland February 24-27, 2014

[2]. Egebäck, K-E, Pettersson, E. "Research on a Scania 11 liter Ethanol Fueled Bus Engine". Research Report TULEA 1996:13, Luleå University of Technology. 1996.

[3]. 3. Brinkman, N.D., Ecklund, E.E., Nichols, R.J. "Fuel Methanol – A Decade of Progress". Society of Automotive Engineers, Inc. 1990. ISBN 1-56091-011-9., 60.

[4]. Lilia C. Fernfindez, "Effects of D-004, a Lipid Extract of the Fruit of the Cuban Royal Palm (Roystonea regia) or the Lipidosterolic Extract: A Controlled, Experimental Study". Current Therapeutic Research, Vol 69(1), 2008

[5]. Edward Ntui Okey and Peggy Ari Okey, "Optimization of biodiesel production from nonedible seeds of Delonix regia (Gul Mohr)". International Journal of Bioresource Technology 2013, Vol. 1(1), PP: 01 – 08.

[6]. Carmen L. Morales et al, "Physico-chemical characterization of the residual cake of D-004 production: lipids extract of the Roystonea regia fruits.Technical note". Cuban Journal of Agricultural Science2013, Vol.47(4), pp.409-411.

[7]. Deepu Krishnan et al, "Lipase catalyzed biodiesel production from delonix regia oil". Int. J. Engg. Res. & Sci. & Tech. 2015, Vol. 4(2), pp 258-264.

[8]. Pawar S.K, HoleJ.A, "Identification of Non-Conventional Seeds Oil as a Potential Feedstock for Biodiesel Production". International Journal of Science and Research 2017, Vol.6(2), pp.545-548.

[9]. Sarat Chandra Patra et al, "Production and characterisation of bio-oil from Gold Mohar (*Delonix regia*) seed through pyrolysis process". Taylor and Francis International Journal of Ambient Energy, Vol.38, pp.788-793

[10]. Oyede O.A. et al, "Chemical and Nutritional Compositions of Flame of Forest (Delonix regia) Seeds and Seed Oil". S. Afr. J. Chem., 2017, Vol.70, pp.16–20

[11]. Nu´bia M. Ribeiro, Angelo C. Pinto, Cristina M. Quintella, et al., "The Role of Additives for Diesel and Diesel Blended (Ethanol or Biodiesel) Fuels: A Review", *Energy & Fuels*, American Chemical Society, *21*, 2433-2445, 2007.

[12]. K.Venkateswarlu, K.Ramakrishna, K.Vijaya Kumar, "Improvement of Engine Performance and Emissions with Ethyl Hexyl Nitrate and Diesel-Biodiesel Blends", *International Energy Journal 13 (2012) 85-96.*

[13]. Matías Insausti and Beatriz S Fernández Band, "Determination of 2-ethylhexyl Nitrate in Diesel Oil Using a Single Excitation Emission Fluorescence Spectra (EEF) and Chemometrics Analysis", Journal on Fundamentals of Renewable Energy and Applications, April 2014, 4:2

[14]. "Project M100 – A Test with Methanol-Fueled Vehicles in Sweden". STU Information no. 640 – 1987. ISBN 91-7850-213-6

[15]. Richards, B., "Methanol-Fueled Caterpillar 3406 Engine Experience in On-Highway Trucks," SAE Technical Paper 902160, 1990, doi:10.4271/902160.

[16]. Chen, H., Yang, L., Zhang, P.-H., Harrison, A. The controversial fuel methanol strategy in China and its evaluation (2014) Energy Strategy Reviews, 4, pp. 28-33.

[17]. Yuen, P., Villaire, W., and Beckett, J., "Automotive Materials Engineering Challenges and Solutions for the Use of Ethanol and Methanol Blended Fuels," SAE Technical Paper 2010-01-0729, 2010, doi:10.4271/2010-01- 0729.

[18]. Peter Ahlvik, Åke Brandberg, Exhaust emissions from light duty vehicles propelled by different fuels. Effects on health, environment and energy usage. (In Swedish only) Avgasemissioner från lätta fordon drivna med olika drivmedel. Effekter på hälsa, miljö och energianvändning. KFB-Rapport 1999:38, 1999.
[19]. Machiela. P. Summary of the Fire Safety Impacts of Methanol as a Transportation Fuel. SAE Paper 901113
[20]. Edited by Malcolm Prinie Inc.: "Evaluation of the Fate and Transport of Methanol in the Environment." AMI Report 3522-22, available for download at the Internet site of AMI at: www.methanol.org, 2001.
[21]. Sileghem, L., Huylebroeck, T., Van den Bulcke, A., Vancoillie, J. et al., "Performance and Emissions of a SI Engine using Methanol-Water Blends," SAE Technical Paper 2013-01-1319, 2013, doi:10.4271/2013-01-1319.
[22]. Naganuma, K., Vancoillie, J., Sileghem, L., Verhelst, S. et al., "Drive Cycle Analysis of Load Control Strategies for Methanol Fuelled ICE Vehicle," SAE Technical Paper 2012-01-1606, 2012, doi:10.4271/2012-01-1606.
[23]. Brusstar, M., Stuhldreher, M., Swain, D., and Pidgeon, W., "High Efficiency and Low Emissions from a PortInjected Engine with Neat Alcohol Fuels," SAE Technical Paper 2002-01-2743, 2002, doi:10.4271/2002-01- 2743.
[24]. Roberts, G., Johnson, B., and Edwards, C., "Prospects for High-Temperature Combustion, Neat Alcohol-Fueled Diesel Engines," SAE Int. J. Engines 7(1):448-457, 2014, doi:10.4271/2014-01-1194.
[25]. Dempsey, A., Walker, N., and Reitz, R., "Effect of Piston Bowl Geometry on Dual Fuel Reactivity Controlled Compression Ignition (RCCI) in a Light-Duty Engine Operated with Gasoline/Diesel and Methanol/Diesel," SAE Int. J. Engines 6(1):78-100, 2013, doi:10.4271/2013-01-0264.
[26]. Bruce Morey. Alternative Fuels Face Challenges. http://saegtl.org/af/data/uploads/afcontent/gtlaf_magarticle_14autd03_01.pdf. Downloaded 2014-12-01
[27]. James Simnick, CRC, CRC Study on Octane Number and Engine Efficiency – Literature Rev. CRC, Baltimore February 2014.

International Journal of Engineering Science Invention (IJESI) is UGC approved Journal with Sl. No. 3822, Journal no. 43302.

M Suresh. "Combustion Performance and Exhaust Emission Analysis of Thurayi and Cuban Royal Palm Seed Biodiesel Blends on CI Engines." International Journal of Engineering Science Invention (IJESI), vol. 07, no. 01, 2018, pp. 66–77.