International Journal on Emerging Technologies **10**(2): 422-426(2019)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Emissions Characteristics of Biogas-Diesel Fuel Blends in Compression Ignition Engine

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(Received 25 May 2019, Revised 06 August 2019 Accepted 19 August 2019)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: The exceeding population around the globe is experiencing two noteworthy issues; quick consumption of regular fuel and natural debasement. Biomass derived biogas is a very promising alternative energy source because of its renewable and clean combustion characteristics compared to fossil petroleum diesel fuel. The main aim of this paper is to explore and highlight the potential of biogas-diesel dual fuel combustion mode at different engine operating conditions. Emissions characteristics of the dual fuel engine were studied at diverse energy share of biogas and compared with conventional diesel. It is inferred from the experimental results, that NO_x and smoke opacity emissions were lower at all engine operating loads, while there was increase in CO, CO_2 and HC emissions at all energy share rates of biogas compared to diesel counterparts.

Keywords: Biogas; dual fuel; emissions; diesel; gas flow

I. INTRODUCTION

Inflexible conservational guidelines, limited fossil fuel reserves, accelerating expenses and augmented necessitate for energy have initiated attention in supplementary progressive and innovative combustion strategies that utilizenon-conventional and alternate fuels as sources of energy. There is continuous pressure on emission control through periodically tightened regulations throughout the world. In this situation, there is an urgent need to promote use of alternative fuels as substitutes for diesel engines [1-3]. Dual fuel engines powered by biogas can be a solution to this drastic scarcity of severe power predominantly in rustic regions in India [4]. It is an attributable fact that conventional diesel engine owns the benefit of much higher thermal efficiency than SI engine at the expense of high NO_x and soot emissions. Hence, the utilization of biomass derived fuel in CI engines will improve the exhalations and sustain high efficiency, which will promote the application of biomass fuel [5-7]. Moreover gaseous fuels are considered good for internal combustion engines, because of their good mixing characteristics with air. The high self-ignition temperature enables them to operate with lean mixtures and higher compression ratios, resulting in an improvement in the thermal efficiency and reduction in emissions [8-9]. Biogas is a potentially renewable, cheaply producible and environment friendly fuel. Biogas can be produced from the variety of organic substances through the anaerobic digestion process. The main constituent of biogas is methane and carbon dioxide. The composition of biogas obtained through anaerobic digestion process depends on the type of feed stocks used, and production processes evolved. Many different types of feed stocks have been explored for the production of biogas, such as cow dung, agricultural waste, animal waste, food waste, non-edible seed cakes, sewage sludge, and municipal waste [10].

Biogas is a low cetane fuel, and it cannot be directly ignited and combusted in conventional diesel engine. It requires an ignition source as the auto-ignition temperature of biogas is high [11]. Therefore, a high cetane rating pilot fuel is required to ignite and combusted the biogas, when in diesel engines. The CO_2 present in the biogas acts as a diluent for the reduction of NO_x tailpipe emission, when it is used in dual fuel engine [12-13]. Many research investigations have been documented on the utilization of biogas in conventional diesel engines on dual fuel mode. It was reported that, the brake thermal efficiency of the engine reduced at low to intermediate loads [14-16], while it remains unchanged, and increased at higher engine operating loads [17-19]. The NO_x and smoke emissions were found to be lower [20-21]. The HC and CO concentration level were reported to be higher in some cases [22] and lower in some researches [23-24].

Karim *et al.* [25] investigated the performance, combustion and emissions characteristics for biogas-diesel dual fuel engines. However, their studies are mainly limited to part load or low load conditions. Nayak *et al.* [26] studied the emissions characteristics of a dual fuel engine operated on saw dust biomass and diesel fuel blends. They found lower NO_x-smoke emissions while higher CO, HC and CO_2 were reported for dual fuelling operation. Significant diesel fuel saving with biomass based fuels under dual fuel mode was reported [27-30].

From the detailed literature review it can be concluded that most of the previous studies have not focused on the emission characteristics of a dual fuel engine with biogas as primary fuel and diesel as pilot fuel. For dual fuel operation, the biogas at different energy substitutions, viz., 20, 40 and 60% was inducted through the suction and diesel was injected as a pilot fuel in this experimentation. The key objectives of this investigations is to obtain biogas through anaerobic digestion of cow dung and kitchen waste and assess the potential of using biogas in a CI engine in view to improve emissions characteristics. Finally, the results obtained from the dual fuel operation were compared with those of diesel operation.

II. MATERIALS AND METHODS

A. Biogas production method

In the present investigation, the primary fuel used was biogas obtained by the anaerobic digestion of cow dung and kitchen waste in a fixed dome type biogas plant. A fixed dome type biogas digester comprises of a digester with a stable, non-portable gas compartment, which be situated on upper piece of the digester. Slurry was set by fraternization of water in cow's excrement in proportionate portion, and fractional amount of kitchen squander in blending supply. The slurry was then guided into the digester holder with the guide of delta compartment, where the composite carbon blends existing in the steers manure and kitchen waste breaks into easier issues by the demonstration of anaerobic organisms in the organization of water. This anaerobic breaking down of composite carbon mixes accessible in cow's fertilizer and kitchen waste secures biogas and a cycle is practiced in roughly 2 months. The biogas so shaped gathers in vault structured top of biogas generator and is provided to the motor with assistance of funnels. The devoured slurry is substituted every once in a while with new slurry to carry on the creation of biogas.

The premium diesel fuel used in the experimental work was procured from local retail petrol pump. The various physio-chemical properties of the tested fuels were in strict compliance with international ASTM standards.

B. Experimentation

In the present investigations the single cylinder, four stroke, natural aspirated direct injection diesel engine, with a rated power output of 6.0 kW at 1500 rpm was used. All the tests were performed at standard fuel injection pressure of 210 bars and static injection timing of 26^o BTDC. All experiments were performed after engine reaches the coolant temperature of 70^{o}C at steady state condition and at a constant speed of 1500 rpm under dual fuel and single fuel mode. The detailed specifications of the test engine are summarized in Table 3. First of all, baseline data were recorded with diesel fuel for comparison. In the dual-fuel operation, biogas from the fixed dome was supplied to the flow meter and controlled amount of biogas was inducted in the inlet manifold. The biogas flow meter gives the volumetric flow of biogas into the engine cylinder. The biogas generated in the biogas plant (fixed dome type) was stored in a gas holder and supplied to the engine by a hose pipe. The gas flow rate was set at various energy levels (20, 40 and 60%) while pilot fuel supply was regulated to maintain remaining engine power. During the experiments, the engine was tested with 20%, 40%, 60%, 80% and 100% load. The exhaust gas emissions measured were CO, CO_2, HC (unburned hydrocarbon), NO_x and smoke opacity were measured by a gas analyser (AVL Digas 444 N) and AVL smoke opacity meter 437 C respectively.

III. RESULTS AND DISCUSSION

The following section illustrated the results of emission characteristics of the diesel engine fuelled with the biogas and pure diesel were tested under different gas flow rate and engine load conditions.

A. Hydrocarbons (HC)

The unburned hydrocarbon levels in exhaust tailpipe shows the quantity of fuel does not participate in combustion and remain unburned. The variation of hydrocarbons with engine loads for test fuels were shown in Fig. 1. Biogas fuelled dual fuel engine suffers from a higher HC emission than that of conventional diesel engine throughout the load spectrum. Same trend was observed by Tarabet *et al.* [31]. This may be due to the induction of biogas through the intake manifold, reduces the volume of the inducted air, and forms a fuel rich mixture zone, increases the partial burning with less oxygen [31]. The unburned hydrocarbon emissions level increases with increase in biogas fuel rate at all engine loads. At lower loads, the pilot fuel injection quantity is low, makes slower flame propagation leads to partial oxidation of fuel thereby increases the level of unburned hydrocarbon in the exhaust [32]. At 20% engine load the level of hydrocarbon under dual fuel mode (500 ppm) when compared to diesel fuel (35.5 ppm).

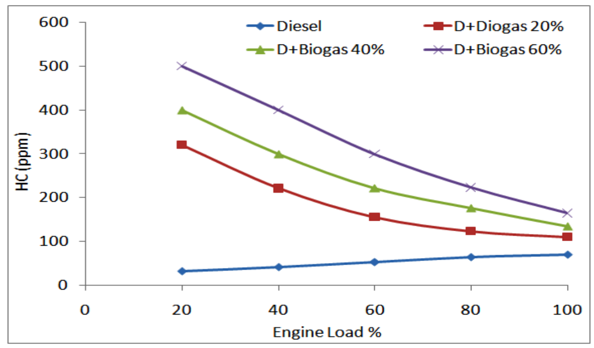

Fig. 1. Variation of HC emissions with load.

At higher loads, due to higher combustion chamber temperature the level of hydrocarbon emission is lower than at lower loads under dual fuel mode. At full load engine condition the hydrocarbon level under maximum biogas flow rate were 220 ppm when compared to fossil petro-diesel (23 ppm).

B. Carbon monoxide (CO)

Carbon monoxide emission is the results of incomplete combustion of fuel-air mixture inside engine cylinder. The emission of carbon monoxide level in exhaust tailpipe represents the incomplete and poor fuel utilization inside combustion chamber due to low temperature of flame propagation and limited supply of oxygen. Fig. 2 shows the variation of CO with engine loads. It can be observed that the CO emission first decreases with the increase in the load up to the part load. Prakash *et al.* [33] also found the similar results. This is mainly attributed due to the higher cylinder gas temperature boosts the rate of combustion [33]. The CO level under dual fuel mode is considerably higher than diesel fuel at all engine loads. Due to the presence of biogas residual that dilutes the charge concentration inside engine cylinder which gives higher CO emission at low to intermediate loads. At 20% load, the concentration of CO emission is (0.32%) under dual fuel mode as compared to diesel fuel (0.30%). With increasing biogas flow rate the CO emission decreases from low load to intermediate level. At higher loads, the cylinder gas temperature is higher leads to improvement in quality of combustion thereby reduces CO level as compared to diesel mode. The CO level at full load under dual fuel mode with 3.2 kg/h was 0.21% as compared to diesel fuel (0.15%).

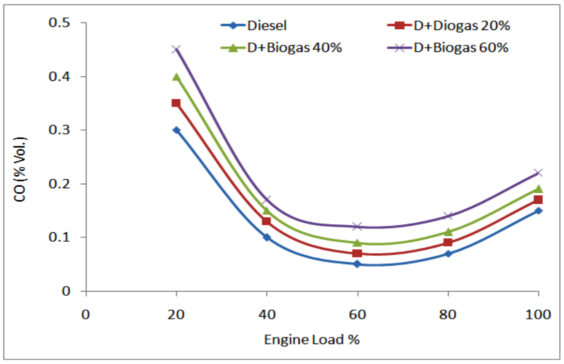

Fig. 2. Variation of CO emissions with load.

C. Carbon Dioxide (CO_2)

Fig. 3 shows the variation of CO_2 emission with engine loads. The CO_2 level in the exhaust tailpipe is higher under dual fuel mode of operation than conventional diesel fuel. It is observed that increasing biogas flow rate the CO_2 level increases at all engine loads. At 20% load the concentration of CO_2 level with 3.2 kg/h biogas flow rate dual fuel operation is (6.2%) when compared with diesel fuel (3.4%). This is mainly due to the dilution of CO_2 present in the biogas composition which gives higher CO_2 emission level [34]. It is inferred from the Fig. 5, the CO_2 emission level increases with increase in engine load for all tested fuels. At full load the concentration of CO_2 level with 3.2 kg/h biogas flow rate dual fuel operation is (9%) when compared with diesel fuel (6.5%).

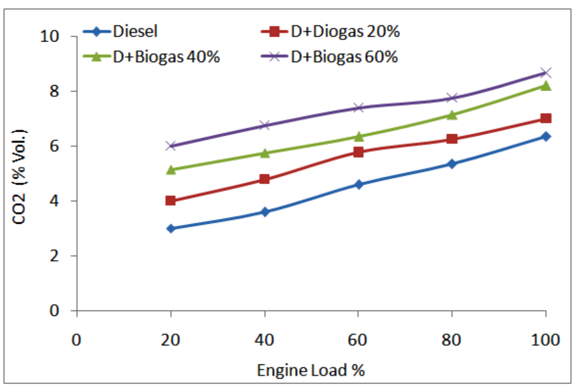

Fig. 3. Variation of CO_2 emissions with load.

D. Oxides of nitrogen (NOx)

Fig. 4 demonstrates the deviation of NOx outflows with the changing engine loads.

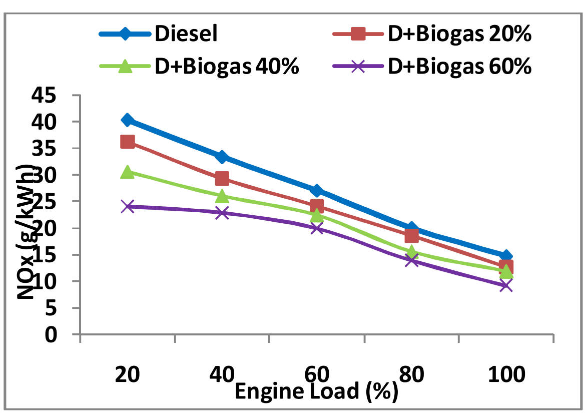

Fig. 4. Variation of NOx emissions with load.

NOx exhalations are seen to be diminished for bi fuel mode in examination with unadulterated diesel.

Expanding mass flow rate of biogas brought about diminishing NOx emanations. The explanation behind same is abundant accessibility of CO_2 in biogas which aides in limiting oxygen accessibility and pinnacle ignition temperature inside the chamber which permit less measures of nitrogen and oxygen to respond [35].

Expanding engine load brings about diminished NOx exhalations. NOx emanations are noted most elevated for customary diesel and least for the greatest mass flow rate of biogas.

E. Smoke opacity

Fig. 5 delineates the deviation of smoke opacity with the load of engine. It is seen that smoke emanation is straightforwardly in extent with engine load.

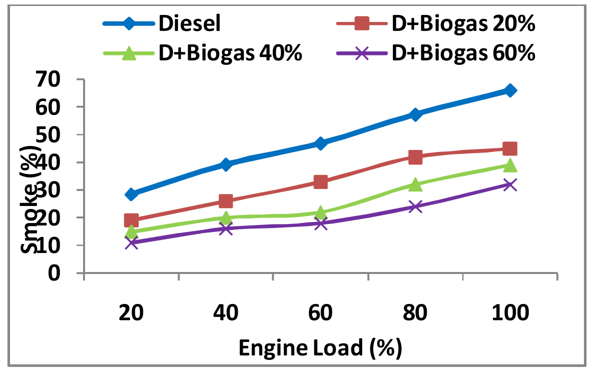

Fig. 5. Variation of Smoke emissions with load.

During the dual fuel activity, smoke discharges are diminished in correlation with gauge diesel and it further decline with the expansion in mass flow rate of biogas. This can be attributable to the existence of methane in biogas which helps in getting less measure of smoke [36].

IV. CONCLUSIONS

An experimental study was performed by utilizing a dual fuel engine and varying the energy share of the biogas. The present experimental investigations resulted in lower emissions of NO_x-smoke relationship trade-off under dual fuel mode operated on biogas-diesel fuels. However, higher CO, CO_2 and HC emissions were reported at all operating loads. Hence, biogas obtained from anaerobic digestion from agricultural wastes is a viable clean fuel substitute to conventional fossil petroleum diesel and hereby eliminating the harmful and hazardous emissions from diesel engine without major modifications and engine related issues. For future scope the performance and combustion characteristics of the dual fuel engine may be taken into account.

ACKNOWLEDGEMENT

The research work reported here is the part of DST-SERB-sponsored project entitled "Studies on combustion, performance and emission characteristics of diesel engine fuelled with Biodiesel and Biogas" (SB/FTP/ETA-306/2013).

Conflict of interest. The authors have no conflict of interest.

REFERENCES

[1]. Banapurmath, N.R., Tewari, P.G., and Hosmath, R.S., (2008). Combustion and emission characteristics

of a direct injection, compression-ignition operated on Honge oil, HOME and blends of HOME and diesel. *International Journal of Sustainable Engineering,* Vol. **1**: 80-93.

[2]. Barik, D., and Murugan, S., (2014). Investigation on combustion performance and emission characteristics of a DI (direct injection) diesel engine fuelled with biogas-diesel in dual fuel mode. *Energy,* Vol. **72**: 760-771.

[3]. Porpatham, E., Ramesh, A., and Nagalingam, B., (2012). Effect of compression ratio on the performance and combustion of a biogas fuelled spark ignition engine. *Energy Conversion and Management,* Vol. **95**: 247–256.

[4]. Bora, J.B., and Saha, U.K. (2015). Comparative assessment of a biogas run dual fuel diesel engine with rice bran oil methyl ester, pongamia oil methyl ester and palm oil methyl ester as pilot fuels. *Renewable Energy,* Vol. **81**: 490-498.

[5]. Jindal, M., Rosha, P., Mahla, S.K., and Dhir, A. (2015). Experimental investigation of performance and emissions characteristics of waste cooking oil biodiesel and n-butanol blends in a compression ignition engine. *RSC Advances,* Vol. **5**: 33863–33868.

[6]. Palash, S.M., Masjuki, H.H., Kalam, M.A., Atabani, A.E., Fattah, I.R., and Sanjid, A. (2015). Biodiesel production, characterization, diesel engine performance, and emission characteristics of methyl esters from aphanamixispolystachya oil of Bangladesh. *Energy Conversion and Management,* Vol. **91**: 149–157.

[7]. Ali, M. O., Rizalman, M., Gholamhassan, N., and Talal, Y. (2015). Optimization of Biodiesel-Diesel Blended Fuel Properties and Engine Performance with Ether Additive Using Statistical Analysis and Response Surface Methods. *Energies,* Vol. **8**: 14136–14150.

[8]. Namasivayam, A.M., Korakianitis, T., Crookes, R.J., Bob-Manuel, K.D.H., and Olsen, J. (2010). Biodiesel, emulsified biodiesel and dimethyl ether as pilot fuels for natural gas fuelled engines. *Applied Energy,* Vol. 87:769–778.

[9]. Porpatham, E., Ramesh, A., and Nagalingam, B. (2008). Investigation on the effect of concentration of methane in biogas when used as a fuel for a spark ignition engine. *Fuel,* Vol. **87**: 1651–9.

[10]. Jingura, R.M., and Matengaifa, R. (2009). Optimization of biogas production by anaerobic digestion for sustainable energy development in Zimbabwe. *Renewable and Sustainable Energy Reviews*, Vol. **13**: 1116-20.

[11]. Barik, D., and Murugan, S. (2013). Performance and emission characteristics of a biogas fueled DI diesel engine. *In: SAE Paper* 2013-01-2507.

[12]. Yoon, S.H., and Lee, C.K. (2011). Experimental investigation on the combustion and exhaust emission characteristics of biogas–biodiesel dual-fuel combustion in a CI engine. *Fuel Processing Technology,* Vol. **92**: 992–1000.

[13]. Barik, D. and Murugan, S. (2014). Investigation on performance and exhaust emissions characteristics of a DI diesel engine fueled with Karanja methyl ester and biogas in dual fuel mode. *In: SAE Technical Paper* 2014-01-1311.

[14]. Luijten, C.C.M., and Kerkhof, E. (2011). *Jatropha* oil and biogas in a dual fuel CI engine for rural electrification. *Energy Conversion and Management,* Vol. **52**: 1426–3.

[15]. Roubaud, A., and Daniel, F. (2005). Improving performances of a lean burn cogeneration biogas engine equipped with combustion prechambers. *Fuel,* Vol. **84**: 2001–7.

[16]. Bedoya, I.D., Arrieta, A.A., and Cadavid, F.J. (2009). Effects of mixing system and pilot fuel quality on diesel–biogas dual fuel engine performance. *Bioresource Technology,* Vol. **100**: 6624–9.

[17]. Violeta, M., Egle, S., Saugirdas, P., Alfredas, R., and Ricardas, V. (2013). Performance and emission characteristics of biogas used in diesel engine operation. *Energy Conversion and Management* Vol. **75**: 224–33.

[18]. Tippayawong, N., Promwungkwa, A., and Rerkkriangkrai, P. (2007). Long-term operation of a small biogas/diesel dual-fuel engine for on-farm electricity generation. *Biosystem Engineering,* Vol. **98**: 26–32.

[19]. Bari, S. (1996). Effect of carbon dioxide on the performance of biogas/diesel dual fuel engine. *Renewable Energy,* Vol. **9**: 1007–10.

[20]. Duc, P.H., and Wattanavichien, K. (2007). Study on biogas premixed charge diesel dual fuelled engine. *Energy Conversion and Management* Vol. **48**: 2286–308.

[21]. Tonkunya, N., and Wongwuttanasatian, T. (2013). Utilization of biogas– diesel mixture as fuel in a fertilizer pelletising machine for reduction of greenhouse gas emission in small farms. *Energy Sustainability and Development,* Vol. **17**: 240–4.

[22]. Mustafi, N.N., Raine, R.R., and Verhelst, S. (2013). Combustion and emissions characteristics of a dual fuel engine operated on alternative gaseous fuels. *Fuel,* Vol. **109**: 669–78.

[23]. Patterson, J., Clarke, A., and Chen, R. (2006). Experimental study of the performance and emissions characteristics of a small diesel genset operating in dual-fuel mode with three different primary fuels.*In: SAE Paper No.* 2006-01-0050.

[24]. Sahoo, B.B., Sahoo, N., and Saha, U.K. (2009). Effect of engine parameters and type of gaseous fuel on the performance of dual-fuel gas diesel engines – a critical review. *Renewable and Sustainable Energy Reviews,* Vol. **13**: 1151–84.

[25]. Karim, G.A., and Amoozegar, N. (1982). Examination of the performance of a dual fuel diesel engine with particular reference to the presence of some inert diluents in the engine intake charge.*In: SAE Paper No.* 821222, 1982.

[26]. Nayak, S.K., and Mishra, P.C. (2016). Emissions from sawdust biomass and diesel blends fuels. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects,* Vol. **38**: 2020-57.

[27]. Papagiannakis, R.G., Rakopoulos, C.D., Hountalas, D.T., and Rakopoulos, D.C. (2010). Emission characteristics of high speed, dual fuel, compression ignition engine operating in a wide range of natural gas/diesel fuel proportions. *Fuel*, Vol. **89**:1397–406.

[28]. Yaliwal, V.S., Banpurmath, N.R., and Tewari, P.G. (2013). Fuel efficiency improvement of a dual fuel engine fuelled with Honge oil methyl ester (HOME), bioethanol and producer gas. *International Journal of Sustainable Energy,* Vol. **7**: 269-82.

[29]. Ramadhas, A.S., Jayaraj, S., and Muraleedharan, C. (2008). Dual fuel mode operation in diesel engine using renewable fuels: rubber seed oil and coir-pith producer gas. *Renewable Energy,* Vol. **33**: 2077-83.

[30]. Yoon, S.H., and Lee, C.S. (2011). Experimental investigation on the combustion and exhaust emission characteristics of biogas–biodiesel dual fuel combustion in a CI engine. *Fuel Processing Technology,* Vol. **92**: 992–1000.

[31]. Tarabet, L., Loubar, K., Lounici, M.S., Khiari, K., Belmrabet, T., and Tazerout, M. (2014). Experimental investigation of DI diesel engine operating with eucalyptus biodiesel/natural gas under dual fuel mode. *Fuel,* Vol. **133**: 129-138.

[32]. Mahla, S.K., Das, L.M., and Babu, M.K.G. (2010). Effect of EGR on Performance and Emission Characteristics of Natural Gas Fueled Diesel Engine. *Jordan Journal of Mechanical and Industrial Engineering,* Vol. **4**: 523-30.

[33]. Prakash, R., Singh, R.K., and Murugan, S. (2013).Experimental investigation on a diesel engine fueled with bio-oil derived from waste wood–biodiesel emulsions. *Energy,* Vol. **55**: 610-8.

[34]. Nathan, S.S., Mallikarjuna, J.M., and Ramesh, A. (2010). An experimental study of the biogas diesel HCCI mode of engine operation. *Energy Conversion and Management,* Vol. **51**:1347–53.

[35]. Mahla, S.K., Papreja, A.P., Singla, V., Dhir, A., Singh, S. and Goga, G., (2017) Investigations on the performance evaluation and emission characteristics of compressed natural gas (CNG) fueled small utility diesel engine. *International Journal on Emerging Technologies,* Vol. **8**(1): 78-81.

[36]. Goga, G., Chauhan, B.S., Mahla, S.K., Dhir, A., (2019). Combined impact of varying biogas mass flow rate and rice bran methyl esters blended with diesel on dual fuel engine, *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects,*1-13.

How to cite this article: Singla, J., Mahla, S.K., Goga, G. and Singla, N. (2019). Emissions Characteristics of Biogas-Diesel Fuel Blends in Compression Ignition Engine. *International Journal of Emerging Technologies*, **10**(2): 422–426.