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NOx Emission and Computational Analysis of Jatropha Curcus Fuel and Crude Oil

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***Abstract*—**Diminishing of conventional fuels and hysterical vehicles emission leads to deterioration of the environment, which emphasize the research to work on biofuels. Biofuels from different sources attract the attention of research due to low emission and biodegradability. Emission of carbon monoxide, carbon dioxide and H-C reduced drastically using Biofuels (B-20) combustion. Contrary to the conventional fuel, engine emission results indicated that nitrous oxide emission is higher in Biofuels. So this paper examines and compares the nitrogen oxide emission of Jatropha Curcus (JCO) B-20% blends with the vegetable oil. In addition to that computational analysis of crude non edible oil performed to assess the impact of composition on emission quality. In conclusion, JCO have the potential feedstock for the biodiesel production after the genetic modification in the plant.

***Keywords*—**Jatropha Curcus, computational analysis, emissions, biofuels.

I. Introduction

AIR pollution is a main concern of health problem in India and Asia pacific countries. Beside the industrial pollution, vehicle emissions are mainly responsible pollutant content for the deterioration of air quality. Recently, exhaust emission has increased many fold due to rapid development of the transport industry and ease availability of vehicles for a large section of society. Due to increases in the numbers of vehicles, emission produced in combustion of petroleum based fuels rises that causes the adverse effect on the environment and health. Moreover, environment assessment authority of India indicates that carbon dioxide (CO_2), nitrogen oxide (NO_X) and carbon monoxide (CO) are the main cause of global warming. The internal combustion (IC) engine of vehicles emits CO_2, NO_X, CO and particulate matter. So, to overcome the problem of emission/ environment degradation, the Government of India (GOI) in association with Ministry of New and Renewable Energy (MNRE) framed the policy to use B20 fuels in all vehicles up to 2017.

From the last decade many researcher across the countries worked on Jatropha Curcus for technically and economically viability. The emissions of all gaseous expect nitrogen oxide (NO_X) reduced substantially in biofuel emissions from engine. The United States Environmental Protection Agency (EPA) estimated an average 10% increase in NOx emissions for a pure (100%) biodiesel fuel compared to conventional diesel fuel [1], [2]. Wu et al. [3] found that the reduction of exhaust emissions fueled with five types of biodiesel individually as a range such as PM, dry soot, HC and CO to be about 53–69%, 79–83%, 45–67%, 4–16%, respectively, but an increase in NOx of 10–23% compared with petroleum diesel. Very few authors have found the reduced NOx emissions for biodiesel fuels combustion [4]–[6]. Sun et al. [7] reported that biodiesel fuel gives higher NOx due to: the advancement of injection timing, increase in ignition delay, higher degree of unsaturation, and high oxygen content, etc. As the use of biodiesel in diesel engine has increased tremendously, higher NOx emissions could become a significant barrier to its spread in the market. Therefore, researchers are persistently looking for a reliable and economically viable solution to this problem. Some of them have already managed to establish some techniques. This will help end users to overcome the problem of biodiesel expansion. Many researchers have examined the combined analysis of the effect of biodiesel combustion on engine performance and emissions, and reduction of the NOx emissions but few of them attempted to review them [8], [9]. This paper presents a comprehensive review on the effects biodiesel combustion on NOx emissions of biodiesel fueled engines, to provide useful information to engineers, policy makers, industrialists and researchers. Articles from highly rated journals as well as SAE technical papers are reviewed to discuss the notable factors affecting NOx emissions of biodiesel fuel. Finally, reduction techniques of the NOx emissions (both pre and post combustion) are described for biodiesel fueled engine.

The higher cetane number of biodiesel implies shorter ignition delay which reduces the combustion temperature as well as residence time, consequently less NOx formation [10], [11]. In general, higher saturated fatty acids biodiesel such as coconut, palm and tallow, produce less NOx than mineral diesel and have a higher cetane number [12], [13]. Despite having a high cetane number, it produces higher NOx than diesel fuel usually. Wang et al. [14] gave a suggestion of this regard that, high CN of biodiesel tend to increase peak pressure and temperature due to shortened ignition delay which leads to enhanced NOx formation. Mueller et al. [15] also investigated the biodiesel NOx effect and reported that somewhat higher cetane number of biodiesel about diesel causes the ignition to occur earlier in the cycle. This allows the combustion products to have a longer residence time at high temperatures, which increases NOx emissions. The Iodine value (IV) of biodiesel directly impacts on NOx emissions. The emissions of NOx increase with an increasing iodine value of biodiesel, which was investigated by

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McCormick et al. [16]. The measurement of the degree of unsaturation of fatty acid is indicative of the iodine value. Thus, a higher degree of unsaturation indicates a higher iodine value. Wyatt et al. [17] carried on emission tests and found that NOx emissions are linearly correlated with an IV of fatty acid ester. Moreover, Peterson et al. [18] conducted emission tests with several FAME fuels and reported that with an increase in IV from 7.88 to 129.5, the NOx emissions were raised by 29.3%.

TABLE I
JATROPHA CURCUS COMPOSITION (WT%) FOR COMPUTATIONAL ANALYSIS

Case	Myristic 14.0	Palmitic 16.0	Stearic 18.0	Oleic 18.1	Linoleic 18.2
1.	V 0.5, 0.75.1 & 1.4	C (12)	C (5)	C (37)	C (19)
2.	C (1.4)	V 7:1:12	C (5)	C (37)	C (19)
3.	C (1.4)	C (12)	V 5.5:5:9.5	C (37)	C (19)
4.	C (1.4)	C (12)	C (9.7)	V 40:3:60	C (19)
5.	C (1.4)	C (12)	C (9.7)	C (37)	V 19:3:41

Palash et al. [19] proposed the model for reduction of NOx emissions from biodiesel fueled engines for both pre and post combustion techniques. The exhaust gas recirculation (EGR) and retarded injection timing are effective methods to reduce the NOx emission. It is also considered as a low-cost technique in comparison with the other conventional techniques. Sohpal et al. [20] examined and compared the emission of Jatropha Curcus (JCO) and Madhuca Longifolia (MIO) B20% blends with vegetable oil. Engine emission results indicated that JCO 20 and MIO 20 fuels reduced the average emission of carbon monoxide by 12 and 11% respectively, and hydrocarbons by 15 and 12% respectively. However, the JCO 20 and MIO 20 fuels slightly increased nitrous oxide emission by 7 and 9%, respectively, and carbon dioxide by 7 and 5% respectively compared to conventional diesel.

Literature reveals that NO_X emission percentage increased, which focus the researcher and central laboratories to emphasis on the emission and parameter influences the NO_X. The objective of this work is to predict the emission of NOx from Jatropha based (B-20) biodiesel. Computational analysis of cetane number, iodine value, and the saponification value of Jatropha based oil with respect to their fatty acid ester composition also performed (Table I), so that there may be no need for testing programs to determine these properties.

II. MATERIAL AND METHOD

Jatropha Curcus transesterfied edible oil collected from National Biofuels Corporation, New Delhi. The test fuels were blended with diesel using a higher speed of homogenizer operated approximately at 2000 rpm. The experimental investigation was carried out using diesel fuel, B20 edible oil, and non-edible Jatropha Curcus (JCO) blend. The test engine was a single cylinder compression diesel engine. The engine test rig exhaust connected to 5 gas analyzer probe. Loads applied on the rope-brake dynamo-meter. The temperature measured using thermocouple placed at appropriate place inside the engine. The room temperature measured prior to conduct of experiments. The detailed specifications of the engine are listed in Table II.

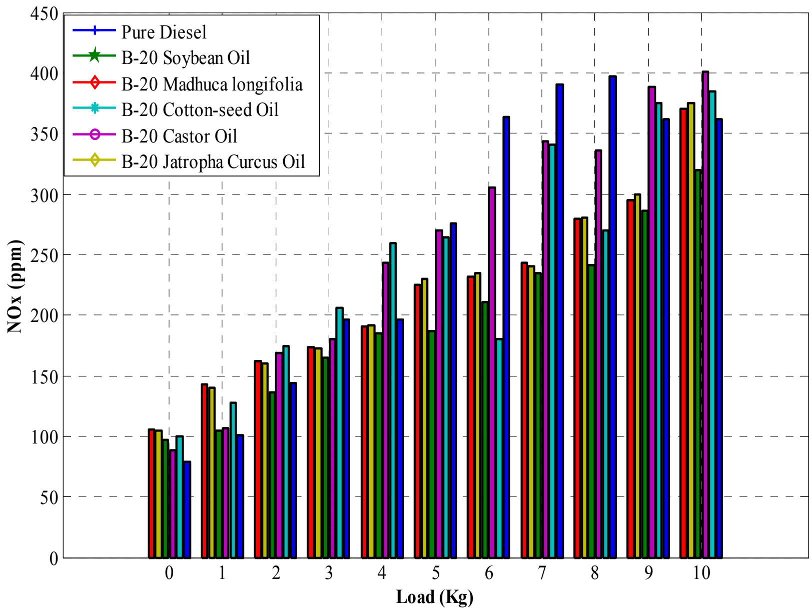

Fig. 1 Variation of NOx emissions with respect to engine loading

The NO values are higher for JCO B20 biodiesel blends than diesel fuel. On average, the JCO B20 produces 5% to 7% higher NO emissions, than diesel fuel over the entire range of loading. This result can be attributed to the leaner air/fuel ratio as biodiesel is an oxygenated fuel and contains 12-18% excess molecular oxygen than pure diesel that raises combustion chamber temperatures and improves combustion. Thus, NO emissions are higher for biodiesel blends than for diesel fuel.

TABLE II
ENGINE SPECIFICATION

Parameters	Range
No. of Cylinders	Single Cylinder
Stroke	139.7 mm
RPM	810
Power	6 HP (4.4 kW)
Compression ratio	16:1

III. RESULTS

A. *Emission Analysis of* NO_x

Biofuels are mostly contained higher percentage of unsaturated fatty acids (Oleic, Linoleic and Palmitic) that rise adiabatic flame temperatures, which cause higher NO emissions. The variation of the NO emissions for pure diesel and biodiesel blend fuels is shown in Fig. 1.

B. *Computational Analysis of Fuel*

Saponification value (SV) an increase with increasing weight percentage of palmitic fatty acid esters from 7 to 12. In other words, the SV increases with increase in the number of double bonds. The relationship between SV and the Cetane Number (CN) was also investigated in the computational analysis. CN shows a decrease with increasing SV and weight percentage of unsaturated fatty acid esters. Computational analysis predicts that as percentage rises above 10 wt.%, a sharp decline in the CN and highest value observed SV as shown in Fig. 2.

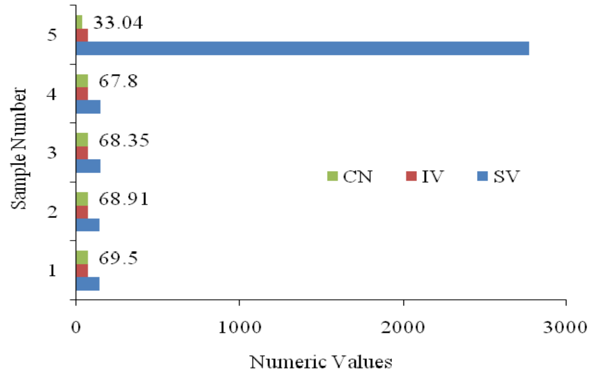

Fig. 2 Variation in Palmitic Wt% (7:1:12)

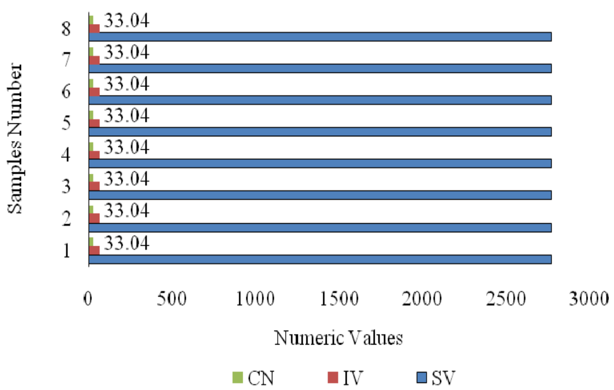

Fig. 3 Variation in Stearic wt.% (5.5:05:9.5)

Stearic acid (Octadecanoic acid, C: N 18:0) having nitrogen content in the ratio of carbon is zero. The virtue of that stearic wt. % from 5.5 to 9.5 does not affect the CN of biofuels as shown in Fig. 3. Virtue of high SV, the immense cost of saponification raised the fuel price. In overall, the influences of stearic acid wt. % are negligible in the whole three process variable which controlled the NOx emission.

Oleic acid (Cis-9-octadecenoic acid) has the carbon: nitrogen ratio 18:1 which makes the impact on CN and IV of biofuels while SV remains constant as shown in the previous case. Oleic acid wt.% variation indicates that CN and IV increase on lower to the higher percentage of Oleic acid as depicted in Fig. 4. The degree of unsaturation is similar to oleic acid, which also affects the cost of bio-fuels.

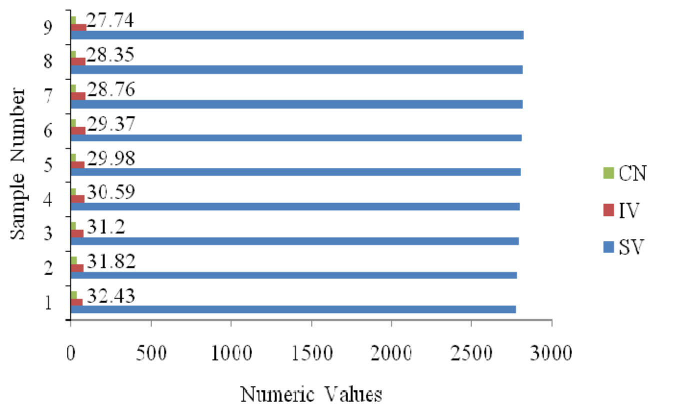

Fig. 4 Variation in Oleic wt.% (40:3:60)

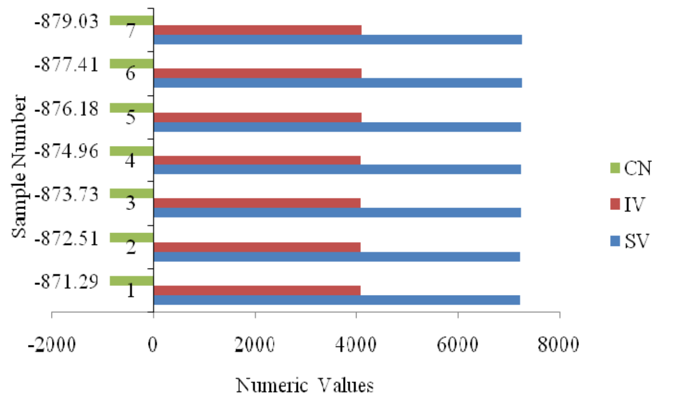

Fig. 5 Variation in Linoleic Wt% (19:3:41)

Linoleic acid (cis-9, 12-octadecadienoic acid) having C: N ratio 18:2, which increase the SV of oil at the extreme. Higher, the degree of unsaturation, observed in Linoleic acid that makes the saponification process more complicated as parallel to the previous results. Computational analysis of oil indicates the negative values of cetane number are negative, which is practically impossible. So the case of Linoleic acid influence on NOx emission is not viable as quoted in Fig. 5.

Myristic acid (Tetradecanoic acid) having the lowest value of saponification values, due to the low degree of unsaturation. CN was highest when 0.75 wt.% tetradecanoic acid in the biofuel composition.Iodine value also limited in this case, that makes it more viable in the context of fuel cost and NOx emissions.

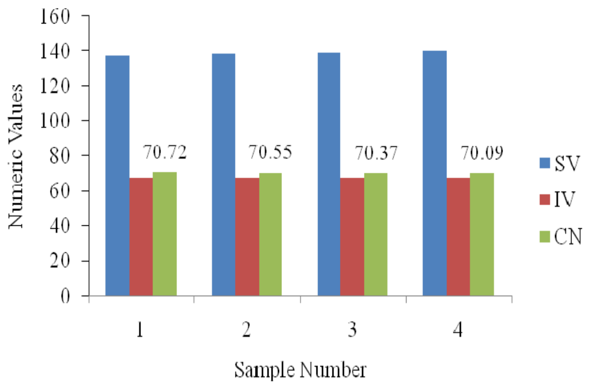

Fig. 6 Variation in Myristic wt.% Compositions (0.5-1.4)

IV. Discussion

The iodine value is the magnitude of the degree of unsaturation in oil and it is a useful parameter in studying oxidative rancidity and chemical stability properties of different oil and biodiesel fuels. A larger quantity of double bonds in the sample has greater potential to polymerize and onward inferior stability. The highest iodine value in this study was 4000 in Linoleic acid case, and the lowest was 65-70 in case 1 and 2. Saponification is the method by which the fatty acids in the glycerides of oil are hydrolyzed using alkali. Saponification value of alkali needed to saponify a definite quantity of oil or fat. This value is useful for a comparative study of the fatty acid chain length in oils. The maximum saponification value in this study was 7000 in Linoleic acid case, and the lowest was 135 in Tetradecanoic acid case.

CN number is the ability of the fuel to ignite promptly after fuel injected. Raised its value, the better emission of fuel, this is one of the important parameters which is counted during the selection of FAMEs for use as biodiesel. Fuels with low CN number will result in difficult starting, noise, and exhaust smoke. In this study CN value is found between 28 and 70. Lowest value observed in the case of Stearic, and highest value of CN found in the case of Myristic.

V. Conclusion

Cetane number is a function of saponification value and iodine values. The lower IV and SV assist to maintain the high CN. The higher cetane number assists in control in delay in ignition, which indirectly handle the NOx emission. From the experimental study and computational analysis, it has observed that Myristic 0.75 wt.%, palmitic 7 wt.%, stearic 5 wt.%, oleic acid 3 wt.%, and linoleic acid 19 wt.%. It has been also observed this composition have low cost and higher CN. These compositions in Jatropha plant can be modified through genetic engineering.

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