Int. J. Chem. Sci.: 14(1), 2016, 161-172
ISSN 0972-768X
www.sadgurupublications.com

WASTE COOKING OIL (WCO): AN IMPERIOUS SUBSTITUTE FUEL FOR DI DIESEL ENGINES

L. KARIKALAN[*] and M. CHANDRASEKARAN

Department of Mechanical Engineering, VELS University, CHENNAI (T.N.) INDIA

ABSTRACT

The objective of this work was to optimize CI engine with WCO (waste cooking oil) biodiesel as fuel through experimental investigation through brake power, fuel economy and smoke emissions. Performance and discharge features were studied using the different WCOB blends and standard diesel. The result shows that the maximum BTE for WCOB 40 at maximum load is 34.48%, which is 2.9% more than diesel fuel. High BSFC noticed for higher percentage of WCO blends due to lower heating value, density and viscosity of the fuel. The exhaust gas temperature attained for diesel is 306°C at maximum load, whereas for WCOB20 and WCOB40 blends it is 278°C and 263°C. The HC emission for WCO blends increases with rise in load. WCOB20, WCOB60, WCOB80 and WCOB100 produce less HC emissions than WCOB40 and diesel. The CO emission of WCOB40 is closer to diesel, moderate at medium load and higher at part loads. CO_2 emission for WCOB blend is lesser than diesel due to incomplete combustion and inadequate supply of oxygen at high load. The NO_X emission for diesel and WCOB40 are 642 ppm and 428 ppm, respectively at part load. The smoke opacity features for diesel and WCOB100 are small and upper in the case of all other WCOB blends. From this study, it is clear that WCOB could replace the fossil fuel in the case of shortages in the near future.

Key words: Diesel, Waste cooking oil, Biodiesel, Performance, Emissions.

INTRODUCTION

Finding alternate sources to fossil fuels for CI engines are prime significant owing to thinning petroleum assets and the ecological concerns of exhaust gases from fossil fuelled engines. Fossil fuel use in transportation is the leading contributor to urban air pollution and to global warming[1]. There searchers evidenced that both vegetable oil and it esters stayed gifted choices as fuel for CI engines[2-4]. Producing biodiesel from cheap feed stocks could become easier and more environmentally friendly thanks to scientists and researchers in all over the world[5]. The usage of biodiesel can prolong the lifecycle of diesel engines since it is added lubricating than diesel fuel. Biodiesel is created from renewable vegetable oil and

[*]Author for correspondence; E-mail: karilk2005@yahoo.co.in

hence forth progresses the fuel or energy safety and economy freedom. More investigation has been conceded out to practice vegetable oil both in neat and modified form[6-9]. Biodiesel is much cleaner than fossil-fuel diesel. In fact diesel engines run better and last longer with biodiesel. Biodiesel is better for the environment because it is made from renewable resources and has lower emissions compared to petroleum diesel[10-12]. It is less toxic than table salt and biodegrades as fast as sugar.

Waste cooking oil

Waste oils and fats can be used as renewable fuel resources. Conversion of waste oils and fats to biodiesel fuel is one possibility but poses some difficulties such as in the use of toxic or caustic materials and by-product disposal[13]. Conversion to biodiesel may also decrease the economic attractiveness of using waste oils as fuels. Using relatively unmodified oils or fats eliminates the problems associated with toxic and caustic precursor chemicals and residual biodiesel alkalinity as the oil is used without altering its chemical properties.

Table 1: Specification of biodiesel fuels

Properties	Diesel	WCO
Density at 15°C (Kg/m^3)	8	887
Kinematic viscosity at 40°C (cSt)	2.72	5.16
Cetane index	46.2	48.05
Flash point (°C)	89	122
Lower heating value (MJ/kg)	42.49	36.59
Acid number (mg KOH/g)	0.10	0.55
Water content (ppm wt.)	57	466

One possibility for the disposal of these products is as a fuel for transport or other uses. Conversion of waste oils and fats to biodiesel fuel has many environmental advantages over petroleum based diesel fuel. The use of waste material as a source of alternative fuel is a practice of increasing popularity among the researchers worldwide. One such high value waste product is waste cooking oil (WCO) or abused fryer oil[14-17]. These can be utilized for production of biodiesel, hence facilitating to lessen the rate of water treatment in the sewerage system and supporting in there processing of resources. Generally cooking oil used for frying are sunflower oil, palm oil, coconut oil etc. as they are easily available, and especially so of the coconut oil, which is abundantly available in south India. It is well known fact that, when oils such as these are heated for an extended time (abuse), they under go oxidation (degradation) and give rise to oxides. The biodiesel reaction is presented in Fig. 2.

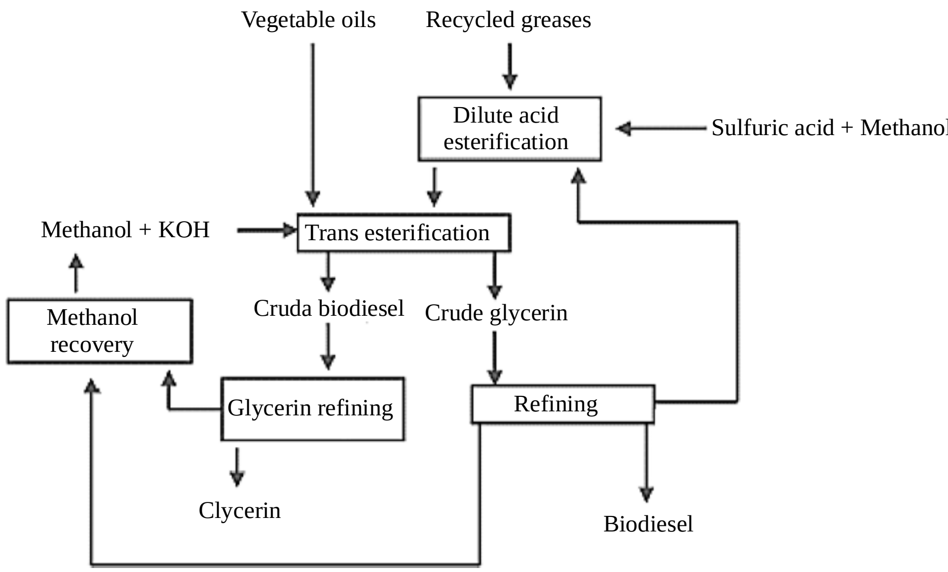

Fig. 1: Transesterification process

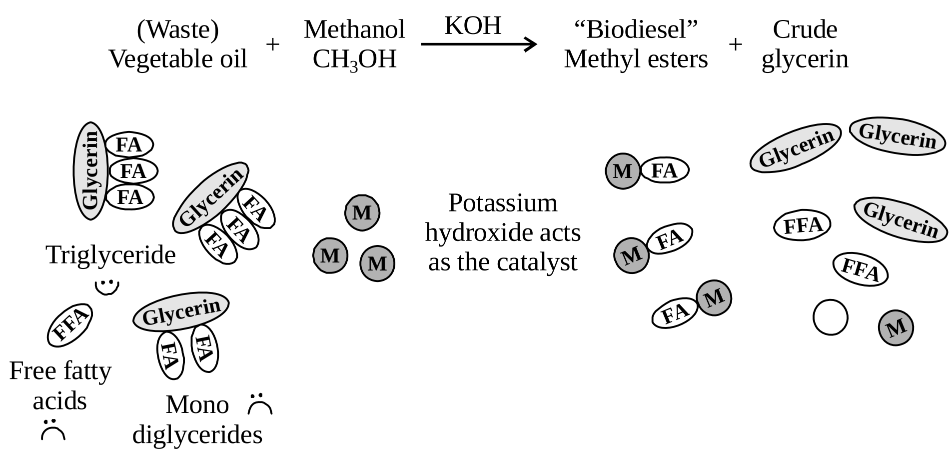

Fig. 2: Biodiesel reaction

WCO afford a feasible substitute to diesel, as they are certainly accessible. These comprise several deprivation crops of vegetable oils and foreign material. These contaminations can be detached by heating and separation. Henceforth this does not avoid its practice as feedstock for biodiesel making. It has been stated that the cetane number of

WCO methyl ester is about 49 and it establishes it's prospective to swap diesel. Many researchers compared the combustion characteristics, the effect of physical and chemical possessions of WCO biodiesel in a direct injection CI engine and noticed that fuels with upper cetane index gave a lesser NOx, HC,CO. WCOB is healthy reputable that biodiesel gives a significant lessening in SO_X emissions and substantial decreases in CO, hydrocarbons, soot, and particulate matter (PM).[18-24]

EXPERIMENTAL

Investigation were conceded on a water cooled, four stroke, single cylinder diesel engine and the performance and pollutant features of the engine with WCO Biodiesel blends (WCOB20, WCOB40, WCOB60, WCOB80 and WCOB100) were gauged and equated using the outcomes of diesel. The exhaust emissions were quantified by a Crypton 290 series Exhaust Gas Analyzer and AVL make Smoke meter was utilized to size the smoke intensity.

Table 2 Engine specifications

Manufacturer	**KIRLOSKAR Oil Engines Ltd**
Engine type	Single cylinder diesel engine
Speed	1800 rpm
Rating at 1500 rpm	5.9 kw
Compression ratio	17.5:1
Fuel injection timing	27˚ BTDC
Method of cooling	Water cooling
Injection pressure	200 bar

The engine was started and run to achieve the stable condition and the engine load was increased gradually to maxi-mum recommended value. The applications of loads were 0%, 25%, 50%, 75%, and 100%, respectively. The engine speed was constant at 1800 rpm. For every load stages, the quantity of fuel consumption, exhaust gas temperature, fuel injection timing, crank angle, hydrocarbon (HC) emission, carbon monoxide (CO) emission, nitrogen oxides (NO_X) emission, smoke emission, combustion chamber pressure and HRR were conceded and recorded the data for several loads. The diesel and biodiesel blends were tried at standard engine specification at normal injection timing 27^o BTDC, injection pressure of 200 bar with compression ratio of 17.5.

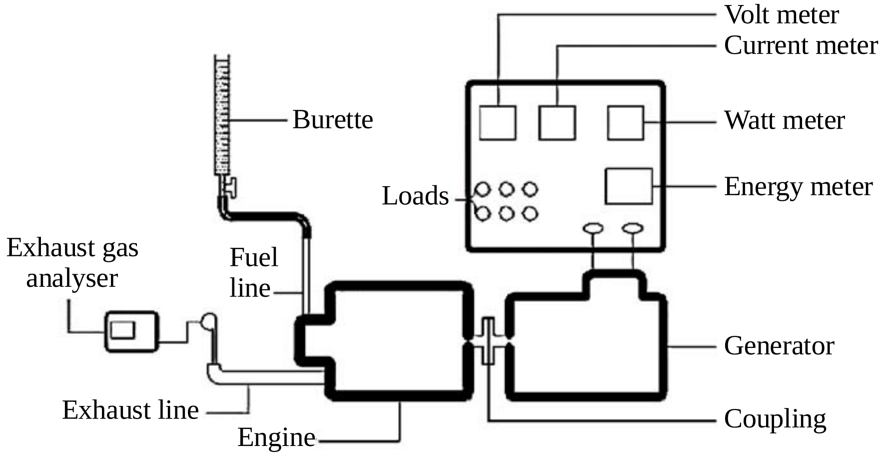

Fig. 3: Experimental setup (line diagram)

RESULTS AND DISCUSSION

Brake thermal efficiency variations with load for WCO blends are displayed in Fig. 4. It has been noticed that that the BTE of blends increases with increase in load applied. The maximum BTE for WCOB 40 at maximum load is 34.48%, which is 2.9% more than diesel fuel. The BTE for diesel, WCOB20 and WCOB40 are 31.58%, 33.12% and 34.48%, respectively. At higher loads, the BTE decreases due to low heating value and increased fuel consumption. BSFC variations with load for different WCO blends are shown in Fig. 5.

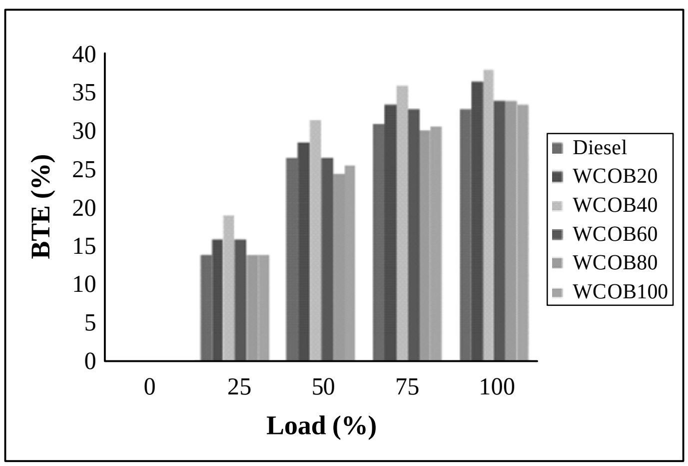

Fig. 4: BTE Vs Load

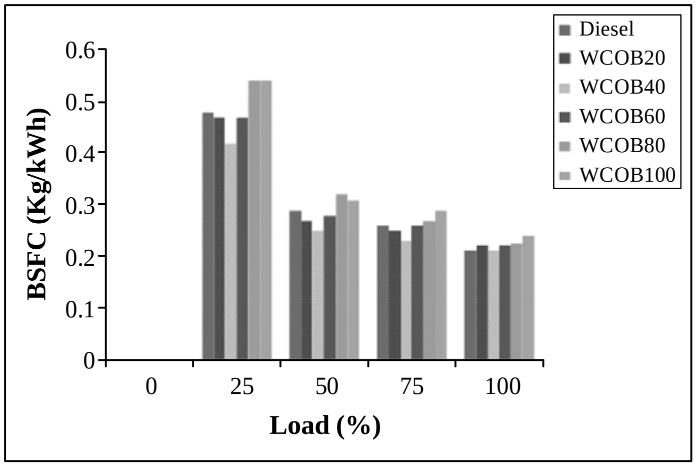

Fig. 5: BSFC Vs Load

The BSFC for WCOB20 and WCOB40 are 3.78 Kg/kWh and 3.82 Kg/kWh, respectively at maximum load. High BSFC noticed for higher percentage of WCO blends due to lower heating value, density and viscosity of the fuel. It is observed that the WCOB40 possess high energy content among the WCOB blends. The EGT for different blends with load is displayed in Fig. 6. The exhaust gas temperature attained for diesel is 306^{o}C at maximum load, whereas for WCOB20 and WCOB40 blends it is 278^{o}C and 263^{o}C. The reduced EGT for WCOB blends may be due to lower calorific value and lower exhaust loss.

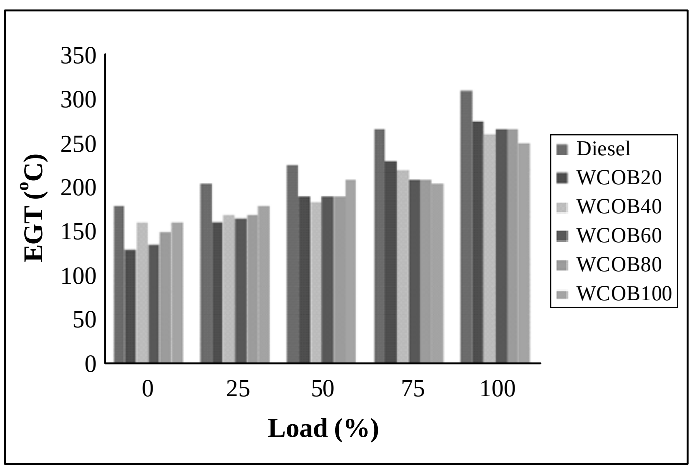

Fig. 6: EGT Vs Load

The variation of HC emissions against load for dissimilar WCO blends is revealed in Fig. 7. The HC emission for WCO blends increases with rise in load. WCOB20, WCOB60, WCOB80 and WCOB100 produce less HC emissions than WCOB40 and diesel. The hydrocarbon emission increases mainly due to fuel viscosity, spray pattern of fuel and longer ignition delay. The CO emission variation with load for WCO blends is displayed in Fig. 8. The CO emission of WCOB40 is closer to diesel, moderate at medium load and higher at part loads. The fuel viscosity and spray characteristics are greatly affecting the CO emission with WCO blends.

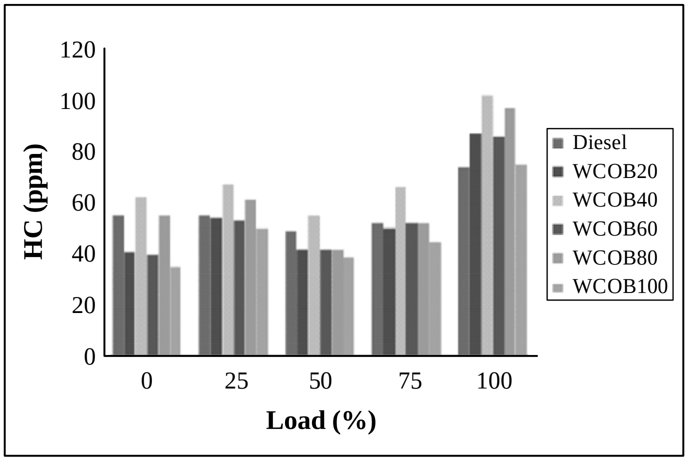

Fig. 7: HC Vs Load

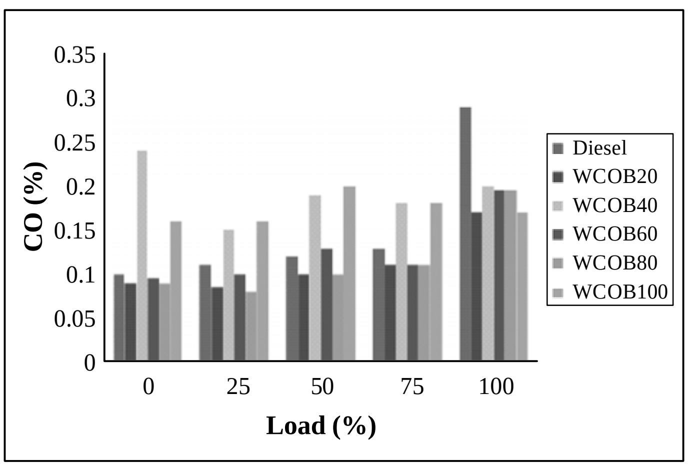

Fig. 8: CO Vs Load

The variation of CO_2 with various loads is shown in Fig. 9. CO_2 emission for WCOB blend is lesser than diesel due to incomplete combustion and inadequate supply of oxygen at high load. More amount of CO_2 indicates the complete combustion of fuel. The CO_2 accumulation leads to environmental issues. The NOx emission variation with load for WCO blends is shown in Fig. 10.

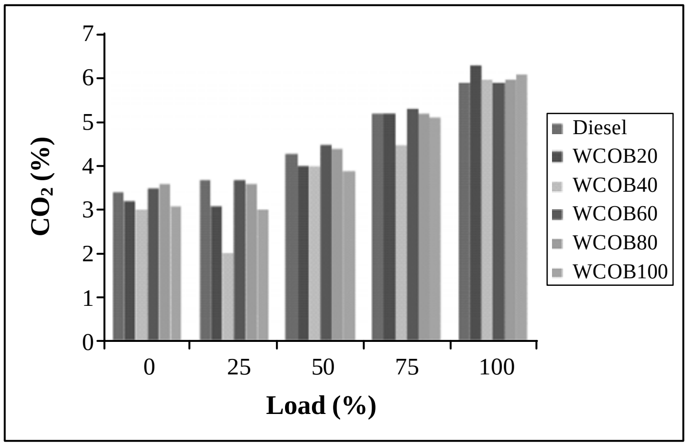

Fig. 9: CO_2 Vs Load

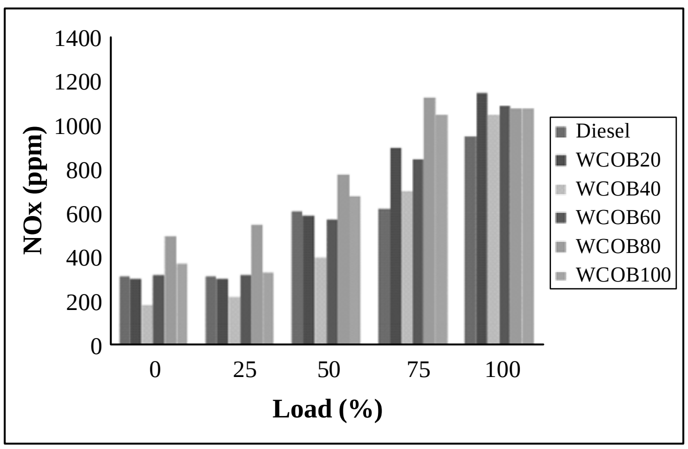

Fig. 10: NOx Vs Load

The NOx emission for WCO blends is upper than diesel except WCOB40 at lower loads. The NOx emission for diesel and WCOB40 are 642 ppm and 428 ppm, respectively at part load. The NOx emission rises with rise in load owing to upper engine temperature at upper loads. Fig. 11 shows that the smoke opaqueness for WCO blends with load. At maximum load smoke opacity for diesel, WCOB20, WCOB40, WCOB60, WCOB80 and

WCOB100 are 53HSU, 70HSU, 52HSU, 62HSU, 73HSU and 42HSU, respectively. The smoke opacity features for diesel and WCOB100 are small and upper in the case of all other WCOB blends. This was owing to the poor atomization of biodiesel blends as equated with diesel.

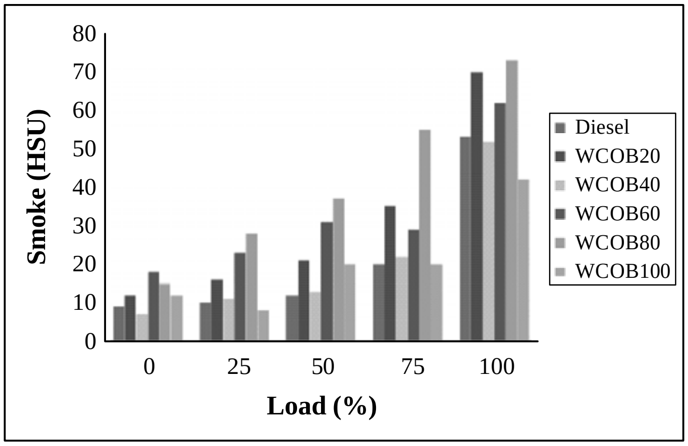

Fig. 11: Smoke Vs Load

CONCLUSION

WCO Biodiesel is a stand-in fuel and cleaner than diesel. It could be utilized straight as fuel for CI engine with no modifying the engine system. From the experimental results, it is clear that –

(i) The BSFC for WCOB20 and WCOB40 are 3.78 Kg/kWh and 3.82 Kg/kWh, respectively at maximum load. High BSFC noticed for higher percentage of WCO blends due to lower heating value, density and viscosity of the fuel. The maximum BTE for WCOB 40 at maximum load is 34.48%, which is 2.9% more than diesel fuel. It has been noticed that that the BTE of blends increases with increase in load applied. The EGT attained for diesel is 306^{o}C at maximum load, whereas for WCOB20 and WCOB40 blends it is 278^{o}C and 263^{o}C due to lower calorific value and lower exhaust loss.

(ii) The HC emission for WCO blends increases with rise in load due to fuel viscosity, spray pattern of fuel and longer ignition delay. The CO emission of WCOB40 is closer to diesel, moderate at medium load and higher at part loads due to the fuel viscosity and spray characteristics of WCO blends. CO_2 emission for WCOB blend is lesser than diesel due to incomplete combustion and inadequate supply of oxygen at high load. More amount of CO_2 indicates the complete combustion of fuel.

(iii) The NOx emission for WCO blends is upper than diesel except WCOB40 at lower loads. The NOx emission rises with rise in load due to upper engine temperature at upper loads. The smoke opacity features for diesel and WCOB100 are small and upper in the case of all other WCOB blends due to the poor atomization of biodiesel blends as equated with diesel.

It is observed that WCO biodiesel has closer performance and emission characteristics as diesel and it indicates that WCO biodiesel can be good alternative fuel for CI engines in the near future.

ACKNOWLEDGEMENT

The authors are grateful to the Head, Department of Automobile Engineering, Hindustan Institute of Technology and Science, Chennai for extending the support to carry out this experimental research work.

REFERENCES

1. S. Altun, Performance and Exhaust Emissions of a D.I. Diesel Engine with Waste Cooking Oil and Inedible Animal Tallow Methyl Esters, Turkish J. Eng. Env. Sci., **35**, 107-114 (2011).
2. A. Mohebbi, M. H. Komaizade, S. Jafarmadar and J. Pashai, Use of Waste Cooking Oil Biodiesel in a Tractor DI Diesel Engine, J. Food, Agri. Environ., **10(2)**, 1290-1297 (2012).
3. S.-H. Liu, Y.-C. Lin and K.-H. Hsu, Emissions of Regulated and PAHs from Waste Cooking Oil Biodiesel Fuelled Heavy-Duty Diesel Engine with Catalyzer, Aerosol and Air Quality Res., **12**, 218-227 (2012).
4. G. L. N. Rao, S. Sampath and K. Rajagopal, Experimental Studies on the Combustion and Emission Characteristics of a Diesel Engine Fuelled with used Cooking Oil Methyl Ester and its Diesel Blends, Int. J. Appl. Sci. Eng. Technol., **4**, 64-70 (2008).
5. B. Ghobadian, H. Rahimi, A. M. Nikbakht, G. Najafi and T. F. Yusaf, Tarbiat Modares University, Iran, Diesel Engine Performance and Exhasut Emission Analysis using Waste Cooking Biodiesel Fuel with an Artificail Neural Network Aid, Renewable Energy, **34(4)**, 976-982 (2009).

6. C. V. Sudhir, N. Y. Sharma and P. Mohanan, Potential of Waste Cooking Oils as Biodiesel Feedstock, Emirates J. Eng. Res., **12(3)**, 69-75 (2007).

7. C. W. Yu, S. Bari and A. Ameen, A Comparison of Combustion Characteristics of Waste Cooking Oil with Diesel as a Fuel in a Direct Injection Diesel Engine, J. Automobile Engg., **216**, 237-243 (2002).

8. M. I. Al-Widyan, G. Tashtoush and M. Abu-Qudais, Utilization of Ethyl Ester of Waste Vegetable Oil as Fuel in Diesel Engines, Fuel Proc. Technol., **76(2)**, 91-103 (2002).

9. K. Murlidharan and D. Vasudevan, Performance, Emission and Combustion Characteristics of a Variable Compression Ratio Engine using Methyl Esters of Waste Cooking Oil and Diesel Blends, Appl. Energy, **88**, 3959-3968 (2011).

10. Abu-Jrai, Jehad A. Yamin, Ala'a H. Al-Muhtaseb and Muhanned A. Hararah, Combustion Characteristics and Engine Emission of a Diesel Engine Fueled with Diesel and Treated Waste Cooking Oil Blends, Chem. Engg., **172**, 129-136 (2011).

11. C. C. Enweremadu and H. L. Rutto, Combustion, Emission and Engine Performance Characteristics of used Cooking Oil Biodiesel-A Review, Renew Sust Energy Rev., **14**, 2863-2873 (2010).

12. M. Canakci, A. N. Ozsezen, E. Arcaklioglu and A. Erdil, Prediction of Performance and Exhaust Emissions of a Diesel Engine Fueled with Biodiesel Produced from Waste Frying Palm Oil, Expert Sys. Appl., **36**, 9268-9280 (2009).

13. M. Pughazhvadivu and K. Jeyachandran, Investigations on the Performance and Exhaust Emission Sofa Diesel Engine using Preheated Waste Frying Oil as Fuel, Renewable Energy, **30**, 2189- 2202 (2003).

14. M. Cetinkaya and F. Karaosmanoglu, A New Application Area for used Cooking Oil Originated Biodiesel: Generators, Energy Fuels, **19**, 645-652 (2005).

15. Z. Utlu and M. S. Kocak, The Effect of Biodiesel Fuel Obtained from Waste Frying Oil on Direct Injection Diesel Engine Performance and Exhaust Emissions, Renewable Energy, **33**, 1936-1941 (2008).

16. A. Hribernik and B. Kegl, Performance and Exhaust Emissions of an Indirect Injection (IDI) Diesel Engine when using Waste Cooking Oil as Fuel, Energy Fuel, **23(3)**, 1754-1758 (2009).

17. W. T. Tsai, C. C. Lin and C. W. Yeh, An Analysis of Biodiesel Fuel from Waste Edible Oil in Taiwan, Renew. Sust. Energy Rev., **11(5)**, 838-857 (2007).

18. M. G. Kulkarni and A. K. Dalai, Waste Cooking Oil an Economical Source for Biodiesel: A Review, Ind. Eng. Chem. Res., **45(9)**, 2901-2913 (2006).

19. M. A. Kalam, H. H. Masjuki, M. H. Jayed and A. M. Liaquat, Emission and Performance Characteristics of an Indirect Ignition Diesel Engine Fuelled with Waste Cooking Oil, Energy, **36**, 397-402 (2011).

20. J. Hwang, D. Qi, Y. Jung and C. Bae, Effect of Injection Parameters on the Combustion and Emission Characteristics in a Common-Rail Direct Injection Diesel Engine Fuelled with Waste Cooking Oil Biodiesel, Renewable Energy, **63**, 9-17 (2014).

21. K. N. Gopal, A. Pal, S. Sharma, C. Samanchi, K. Sathyanarayanan and T. Elango, Investigation of Emissions and Combustion Characteristics of a CI Engine Fueled with Waste Cooking Oil Methyl Ester and Diesel Blends, Alexandria Engg. J., **53**, 281-287 (2014).

22. Ozer Can, Combustion Characteristics, Performance and Exhaust Emissions of a Diesel Engine Fueled with a Waste Cooking Oil Biodiesel Mixture, Energy Conversion and Manage., **87**, 676-686 (2014).

23. G. R. Kannan and R. Anand, Effect of Injection Pressure and Injection Timing on DI Diesel Engine Fuelled with Biodiesel from Waste Cooking Oil, Biomass and Bioenergy, **46**, 343-352 (2012).

24. Y.-C. Chang, W.-J. Lee, L.-C. Wang, H.-H. Yang, M.-T. Cheng, J.-H. Lu, Y. I. Tsai and L.-H. Young, Effects of Waste Cooking Oil-Based Biodiesel on the Toxic Organic Pollutant Emissions from a Diesel Engine, Appl. Energy, **113**, 631-638 (2014).

Revised : 28.11.2015 *Accepted : 30.11.2015*