International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-4, February 2020

Biodiesel, Promising Fuel and its Impact on Performance of IC Engine

Shiv Kumar Sonkar, Prashant Baredar, Pushyamitra Mishra

Abstract*: Biodiesel is an effective alternative fuel that can be used in vehicles. These biodiesels can be obtained from different sources such as vegetable oil, animal oil, non-food biomass, algae and artificially obtained oil. This document reviews different works considering the utilization of biodiesel, its blends and the impact on the IC engine performance and emission. These review study are categorized in four categories in order to get a clearer idea of the biodiesel and its impact on the engine. These categories are divided as engine performance, engine emissions mainly of NOx, impact of biodiesel on engine component and vice versa, and different generations of biodiesel. The first category describes the research work on the impact of biodiesel on the emission of NOx. Several investigations have been studied regarding this and presented in this review. Second category in this document deals with the effect of biodiesel when used in an IC engine, on the performance of IC engine and also the piston thrust inside the chamber. The third category shows several investigations that were studied and presented the work regarding the effects of biodiesel on the engine components, such as fuel delivery materials (FDM). It also has been seen that the deterioration of biodiesel can also happen under common rail diesel engine operation. And the last categorization was done considering the yield of biodiesel which is divided on the basis of its origin into four generations from where biodiesel is actually extracted. Several authors have performed their works which adheres the last category and explained the different impact of different generation of biodiesel. In the applications, it was observed that it has been seen as the accurate replacement of diesel especially in the IC engines. Also the much lesser harmful emission and less amount of emission are observed. After all these, the performance of engine is also seen as improved.

***Keywords:* Animal oil, Biodiesel, FDM (Fuel Delivery Material), Fuel emission, IC engine, Non-food biomass, vegetable oil.**

I. INTRODUCTION

A contrasting situation has now emerged in front of the world regarding fuel consumption. There is a high demand of fuel or energy resource to fulfill and satisfy needs and to fulfill this; fossil fuels are used all over the world extensively which creates a crisis of depletion.

Revised Manuscript Received on February 28, 2020.
***** Correspondence Author
Shiv Kumar Sonkar*, Assistant Professor, Department of Electrical and Electronics, SIRTS, Bhopal, India.
Prashant V. Baredar, Chairman & Professor & Head, Department of Energy, Energy Centre, MANIT, Bhopal, India.
Pushyamitra Mishra, Assistant Professor, Department of Mechanical Engineering, MANIT, Bhopal., India.

On the contrary, demand is still up surging as world population continues to grow along with the fast industrialization, urbanization and economic growth (Xiao et al.). High scientific growth has managed to predict the future in a precise manner and thus prediction comes for the explicitly used fossil fuels for the energy which evaluates that future comes with their depletion. Petroleum, coal and methane being exhaustible are major sources of energy in current time. Data speaks about the consumption of fuel as around 86% of fossil fuel was used as primary energy in 1973 whereas in 2015, this has degraded to 8% less than in 1973. The production is predicted to reach to its limit in 2020 while China and India becoming the main consumer (Singh et al.). Now, if someone looks around, they can find themselves covered with day to day usage of fossil fuels. Transportation, agriculture and industries are the three major sectors which totally rely on fossil fuels. Rudolf Diesel, who invented diesel engine, had proposed the idea of biodiesel in world fair, Paris in 1900. Peanut oil was being said by him as the local crops can be used to extract diesel from them.

A. Biodiesel

Biodiesel is a fuel which is obtained from plants and animals through different processes of refining and transformation (Yaşar). Exploring into the current researches that have explained so much about the fuels and their applications, biodiesel and its applications in IC engines have always been leading from the front. It is the movement from thousand problems to thousands of solutions as biodiesel delivers solutions of not only energy crisis, but also the safety of environment (Ogunkunle and Ahmed).

B. Biodiesel – Extraction Processes

As the world is pounding for an alternative fuel to be used instead of diesel in compression ignition engine, biodiesel has come across research scholars which tend to provide and deliver similar properties and outcomes without any bigger mechanical modification when compared to diesel. Biodiesel extraction process varies based on their feedstock and origin (Yan and Yan). The different types of techniques and synthesis process of biodiesel are described below –

1. Pyrolysis: Pyrolysis is also known as thermal cracking. The term thermal cracking itself describes the process of transforming a substance to another with the help of heating, catalyst may or may not take part. This type of heating is done in the absence of air or oxygen to break the chemical bond and produce smaller molecules (Tan et al.).
2. Transesterification Process: Transesterification process delivers huge conversion rate as well as reaction rate in the given amount of time.

It is a chemical process in which transesterification of triglycerides of fatty acids happens and converts it into biodiesel with the help of methanol or ethanol as catalyst. In this, glycerin is produced as a byproduct of this reaction (Demirel).

3. Biochemical Process: Biochemical process is the in which a substance is broken down and converted through a biological process such as fermentation of sugars in biomass crops to alcohol. Organic compounds are broken by several enzymes and microorganisms and organic compounds gets converted into biomass feedstock into alcohols and biofuels (Abou-shanab).

C. Biodiesel – An Alternate fuel

Biodiesel is considered to be the best of the time, because of its huge similarity with the diesel in terms of energy and also in reduction of emissions and being a renewable source of energy. It is the best replacement of diesel in terms of exhaustibility as it is inexhaustible. On the perfect note, its production is also from the natural crops such as plant oil, animal fat and microorganism, thus completely eco-friendly in nature and has a huge potential as an energy resource (Ramkumar and Kirubakaran, 2016). Since the biodiesel is all eco-friendly and is also produced from the natural things, it becomes a carbon close plant. This means that, there is almost no carbon emission in the atmosphere as it is produced from the nature and goes back to nature, with much lower emissions compared to the emissions from combustions of other fossil fuels. Biodiesel, for sure has an upper edge over the conventional diesel (fossil fuel). One major concern due to its production is, when certain land is dedicated towards biofuel feedstock, that land will not be available for the production of food crops (Wong et al., 2019).

Not only the air and land, but also the sea, is badly affected region due to emissions from the combustion of fossil fuels. Since transportation and shipping activities are considered to be two most big industries using the fossil fuel energy. The strictness of norms and rules from International Maritime Organization forced to explore another alternative for the growing energy demands (Vedharaj et al., 2013). And the reason that has emerged from sea is that it reduces the toxic gaseous emissions and also the dependency of fossil fuels (Balamurugan, Arun and Sathishkumar, 2018). The major aspect of biodiesel is that there is no need for any huge modifications in the engine or fuel, to operate in place of diesel. They already meet the world standards to be directly used in diesel engine. This is mainly because of similar combustion characteristics between the biodiesel and conventional diesel. Rudolf Diesel has already confirmed biodiesel's use in the future (Mohd Noor, Noor and Mamat, 2018). On the other hand, road and air transportation are also the majorly affected segments due to emission from the combustion of fossil fuels. The biodiesel are one of the best alternatives for IC Compression Ignition engines (Tamilselvan, Nallusamy and Rajkumar, 2017). Pure biodiesel may or may not give reduced emissions, but blends of biodiesel with diesel gives a lower opacity of smoke on comparison to diesel fuel. 45% with B70 and 60% with pure diesel was decreased. Brake thermal efficiency of soya biodiesel blends are found to be lower than they are found to be in diesel. The lowest BSFCs (brake specific fuel consumption) are 240.53, 257.16, 259.91, 263.88, and 270.35 g/kW h for diesel fuel, B30, B50, B80 and B100 respectively by (Ramalingam, Rajendran and Ganesan, 2018). On further comparing with diesel fuel, it was found that CO and smoke emission were decreased by a substantial amount.

(Chaurasiya et al., 2019) explored the possibilities of biodiesel obtained from Jatropha, soybean and waste cooking oil to be an appropriate alternative for diesel in IC compressed ignition engine. Not just the pure biodiesel but its blends with diesel were also evaluated for its properties similar to biodiesel in combustion. Blend was in proportion of oil changing from 20% to 50%. (Dubey et al., 2020) analyzed several other possibilities of extracting biodiesel instead of going mainstream with the edible crops. The exploration accounts for analyzing the non-edible crops or oils producing the biodiesel for use. Hiptage Benghalensis is one of the non-edible crops containing the ricinoleic acid in the seeds and producing biodiesel of the similar properties than that of diesel. The plant is studied for its physiochemical properties and thermal properties.

Different aspects of biodiesel starting from its origin till its performance along with engine performance have been explored in this work. These categories are described in the following tables on different aspects of biodiesel spreading its impact all over the world for its possibilities in energy sector and regarding environmental awareness.

II. METHODOLOGY

A. Biodiesel – Impact on the emission of NOx

There are some fundamental benefits that make diesel one of the most suited fuels for energy extraction. Not only its calorific value is high, but also less setup cost, great energy efficiency, stability and power generation, i.e. brake specific fuel consumption. And this is the reason, why it is used at so many places and has broad range of applications which in turn has caused the crisis of its depletion (Hoekman and Robbins, 2012). So, there is a huge demand of a substitute of the fossil fuels that can sustain more, and also be eco-friendly. Environmental aspect has been one of the major aspects in current scenario and this increases the chances of biofuels to be suitably seated at the vacant place. Biodiesel has emerged as the lone alternative and has gained suitable attention from the researchers all over the world. As it is a substitute when used with a blend can directly be replaced with diesel in diesel engine (Mirhashemi and Sadrnia, 2019).

As the demand increases, and stock decrease, prices tend to rise up. Similar thing has happened so far with the fossil fuels as the demand of local public and rapid industrialization is increasing day by day. One of the major reasons, such attention is paid to biodiesel from all the researchers around the globe (Aurélio et al., 2017). Biodiesel is a non-toxic, biodegradable and renewable alternative fuel that can be used with no engine modifications. But still, in today's world of efficiency and accuracy, the more and more researches are needed to explore the complete possibilities of the biodiesel used in an engine. Therefore, one such study was conducted in which, performance emission considerations were made on a single cylinder, four stroke, and steady speed diesel engine.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

This was done by forming different blends of methyl ester taken from soybean and simulation analysis was performed on Diesel-rk. The simulation software was used to assess optimization tactics for reduction of NOx emissions from biodiesel combustion (Al-dawody and Bhatti, 2013).

Several studies were performed to explore the possibilities of emissions. This study describes the different proportions of blend formation of biodiesel and diesel and their effects on the NOx formation at the time of emission. This sets a definite way in which, how blend properties affect the emission status of NOx and other impurities (Thangaraja, Anand and Mehta, 2016)(Karavalakis et al., 2017).

Different other literature works have also been studied about "Biodiesel – Impact on the emission of NOx" and are presented in table I.

TABLE I. BIODIESEL – IMPACT ON THE EMISSION OF NOX

Author/Year	Title	Theory	Results
(Mao et al.)	"Experimental Research on Effects of Biodiesel Fuel Combustion Flame Temperature on NOX Formation Based on Endoscope High-speed Photography"	"Investigation is performed on the effects of biodiesel on NOx formation through Endoscope high-speed photography. Three different ratios of blends of biodiesel and diesel were taken (B0, B50 and B100) and performed on a diesel engine."	"As the biodiesel increases in the ratio of fuel proportion, the peak values of VNO, M VNO, SNO and ηNO also increased whereas ϕNO got reduced. It is observed that higher the proportion of biodiesel, less NOx formation, and more environmental friendly."
(Dimitriou et al.)	"Adopting biodiesel as an indirect way to reduce the NOx emission of a hydrogen fumigated dual-fuel engine"	"To decrease the level of NOx emissions, a mend of low-sulphur and aromatics fuel is used in hydrogen fumigated dual-fuel engine. Effects of using waste cooking oil biodiesel instead of diesel and operated engine on greater EGR rates."	"With the use of biodiesel, hydrogen combustion engine worked at higher EGR rates lacking the aggravating of soot emissions. Greater EGR rates lead to reduced NOx by 64% and also decreased other emissions such as carbon monoxide and hydrocarbons."
(Chen et al.)	"NOx emission of biodiesel compared to diesel: Higher or lower?"	"To find out NOx emission depending upon biodiesel combustion traits, an experiment was conducted. Outcomes were noted based on different loadings and variable engine speed. Effects of high viscosity and distillation temperature were considered on the air-fuel mixture and spray quality."	"With low and medium speeds of engine, at low loads, short reduction is seen in NOx emission. As the load increased, the injection pressure and in-cylinder thermal conditions were improved along with the effects of increased speed which strengthens air swirl movement."
(Wei et al.)	"Combustion process and NOx emissions of a marine auxiliary diesel engine fuelled with waste cooking oil biodiesel blends"	"A marine auxiliary diesel engine was selected to observe the effects on NOx emissions due to the use of four blends of biodiesel and diesel in different proportions in which biodiesel is obtained from waste cooking oil."	"As the ratio of biodiesel increased in blends, PHRR (Peak Heat Release Rate) reduced in almost all operating conditions. This helped NOx to decrease in emission. But as the in-cylinder temperature decreased, the slight increase in NOx was observed. Peak reductions of PHRR at 1,500 rpm and 1,050 rpm were 19.86% and 11.04% respectively."

B. Biodiesel – Impact on the performance of Engine

Another aspect of biodiesel fuel is the impact that it causes on the performance of IC engine. For over a century now, automobile segment and power technologies have been completely dependent over petroleum fuels.

To even generate electricity, fossil fuels are burned down (Piloto-rodríguez et al., 2017). While talking about a shift from the diesel to biodiesel, a thorough and in depth exploration is what is always needed of the fuel. As far as the fuel properties are concerned, these are the key factors which determine durability of engine, efficiency of engine, performance and emissions from it.

Also if the fuel properties are known, then it is further easier to design the engine and its components such as fuel dispensing, combustion chamber (Kumar, Babu and Kumar, 2017).

Environmental issue is the most hyped and concerned topic all over the world. As the climate change has been observed for real, the research and studies have increased tremendously towards reaching to a suitable alternative.

As the research for biodiesel is increasing, exploration studies of the technology that produces biodiesel from microalgae is still in its initial phase. Still microalgae has been taken to extract biodiesel on a large scale and used to improve the performance of engine (Aminul, Heimann and Brown, 2017). Hence table II shows the methodology followed by different authors for enhancing the impact of performance of engine using biodiesel.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

TABLE II. BIODIESEL – IMPACT ON THE PERFORMANCE OF ENGINE

Author/Year	Title	Theory	Results
(Singh and Sandhu)	"Performance, emission and combustion characteristics of multi-cylinder CRDI engine fueled with argemone biodiesel/diesel blends"	"Performance, emission and combustion traits were tested for a 4-cylinder intercooled, turbocharged and common rail direct injection engine by combustion of argemone biodiesel blend with diesel. Blends namely AB10, AB20, AB30, AB50 and just biodiesel were investigated for their properties and effects with the norms of ASTM D6751."	"Blends of biodiesel shows better performance at part and high load instead of low load condition. AB20 is the blend at high loading condition, which showed the enhancement of 7.88% in brake specific fuel consumption (BSFC) and 5.5% in brake thermal efficiency (BTE)."
(Simsek)	"Effects of biodiesel obtained from Canola, sefflower oils and waste oils on the engine performance and exhaust emissions"	"Biodiesel obtained from the mixture of canola, safflower and waste oil and also formed blend with diesel of different proportions, were both investigated to improve the engine performance, reduce the emission in a four stroke, single cylinder, air cooled, direct injection diesel engine."	"It was observed that blend BD10, BD20, BD30, BD50, BD75 and BD100 increased the Brake specific fuel consumption by 3.79%, 6.47%, 9.27%, 12.89%, 15.55% and 19.80%, correspondingly in comparison to BD0. Brake thermal efficiency is increased on an average of 4.20%, 3.37%, 2.22%, 0.73%, 0.80% and got reduced by 1.95% respectively in comparison to BD0."
(Nautiyal et al.)	"Experimental assessment of performance, combustion and emissions of a compression ignition engine fuelled with Spirulina platensis biodiesel"	"A rare biodiesel which was extracted from Spirulina platensis algae was used to investigate the performance, combustion traits of biodiesel and emission characteristics of diesel engine."	"Heat Release Rate (HRR) with biodiesel was observed as low when compared to the diesel. As the proportion of biodiesel in the blend is increased, the peak pressure rise reduced due to shorter ignition delay of biodiesel."
(Rathore et al.)	"Experimental investigation of performance characteristics of compression-ignition engine with biodiesel blends of Jatropha oil & coconut oil at fixed compression ratio"	"Biodiesel from two sources were taken, one was edible (coconut) and another was non-edible vegetable oil (Jatropha) and investigation was performed by making blends with pure diesel for finding the impacts on CI engine performance of fixed compression ratio of 18."	"A blend of Jatropha came out to be the best in terms of Brake specific fuel consumption showing minimum deviation among all blends compared to diesel. B-20 blend was much closer to diesel oil followed by coconut oil. In Brake thermal efficiency, B-20 was the only blend which was almost similar to diesel and every other was slightly lower."
(Yesilyurt et al.)	"The production of biodiesel from safflower (Carthamus tinctorius L.) oil as a potential feedstock and its usage in compression ignition engine: A comprehensive review"	"A review was done on the biodiesel obtained from safflower plant on the performance of engine, its emission characteristics and combustion traits and comparison with the pure diesel fuel."	"The engine performance was found to be comparable to that of pure diesel along with its combustion and emission traits. There were reduced amount of engine torque, brake power, and brake thermal efficiency values that were observed whereas Brake specific fuel consumption was increased."
(Uyumaz)	"Combustion, performance and emission characteristics of a DI diesel engine fueled with mustard oil biodiesel fuel blends at different engine loads"	"Blends of mustard oil biodiesel and diesel were investigated for the effects on the engine performance, combustion and emission traits. These blends were M10, M20 and M30 and D100 represented pure diesel fuel at peak brake torque speed of 2200 rpm running on variable load conditions which were 3.75, 7.51 11.25, 15 Nm along with full load."	"With M10 blend, Indicated thermal efficiency reduced by 6.8% and BSFC reached up to 4.8% on comparison to D100 in total load condition. There was no such big difference observed in the cylinder pressure with blends and pure diesel."

C. Biodiesel – Impact on Engine Components, oil and vice versa

In the current scenario, a substitute for the fossil fuel to shows almost similar fuel properties and provide almost similar outcomes for energy demand, is held high as a heated topic in the world. As far as its properties are concerned, it is considered to be the exact replacement of diesel in CI engines. But there are still some major issues remained untouched. As the biodiesel, comprised of unsaturated molecules, oxygenated moieties and free fatty acids are very reactive in nature with metal surfaces which leads to its concern on interaction with the metal parts of engine (Fazal, Rubaiee and Al-Zahrani, 2019). Hence table III shows the impact of engine component and oil on the biodiesel and vise versa.

TABLE III. BIODIESEL – IMPACT ON ENGINE COMPONENTS, OIL AND VICE VERSA

Author/Year	Title	Theory	Results
(Chandran)	"Compatibility of diesel engine materials with biodiesel fuel"	"Compatibility of biodiesel with Fuel Delivery Materials (FDM) was assessed. This is specifically under the physical operation of diesel engine. As the operation of engine means variable temperature and pressure, thus it was necessary to assess the deterioration of FDM under the practical conditions."	"Novel immersion method was used instead of typical immersion method, in which addition of fuel renewal performed which showed better adequacy between FDM and biodiesel in practical conditions. Thus, it is seen that, focusing more on the engine operating conditions will give fine results for the compatibility of the biodiesel and engine."
(Pereira et al.)	"Impact of pure biodiesel fuel on the service life of engine-lubricant: A case study"	"Effects of biodiesel on the lubricant of oil of the engine were studied. This was a long term study of 18 months, under which a fleet of buses (7 buses) were monitored in urban public transportation in the Curitiba city, Southern Brazil."	"The most sensitive characteristic trait of the engine lubricant oil was affected by the use of biodiesel is viscosity. The service-life mileage of lubricant was reduced from 20,000 km to 13,000 km for mono-articulated buses and 15,000 km to 10,000 km for bi-articulated buses."
(Reddy et al.)	"Effect of non-edible oil and its biodiesel on wear of fuel injection equipment components of a genset engine"	"Investigation was performed on the effects of Karanja oil (KO100), and Karanja biodiesel (KOME100) on the wearing of fuel injection equipment (FIE) test rig which was specifically designed and fabricated for this. Optical microscopy was also applied to find out the surface wear."	"Optical microscopy showed that there occurs least wear due to Karanja oil and maximum wear due to mineral diesel on FIE. The magnifications of 100, 200 and 300X helped to find out the wear. Wear basically occurs because of stresses generated mechanically and thermally and the chemical reactivity of the fuel."
(Chandran et al.)	"Deterioration of palm biodiesel fuel under common rail diesel engine operation"	"To investigate the effect of Common Rail Diesel Engine (CRDE) on biodiesel obtained from palm, an engine test bed having a Toyota 1KD-FTV engine was used. It was then coupled to an eddy current dynamometer and then functioned on two speed-load test cycles."	"Water content and TAN (Total Acidic Number) value remains untouched, comes to know at the end of the functioning of CRDE on both test cycles. Biodiesel conductivity value was the ideal indicator to demonstrate the deterioration level which finally concludes the adequacy between biodiesel and FDM (Fuel Delivery Material)."

D. Biodiesel – Different generations and their impact

The major lifelines of the modern developed and developing world is, fueled with petroleum. Fuel extracted from petroleum is extensively used in agriculture, industries, transport and electricity generation and with this extensive use, its crisis problem has occurred. Therefore, an appropriate substitute fuel is need to fulfill energy demands of today's world (Bhuiya et al., 2015). As the world is meeting biodiesel as its option, it becomes of utmost importance to study about the emission impacts of this alternative fuel when used in engines. Different blends of biodiesel and diesel are used together to reduce the emission. Emissions of these blends mainly depend upon their origin or feedstock from where biodiesels are produced. There are four categories namely generations which are divided based on the feedstock of biodiesel. These can be obtained from soybean oil, palm oil, waste frying oil etc. (Almeida et al., 2016). Generation 1 is the category in which biodiesel is obtained from food crops like wheat, soybean etc. Generation 2 on the other hand is derived from non-food crops or non-edible crops such as agricultural residues, lignocellulosic biomass etc. Generation 3 is derived from the algae and other microbes and generation 4 is an extension of generation 3 in which algae is modified with the help of genetic engineering and properties and cellular metabolism are altered (Singh Sikarwar et al., 2017). In the table IV, different works are presented regarding the use of different generations of biodiesel and their impact on engine emissions and performance.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

TABLE IV. BIODIESEL – DIFFERENT GENERATIONS AND THEIR IMPACT

Author/Year	Title	Theory	Results
(Tayari et al.)	"Comparative assessment of engine performance and emissions fueled with three different biodiesel generations"	"Investigation carried out to compare the difference in the performance of engine and emission levels of different particles and gases by using the biodiesel of three different generations. Methanol and KOH were used as catalysts to form Methyl esters from Eruca Sativa (ES), waste cooking oil and Microalgae Chlorella Vulgaris (MCV)."	"MCV was turned out to be the best among all the three generations. It showed a minimal decrease in power and slight increase in BSFC on comparison to diesel. A small increase in NOx was observed. ES and WCO reduced formation of NOx with a small margin. Thus, blends of MCV were found to be the best of all generation."
(Rajak and Verma)	"Influence of combustion and emission characteristics on a compression ignition engine from a different generation of biodiesel"	"Effects of two key factors, i.e. compression ratio and engine load on the combination of first, second and third generation based biodiesel making blend with diesel, so that their combine effect can be evaluated on the piston force, tip penetration, soot generation and sauter mean diameter."	"The biodiesel blends that are used can effectively reduce soot emission by 6.1% when Karanja (first generation) is used, 25.9% with the help of Jatropha curcas (second generation) and 5.59% by using spirulina (third generation). It was keenly observed that with the increase of compression ratio, soot emission increases."
(Sakthivel et al.)	"A review on the properties, performance and emission aspects of the third generation biodiesels"	"Biodiesel obtained from the non-edible feedstocks are considered as third generation biodiesel whose effects are studied on the diesel engine performance and emission characteristics."	"It was found that different types of feedstocks lead to variable properties of biodiesel. It causes substantial effect on the engine potential performance and dynamic traits of emission. Emissions of noxious pollutants are also reduced with the use of biodiesel."
(Nabi and Rasul)	"Influence of second generation biodiesel on engine performance, emissions, energy and exergy parameters"	"Three non-edible biodiesel blends with diesel, for studying and comparing the diesel engine performance, emissions, energy and exergy considerations. The preparation of the blends was performed by maintaining around 3.3 wt% of oxygen. Waste cooking oil and macadamia (Macadamia integrifolia) were chosen for the investigation."	"With almost similar performance level when compared to that of diesel engine, there is phenomenal decrease in the emissions of unburnt hydrocarbons, carbon monoxide and particulate matter, with a slight increase of NOx, with use of biodiesel blends."

III. RESULTS

Based on the above tables mentioned in the methodology section, it is observed that the performance parameters of any engine is impacted by the modifications in the biodiesel material, design of engine and component used, etc. therefore a comparative graph is obtained as the final result plotted in figure 1, which shows the comparison of engine performance. The performance is evaluated by the reduction in NOx content from the combustion of biodiesel.

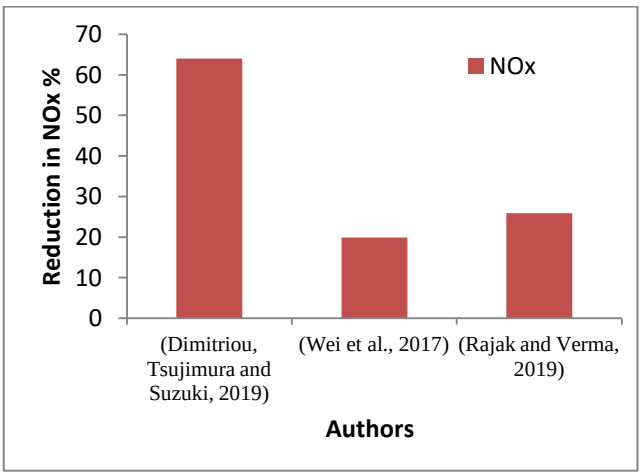

Fig. 1.Comperision of engine performancr based on NOx reduction

Second parameter is based on the improvement of brake thermal efficiency (BTE). Figure 2 shows comparison between different levels of improvement in the BTE by different authors regarding the performance of biodiesel engine.

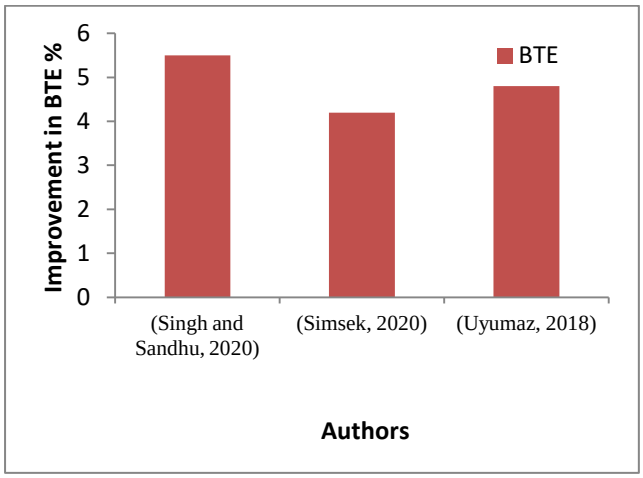

Fig. 2.Comperision of engine performancr based on BTE improvement

IV. CONCLUSION

The study in the work is focused on biodiesel and the different aspects of its impacts over the energy consumption and environment. Several studies have been taken into consideration and then are structured in a frame exploring four different aspects of biodiesel in such a way, so as to study the origin of biodiesel as well as its final application. The categorization of this study was based upon the performance of final application of biodiesel and the type of oil used to extract biodiesel.

- The first category reads the research work regarding the impact of biodiesel on the emission of NOx. Several research works have been studied regarding this and it can be concluded that, biodiesels have been successful in reducing the harmful emissions from exhaust of IC engine. These further can be improved by adding additives or making blends with diesel itself.
- Second deals with the impact of biodiesel when used in IC engine, on the performance of IC engine and similar parameters. It has been observed that pure biodiesel were effective in increasing the efficiency and the performance of the engine in a slight manner but when blends of biodiesel with diesel are used, then the torque obtained is better than the conventional one. Also, it reduces the number of unburnt carbon thus, adding in overall efficiency improvement.
- In the third category, several research works are studied regarding the effects of biodiesel in the engine components, especially fuel delivery materials. This is not only about the engine components but also the deterioration of biodiesel under common rail diesel engine operation. The study shows different biodiesel which has negative impact upon the material of fuel delivery components. Also, some biodiesel showed the behavior of deteriorating the engine oil. In some literature works, due to material of engine, biodiesel got deteriorated. For the future work, different blends can be tried out for the improving the performance of biodiesel and non-reactive with the FDM (Fuel Delivery Material).
- Last category describes the biodiesels that can be obtained from different sources such as vegetable oil, animal oil, non-food biomass, algae and artificially obtained oil. In this, some researchers have performed only the performance analysis of any single generation of biodiesel on the performance of engine. Whereas some literature works compared the three generations of the biodiesel. It has been observed that, second generation biodiesel turns out to be the best in reduction of soot emission but as soot emission increases, compression ratio also increases. Further, these studies can be carried out along with comparison of more number of different biodiesels of different generations.
- From the result graphs, it can be concluded that, "(Dimitriou, Tsujimura and Suzuki, 2019)" had the maximum reduction in the NOx in their research of about 64%. In terms of brake thermal efficiency, the maximum efficiency improved was about 5.5% by "(Singh and Sandhu, 2020)".

ACKNOWLEDGMENT

I would like to Thankfully acknowledge my Guide Dr. Prashant Baredar and Dr. Pushyamitra Mishra for the kind support extended to me in preparing and finalizing my research paper for publishing in the esteemed journal.

REFERENCES

1. Abou-shanab, R. (2015) 'Green Renewable Energy For Sustainable Socio-Economic Development', (September 2015).
2. Al-dawody, M. F. and Bhatti, S. K. (2013) 'Optimization strategies to reduce the biodiesel NOx effect in diesel engine with experimental verification', *Energy Conversion and Management*, 68, pp. 96–104. doi: 10.1016/j.enconman.2012.12.025.
3. Almeida, M. De *et al.* (2016) 'Comparative study of emissions from stationary engines using biodiesel made from soybean oil , palm oil and waste frying oil', *Renewable and Sustainable Energy Reviews*. Elsevier, (November 2016), pp. 1–16. doi: 10.1016/j.rser.2016.12.040.
4. Aminul, M., Heimann, K. and Brown, R. J. (2017) 'Microalgae biodiesel : Current status and future needs for engine performance and emissions', *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, 79 (May 2017), pp. 1160–1170. doi: 10.1016/j.rser.2017.05.041.
5. Aurélio, M. *et al.* (2017) 'Comparative study of NOx emissions of biodiesel-diesel blends from soybean, palm and waste frying oils using methyl and ethyl transesterification routes', 194, pp. 144–156. doi: 10.1016/j.fuel.2016.12.084.
6. Balamurugan, T., Arun, A. and Sathishkumar, G. B. (2018) 'Biodiesel derived from corn oil – A fuel substitute for diesel', *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, 94 (March 2018), pp. 772–778. doi: 10.1016/j.rser.2018.06.048.
7. Bhuiya, M. M. K. *et al.* (2015) 'Prospects of 2nd generation biodiesel as a sustainable fuel — Part: 1 selection of feedstocks , oil extraction techniques and conversion technologies', *Renewable and Sustainable Energy Reviews*. Elsevier, pp. 1–20. doi: 10.1016/j.rser.2015.04.163.
8. Chandran, D. *et al.* (2016) 'Deterioration of palm biodiesel fuel under common rail diesel engine operation', *Energy*. Elsevier Ltd, pp. 1–10. doi: 10.1016/j.energy.2016.11.136.
9. Chandran, D. (2020) 'Compatibility of diesel engine materials with biodiesel fuel', *Renewable Energy*. Elsevier Ltd, 147, pp. 89–99. doi: 10.1016/j.renene.2019.08.040.
10. Chaurasiya, P. K. *et al.* (2019) 'Combustion and emission characteristics of diesel fuel blended with raw jatropha, soybean and waste cooking oils', *Heliyon*. Elsevier Ltd, 5(5), p. e01564. doi: 10.1016/j.heliyon.2019.e01564.
11. Chen, H. *et al.* (2018) 'NOx emission of biodiesel compared to diesel : Higher or lower ?', *Applied Thermal Engineering*. Elsevier, 137(February), pp. 584–593. doi: 10.1016/j.applthermaleng.2018.04.022.
12. Demirel, Y. (2018) *Biofuels*. doi: 10.1016/B978-0-12-809597-3.00125-5.
13. Dimitriou, P., Tsujimura, T. and Suzuki, Y. (2019) 'Adopting biodiesel as an indirect way to reduce the NOx emission of a hydrogen fumigated dual-fuel engine', *Fuel*. Elsevier, 244(November 2018), pp. 324–334. doi: 10.1016/j.fuel.2019.02.010.
14. Dubey, K. K. D. *et al.* (2020) 'Industrial Crops & Products Biodiesel production from Hiptage benghalensis seed oil', *Industrial Crops & Products*. Elsevier, 144 (December 2019), p. 112027. doi: 10.1016/j.indcrop.2019.112027.
15. Fazal, M. A., Rubaiee, S. and Al-Zahrani, A. (2019) 'Overview of the interactions between automotive materials and biodiesel obtained from different feedstocks', *Fuel Processing Technology*. Elsevier, 196 (April 2019), p. 106178. doi: 10.1016/j.fuproc.2019.106178.
16. Hoekman, S. K. and Robbins, C. (2012) 'Review of the effects of biodiesel on NOx emissions', *Fuel Processing Technology*. Elsevier B.V., 96, pp. 237–249. doi: 10.1016/j.fuproc.2011.12.036.
17. Karavalakis, G. *et al.* (2017) 'Application of low-level biodiesel blends on heavy-duty (diesel) engines: Feedstock implications on NOx and particulate emissions', *Fuel*. Elsevier Ltd, 181(2016), pp. 259–268. doi: 10.1016/j.fuel.2016.05.001.
18. Kumar, M. V., Babu, A. V. and Kumar, P. R. (2017) 'The impacts on combustion , performance and emissions of biodiesel by using additives in direct injection diesel engine', *Alexandria Engineering Journal*. Faculty of Engineering, Alexandria University. doi: 10.1016/j.aej.2016.12.016.

19. Mao, G. *et al.* (2020) 'Experimental Research on Effects of Biodiesel Fuel Combustion Flame Temperature on NOX Formation Based on Endoscope High-speed Photography', *Journal of the Energy Institute*. Energy Institute. doi: 10.1016/j.joei.2020.01.002.
20. Mirhashemi, F. S. and Sadrnia, H. (2019) 'NO X emissions of compression ignition engines fueled with various biodiesel blends: A review', *Journal of the Energy Institute*. Elsevier Ltd, (X). doi: 10.1016/j.joei.2019.04.003.
21. Mohd Noor, C. W., Noor, M. M. and Mamat, R. (2018) 'Biodiesel as alternative fuel for marine diesel engine applications: A review', *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, 94(April), pp. 127–142. doi: 10.1016/j.rser.2018.05.031.
22. Nabi, M. N. and Rasul, M. G. (2018) 'In fl uence of second generation biodiesel on engine performance , emissions , energy and exergy parameters', *Energy Conversion and Management*. Elsevier, 169 (March 2018), pp. 326–333. doi: 10.1016/j.enconman.2018.05.066.
23. Nautiyal, P. *et al.* (2020) 'Experimental assessment of performance, combustion and emissions of a compression ignition engine fuelled with Spirulina platensis biodiesel', *Energy*. Elsevier Ltd, 193, p. 116861. doi: 10.1016/j.energy.2019.116861.
24. Ogunkunle, O. and Ahmed, N. A. (2019) 'A review of global current scenario of biodiesel adoption and combustion in vehicular diesel engines', *Energy Reports*. Elsevier Ltd, 5, pp. 1560–1579. doi: 10.1016/j.egyr.2019.10.028.
25. Pereira, F. M. *et al.* (2020) 'Impact of pure biodiesel fuel on the service life of engine-lubricant: A case study', *Fuel*, 261(June 2019). doi: 10.1016/j.fuel.2019.116418.
26. Piloto-rodríguez, R. *et al.* (2017) 'Assessment of diesel engine performance when fueled with biodiesel from algae and microalgae: An overview', *Renewable and Sustainable Energy Reviews*. Elsevier, 69(October 2016), pp. 833–842. doi: 10.1016/j.rser.2016.11.015.
27. Rajak, U. and Verma, T. N. (2019) 'Engineering Science and Technology , an International Journal Influence of combustion and emission characteristics on a compression ignition engine from a different generation of biodiesel', *Engineering Science and Technology, an International Journal*. Karabuk University, (X). doi: 10.1016/j.jestch.2019.04.003.
28. Ramalingam, S., Rajendran, S. and Ganesan, P. (2018) 'Performance improvement and exhaust emissions reduction in biodiesel operated diesel engine through the use of operating parameters and catalytic converter: A review', *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, 81(August 2018), pp. 3215–3222. doi: 10.1016/j.rser.2017.08.069.
29. Ramkumar, S. and Kirubakaran, V. (2016) 'Biodiesel from vegetable oil as alternate fuel for C.I engine and feasibility study of thermal cracking : A critical review', *Energy Conversion and Management*. Elsevier Ltd, 118, pp. 155–169. doi: 10.1016/j.enconman.2016.03.071.
30. Rathore, Y., Ramchandani, D. and Pandey, R. K. (2019) 'Experimental investigation of performance characteristics of compression-ignition engine with biodiesel blends of Jatropha oil & coconut oil at fixed compression ratio', *Heliyon*. Elsevier Ltd, 5 (July 2019), p. e02717. doi: 10.1016/j.heliyon.2019.e02717.
31. Reddy, S. M. *et al.* (2018) 'Effect of non-edible oil and its biodiesel on wear of fuel injection equipment components of a genset engine', *Fuel*. Elsevier, 222 (February 2018), pp. 841–851. doi: 10.1016/j.fuel.2018.02.132.
32. Sakthivel, R. *et al.* (2018) 'A review on the properties , performance and emission aspects of the third generation biodiesels', *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, 82(5), pp. 2970–2992. doi: 10.1016/j.rser.2017.10.037.
33. Simsek, S. (2020) 'Effects of biodiesel obtained from Canola, sefflower oils and waste oils on the engine performance and exhaust emissions', *Fuel*. Elsevier, 265(November 2019), p. 117026. doi: 10.1016/j.fuel.2020.117026.
34. Singh, D. *et al.* (2019) 'A review on feedstocks, production processes, and yield for different generations of biodiesel', *Fuel*. Elsevier, (July 2019), p. 116553. doi: 10.1016/j.fuel.2019.116553.
35. Singh, M. and Sandhu, S. S. (2020) 'Performance, emission and combustion characteristics of multi-cylinder CRDI engine fueled with argemone biodiesel/diesel blends', *Fuel*. Elsevier, 265 (December 2019), p. 117024. doi: 10.1016/j.fuel.2020.117024.
36. Singh Sikarwar, V. *et al.* (2017) 'Progress in biofuel production from gasification', *Progress in Energy and Combustion Science*, 61. doi: 10.1016/j.pecs.2017.04.001.
37. Tamilselvan, P., Nallusamy, N. and Rajkumar, S. (2017) 'A comprehensive review on performance, combustion and emission characteristics of biodiesel fuelled diesel engines', *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, 79 (May 2017), pp. 1134–1159. doi: 10.1016/j.rser.2017.05.176.
38. Tan, Y. H., Mujawar, M. N. and Kansedo, J. (2019) 'Biodiesel Synthesis using Natural Solid Catalyst Derived from Biomass Waste–AReview', *Journal of Industrial and Engineering Chemistry*. The Korean Society of Industrial and Engineering Chemistry. doi: 10.1016/j.jiec.2019.09.022.
39. Tayari, S., Abedi, R. and Rahi, A. (2020) 'Comparative assessment of engine performance and emissions fueled with three different biodiesel generations', *Renewable Energy*. Elsevier Ltd, 147, pp. 1058–1069. doi: 10.1016/j.renene.2019.09.068.
40. Thangaraja, J., Anand, K. and Mehta, P. S. (2016) 'Biodiesel NO x penalty and control measures - a review', *Renewable and Sustainable Energy Reviews*. Elsevier, 61(x), pp. 1–24. doi: 10.1016/j.rser.2016.03.017.
41. Uyumaz, A. (2018) 'Combustion, performance and emission characteristics of a DI diesel engine fueled with mustard oil biodiesel fuel blends at different engine loads', *Fuel*. Elsevier, 212(October 2017), pp. 256–267. doi: 10.1016/j.fuel.2017.09.005.
42. Vedharaj, S. *et al.* (2013) 'Experimental investigation of kapok (Ceiba pentandra) oil biodiesel as an alternate fuel for diesel engine', *Energy Conversion and Management*. Elsevier Ltd, 75, pp. 773–779. doi: 10.1016/j.enconman.2013.08.042.
43. Wei, L. *et al.* (2017) 'Combustion process and NOx emissions of a marine auxiliary diesel engine fuelled with waste cooking oil biodiesel blends', *Energy*. Elsevier B.V. doi: 10.1016/j.energy.2017.12.012.
44. Wong, K. Y. *et al.* (2019) 'Biodiesel process intensification through catalytic enhancement and emerging reactor designs: A critical review', *Renewable and Sustainable Energy Reviews*, 116 (September 2019). doi: 10.1016/j.rser.2019.109399.
45. Xiao, H. *et al.* (2018) 'An investigation of the friction and wear behavior of soybean biodiesel', *Tribology International*. Elsevier Ltd. doi: 10.1016/j.triboint.2018.10.037.
46. Yan, J. and Yan, Y. (2017) *Biodiesel Production and Technologies*, *Encyclopedia of Sustainable Technologies*. Elsevier. doi: 10.1016/B978-0-12-409548-9.10110-1.
47. Yaşar, F. (2020) 'Comparision of fuel properties of biodiesel fuels produced from di ff erent oils to determine the most suitable feedstock type', 264 (November 2019). doi: 10.1016/j.fuel.2019.116817.
48. Yesilyurt, M. K. *et al.* (2019) 'The production of biodiesel from safflower (Carthamus tinctorius L.) oil as a potential feedstock and its usage in compression ignition engine: A comprehensive review', *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, (November 2019), p. 109574. doi: 10.1016/j.rser.2019.109574.

AUTHORS PROFILE

Shiv Kumar Sonkar: He is currently working as Assistant Professor at SIRTS, Bhopal in the Department of Electrical and Electronics. He has more than nine years of experience in the same domain. He is pursuing PhD. Degree from MANIT, Bhopal.

Prashant V. Baredar: He is working as Chairman & Professor & Head of Department, in Department of Energy, Energy Centre, MANIT, Bhopal. He holds PhD degree and has 24 years of experience with 53 published research articles. He is also a Reviewer for six International Journal.

Pushyamitra Mishra: He is working as Assistant Professor in the Department of Mechanical Engineering, MANIT, Bhopal. He holds PhD degree and has 13 years of experience with 20 published research articles.