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Thevetia peruviana as a potential biodiesel for diesel engines: Review approach

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Abstract

Alkyl esters of long-chain fatty acids, more commonly methyl esters, make up the alternative and renewable fuel for diesel engines known as biodiesel. This fuel is typically produced using non-toxic biological resources like edible and inedible vegetable oils, animal fats, used cooking oils, and oil from algae. Although there are numerous steps in the manufacturing of biodiesel, the transesterification method is successfully used to lower the high viscosity of triglycerides and enhance other properties of the fuel. Since it is a renewable, biodegradable, non-toxic, and environmentally friendly fuel, biodiesel has been selected as one of the interesting alternative fuels and has gained a lot of attention worldwide. The current food crisis and daily rise in feedstock prices make it economically unviable to create biodiesel using food-grade vegetable oils. The use of non-traditional, low-cost feedstocks that are not edible and come from wild plants to make biodiesel has received a lot of interest. Using these unconventional and non-edible feedstocks can be sustainable for the manufacture of biodiesel because they have the ability to reclaim wasteland and do not compete with food crops. *Thevetia peruviana*, a non-edible feedstock, with a 60-65% oil content. This research attempts to analyze biodiesel synthesis, fuel qualities, and blending effects using this oil.

Keywords: *Thevetia peruviana*, biodiesel, transesterification, performance, combustion, emission

1. Introduction

Thevetia peruviana is ordinarily found in the world's jungles and sub-jungles locations, yet it is local to Central and South America [1]. The plant gives the fruits consistently, giving a consistent supply of seeds. The plant, developed as supports, can create 400 to 800 fruits for each annum, relying upon the plant's age. Flowers were like funnel-shaped, with their petals were spirally twisted. Fruits were fairly globular, and they had fleshy mesocarp and had 4-5 cm diameter. Fruits that had green color shading and became dark on aging. Every fruit contains a nut that is transversely and longitudinally divided. Matured fruit contained 2-4 seeds, and the plant bears milky juice at all parts [2-5]. The plant developed to around 2-6 m in tall, and leaves are spirally arranged, direct, and around 13-15 cm long [6, 7]. *Thevetia peruviana* is a plant with no financial worth, under-utilized and lesser-known. The seed contains 60-65% of oil, and the cake contained 30-37% protein. The oil would be non-edible due to cardiac glycoside present in it. The seed has a health benefit and would thus be able to be utilized as an elective protein source in the creature feed plan [8-10]. It will decrease rivalry among humans and animals for the conventional protein sources if it is prepared healthily. The seed oil helps in oleo-chemical creation, for example, soaps, shampoos, and biodiesel. African nations are urged to include the resources for the development of that plant for diminishing the large dependability upon it. The plant could be developed in wastelands. The plant required least water when it is in the developing stage. Three thousand saplings could be planted in 1 ha, and out of that, around 52.5 tons of seeds (around 3500 kg of the kernel) could be gathered. Subsequently, around 1750 L of oil could be acquired from 1 ha of wasteland. Abhorred by herbivorous animals, the plant can be developed on side of the road and street dividers in interstates for beautification, ecological insurance and simultaneously for the creation of biodiesel. Because of high oil and protein substance, and its accessibility, the plant has a potential for different utilizations and it very well might be utilized for biodiesel creation [11-15]

2. Production of biodiesel

The transesterification of *T. peruviana* oil to dimethyl carbonate proceeds by a first-order mechanism.The corresponding values of the activation energies and rate constants were determined. The maximum yield of 97.50% was obtained for the transesterification of *T. peruviana* oil within 90 min at 85 °C at an agitation speed of 200 rpm [17]. The 96 wt. % of the oil was converted to biodiesel at 32 °C in 3 hr. The wt. % composition of the biodiesel was methyl oleate 43.72, methyl palmitate 23.28, methyl linoleate 19.85, methyl stearate 10.71 and methyl arachidate 2.41. The biodiesel was free from sulfur and has exhibited a high cetane number of 61.5 [18]. Yellow oleander oil with proper free fatty acid limit was pre-treated with NaOH as catalyst and anhydrous methanol amount as 20% of oil volume. The produced yellow oleander methyl ester was characterized. It was found that, gross calorific value as 37.74 MJ/kg, flash point of 118 °C, Kinematic viscosity at 40 °C of 5.96 mm^2/s, specific gravity of 0.8874 and density at 15 °C of 887 kg/m^3. All the tested parameters were within the accepted limits of the biodiesel thus making it an alternate fuel as transportation fuel for diesel engines [19]. The reduction of free fatty acid (FFA) of the oil to 0.65 ± 0.05 wt. % was realized using ferric sulfate of 3 wt. %, methanol/FFA molar ratio of 9:1 and reaction time of 40 min [20]. The optimized values of transesterification process parameters were 75 minutes of reaction time at temperature of 70 °C with a methanol: oil ratio of 11:1 (v/v) and catalyst concentration of 2.8 grams (w/v), where calcium oxide (CaO) was used as heterogeneous base catalyst [21].

2.1. Transesterification process

In the transesterification process, the raw oil of *Thevetia peruviana* is converted into biodiesel of *Thevetia peruviana*. Transesterification (TE) process involves heating the raw oil in a flask with three necks in which a magnetic stirrer is placed. The required amount of methanol and sodium hydroxide catalyst is added to the flask. This mixture is kept for 2-3 h for the reaction purpose. After this, the mixture is placed in a separating flask overnight in which biodiesel and glycerol formation occur. The glycerol is removed out, and crude biodiesel is obtained. This unrefined biodiesel is washed with hot water so that there is the separation of phase in between water and biodiesel. This biodiesel consists of some water content removed by heating the biodiesel in a heating oven so that all the water content is removed and pure biodiesel is obtained. In the present study, the TE reaction is referred to previous investigations. The flow chart regarding the conversion of raw oil into biodiesel is shown in Figure 1.

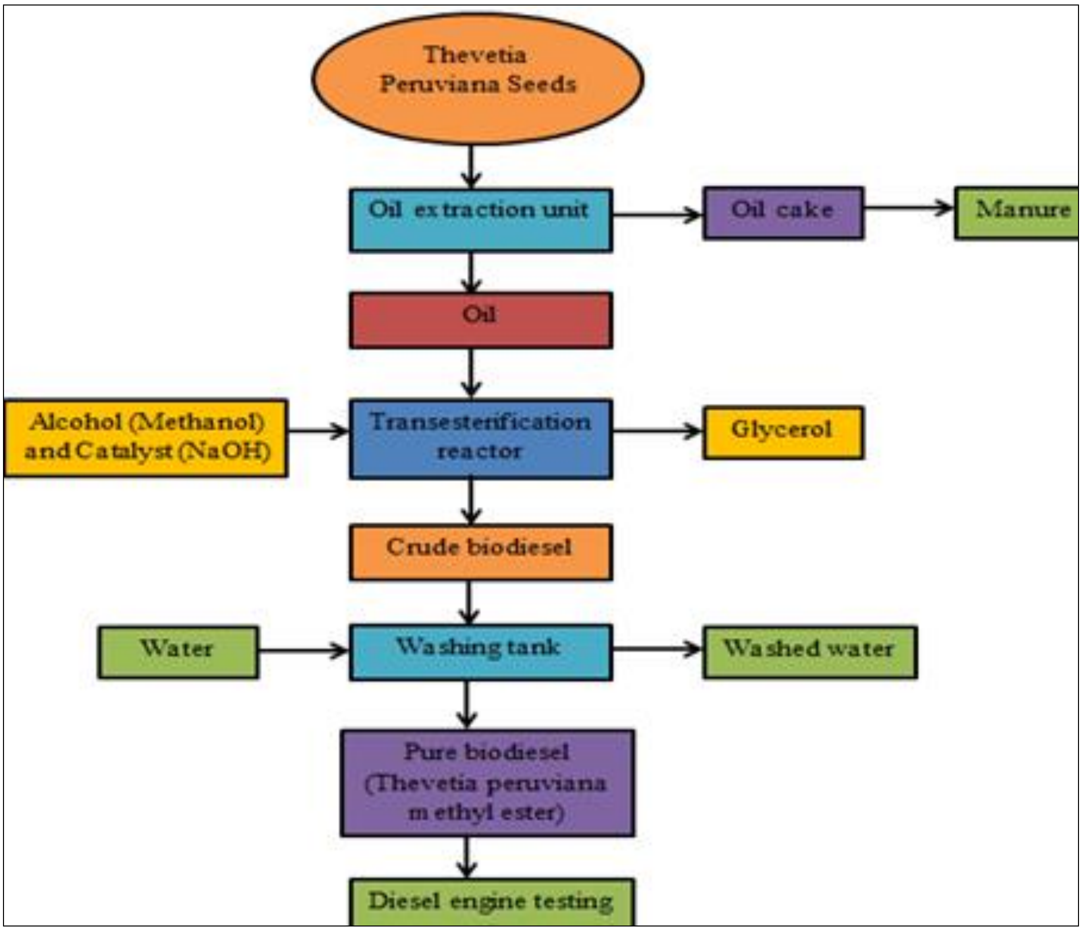

Fig 1: Flow chart of biodiesel production [5]

3. Performance, combustion and emission characteristics

As the concentration of the blends was increased there was a marginal drop in the brake thermal efficiency, however there was an improvement in the brake specific fuel consumption. There was no significant change in the nitric oxides emissions. There was a drastic reduction in the hydrocarbon and carbon monoxide emissions were found. Among various blends, B30 at 240 MPa of injection pressure reported lower emissions than B10 and B20 [1].

Brake thermal efficiency of the reactivity controlled compression ignition engine increased up to 40% gaseous fuels energy share. The engine-out hydrocarbon and carbon monoxide emissions of compressed biogas at all gaseous fuels energy share were more as related to compressed natural gas. The engine-out nitric oxide emissions of reactivity controlled compression ignition engine fuelled with compressed natural gas at all gaseous fuels energy share were higher as related to compressed biogas [2].

Injection of 10% gasoline drastically reduced the nitric oxide emissions by 6.67% and soot emission by 4.52% compared to diesel mode. There was penalty of high hydrocarbon and carbon monoxide emissions by 12.5% and 7.6% respectively [3]. With the use of 230 bar injection pressure, 26° BTDC injection timing, and 5 whole nozzle raises brake thermal efficiency and nitric oxide emissions while lowering hydrocarbon, carbon monoxide, and smoke emissions [4].

Reactivity controlled compression ignition mode of operation at 10% of pentanol in injected fuels exhibited higher brake thermal efficiency of 22.15% for diesel and pentanol fuel combination, which is about 9.1% and 27.3% higher than other B20 and pentanol, B100 and pentanol fuel combinations respectively. As the percentage of pentanol increased in injected fuels, hydrocarbon and carbon monoxide emissions were increased while nitric oxide and smoke emissions were decreased. Among various fuel combinations tested diesel and pentanol fuel combination exhibited lower hydrocarbon, carbon monoxide and smoke emissions and higher nitric oxide emissions. At 10% pentanol in injected fuels, the highest heat release rate and in-cylinder pressure are found for diesel and pentanol fuel combinations compared with other fuels [5].

Fuel consumption, carbon monoxide, unburnt hydrocarbon and smoke formations are spotted to be less besides higher nitric oxide emissions compared to conventional mechanical fuel injection system operation. Precise injection of gaseous fuels in the manifold injection along with conventional mechanical fuel injection system amenities can additionally provide further improvement in power characteristics and emission stability [6].

Among various injection nozzles studied 5-hole nozzle exhibited higher peak pressure rise as compared with 3-hole and 4-hole injection nozzles. From various fuel blends studied B0 blend provided higher peak pressure rise as compared with B20, B40, B60, B80 and B100 [7].

The brake thermal efficiency of biodiesel blends was found to be lower compared to diesel at all power output. Brake specific fuel consumption for blends of biodiesel blends was higher when compared with diesel. Total fuel consumption for diesel was less as compared to biodiesel blends. Hydrocarbon and carbon monoxide emissions for diesel were lower as compared to biodiesel blends. Nitrogen oxide emissions were higher for diesel as compared to biodiesel blends. Among the biodiesel blends tested, B10 and B20 provided the best performance with reduced emissions. Hence, B10 and B20 blends were recommended for existing diesel engine. At all injection nozzles tested 5 hole injection nozzle exhibited higher brake thermal efficiency, lower brake specific fuel consumption, lower hydrocarbon and carbon monoxide emissions and higher nitrogen oxide emissions. Hence 5 whole injection nozzle was recommended for existing diesel engine [8].

Mixing of 5% di-ethyl-ether with *Thevetia peruviana* seed oil increased the brake thermal efficiency. The brake thermal efficiency was 34.9% with 5% of di-ethyl-ether, with neat *Thevetia peruviana* seed oil it was 28.2%, and all biofuels had highest value of combustion duration compared to that of diesel [9].

Brake thermal efficiency for petro-diesel at full load condition was 35.14%, whereas for the blends B5, B10, B15, B20, B30 and B100 were 28.19%, 29.39%, 30.97%, 32.08%, 33.06% and 33.61% respectively. Blends of biodiesel have brake thermal efficiency lower than petro-diesel [10].

For all the fuels tested the brake thermal efficiency increased with increase in load. The BTE of biodiesel was found to be lower compared to diesel at all power output. At 80% load condition all tested fuels provided higher brake thermal efficiency than at 100% load condition. As the load increased, the brake specific fuel consumption decreased. The brake specific fuel consumption for biodiesel blends was higher when compared with diesel. The neat diesel exhibit lower amount of hydrocarbon and carbon monoxide emissions and higher amount of nitric oxide emissions as compared to biodiesel blends [11].

Among various injection pressures studied 230 bar injection pressure exhibited higher peak pressure rise as compared with 210 bar and 250 bar injection pressures. From various injection timings studied 26° bTDC exhibited higher peak pressure rise as compared with 20° bTDC and 23° bTDC injection timings [12].

The 75% load variation exhibited higher brake thermal efficiency as compared with 50% load variation. Higher brake thermal efficiency about 29.74% was obtained for D+CNG fuel combination at 75% load. The compressed natural gas resulted in higher brake thermal efficiency as compared with compressed biogas. The reactivity controlled compression ignition engine fuelled with biodiesel showed lower brake thermal efficiency as compared with diesel. 75% load variation provided lower hydrocarbon emissions as compared with 50% load variation. Out of the various fuel combinations studied D+CNG resulted into lower amount of hydrocarbon emissions. The reactivity controlled compression engine operated with biodiesel operation resulted into higher quantity of hydrocarbon emissions related with diesel combustion. 75% load variation exhibited higher nitric oxide emissions as compared with 50% load variation. Higher nitric oxide emissions were obtained for D+CNG fuel combination. Lower nitric oxide emissions were obtained for biodiesel operation. 75% load variation provided lower amount of smoke emissions related with 50% load variation. Among various fuel combinations D+CNG exhibited lower quantity of smoke emissions related with other fuel combinations. Biodiesel fuelled reactivity controlled compression engine showed higher smoke emissions related with engine fuelled with diesel [13].

Among the different injection timings studied, the D+CNG mixture exhibited higher brake thermal efficiency, about 29.32% was found at 50° aTDC injection timing, which was about 1.77, 3.58, 5.56, 7.51, and 8.54% higher than D+CBG, B20+CNG, B20+CBG, B100+CNG, and B100+CBG fuel combinations. The highest brake thermal efficiency, about 30.25%, was found for the D+CNG fuel combination at 6-ms injection duration, which was about 1.69, 3.48, 5.32%, 7.24, and 9.16% higher as compared with the D+CBG, B20+CNG, B20+CBG, B100+CNG, and

B100+CBG fuel combinations. At all injection timings and injection durations, higher emissions of nitric oxide along with lower emissions of smoke, carbon monoxide and hydrocarbon were found for D+CNG mixture as related to other fuel mixtures. At all injection timings and injection durations, D+CNG provided higher in-cylinder pressure and heat release rate as compared with other fuel combinations [14].

The brake thermal efficiency decreased with the increase in n-butanol percentage. Highest brake thermal efficiency obtained for diesel and n-butanol fuel combination at 10% of n-butanol. The nitric oxide emissions decreased with the increase in n-butanol percentage. Highest nitric oxide emissions obtained for diesel and n-butanol fuel combination at 10% of n-butanol. The hydrocarbon emissions increased with the increase in n-butanol percentage. Lowest hydrocarbon emissions obtained for diesel and n-butanol at 10% of n-butanol in injected fuels. The carbon monoxide emissions increased with the increase in n-butanol percentage. Lowest carbon monoxide emissions obtained for diesel and n-butanol at 10% of n-butanol in injected fuels. As the percentage of n-butanol increased smoke emissions decreased. Lowest smoke emissions obtained for diesel and n-butanol at 10% of n-butanol in injected fuels [15]. As the concentration of the blends is increased there is a marginal drop in the brake thermal efficiency. Increasing the hydrogen gas flow rates reduces brake thermal efficiency, smoke, carbon monoxide and hydrocarbon emissions while nitric oxide emissions from dual fuel engine increased. The engine operated by renewable fuel combinations of biodiesels and hydrogen in dual fuel mode engine can facilitate partial as well as complete substitution for fossil fuels and reduce the greenhouse gas emissions [16].

For 3 hole nozzle, highest peak pressure rise was found to be 59.63 bar for diesel fuel at 2.35 kW of brake power and 230 bar injection pressure, 57.11 bar for B20 fuel at 3.52 kW of brake power and 210 bar injection pressure and highest indicated mean effective pressure was found to be 15.63 bar for diesel fuel at 3.52 kW of brake power and 230 bar injection pressure, 15.73 bar for B20 fuel at 3.52 kW of brake power and 250 bar injection pressure [22].

4. Conclusions

Currently, more attention has been devoted to the application of low cost non-conventional and non-edible feedstocks from the wild plants to produce biodiesel. Plants bearing non-edible seeds have the potentials of reclaiming wasteland and do not compete with food crops and utilization of these non-conventional and non-edible feedstocks can be sustainable for biodiesel production. Yellow oleander (*Thevetia peruviana*) seed oil is a promising non-edible biodiesel feedstock that will not compete with food crops. It has several advantages as a renewable biodiesel feedstock because the seed is rich in oil content having 60-65% oil. The plant can be cultivated in wastelands or marginal lands and it requires minimum water as well as minimum care when it is in growing stage. Hated by herbivorous animals, the plant can also be grown on roadsides and road-dividers in expressways for beautification, environmental protection and at the same time for the production of biodiesel. The plant starts flowering after one and a half year and gives fruits throughout the year providing a steady supply of seeds. *T. peruviana* seed oil can be converted into biodiesel.

5. References

1. Wang X, Zhang Y, Karthikeyan C, Boomadevi P, Marousek J, Nasif O, *et al*. Role of injection pressure on fuel atomization and spray penetration on the *Thevetia peruviana* and Jatropha curcas biodiesel blends with nanoparticle, Fuel. 2022;324(B):124527, https://doi.org/10.1016/j.fuel.2022.124527.
2. Harari PA, Yaliwal VS, Banapurmath NR. Experimental investigation on the effect of gaseous fuels energy share on reactivity controlled compression ignition mode of combustion operated with gaseous fuels and liquid fuels, Materials Today: Proceedings. 2022;52(3):1121-1130, https://doi.org/10.1016/j.matpr.2021.11.006.
3. Harari PA, Banapurmath NR, Yaliwal VS, Khan TMY, Soudagar MEM, Sajjan AM. Experimental studies on performance and emission characteristics of reactivity controlled compression ignition (RCCI) engine operated with gasoline and *Thevetia peruviana* biodiesel, Renewable Energy. 2020;160:865-875, https://doi.org/10.1016/j.renene.2020.07.009.
4. Deokar AJ, Harari PA. Effect of injection pressure, injection timing and nozzle geometry on performance and emission characteristics of diesel engine operated with *Thevetia peruviana* biodiesel, Materials Today: Proceedings. 2021;47(10):2622-2626, https://doi.org/10.1016/j.matpr.2021.05.198.
5. Harari PA, Banapurmath NR, Yaliwal VS, Soudagar MEM. Experimental investigation on compression ignition engine powered with pentanol and Thevetia peruviana methyl ester under reactivity controlled compression ignition mode of operation, Case Studies in Thermal Engineering. 2021;25:100921, https://doi.org/10.1016/j.csite.2021.100921.
6. Marikatti M, Banapurmath NR, Yaliwal VS, Basavarajappa YH. Hydrogen injection in a dual fuel engine fueled with low-pressure injection of methyl ester of *Thevetia peruviana* (METP) for diesel engine maintenance application, Energies. 2020;13:5663. DOI: 10.3390/en13215663.
7. Deokar AJ, Harari PA, Reddy CP. Effect of injection parameters on the combustion characteristics of diesel engine operated with *Thevetia peruviana* methyl ester, International Journal for Modern Trends in Science and Technology. 2021;7(12):315-320.
8. Deokar AJ, Harari PA, Sutar SE, Hodage PP, Patil JV, Kole AR. Effect of nozzle whole geometry on compression ignition engine fuelled with *Thevetia peruviana* biodiesel, International Journal of Innovative Research in Science, Engineering and Technology. 2018;7(12):11861-11871. DOI: 10.15680/IJIRSET.2018.0712031.
9. Raj SV, Manokar AM. Combustion characteristics of di-ethyl ether mixed *Thevetia peruviana* seed oil, Journal of Chemical and Pharmaceutical Research, 2016;8(7):424-430.
10. Jeremiah M, Betty M, Erich O, Austin A, Geoffrey O. The engine performance, combustion, and emission of yellow oleander (*Thevetia peruviana*) biodiesel and blends, Algerian Journal of Renewable Energy and Sustainable Development. 2022;4(2):136-148.

11. Harari PA, Deokar AJ, Sutar AS, Patil AK, Patil SD, Patil SS. Comparison of various B20 biodiesel blends in diesel engines, International Journal of Research in Advent Technology. 2019;7(4):294-305.
12. Harari PA, Deokar AJ, Jadhav SD, Narvekar RP, Nimbalkar PY, Kamble VA. Effect of injection timing on compression ignition engine fuelled with *Thevetia peruviana* biodiesel, International Journal of Innovative Research in Science, Engineering and Technology. 2019;8(5):5744-5754.
13. Harari PA, Yaliwal VS, Banapurmath NR. Effect of CNG and CBG as low reactivity fuels along with diesel and TPME as high reactivity fuels in RCCI mode of combustion by varying different loads, Materials Today: Proceedings. 2021;47:2491-2494, https://doi.org/10.1016/j.matpr.2021.04.557.
14. Harari PA, Banapurmath NR, Yaliwal VS, Khan TMY, Badruddin IA, Kamangar S, *et al*. Effect of injection timing and injection duration of manifold injected fuels in reactivity controlled compression ignition engine operated with renewable fuels, Energies. 2021;14:4621. https://doi.org/10.3390/en14154621.
15. Harari PA, Yaliwal VS, Banapurmath NR. Experimental studies on RCCI engine powered with n-butanol and *Thevetia peruviana* methyl ester, Techno-Societal; c2020. https://doi.org/10.1007/978-3-030-69925-3_10.
16. Muralidhara DM, Banapurmath NR, Udayaravi M, Reddy CP, Harari PA, Karthik T. Effect of hydrogen flow rates on the performance of two biodiesels fuelled dual fuel engine, Materials Today: Proceedings. 2022;49:2189-2196, https://doi.org/10.1016/j.matpr.2021.09.090.
17. Panchal BM, Deshmukh SA, Panchal DS, Sharma MR. Kinetics of the trans esterification of non-edible *Thevetia peruviana* seed oil with dimethyl carbonate catalyzed by potassium methoxide, Egyptian Journal of Petroleum. 2017;26(2):363-370. https://doi.org/10.1016/j.ejpe.2016.05.013.
18. Deka DC, Basumatary S. High quality biodiesel from yellow oleander (*Thevetia peruviana*) seed oil, Biomass and Bioenergy. 2011;35(5):1797-1803. https://doi.org/10.1016/j.biombioe.2011.01.007.
19. Rupasianghe CP, Gunathilaka KSS. Disaster Risk Reduction through biodiesel from yellow oleander (*Thevetia peruviana*), Procedia Engineering. 2018;212: 591-597, https://doi.org/10.1016/j.proeng.2018.01.076.
20. Ighose BO, Adeleke IA, Damos M, Junaid HA, Okpalaeke KE, Betiku E. Optimization of biodiesel production from *Thevetia peruviana* seed oil by adaptive neuro-fuzzy inference system coupled with genetic algorithm and response surface methodology, Energy Conversion and Management. 2017;132:231-240. https://doi.org/10.1016/j.enconman.2016.11.030.
21. Arun SB, Suresh R, Avinash E. Optimization of biodiesel production from yellow oleander (*Thevetia peruviana*) using response surface methodology, Materials Today: Proceedings. 2017;4(8):7293-7301, https://doi.org/10.1016/j.matpr.2017.07.059.
22. Harari PA, Akshatha DS, Manavendra G. Effect of injection pressure and nozzle whole diameter on combustion parameters of CI engine fuelled with B20 neem blend, International Journal of Innovative Research in Science, Engineering and Technology. 2015;4(5):2857-2870. DOI: 10.15680/IJIRSET.2015.0405028.