# Effect of Simarouba Biodiesel on Performance and Emissions of CI Engine

**Nithyananda B S, Anand A, G V Naveen Prakash, K B Vinay, Naveen Ankegowda**

***Abstract*** ***Biodiesel is explored as one of the promising fuel alternative to diesel. Most of the biodiesel production comes from first generation feedstocks like edible oils. Nowadays, nonedible oils are getting much attention as potential second generation tree borne oil feedstock. In this regard, the present investigation focusses on preparation of biodiesel from non edible simarouba oil with NaOH and Conc. $H_2SO_4$ as catalyst using methanol. The simarouba biodiesel is blended with diesel by 5 % and 20% on volume basis. The fuel properties of simarouba biodiesel blends B5 and B20 were estimated using standard methods and matched with ASTM standards. The SB5 and SB20 biodiesel blends were experimented on CI engine at injection pressure (IP) of 200 bar and 250 bar for improved performance and reduced emissions.***

***Index Terms: Nonedible oil, simarouba, emission, compression ignition, second generation feedstock.***

## I. INTRODUCTION

India depends on foreign countries for fossil fuels to satisfy its energy demand and with population and economic growth the demand for energy will continue to rise. Fossil fuels are non-renewable energy resources which impacts the climate. Increased use of fossil fuel use thus brings pressure from global countries to reduce environmental impact and mitigate climate change. The price of crude oil has been fluctuating in the global market and has significantly increased in the recent years. Such unpredictable cost escalation of crude oil prices is causing increased energy bill and affecting severely economies around the world especially developing countries like India. The demand for crude oil is rising day by day since most of our energy requirement is satisfied from it. Therefore countries around the world are looking for alternative to fossil fuels, which is cleaner and environmental friendly. Researchers across the globe have identified the biofuels as alternative and focused on exploring it further. The tree borne oil seeds have been identified as promising feedstocks for the preparation of biodiesel in India. The promotion of biodiesel solves two major problems in India especially in rural areas since agricultural growth lags behind. The biodiesel promotion program stimulates rural employment opportunities and solves energy problems.

**Revised Manuscript Received on December 5, 2019.**

*Correspondence Author

**Nithyananda B. S***, Dept. of Mechanical Engineering, Vidyavardhaka College of Engineering, VVCE, India. Email: bsn@vvce.ac.in

**Anand A,** Dept. of Mechanical Engineering, National Institute of Engineering, NIE, India. Email: anand@nie.ac.in

**Dr. G.V Naveen Prakash**, Dept. of Mechanical Engineering, Vidyavardhaka College of Engineering, VVCE, India. Email: gvnp@vvce.ac.in

**Dr. K B Vinay,** Dept. of Mechanical Engineering, Vidyavardhaka College of Engineering, VVCE, India. Email: vinaykb@vvce.ac.in

**Naveen Ankegowda** , Dept. of Mechanical Engineering, Vidyavardhaka College of Engineering, VVCE, India. Email: naveen@vvce.ac.in

In this regard, the present research is focussed on identifying non-edible feedstock as viable feedstock for biodiesel preparation. The simarouba oil is explored further as a fuel in engine. The biodiesel is processed from simarouba oil and blended with diesel. The simarouba biodiesel blends SB5 and SB20 were tested on engine by varying injection pressure to determine its performance and exhaust emissions. The responses for performance and emissions were recorded and further analysis is done.

## II. METHODOLOGY

The methodologies adopted to achieve the required objectives are as follows

- Estimation of FFA Percentage.
- Preparation of biodiesel from simarouba oil
- Blending of simarouba biodiesel with diesel
- Estimation of Fuel properties for blends of simarouba biodiesel.
- Performance study on CI engine by varying IP to 200 bar and 250 bar.
- Emission study of CI engine by varying IP to 200 bar and 250 bar.

### A. Estimation of FFA Percentage

Simarouba oil extracted from the simarouba seeds possess high viscosity and poor combustion feature because of presence of FFA [4]. Preparation of biodiesel is based on the FFA %. If percentage of FFA in vegetable oil is more than 4%, two-stage process (esterification &transesterification) is employed. In transesterification reaction, FFA and water produce adverse effects since the presence of FFA and water leads to soap and consumes more catalyst [8]. The simarouba oil having FFA of 5% is determined by titrating it against NaOH solution.

### B. Preparation of Simarouba Biodiesel

The two stage process Esterification and Transesterification is adopted to produce fatty acid methyl esters from triglycerides as shown in Fig.1.The simarouba oil is poured in a reaction bottle and heated 10 mins to 60˚C temperature by stirring continuously. Later, Methanol and NaOH solution is transferred into a reaction bottle with constant slow stirring at 60˚C temperature. The process is continued for another 2 hrs at the same reaction temperature. After process is completed, processed oil is transferred into separating funnel and then allowed for settling. After settling, three layers is observed. The biodiesel settles at top layer, glycerol at middle layer and NaOH catalyst at lower layer [9].



Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The methanol can be recovered from biodiesel and can be reused. The biodiesel is splashed with water of 35°C without any agitation in the washing funnel and allowed to settle for 1 hr. the soapy water is observed at the bottom layer of washing funnel and is drained down. The process of washing is done several times, until the clean water is observed. The clean water indicates that the simarouba is free from catalyst. To remove moisture from biodiesel, it is heated in reaction vessel to 110˚C. Finally the biodiesel is cooled down to room temperature and neat biodiesel is stored in container.

### C. Preparation of Biodiesel Blends

The obtained simarouba biodiesel is blended with diesel by 5% and 20% on volume basis to prepare SB5 and SB20 blend. The blends are tested for their fuel properties and compared with standards. Further, the blends

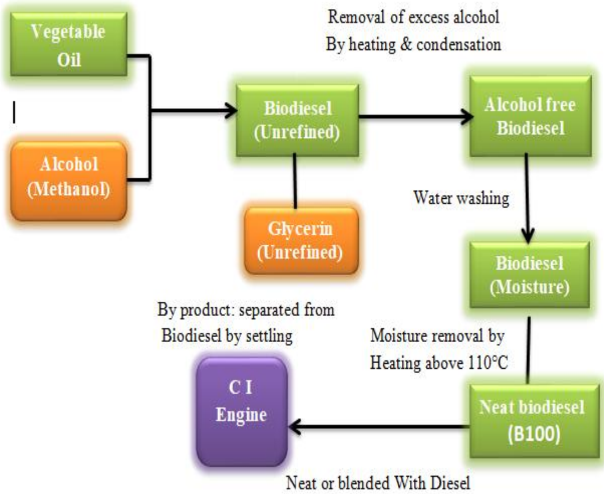



**Fig. 1 Flowchart showing biodiesel production**

## III. EXPERIEMENTAL SETUP

Kirloskar make four stroke CI engine with eddy current dynamometer is used to conduct experiments. Simarouba biodiesel blends (B5 andB20) and diesel was used on CI engine. Results were noted for different load conditions. Performance responses like brake power, mass flow rate, BSFC, BTE, volumetric efficiency and various emissions were evaluated. Table 1 shows the specification of diesel engine used for experimentation.

**Fig.2 Single cylinder CI engine**

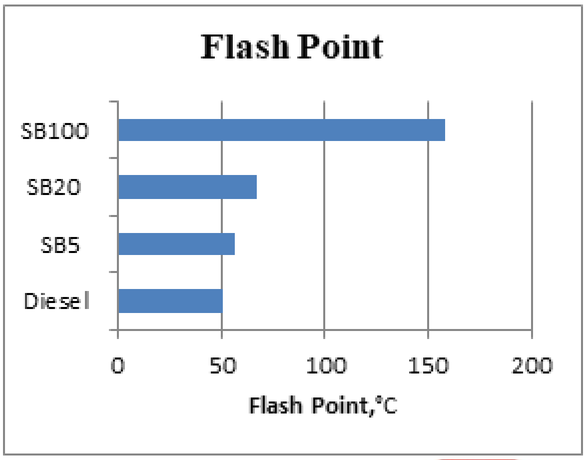
**Table 1 Specification of CI engine**

| TYPE | KIRLOSKAR |
|---|---|
| DETAIL | COMPUTERISED 4-STROKE DIESEL ENGINE WITH EDDY CURRENT DYNAMOMETER |
| BHP | 5.2 KW |
| CR | 17.5:1 |
| BORE | 102 |
| STROKE | 110 |
| SPEED | 1500 rpm |

## IV. RESULTS AND DISCUSSION

### *A. Evaluation of Fuel Properties of Biodiesel Blends*

Fig. 3 represents the flash point variation of simarouba biodiesel blends. From Fig. 3, it can be opined that flash point (FP) of the biodiesel is very high and it is better than diesel. Simarouba biodiesel with B20 shows higher flash point which is 23.88% more compared to diesel. To run the diesel engine with fuel having high flash point need to have very high compression ratio. The flash point drops as when the biodiesel are blended with the diesel and increases when blend percentage is increased. The volatility of fuel is signified by its flash point. Lower volatility fuel signifies the high flash point and fire point.





Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

**Fig. 3 Comparison for Flash Point of simarouba biodiesel blends**

Fig. 4 shows the variation of fire point for Simarouba biodiesel. It can be observed that increase in biodiesel blend percentage increases fire point and simarouba biodiesel B20 blend shows higher fire point which is 17.81% higher than diesel.

Density is considered to be important property of fuel which affects the quantity of fuel injected into engine [10]. Fig. 5 shows the density variation for various blends of simarouba biodiesel. The blending of neat biodiesel with diesel leads to recued density. When percentage of blend is increased, density increases. Biodiesel blend SB20 has higher density which is 2.96% higher compared to diesel.

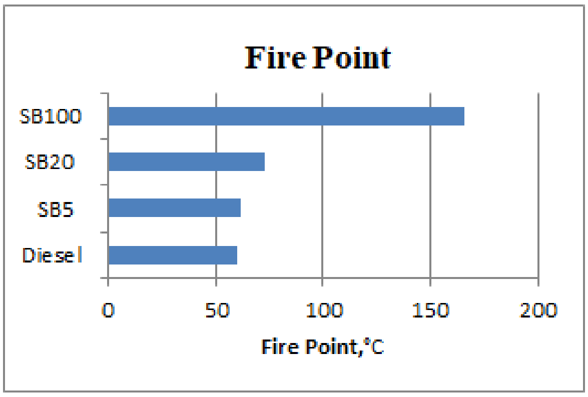



**Fig. 4. Comparison for Fire Point of simarouba biodiesel blends**

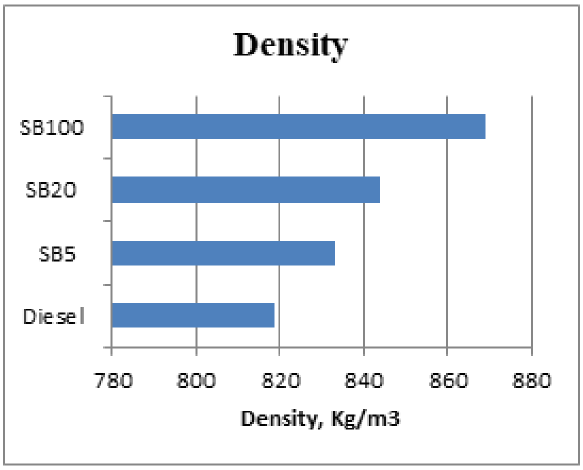



**Fig. 5. Comparison for density of simarouba biodiesel blends**

The atomization of fuel droplets is affected by viscosity of fuel. High viscosity of fuel causes poor atomization. The fuel pump can deliver fuel easily and fine atomized droplets can be obtained for less viscous fuel. From Fig. 6, it is seen that viscosity of the biodiesel blends increases as the biodiesel blend percentage is increased. Simarouba biodiesel B5 blend has less viscosity compared to other biodiesel blends, which is 6.94% higher than diesel.

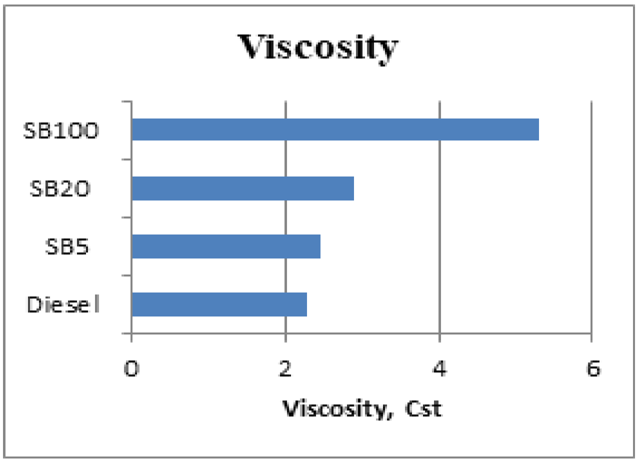



**Fig. 6. Comparison for viscosity of simarouba biodiesel blends**

The suitability of biodiesel as alternative fuel is signified by calorific value as it specifies energy density of fuel. The biodiesel has high content of oxygen compared to diesel and it is accepted that the biodiesel has 10 % less energy content than diesel. It is observed that the pure biodiesel (B100) has heat value lesser than diesel. Fig. 7 shows the calorific value variation for blends of simarouba biodiesel and diesel. It is also seen that the calorific value of biodiesel decreases with increase in its blend percentage.

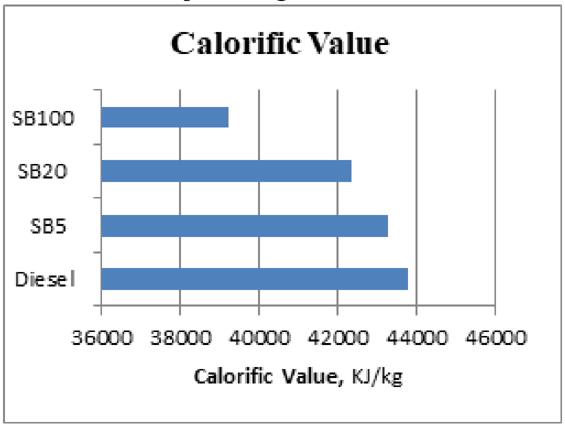



**Fig. 7. Comparison for calorific value of simarouba biodiesel blends**

### *B. Performance Analysis of Simarouba Biodiesel by Varying Injection Pressure*

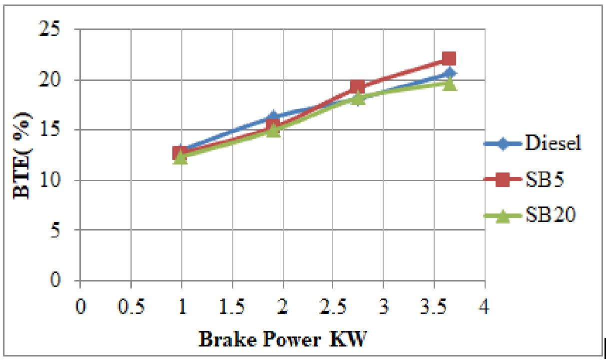



**Fig. 8: Variation of BTE at IP of 200 bar**

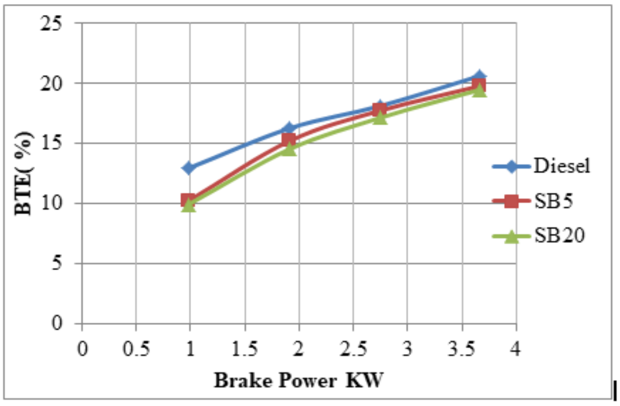



**Fig. 9: Variation of BTE at IP of 250 bar**

Fig. 8 and Fig. 9 show variation of brake thermal efficiency for B5 and B20 blend of simarouba at injection pressure of 200 bar and 250 bar respectively. The BTE of diesel and biodiesel blends is found to increase with increase in brake power. Biodiesel SB5 blend at injection pressure of 200 bar shown 6.5% higher BTE compared to diesel at full load. Also it can be observed that SB5 has higher BTE compared to SB20 at both injection pressures.

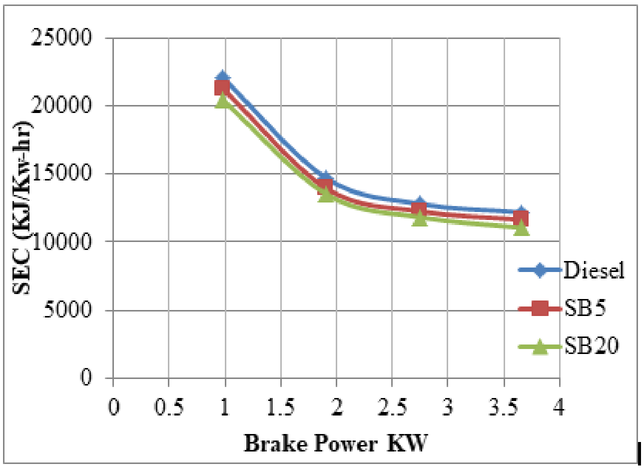



**Fig. 10. Variation of SEC at IP of 200 bar**

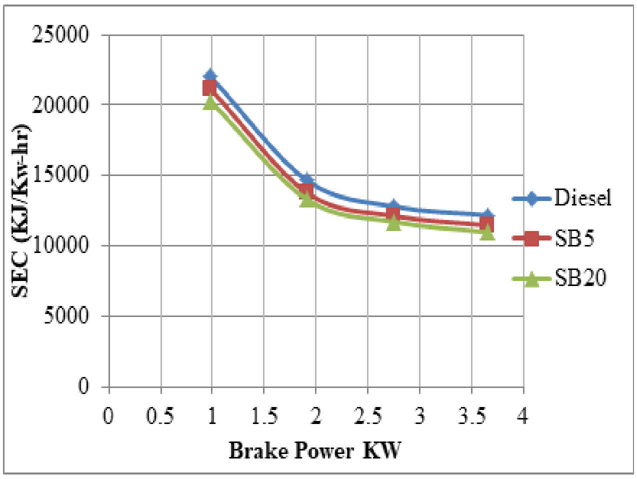



**Fig. 11. Variation of SEC IP at of 250 bar**

Fig. 10 and Fig. 11 show the specific energy consumption (SEC) variation of simarouba biodiesel blends (SB5 & SB20) and diesel. From Fig. 10 and Fig. 11, it is found that with increase in brake power, SEC decreases at both injection pressures. From the figures it is evident that varying the injection pressures has not shown any significant difference with respect to energy consumption. SB20 has 10.96% lower SEC than diesel at IP of 250 bar.

### C. *Emission Analysis of Simarouba Biodiesel By Varying Injection Pressure*

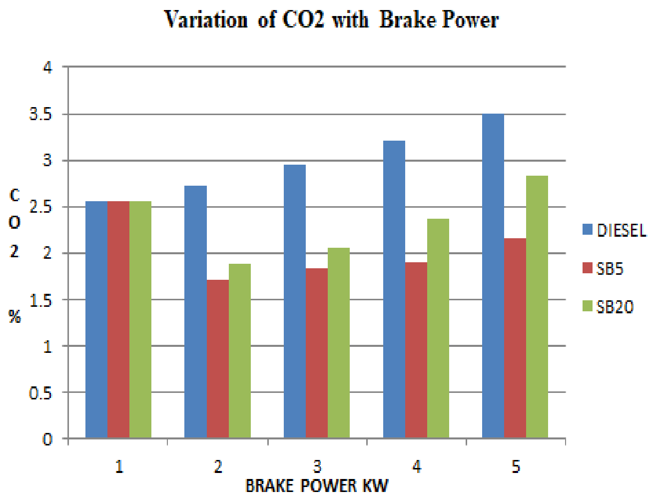



**Fig. 12. CO2 emission variation with BP at IP of 200 bar**

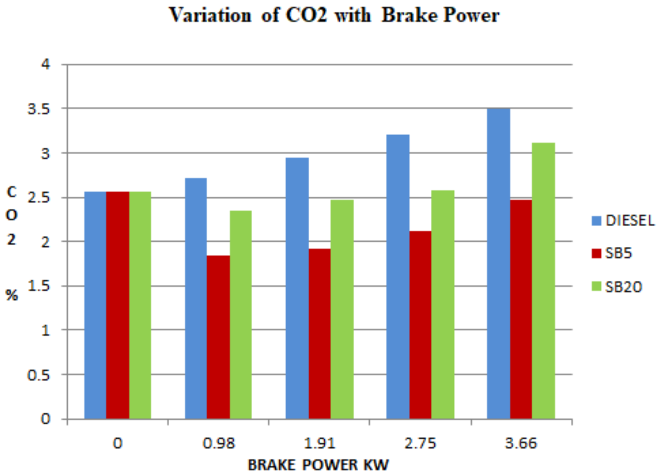



**Fig. 13. CO2 emission variation with BP at IP of 250 bar**

From Fig.12 and Fig.13, it can be found that biodiesel blends have lower emission of $CO_2$ than diesel. This is because biodiesel has esters with oxygen molecules which may help in better combustion compared to petro diesel. SB5 blend shows lower $CO_2$ emissions at all loads compared to other blend, which is 62.04% lower than diesel in full load condition at IP of 200 bar. At 250 bar injection pressure, SB5 blend shows lower $CO_2$ emission at all loading condition, which is 41.7 % lower than diesel.

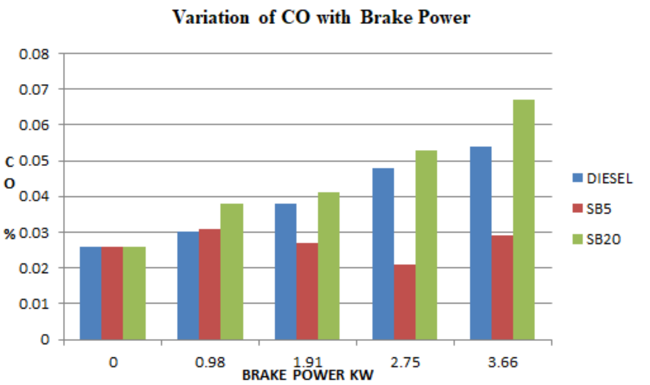


**Fig.14. Comparison of CO Emission at IP of 200 bar**

Fig. 14 and Fig. 15 shows the CO emission variation for Simarouba biodiesel blends at IP of 200 bar and 250 bar respectively.

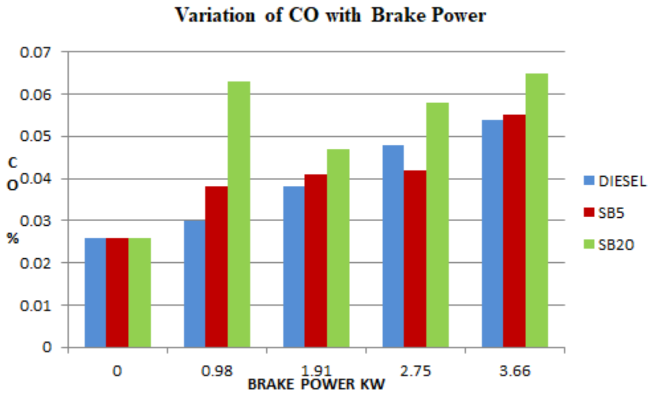



**Fig. 15. Comparison of CO Emission at 250 bar injection pressure**

From Fig. 14 and Fig. 15, it is found that the CO emission of engine increases with increase in brake power. The CO emission of SB20 biodiesel blends is higher in both injection pressures. CO emission of SB20 is 16.92% higher than diesel CO emission.

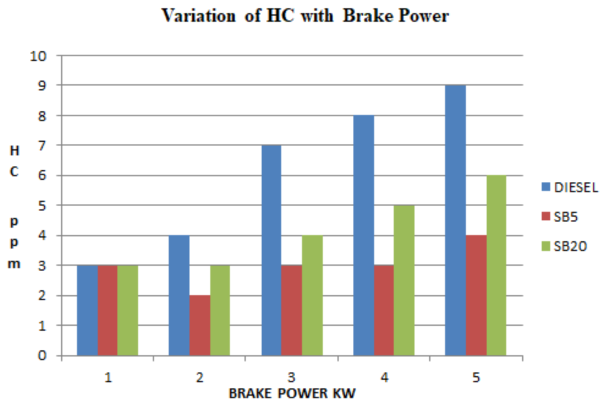



**Fig. 16. Comparison of HC Emission at IP of 200 bar**

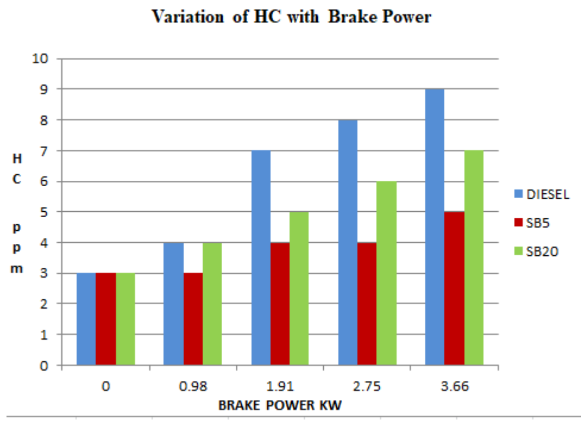



**Fig. 17. Comparison of HC Emission at IP of 250 bar**

The variation of HC emission with BP and injection pressure is shown in Fig.16 and Fig.17. It is evident that biodiesel has lesser HC emission than diesel. This is because the biodiesel leads to more complete combustion compared to diesel due to presence of more oxygen molecules. It can be seen from Fig. 14 that Simarouba B5 blend shows lower hydrocarbon emission, which is 125% lower than diesel at IP of 200 bar.

Fig. 18 and Fig. 19 show the variation of engine NOx emission for simarouba biodiesel blends with BP for 200 bar and 250 bar IP.

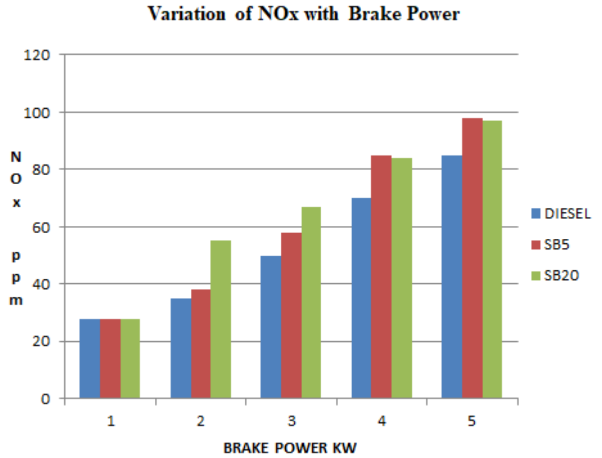



**Fig. 18. Comparison for NOX Emission at IP of 200 bar**

It is well known that biodiesel produces more $NO_x$ emission than diesel due to the presence of oxygen. This leads to complete combustion and increase in combustion temperature. Since $NO_x$ emission is linked to combustion temperature, it increases with complete combustion. When the blend percentage is increased, $NO_x$ emission of engine is found to be increased. It is evident from Fig. 16 that diesel has shown minimum $NO_x$ emission at both injection pressure.

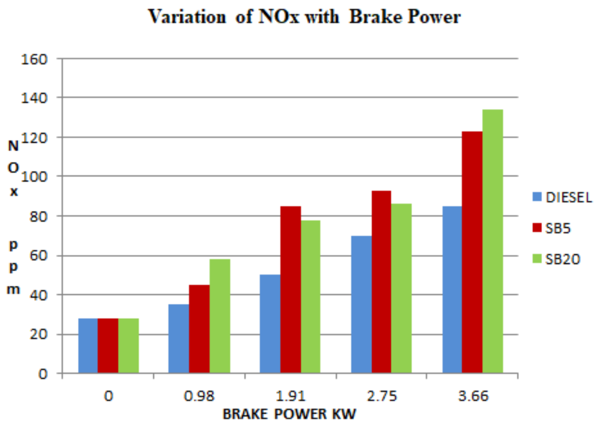



**Fig. 19. Comparison for NOX Emission at IP of 250 bar**

$NO_X$ emissions of Simarouba biodiesel B5 blend is 30.89% more than diesel at IP of 250 bar. When IP is increased to 250 bar, NOx emission is also increased for all biodiesel blends and load conditions. Therefore raising the injection pressure for biodiesel increases the $NO_x$ emissions of engine.

## V. CONCLUSION

The following observations are drawn with the results obtained.

- SB5 shows higher BTE which is 6.48 % more than diesel.
- The CO emission of SB5 at 200 bar injection pressure is



*Published By:*
*Blue Eyes Intelligence Engineering*
*& Sciences Publication*

86.21% lesser compared to diesel.

- The $CO_2$ emission of SB5 at 200 bar injection pressure is 62.04% lesser compared to diesel.
- The HC emission of SB5 at injection pressure of 200 bar is 125% and at 250 bar 80% lesser compared to diesel.
- Biodiesel blends shows less SEC in all load condition and injection pressures than diesel.
- Simarouba biodiesel can be used as fuel in CI engine.

## REFERENCES


1. Mohammed I. Jahirul, Richard J. Brown, Wijitha Senadeera, Ian M. O'Hara and Zoran D. Ristovski, "The Use of Artificial Neural Networks for Identifying Sustainable Biodiesel Feedstocks", Energies (2013), ISSN 1996-1073, pp. 3764-3806.
2. "India: Biofuels Annual Report", USDA foreign Agriculture service, 2015.
3. S.V. Katkur and A. A. Pawar "Performance, Emission analysis of diesel engine by mixing of two biodiesels blended with diesel as alternative fuel", International Engineering Research Journal (IERJ) (2015), Vol. 1, Issue 7, ISSN 2395-1621, pp.533-538
4. Naveena P, Vinod R and Prashanth Reddy "Experimental investigation on the performance and emission characteristics of simarouba glauca oil as an alternate fuel in variable compression ignition engine", International Journal of Engineering Research & Technology (IJERT) (2015), Vol. 4, ISSN: 2278-0181.
5. Jinlin Xue, Tony E. Grift and Alan C. Hansen, "Effect of biodiesel on engine performances and emissions", Elseveir (2011), pp. 1099-1114.
6. J. Kanna kumar, P. Mallikarjuna Reddy and K. Hemachandra Reddy " Effect of fuel temperature on diesel engine performance and emissions using cotton seed based bio-diesel and additive ac2010a", International Journal of Green Chemistry and Bioprocess (2014), ISSN 2277-7199, pp. 9-13.
7. A.E. Atabania,,, A.S. Silitonga , Irfan Anjum Badruddina, T.M.I. Mahliaa, H.H. Masjukia and S. Mekhilefd "A comprehensive review on biodiesel as an alternative energy resource and its characteristics", Elseveir (2012), pp. 2071-2090.
8. Fengxian Qiu, Yihuai Li, Dongya Yang, Xiaohua Li and Ping Sun, "Biodiesel production from mixed soybean oil and rapeseed oil", Elseveir (2011), pp.2050-2055.
9. R.B.V.Murali, Y.V.Hanumantha Rao, K.Venkateswarlu, V.Ranjith Kumar "Performance and Emissions evaluation of diesel engine with pre-heated bio diesel", International Journal of Engineering Science Invention ( 2013), Vol. 2, ISSN (Online): 2319 – 6734, pp.63-71.
10. N.A.Channe, P.P.Kankam and R.A.Tonge "Preheating of biodiesel for the improvement of the injection, ignition and emission characteristics: A review", International journal for engineering applications and Technology, ISSN: 2321-8134, pp. 136-142.
11. Amir Khalid, M. Syamim, N. Mustaffa, Azwan Sapit, Izzuddin Zaman, B. Manshoor and Syahrullail Samion "Experimental investigations on the use of preheated biodiesel as fuel in various load conditions of diesel engine", Australian Journal of Basic and Applied Sciences( 2014), ISSN:1991-8178, pp. 423-430.
12. Belachew Tesfa, Fengshou Gu, Rakesh Mishra and Andrew Ball "Emission characteristics of a CI engine running with a range of biodiesel feedstocks", Energies ( 2014), ISSN 1996-1073, pp. 334-350.


## AUTHORS PROFILE

**Mr. Nithyananda B S** is Assistant Professor in the Department of Mechanical Engineering, VVCE, Mysuru. He did his BE in Mechanical Engineering from PESCE, Mandya in the year 2010and M.Tech in CAMS from VVCE Mysore in the year 2013. He is life member of Indian Society of Technical Education (ISTE). His areas of interest include Biodiesel, Industrial Automation, 3D Printing, Artificial Intelligence and Machine Learning.

**Mr. Anand A** is Assistant Professor in the Department of Mechanical Engineering, NIE, Mysuru. He did his BE in Mechanical Engineering from SJCE, Mysore in the year 2005 and M.Tech in CAMS from VVCE Mysore in the year 2011. He is life member for Institution of Engineers of India (IEI) , Indian Society of Technical Education (ISTE) and Indian Society of Heating, Refrigerating and Air-conditioning Engineers (ISHRAE). His areas of interest include Industrial Automation, Finite Element Methods, Fracture Mechanics, and Biodiesel.

**Dr G V Naveen Prakash** received his BE degree in Mechanical Engineering from University of Mysore. M.Tech in Production Engineering Systems Technology from VTU and Ph.D in Mechanical Engineering from VTU in 2011. His major research interest areas are condition monitoring, composite and Biodiesel. He is working as Professor and Head in the Department of Mechanical Engineering, VVCE, Mysuru. He has more than 16 years of teaching, 10yeras of research and 1.5 years of industry experience. He is a life member of ISTE, SME and IE(I).

**Dr. Vinay K B** working as Associate professor at Mechanical Engineering Department, VVCE, Mysore. He completed B.E, M.Tech and Ph.D in Mechanical engineering from University of Mysore and Visvesvaraya Technological University. He has presented 16 papers in national and international conferences and published 07 papers in Journals. Teaching experience 15 years. Research interests are Incubation, Heat Transfer and fluid flow, Quality Management, Operations Management, Entrepreneurship, Engineering system Design. Life member of ISTE.

**Mr. Naveen A (Naveen Ankegowda)** is presently working as assistant professor at VVCE, Mysuru, India. He has obtained his bachelor's degree in Mechanical Engineering from KIT,Tiptur , Karnataka, India and Master Degree in Maintenance from SJCE, Mysuru, India. He has published more than 15papers in journals and conferences. He is the member for MISTE professional body.