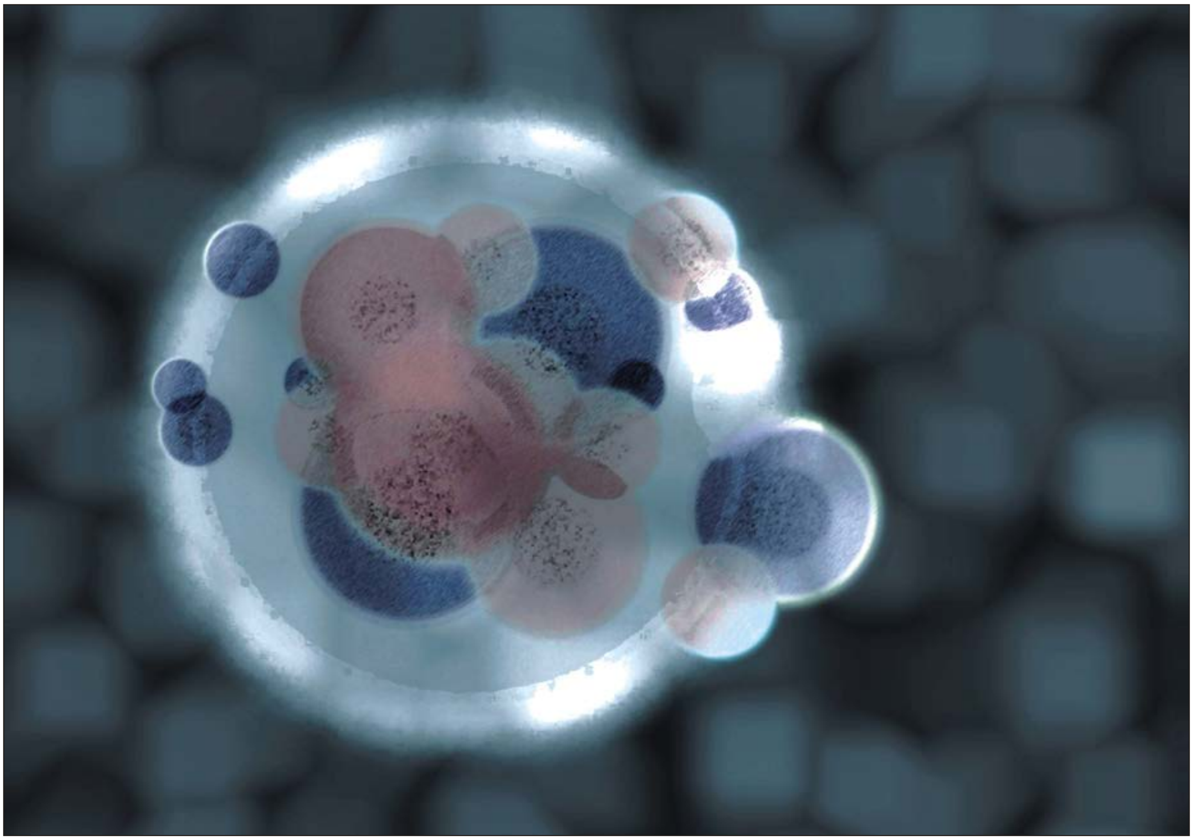

Journal of Biological Sciences

ISSN 1727-3048

OPEN ACCESS Journal of Biological Sciences

ISSN 1727-3048
DOI: 10.3923/jbs.2020.88.93

Research Article
Performance and Emission Characteristics of Diesel Engine Using Watermelon Seed Oil Methyl Ester

Jobi Xavier

Department of Life Sciences, Christ University, 560029 Bangalore, India

Abstract

Background and Objective: Looking at the present world scenario, sustainable development and environment-friendly living have become the most significant focus. In this study, the efficiency of watermelon seeds in the production of biodiesel was tested. Furthermore, watermelon seeds are evaluated to see if they can be used as a feedstock for the production of biodiesel. **Materials and Methods:** Watermelon oil was made into biodiesel through transesterification and evaluated the properties of the biodiesel like flash point, fire point, viscosity, calorific value and specific gravity. Various blends of biodiesel, i.e., B10, B20 and B30, were prepare and measured the properties of these blends. The above mixtures were used in a diesel engine, carried out performance tests and emissions tests and compared these results with petro-diesel. **Results:** This study identified the best blend that can be used as a working fuel. As per the blends prepared (B10, B20, B30), B10 proved more efficient in starting the machine. B10 had the highest amount of diesel and less viscosity. It had a minimum viscosity, among others. B10 has the minimum value of the flashpoint and fire point. B10 had the entire characteristics similar to all diesels. **Conclusion:** The best blend was identified as B10 in terms of performance and can be used as a potential feedstock for the production of biodiesel.

Key words: Biodiesel, watermelon, blends, biofuel, viscosity, emissions test

Citation: Jobi Xavier, 2020. Performance and emission characteristics of diesel engine using watermelon seed oil methyl ester. J. Biol. Sci., 20: 88-93.

Corresponding Author: Jobi Xavier, Department of Life Sciences, Christ University, 560029 Bangalore, India

Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

We live in a world where energy is going to be a limiting factor responsible for the growth of the nations. Since machines play an important part of our life and we need different kind of machines for different purposes in our daily life, it is very important to maintain a continuous supply of fuel for these machines. Diesel engine plays a crucial and indispensable role in today's world and at the same time contributes to pollution extensively[1]. Since the resources that are used to produce petrol and diesel are getting depleted day by day, it is very evident that we need to look for alternate source of fuels. People look at biodiesel as an alternate that meets the immediate and future demands of the world. Asokan *et al.*[1] has reported that bio-diesel, an oxygenated fuel, gives better emission characteristics of CO_2, hydrocarbons, CO and other harmful elements. Biodiesel based on non-edible and edible oils is already advanced in major European countries, Japan, Malaysia, Australia etc., where regular production is at full pace. Major automobile companies have also approved the use of 10-20% bio-diesel mixture in their automobiles[1].

Considering the present rate of energy consumption fossil fuels will not last long. Primary energy consumption grew at a rate of 2.9% last year, almost double its 10 years average of 1.5% per year and the fastest[2] since 2010. British petroleum's annual report on global oil reserves says that as of the end of 2013 earth has nearly 1.688 trillion barrels of crude oil which will last 54 years at current rates of extraction[3]. This is a severe threat to the world and its growth. To attain energy security, the world needs to turn towards alternative fuel sources like biofuel. Over the last fifty few years, the world has seen considerable growth in the use of alternative fuels. One of them is ethanol, which is mixed with regular petroleum fuels and used in car engines[4]. Another example is biodiesel production from vegetable oil. Biodiesel has become a top-rated solution over the last decade with a variety of sources available for its production[5].

Biodiesel refers to a vegetable oil or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, ethyl or propyl) esters. Biodiesel is typically made by chemically reacting lipids (e.g., vegetable oil, animal fat) with an alcohol producing fatty acid esters[5]. Biodiesel is a renewable, clean-burning diesel replacement for petroleum, creating jobs and improving the environment. It can be made from a diverse mix of feedstock, including recycled cooking oil, soybean oil and animal fats. The production of biodiesel using a variety of resources was grown significantly in recent years. Recent studies have focussed on feedstock from algae and bryophytes[6].

It has been proved that biodiesel can be used as an additive in formulations of diesel to increase the lubricity and it has a viscosity similar to petroleum diesel[7]. Bharadwaz *et al.*[8] revealed that biodiesel can be used in pure form (B100) or may be blended with petroleum diesel at different concentrations in most modern diesel engines. The possibility of utilizing blends of bioethanol (5, 10 and 15%) and fossil diesel with the help of a surfactant has been explored in the study conducted by Hansdah *et al.*[9]. Biodiesel is, at present, the most attractive market alternative among the non-food applications of vegetable oils for transportation fuels. Biodiesel-a fuel comprised of mono-alkyl esters of long-chain fatty acids are derived from vegetable oils or animal fats, designated B100 and meeting the requirements of ASTM D 6751. Biodiesel Blend, a blend of biodiesel fuel meeting ASTM D 6751 with petroleum-based diesel fuel, is designated BXX, where XX represents the volume percentage of biodiesel fuel in the blend[10].

Biodiesel is made through a chemical process called transesterification through which the glycerin will be separated from the fat or vegetable oil. This process will give 2 products, i.e., methyl esters (the chemical name for biodiesel) and glycerin (the byproduct usually used in soaps and other products). Biodiesel is meant to be used in standard diesel engines and is thus distinct from the vegetable and waste oils used to fuel converted diesel engines. Biodiesel can be used alone or blended with petrol-diesel in any proportions[11].

Schmidt[11] claims that studies on biodiesel emissions have started for almost 30 years ago. In that time, biodiesel has undergone the most rigorous testing of any alternative fuel. The fuel is usually evaluated by the EPA under the Clean Air Act Section 211(b). Many studies have conducted to examine the effect of hundreds of regulated and non-regulated exhaust emissions and the potential health effects of these emissions[7].

Watermelon seed oil is extracted by pressing from the seeds of the *Citrullus vulgaris* (watermelon). Traditionally, the seeds are extracted from the seed casing and dried in the sun. Once dried, the seeds are pressed to extract the oil. Watermelon seeds are consumed as snack food worldwide and are used to prepare edible oil in some countries. The seed oil consists of 59.6% linoleic acid (18:2n-6) and 78.4% total unsaturated fatty acids. The predominant fatty acid in the oil is linoleic acid, which was followed by oleic, palmitic and stearic acids. The refractive index, acid value, peroxide value and free fatty acids of watermelon seed oil were determined to be 1.4696 (25°C), 2.82 (mg KOH g^{-1} oil), 3.40 (m equiv oxygen kg^{-1} oil) and 1.41 (as oleic acid %), respectively[12].

At present, few studies[13-16] have done in the prospects of using watermelon seeds as a potential feedstock for the production of biodiesel. Now it has become more essential to study on alternative fuel, which can replace the fossil fuels. The present study was an attempt to show in detail how the production of biodiesel could be possible from watermelon seeds. In the present study, it was also experimented that biodiesel produced from watermelon seed oils could be used as an alternative to the fossil fuel that would work with diesel engines.

MATERIALS AND METHODS

Study area: The present study was carried out at Life Science Laboratory of Christ University, Bangalore Central Campus, Bengaluru, from June, 2017 to March, 2018.

Collection of seeds: The seeds of watermelon were collected from fruit juice vendors of Bangalore. The seeds were then dried in the sun for a couple of days (Fig. 1).

Production of oil: The seeds were crushed to obtain the oil. The oil expeller method was used to extract the oil. The raw materials were squeezed under high pressure in a single step. An expeller press, a screw-type machine that presses oil seeds through a caged barrel-like cavity was used. Raw materials entered one side of the press and waste products exited the other side. The machine used friction and continuous pressure from the screw drives to move and compress the seed material. The oil seeped through the small openings. Oils extracted in this method were called cold-pressed oils. The residue from this process was given away for composting to produce manure. This oil was then refined and filtered. Filters of fine hole size were used to remove particles of seed matter. Other impurities were removed by settling. The oil obtained after this was pretty refined and ready for conversion to biodiesel. The above process yielded 6-7 L of watermelon seed oil[17].

Transesterification: The oil was esterified to obtain diesel. 500 mL of oil was taken and heated to about 70°C. To this mixture, about 300 mL of methanol and 8-10 g of sodium hydroxide pellets were added and mixed well till complete dissolution was obtained. This mixture was poured into a beaker and placed over magnetic stirrer and then stirred slowly for about 60-70 min. After the entire reaction was done, the mixture was poured into a separating flask and left it to rest for a few hours. After a few h, a dark layer of liquid

Fig. 1: Watermelon seeds collected from various sources

Fig. 2: Blends prepared

was formed at the bottom which was glycerin and was removed and discarded. The liquid left in the flask was biodiesel. This procedure was repeated for all the oil. The biodiesel was heated to about 70°C and added to a separator and shaken well. It is left to settle for 15-20 min. Remove the water after word. This above step removed any soap formed in the diesel. This step was repeated three times to remove all water contents if any left. This gave pure biodiesel ready to be used as a fuel[18].

Preparation of blends (B-10, B20, B30): Biodiesel was used as blended with diesel at suitable proportions. B-10 was meant that there was 10% biodiesel by volume in the blend. One litre of B-10 was prepared by blending of 100 mL of biodiesel and 900 mL of diesel. The beaker containing the B-10 was kept over the magnetic stirrer and stirred for about 5-10 min. The above mixture was bottled (Fig. 2). The same procedure was used B20 and B30 using their respective proportions of 200 and 300 mL of biodiesel and made[18] up to the 1 L.

Measurement of various properties

Flash point and fire point: The flashpoint and fire point was measured using the standard Pensky Marten Apparatus. A sample of about 50 mL of the fuel was added to the cup. The sample was heated continuously. For every two-degree rise in temperature, a burning splinter was brought near the apparatus and the small window was opened to check for a flash. This was done until there was a clear momentary flash obtained. At this temperature, the flashpoint was obtained. The process was continued until the fuel burned for at least five seconds continuously. At this temperature, the fire point was obtained[19].

Calorific value: The calorific value of the fuel was measured using a bomb calorimeter. A bomb calorimeter was a type of constant-volume calorimeter used in measuring the heat of combustion of a particular reaction. Electrical energy was used to ignite the fuel. As the fuel was burning, it heated up the surrounding air, which expanded and escaped through a tube that led the air out of the calorimeter. When the air was escaping through the copper tube, it was also heated up water outside the tube. The change in temperature of the water allows for calculating the calorie content of the fuel[20].

Engine testing of fuels: The various blends were (B10, B20, B30, B100) were tested in a multi-fuel engine at Mechtrix Engineering Group Bangalore. Performance test using Eddy current loading was carried out on the engine with the various blends for injection timing 23 and injection pressure 210 bars. Also, emission tests were carried out side by side using an electric gas analyser[21].

RESULTS

Flash point and fire point: The temperature at which the flash was observed at the surface of biodiesel is the flash point and the temperature at which the biodiesel starts burning is the fire point. The measured values were given in Table 1. Flash and fire point were 148 and 159°C for watermelon crude oil biodiesel, respectively and 90 and 118 C for watermelon B100-pure biodiesel whereas diesel 62 and 74°C. The results indicated that values of watermelon biodiesel were higher than diesel fuel therefore the biodiesel is safe for handling.

Calorific value: The calorific value of a fuel is defined as the amount of heat released during combustion when a unit quantity of the fuel is burnt. The calculated calorific values of watermelon crude oil, B100, B10, B20 and B30 were 35882, 36137, 43213, 42427, 41641 kJ kg^{-1} respectively while calorific value of diesel fuel is 44800 kJ kg^{-1} (Table 2).

Table 1: Flash and fire point of the various blends of biodiesel and watermelon crude oil

Fuel	Flash point (°C)	Fire point (°C)
Watermelon crude oil	148	159
B100-pure biodiesel	90	118
B10-10% biodiesel	46	65
B20-20% biodiesel	52	70
B30-30% biodiesel	56	74
Diesel	62	74

Table 2: Calorific value of the various blends of biodiesel and watermelon crude oil

Fuel	Calorific value (kJ kg^{-1})
Watermelon crude oil	35882
B100-pure biodiesel	36137
B10-10% biodiesel	43213
B20 -20% biodiesel	42427
B30 -30% biodiesel	41641
Diesel	44800

Table 3: Brake thermal efficiency (BTE) and specific fuel consumption (SFC) of different biodiesels and blends at different loads of B10 blend of biodiesel

Blends	Speed (rpm)	Load	BTE (%)	SFC
B10	1460	5	23.485	0.759
B10	1440	10	45.140	0.379
B10	1420	15	64.051	0.253
B10	1394	20	82.961	0.190

Table 4: Brake thermal efficiency (BTE) and specific fuel consumption (SFC) of different biodiesels and blends at different loads of B20

Blends	Speed (rpm)	Load	BTE	SFC
B20	1460	5	23.923	0.759
B20	1440	10	45.981	0.379
B20	1420	15	65.244	0.253
B20	1394	20	84.506	0.190

Table 5: Brake thermal efficiency (BTE) and specific fuel consumption (SFC) of different biodiesels and blends at different loads of B30 blend

Blends	Speed (rpm)	Load	BTE	SFC
B30	1460	5	24.054	0.759
B30	1440	10	46.842	0.379
B30	1424	15	68.365	0.253
B30	1400	20	87.355	0.190

Performance characteristics: The variation of brake thermal efficiency of watermelon seed biodiesel in different blends at varying load conditions are given in Table 3-5. BTE tells us that how efficiently heat is converted into mechanical work. The brake thermal efficiency increases with increase in load. At 20% of the load, the BTE of B10 is higher 82.961% than those of other blends and is much closer to that of diesel.

Table 3-5 show the variation in specific fuel consumption watermelon seed biodiesel in different blends at varying load conditions. The SFC decreases with increase in load. Since BSFC is proportional to the calorific value and amount of fuel injected, due to high calorific value and low mass of diesel, SFC for diesel is lower than biodiesels for the same engine output.

Table 6: Emission of CO, HC, CO_2 O_2 NOx with respect to different load and blends

Load (kg)	Blend	CO vol (%)	HC ppm-vol	CO_2 vol (%)	O_2 vol (%)	NOx ppm-vol
5	B10	0.06	25	5.6	13.64	702
5	B20	0.07	26	7.3	13.76	983
5	B30	0.08	29	7.3	13.45	983
10	B10	0.13	32	5.6	13.33	726
10	B20	0.15	39	7.2	15.40	1130
10	B30	0.16	39	9.0	16.50	1263
15	B10	0.21	48	5.8	17.80	947
15	B20	0.24	54	9.5	18.59	1340
15	B30	0.32	56	11.1	19.30	1339

Emission characteristics

Emission of CO: Table 6 shows the emission of CO (in %) for watermelon seed biodiesel in different blends of at different loading conditions at 1500 rpm. Due to combustion in low flame temperature and insufficient supply of oxygen, Carbon monoxide is produced. CO emission increases with increase in load because of temperature rise, lack of oxygen at high speed and low combustion timing.

Emission of Nox: All blends showed higher levels of NOx emission at high loads due to enhanced combustion and higher flame temperature compared to lower loads as NOx increased with increase in heat release rate and combustion (Table 6).

Emission of HC, CO_2 and O_2: The HC (hydrocarbon), CO_2 and O_2 emissions of biodiesels were found to be much lesser than those of diesel at different loading conditions. The HC emission of B10 was 48 ppm. CO_2 and O_2 emissions are also found to be less in B10 when compared to other blend. As the load increased the emission of HC, CO_2 and O_2 was also found to be increasing (Table 6).

DISCUSSION

The study revealed that the performance and combustion characteristics of blend B10 of Watermelon seed oil biodiesel was very close to that of the diesel while the emission characteristic was better than diesel. Biodiesel, an alternate source of fuel, holds a great potential for the future fuel source. Various researchers have demonstrated that vegetable oil can be converted to biodiesel by a simple transesterification process[22-24]. The vegetable wastes can be converted into a wide variety of energy carriers (biogas, biodiesel, ethanol, methanol, diesel, gasoline, hydrogen) of fuel through conversion technologies and thus have the potential to be significant new sources of energy for the 21st century[22,25]. The present study also gives the methodology for the production of biodiesel from watermelon seed oil. The interest in biodiesel could be attributed to its biodegradable nature, non-toxicity and low carbon dioxide, low hydrocarbon and low nitrogen emissions[22]. Radhakrishnan *et al.*[26] demonstrated in their experiment with palm biodiesel from palm oil that emission characteristics showed a detectable decrease in emission of NOx, CO and HC. The present study also presents the similar results of the decrease in emissions of NOx, CO and HC. Teja and Alagumurthi[24] in their study on watermelon methyl ester in diesel engine revealed that the replacement of diesel by WME has shown a slight reduction in brake thermal efficiency with a slight increase in brake-specific fuel consumption. Furthermore, the watermelon methyl ester (WME) addition to diesel reduced the unburned hydrocarbon, CO and NOx. Critical analysis of combustion aspects was also carried out and it showed prolonged ignition delay during WME addition with diesel[24]. The present study conducted on watermelon seed oil exhibited the same result in specific fuel consumption and break thermal efficiency.

Studies conducted by Asokan *et al.*[1] have revealed that the performance and combustion characteristics of blend B20 of Watermelon seed oil biodiesel and papaya seed oil biodiesel mixed in 1:1 ratio was very close to that of the diesel while the emission characteristic was better than diesel. The major reason for reduced efficiency in the increasing blends could be lower volatility and calorific value, larger molecular mass and a slightly high viscosity of the bio-diesel blends. An additional conceivable reason could be slow burning rates of the bio-diesel blends. A supplementary imaginable reason could be the release of a higher amount of energy during the combustion of diesel[27]. Thus, the blend B10 of watermelon seed biodiesel could be successfully used as a source of alternative fuel in the diesel engine, which would reduce the overall consumption of diesel.

CONCLUSION

Watermelon can be used to produce biodiesel. The blends met the ASTM standards in terms of flash point, fire point, emissions etc. Biodiesel was purely obtained from the transesterification process. The best blend acquired was that of B10 in terms of performance.

It can be concluded that watermelon oil is a potential feedstock for the production of biodiesel.

SIGNIFICANCE STATEMENT

"This study discovered that blend B10 of watermelon seed biodiesel could be successfully used as a source of alternative fuel in the diesel engine that can be beneficial for society. This study will help the researchers to uncover the critical areas of biodiesel blends."

ACKNOWLEDGMENT

This current study was supported by Christ University and the authors are grateful to the management and staff of Christ University, Bengaluru.

REFERENCES

1. Asokan, M.A., S. Kamesh and W. Khan, 2018. Performance, combustion and emission characteristics of diesel engine fuelled with papaya and watermelon seed oil bio-diesel/diesel blends. Energy, 145: 238-245.
2. British Petroleum Company, 2019. BP Statistical Review of World Energy. British Petroleum Company, London.
3. British Petroleum Company, 2013. BP Statistical Review of World Energy. British Petroleum Company, London.
4. Clerici, A. and G. Alimonti, 2015. World energy resources. EPJ Web Conf., Vol. 98. 10.1051/epjconf/20159801001.
5. Jayaveera K.N., 2003. Non-traditional oils-a vital source of energy. Proceedings of Renewable Energy Science Series XII, pp: 82-88.
6. Mondal, M., S. Goswami, A. Ghosh, G. Oinam and O.N. Tiwari *et al*., 2017. Production of biodiesel from microalgae through biological carbon capture: A review. 3 Biotech, Vol. 7. 10.1007/s13205-017-0727-4.
7. Bünger, J., J. Krahl, O. Schröder, L. Schmidt and G.A. Westphal, 2012. Potential hazards associated with combustion of bio-derived versus petroleum-derived diesel fuel. Crit. Rev. Toxicol., 42: 732-750.
8. Bharadwaz, Y.D., B.G. Rao, V.D. Rao and C. Anusha, 2016. Improvement of biodiesel methanol blends performance in a variable compression ratio engine using response surface methodology. Alex. Eng. J., 55: 1201-1209.
9. Hansdah, D., S. Murugan and L.M. Das, 2013. Experimental studies on a DI diesel engine fueled with bioethanol-diesel emulsions. Alex. Eng. J., 52: 267-276.
10. Anonymous, 2012. Biodiesel basics. https://www.biodiesel.org/
11. Schmidt, C.W., 2007. Biodiesel: Cultivating alternative fuels. Environ. Health Perspect., 115: A87-A91.
12. Maynard, D. and D.N. Maynard, 2012. Cucumbers, Melons and Watermelons. In: The Cambridge World History of Food, Part 2, Kiple, K.F. and K.C. Ornelas (Eds.)., Medical History, 46. Cambridge University Press, UK., pp: 267-270.
13. Sui, X., L. Jiang, Y. Li and S. Liu, 2011. The research on extracting oil from watermelon seeds by aqueous enzymatic extraction method. Procedia Eng., 15: 4673-4680.
14. Duduyemi, Oladejo, S.A. Adebanjo and K. Oluoti, 2013. Extraction and determination of physico-chemical properties of watermelon seed oil (*Citrullus lanatus* L) for relevant uses. Int. J. Scient. Technol. Res., 2: 66-68.
15. Ogunwole, O.A., 2015. Production of biodiesel from watermelon (*Citrullus lanatus*) seed oil. Leonardo J. Sci., 27: 63-74.
16. Ogunwa, K.I., S. Ofodile and O. Achugasim, 2015. Feasibility study of melon seed oil as a source of biodiesel. J. Power Energy Eng., 3: 24-27.
17. An, H., W.M. Yang, A. Maghbouli, J. Li, S.K. Chou and K.J. Chua, 2013. Performance, combustion and emission characteristics of biodiesel derived from waste cooking oils. Applied Energy, 112: 493-499.
18. Srivastava, A. and R. Prasad, 2000. Triglycerides-based diesel fuels. Renewable Sustainable Energy Rev., 4: 111-133.
19. Altenburg, T., H. Dietz, M. Hahl, N. Nikolidakis, C. Rosendahl and K. Seelige, 2009. Biodiesel policies for rural development in India-A report. Rural India J., 3: 67-80.
20. Srivastava, P.K. and M. Verma, 2008. Methyl ester of Karanja oil as an alternative renewable source energy. Fuel, 87: 1673-1677.
21. Chauhan, B.S., N. Kumar, H.M. Cho and H.C. Lim, 2013. A study on the performance and emission of a diesel engine fueled with Karanja biodiesel and its blends. Energy, 56: 1-7.
22. George, A.B., M. Joy, J. Xavier and E. Venkatanagaraju, 2020. Production of biodiesel from agro-industrial waste. Int. J. Pharm. Sci. Res., 11: 978-986.
23. Kathirvelu, B., S. Subramanian, N. Govindan and S. Santhanam, 2017. Emission characteristics of biodiesel obtained from jatropha seeds and fish wastes in a diesel engine. Sustainable Environ. Res., 27: 283-290.
24. Teja, N.B. and N. Alagumurthi, 2018. Emission, performance and combustion study on watermelon methyl ester in diesel engine. Int. J. Ambient Energy. 10.1080/01430750.2018.1542628.
25. Agarwal, A.K., 2007. Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Prog. Energy Combust. Sci., 33: 233-271.
26. Radhakrishnan, S., D.B. Munuswamy, Y. Devarajan, T. Arunkumar and A. Mahalingam, 2018. Effect of nanoparticle on emission and performance characteristics of a diesel engine fueled with cashew nut shell biodiesel. Energy Sources Part A: Recov. Utilization Environ. Effects, 40: 2485-2493.
27. Knothe, G., 2001. Historical perspectives on vegetable oil-based diesel fuels. Inform, 12: 1103-1107.