Study on performance and emission characteristics of split injection CRDi engine fueled with orange peel oil and diethyl ether

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Abstract: The constant increase in energy demand and the environmental issues due to higher utilisation of diesel fuel is frightening. The replacement of diesel fuel with biodiesel is the most viable solution to minimize the diesel fuel consumption and greenhouse gas emissions. The biodiesel with orange peel oil (OPO) and diethyl ether (DEE) can serve as a valuable alternative fuel, as OPO is naturally available with higher energy efficiency. The extracted orange peel oil characteristics gave its chemical and physical properties, which are suitable for using as additive for diesel fuel. The mixture is prepared with 30% DEE and 70% of OPO to get B5 (950 ml Diesel + 35 ml OPO + 15 ml DEE) and B15 (850 ml Diesel + 105 ml OPO + 45 ml DEE) mixtures. In this study, a split injection CRDi engine is used to conduct performance and emission tests using the above three fuel options. The tests were conducted using the new blend for different engine operating conditions and the brake thermal efficiency of B5 mixture offers 0.6% to 2.3% higher values in comparison with diesel fuel.

Keywords: Alternate Fuel, Biodiesel, Split Injection, Orange Peel Oil, Diethyl Ether, Biofuel.

1. Introduction
In past years, long consideration has been paid to numerous fuels towards reducing the emission of greenhouse gases discharged into the air. Various fuels utilized for transportation resulted in the huge emission of greenhouse gases. Hence, it is essential to form all attainable efforts to identify and use of alternate fuels. The increasing market value of crude oil is yet another concern for developing countries due to higher import volume. Energy utilization in India is 4% of worldwide energy, and it is the fifth biggest nation in energy utilization after USA, China, Russia, and Japan. At present, India imports 80% of absolute unrefined petroleum necessity. The petroleum diesel share is 40% of the absolute utilization of oil based commodities. Necessity of diesel in India is multiple times higher than petroleum and utilization of diesel has been multiplied over the most recent couple of many years. As
the vehicle possession has expanded, it is extended that the interest for petroleum and diesel in the year 2021-22 will be heightened to 31 MMT and 110 MMT separately [1-7]. Diez et al. learned about the split infusion in a single cylinder optical diesel motor. This examination researches the results of split infusion ways by means of significant level of EGR (Exhaust Gas Recirculation) in ignition execution & discharges on single cylinder DI optical fuel. Examination is decided on the results of injection fleeting plan of split injection ways. A Ricardo Hydra single chamber was used in that run of the mill test ways like cylinder pressure data, heat unharness investigation and fumes discharges examination were applied. Optical strategies like direct spray and burning mental picture were applied by implies that of a rapid imaging framework with a copper fume optical maser brightening framework and a fast two-shading framework was applied to get in-chamber Diesel ignition temperature and residue estimations appropriations [8]. Giwa et al. studied that utilizing orange peels for essential oil production. The extraction of volatile oil was accomplished in one amongst the laboratories of Abu-Bakr Tafawa Balewa University, Bauchi, African nation victimization water distillation, steam distillation and solvent extraction strategies on a laboratory scale. The orange peels used were no inheritable from daily Market, Bauchi, and Bauchi State, Nigeria. The orange peels were washed, cleaned with water and sundried for 5 days. The dried peels were then small-grained before being employed in every of the extraction strategies investigated during this work [9]. Howa et al. considered that impact of split injection and injection timing techniques in Emissions, combustion and performance characteristics of Diesel Engine Fuelled by means of Bio diesel mixed fuels. An amazingly lower NOx level under a hundred ppm are frequently gotten by hinder start of injection worldly request for every one of the B20 and B50 fuel activities and with triple injection subject. Different split infusion is a reasonable methodology to diminish NOx and smoke discharges with bio diesel [10]. Nataraj Ganesan et al. considered the presentation and discharge attributes of single cylinder diesel engine fueled by squander orange peel oil biodiesel mixed with Antioxidant Additive. Skin Oil was removed from the waste orange peel by dissolvable extraction technique. The exploratory examination uncovers that the oxides of nuclear number 7 emission region unit extensively diminished for OB20L5 and OB20L10 in contrast with OB20 and fuel. Also, the expansion of Associate in nursing inhibitor added substance to biodiesel inside the engine marginally diminishes the brake warm strength (BTE) in contrast with OB20 detectably. Additionally, it completely was noticed that the option of inhibitor added substance to OB20 marginally will expand natural compound, monoxide and smoke discharges [11]. Sivalakshmi et al. (2013) considered that impact of effect of biodiesel and its mixes with Diethyl Ether on the emissions, performance, and burning from a CI Engine. The outcomes demonstrate that top pressure of cylinder and warmth unharness pace is superior for BD5 than slick biodiesel. Monoxide outflows particularly at complete burden and fume discharges all things as oxides of component and natural compound emission increment for BD5 than those of slick biodiesel at most motor hundreds. The brake warm strength of BD5 is higher when contrasted with biodiesel [12].

This study is in an underlying stage which expects to utilize Orange Peel Oil as the crude material for biodiesel creation. With the upgrades proposed in each exploration of Orange Peel Oil, this is exceptionally evident that in future the aloe vera can be a practical crude material for biodiesel preparation [13-16].

2. Materials and methods
2.1. Experimental Setup
The plan includes single chamber, 4 stroke, fixed Variable Compression Ratio (VCR) CI engine, at an assessed expediency of 1500 rpm around develops a 5.4 kW. It is related with vortex current dynamometer for applying various burdens. By exceptionally arranged slanting chamber block strategy, the weight extent can be changed endlessly the engine and without adjusting the burning
chamber figuring. In accomplishing the work in the motor, different sensors are used, for instance, a mass stream sensor is used to find the mass stream pace of air goes into the chamber. A non-contact PNP sensor gives a heartbeat yield at each driving rod upset which measures the engine RPM. Using ‘K’ type thermocouples, the temperature of gases and water at various centers are evaluated. The itemized design of preliminary set up is showed up in figure 1.

The fuel use is assessed with the help of pair of optical sensors, one at top and another at the base to offer a hint to the PC to start and stop the time. The time taken for the usage of fuel at a fixed volume is resolved. Using a load cell transducer sort of strain check base, power is assessed. The yield of the electronic load cell is related with the load cell transmitter. By then, through interface card the yield of the load cell transmitter is related with the port of USB. Utilizing the Piezoelectric Transducer, the chamber pressure is resolved. By then, signals are dealt with to charge intensifier from pressure transducer. For cooling water and calorimeter water stream assessment rotameters are used. In like manner, the rotational encoder is used to record the engine speed and moreover the wrench edge position. These are totally given the engine game plan for assessing start weight and wrench edge assessments. Through an in-manufactured data getting system, the engine is interfaced with the PC.

The process of biofuel preparation, which mixes diesel fuel with Orange Peel Oil (OPO) and Diethyl Ether (DEE). In both B5 and B15 mixtures, the OPO and DEE proportion is followed as 70 % of OPO and 30% of DEE. By performance examination software of engine, the routine of engine & burning boundaries, for example, BSFC (Brake Specific Fuel Consumption), BP (Brake Power), BTE (Brake Thermal Efficiency), mechanical effectiveness, cylinder pressure, heat balance and warmth discharge rate were resolved. The opacity of the fume gas from the motor is estimated with the AVL 437C Smoke-Meter. Outflows like NOx, HC, CO2, and CO are estimated utilizing AVL 444 - 5 gas analyzer. Testing is done at various pressure proportions with various Loads (no load to full load).

![Figure 1. Experimental Setup](image-url)
2.2. Engine Specifications

Table 1. Specifications of Engine

| Sl. No. | Items                        | Specifications                                           |
|--------|------------------------------|---------------------------------------------------------|
| 1      | Engine                       | Kirloskar TV1                                           |
| 2      | Power and Speed              | 3.5 kW and 1500 rpm                                     |
| 3      | Type of Engine               | Single cylinder, Split Injection and 4 Stroke           |
| 4      | Compression Ratio            | 17.5:1                                                  |
| 5      | Bore and Stroke              | 87.5 mm and 110 mm                                     |
| 6      | Method of Loading            | Eddy Current Dynamometer                                |
| 7      | Method of Starting           | Electrical Starting                                     |
| 8      | Method of Cooling            | Water                                                   |
| 9      | Type of Ignition             | Compression Ignition                                    |
| 10     | Pilot Fuel Injection Timing  | 53° Before TDC                                           |
| 11     | Main Fuel Injection Timing   | 23° Before TDC                                           |
| 12     | Nozzle Opening Pressure      | 500 bar                                                 |
| 13     | Lubricant Oil                | SAE 40                                                  |

2.3. Emission Analyzer

Smoke meter is utilized to quantify the force of smoke present in the fumes gas and the smoke meter specification is given in the Table 2, it is used to measure the CO₂, CO, O₂, HC, and NOx present in fumes gas. This analyser consists of four detectors namely, Non-Dispersive Infrared Detector (NDIR) which, detects CO and CO₂ emission, Chemiluminescence Detector (CLD) which detects NOx emission, Flame Ionization Detector (FID) which identifies HC emission and Lambda sensor which detects the O₂.

Table 2. Emission Analyzer and Smoke Meter Specification

|                   | Emission Analyzer                      | Smoke Meter                               |
|-------------------|----------------------------------------|-------------------------------------------|
| **Emission Analyzer** |                                        | **Smoke Meter**                          |
| Type              | AVL DI Gas 444                          | Type                                     |
| CO                | 0 - 15 %                                | Opacity                                  |
| CO₂               | 0 - 20 %                                | 0-100 in %                               |
| HC                | 0 - 30,000 ppm                          | Absorption                               |
| O₂                | 0 - 25 %                                | 0-99.99 m-1                              |
| NOx               | 0 - 5000 ppm                            | Speed                                    |
|                   |                                        | 400 - 6000 min-1                         |
|                   |                                        | Oil Temperature                          |
|                   |                                        | 0 - 150 °C                               |
|                   |                                        | Max smoke temperature                    |
|                   |                                        | 250 °C                                   |
3. Results and Discussions

3.1. Brake Thermal Efficiency

Figure 2 represents the contrast of BTE with various BMEP. The BTE (Brake Thermal Efficiency) raised with the raise in load for all bio diesel blends as well as Diesel. The BTE is higher for Diesel than all the other blends of biodiesel when operated at full loads. But at initial and part loads, the BTE is similar to that of Diesel when biodiesel is operated with additive. Although OPO+DEE has equal calorific value to Diesel, the BTE is similar to Diesel because of the additive Diethyl Ethyl Ether (DEE). The oxygen molecules in the additive make combustion, thus producing same thermal efficiency as of Diesel.

3.2 Brake Specific Fuel Consumption

The introduction of a fuel is chiefly established on the power yield that it generates when fuel is scorched in the burning chamber. The OPO+DEE biodiesel in different blends in with Diesel is attempted in the variable pressure motor with a predictable weight extent of 17.5:1. The SFC (Specific Fuel Consumption) execution and BTE (Brake Thermal Efficiency) for different blends of OPO+DEE biodiesel is differentiated and the Diesel. The figure 3 represents the assessment of Specific Fuel Consumption with stacking condition for different blends and unadulterated Diesel.

Explicit fuel utilization may be the measure of fuel expended towards create power of one unit. Figure 3 represents the correlation of Fuel utilization for different mixes of OPO+DEE biodiesel. As of the figure 3, unmistakably at whatever point the Load is expanded the particular Fuel utilization is diminished. Along with all the mixes, diesel has the lesser measure of fuel utilization in light of its superior calorific worth though the wide range of various mixes have more fuel utilization than Diesel. B15 have extra measure of fuel utilization than various biodiesel mixes. B5 has smallest amount of fuel utilization between two bio diesel mixes. This guarantees that, increment in level of OPO+DEE expands fuel utilization.
3.3 Cylinder Pressure

The variety of chamber pressure for B5 mixes of bio diesel be representing in Figure 4. As of the diagram, it was apparent that the chamber weight of diesel (80.70 Bar) is considerably greater in correlation by means of this mix of biodiesel. Meant for bio diesel the peak pressure was discovered to be practically comparative for this mix with added substance. The Peak pressure of B5 was discovered to be 80.70 bar individually. B5 has somewhat higher peak pressure, which was a consequence of marginally enhanced ignition. B15 have marginally helpless burning. The Peak Pressure of B5 bio diesel with added substance happened 5° wrench point previous to the Peak Pressure of diesel. This is expected to the enhanced Cetane list of B5 with added substance.

Figure 3. BSFC vs. Load

Figure 4. Crank Angle of B5 blend vs. Cylinder Pressure
The variety of chamber pressure for B15 mixes of bio diesel was represented on Figure 5. As of the chart, it is obvious that the diesel Cylinder Pressure (82.24 Bar) is significantly greater in examination by means of this mixes of biodiesel. For biodiesel the peak pressure was discovered to be practically comparative for this mixes with added substance. The peak pressure of B15 was discovered to be 82.24 bar individually. B15 has marginally superior Peak Pressure which was an after effect of somewhat enhanced ignition. When contrasted with B15 is B5 had somewhat helpless burning. The peak pressure of B15 biodiesel with added substance happened 4° wrench edge before the pinnacle weight of diesel. It is expected to the enhanced Cetane list of B15 with added substance.

3.4 CO2 Emission

Fuel, which was used to push the motor vehicle, comprises of C & H atoms. The Carbon particles at hand in the Fuel joins by means of the oxygen commencing the inlet manifold and structures CO₂ during the ignition cycle. The Figure 6 represents the measure of carbon dioxide (CO₂) emission for B5 & B15 with OPO+DEE and Diesel fuel. Unadulterated Diesel transmits the most noteworthy measure of CO₂ contrasted and different mixes. At 25% and half burden the discharge was small yet at superior loads the outflow arrives at the most extreme stage contrasted and different mixes and the blends For B5 and B15 with added substance, the CO₂ emission happens greatest at 100% load. For B5 with added substance, the discharge is more and it is almost equivalent to the measure of Diesel emissions. For B15 with added substance, the discharge is at first more at the lower stacks however when the heap is expanded the outflow is lower contrasted and different mixes.
3.5 NO\textsubscript{X} Emissions

The NO\textsubscript{X} is formed because of the peak combustion heat (oxygen concentration) on the engine cylinder, which has to counteract effectively. This is done by exhaust gas recirculation system as it prevents the oxidation of nitrogen. The NO\textsubscript{X} formation is lesser in rich mixtures and greater in lean mixtures. The engine fueled with biodiesel, B5 with DEE produced 380 ppm, 1059 ppm, 1713 ppm, 2170 ppm and 2284 ppm for 0%, 25%, 50%, 75% and 100% loading conditions; B15 with DEE produced 480 ppm, 1166 ppm, 1743 ppm, 2263 ppm and 2314 ppm for 0%, 25%, 50%, 75% and 100% loading conditions. The B5 with DEE provided 1713 ppm Nitrous Oxide at 25% load and an increase in load increased Nitrous Oxide to 2170 ppm and 2284 ppm at 75% and 100% load, respectively. The B15 with DEE provided Nitrous Oxide of 1166 ppm at 25% load, 2263 ppm and 2314 ppm for 75% and 100% load, respectively. For increase in percentage of OPO+DEE blends with additive, the B5 fuel with additive resulted in decrease in NO\textsubscript{X} compared to the neat Diesel as shown in figure 7. And also increase in EGR rate further decreases the NO\textsubscript{X} emissions. A maximum Nitrous Oxide of 2205 ppm was gained at 100% load for Diesel. In case of B15 with additive applied at varying rates, makes lesser emission of NO\textsubscript{X}. This ensures that, degree of reduction of NO\textsubscript{X} emissions is due to low temperature OF working fluid in the combustion cylinder as the exhaust fume displaces fresh air goes into the chamber thereby lowering the oxygen concentration. The flame temperature gets reduced as the exhaust mixed with intake air thus increasing the intake mixture’s specific heat. Thus, NO\textsubscript{X} gets reduced by the effect of low oxygen and reduced flame temperature. The biodiesel with additive shows a slight decrease in NO\textsubscript{X} emissions and when applied at different decreased rates it further exhibits lesser NO\textsubscript{X}. So, DEE resulted in good response for controlling NO\textsubscript{X} in CI engines for the biodiesel B5. The minimum NO\textsubscript{X} recorded for 100% load is 2284 ppm compared to Diesel.B5&B15 and Diesel had moreover similar NO\textsubscript{X} emission.B5&B15 fuel had 0.5% to 1% decreased NO\textsubscript{X} emission at peak cylinder pressure. But biodiesel is completely burned and attain more heat release rate in the cylinder.
3.6 Hydrocarbon Emissions
The hydrocarbon arrangement relies upon the kind of fuel utilized and it will fluctuate as indicated by the distinctive fuel mixes properties. The hydrocarbon development additionally relies upon the burning cylinder geometry, blemished ignition and affidavit on the burning chamber dividers, oil on ignition chamber dividers lastly the motor working conditions. The hydrocarbon outflow of the motor powered with Diesel was 7.5 ppm, 11.5 ppm, 27 ppm, 37 ppm and 50 ppm for 0%, 25%, half, 75% and 100% stacking conditions, respectively. The engine filled with biodiesel, B5 with DEE created 6 ppm, 10 ppm, 20 ppm, 34 ppm and 55 ppm for 0%, 25%, half, 75% and 100% stacking conditions, individually.
Addition of (OPO+DEE) in the structure of B5 and B15 fuel had higher HC outflow fuel in the 100% load condition because of the incomplete oxidation of fuel molecules. The motor fuelled with biodiesel, B15 with DEE delivered 7 ppm, 10 ppm, 25 ppm, 36 ppm and 34 ppm for 0%, 25%, half, 75% and 100% stacking conditions, separately. For increment in level of OPO+DEE mixes, the B15 fuel with added substance brought about increment in HC contrasted with the slick Diesel as appeared in figure 8. A greatest HC of 52 ppm was acquired at 100% burden for B5 with DEE is contrasted and slick Diesel. This guarantees that, increment in HC is because of the lacking measure of oxygen in the ignition chamber that happened at B5 added substance. A slight increment in HC outflows is noted in biodiesel added substance mixes contrasted with the flawless Diesel.

3.7 Smoke Opacity
Smoke is an evil impact of burning cycle. It is the mix of gases, fluid and airborne strong particulates delivered during ignition of fuels in the engines and smoke is by and large of three kinds, for example, dark smoke, blue smoke and white smoke. Smoke causes different issues and wellbeing impacts to the climate and people. It is estimated regarding opacity. The investigation of discharges in the trial is introduced underneath. Figure 9 shows the variety in smoke darkness for biodiesel with added substance at various activity. The motor powered with Diesel created smoke in haziness of 5.8%, 13.9%, 27.6%, 46.7% and 40.5 % for 0%, 25%, half, 75% and 100% stacking conditions, separately. The engine fueled with biodiesel, B5 with DEE created smoke of 6.3 %, 23.7 %, 25.2%, 27.2% and 41.9% for 0%, 25%, half, 75% and 100% loading conditions, individually. B15 with DEE delivered smoke of 6.5 %, 27.1 %, 32.9 %, 40.3 % and 43.2% for 0%, 25%, half, 75% and 100% loading conditions, separately. A slight increment in smoke emissions is noted in biodiesel added substance mixes with contrasted with the flawless Diesel.

![EMISSION GRAPH of HC](image)

Figure 8. HC Emission vs. Load
4 Conclusion

The Performance, Emission, and Combustion characteristic of OPO+DEE bio diesel is experimented by means of the CRDi engine. From the test work, the accompanying outcomes are finished up as follows.

- Along with all the mixes, Bio Diesel & Diesel include a related measure of fuel utilization because of its equivalent calorific value. B15 have extra specific fuel utilization than the other bio Diesel mixes. B5 with additive at different load rates considerably decreases the specific fuel consumption fuel compared to Diesel. This ensures that, remain same in percentage of Orange Peel Oil and Diethyl Ester had same amount of heat release rate in these blends.

- The BTE is higher for Biodiesel than the wide range of various blends of biodiesel and Diesel when operated at full loads. But during initial and part load conditions, the BTE is similar to that of Diesel when biodiesel is operated with additive. Increases the BTE at all the loads due to the high peak combustion pressure. Overall, BTE 0.5 % shows higher thermal efficiency at all operating conditions.

- In all biodiesel mixes, the Peak Pressure was discovered to be practically higher with diesel. B5 has greater Peak Pressure, which is a consequence of somewhat enhanced burning. It is expected to the enhanced cetane index of B5 with added substance. When high pressure is applied, at 500 bar, the combustion pressure has to be increased but due to the diethyl ethyl ether (DEE) it is slightly higher than B15 with additive. In Net Heat Release Rate B5 and B15 had higher peak heat release rate in engine.

- For increment in level of OPO+DEE mixes, the B5 fuel with added substance brought about decline in HC contrasted with the perfect diesel. Conversely, increment in B15 builds the HC discharges. A slight lessening in HC outflows is noted in biodiesel added substance mixes contrasted with the slick diesel.
• For reduction in percentage of OPO+DEE blends with additive, the B5 fuel with additive resulted in decrease in NOx compared to the neat diesel and increase in B15 rate further decreases the NOx emissions. The biodiesel with additive shows a slight decrease in NOx emissions. Hence, DEE with OPO resulted in good response for controlling NOx in CI engines for the Biodiesel B5.

• In biodiesel with B5 with additive, CO2 emissions are considerably reduced at 20%. However, at 10%, emissions are marginally reduced. This ensures that, increase in CO2 decreases the CO2 emissions. Comparatively, less CO2 emissions are produced with respect to other blends and diesel.

• For increment in level of OPO+DEE mixes, the B50 fuel with added substance brought about increment in smoke contrasted with the neat diesel. Interestingly, increment in rate expands the smoke. A slight diminishing in smoke outflows is noted in biodiesel added substance mixes with contrasted with the neat diesel.

The demand for fixed, eco-friendly and sustainable energy supply is required to control the interest for bio fuel over the globe. Due to higher orders for bio fuel mixing in car enterprises and expanding government uphold for eco-accommodating other options, the worldwide utilization of bio fuel is relied upon to develop at a noteworthy level later on. For road transport, ethanol and bio fuels speak to the larger part portion of renewable sources in worldwide energy request. The United States, China, and Brazil are relied upon to show greatest development later on because of their orders of bio fuel mixing. China is the most encouraging business sector for bio fills because of expanding energy security concerns and responsibility to diminish the carbon emission levels.

References
[1] Ashok B., Nanthagopal K., Arumuga Perumal D., Babu J.M., Anmol Tiwari and Akhil Sharma 2019 Investigation on CRDi Engine Characteristic Using Renewable Orange-Peel Oil  *Energy Conversion and Management* 180 1026–1038.
[2] Ashok B., Nanthagopal K., Saravanan B., Somasundaram P., Jegadheesan C., Bhaskar Chaturvedi, Shivam Sharma and Gaurang Patni 2018 A novel study on the effect Lemon Peel oil as a fuel in CRDI Engine at various injection strategies  *Energy Conversion and Management* 172 517–528.
[3] Jegadheesan C, Somasundaram P, Meenakshipriya B, Vignesh UP 2013 Investigation on the effects of conventional fossil fuel to the environment and research on renewable fuels with reduced emission using biodiesel, diethyl ether and hydrogen  *Nature Environment and Pollution Technology* 12 (4), 661
[4] Ayyasamy, T., Balamurugan, K., & Duraisamy, S. 2018 Production, performance and emission analysis of Tamanu oil-diesel blends along with biogas in a diesel engine in dual cycle mode  *International Journal of Energy Technology and Policy*, 14(1), 4-19.
[5] Dinesh, K., Tamilvanan, A., Vaishnavi, S., Gopinath, M., & Mohan, K. R. 2019 Biodiesel production using Calophyllum inophyllum (Tamanu) seed oil and its compatibility test in a CI engine. Biofuels, 10(3), 347-353.
[6] Sathiskumar S, Dhavaneeswaran N and Dhanush Guru R 2019 Performance and Emission Testing of Methyl Ester of Aloe vera using Metal Oxide as Additive in CI Engine  *International Journal of Innovative Technology and Exploring Engineering* 9 126-133.
[7] Ashrafur Rahman S.M., Hossain F.M., Thuy Chu Van, Ashley Dowell, Islam M.A., Thomas J. Rainey, Zoran D. Ristovski and Richard J. Brown 2017 Comparative Evaluation of The Effect of Sweet Orange Oil-Diesel Blend on Performance and Emissions of a Multi-Cylinder Compression Ignition Engine  *AIP Conference Proceedings* 1851 020007 .
[8] Diez and Zhao 2010 Investigation of Split Injection in a Single Cylinder Optical Diesel Engine  *SAE Technical Paper* 01 0605.
[9] Giwa Saidat Olanipekun, Mahmood Muhammad and Abdulwahab Giwa 2018 Utilizing orange peels for essential oil production  *ARPN Journal of Engineering and Applied Sciences* 13 (1) 17- 26.
[10] Howa H.G., Masjuki H.H., Kalam M.A. and Teoh Y.H. 2017 Influence of Injection Timing and Split Injection Strategies on Performance, Emissions, And Combustion Characteristics of Diesel Engine Fuelled with Biodiesel Blended Fuels Elsevier, Fuel 213 106–114.

[11] Nataraj Ganesan and Senthilkumar Masimalai 2019 Experimental investigation on a performance and emission characteristics of single cylinder diesel engine powered by waste orange peel oil biodiesel blended with antioxidant additive Taylor & Francis, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects 1-12.

[12] Sivalakshmi S. and Balusamy T. 2013 Effect of Biodiesel and Its Blends with Diethyl Ether on the Combustion, Performance and Emissions from a Diesel Engine Elsevier, Fuel 106 106–110.

[13] Xiangrong Li, Haobu Gao, Luming Zhao, Zheng Zhang, Xu He and Fushui Liu 2016 Combustion and Emission Performance of a Split Injection Diesel Engine in A Double Swirl Combustion System Energy 114 1135-1146.

[14] Yehliu Kuen, Boehman Andre and Armas Octavio 2010 Emissions from different alternative diesel fuels operating with single and split fuel injection Elsevier, Fuel 89 423-437. Purushothaman, K. and Govindan, Nagarajan. 2010 Studies on the characteristics of orange oil—diethyl ether in a direct injection diesel engine International Journal of Engine Research - INT J ENGINE RES 11 219-228.

[15] Siva Ramasamy, Munuswamy Dinesh and Devarajan Yuvarajan 2018 Emission and performance study emulsified orange peel oil biodiesel in an aspirated research engine Petroleum Science 6 1-7.

[16] Boopalan N, Sathishkumar S, Jeevabharathi R, Gokulraj D 2020 Experimental Investigation on Performance and Emission Characteristics of Biodiesel Fuelled Compression Ignition Engine with Oxygen Enrichment International Journal of Advanced Science and Technology 29 4054-4063.