International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 16s,2025
https://theaspd.com/index.php

Production Of Biodiesel From Second Generation Non-Edible Amoora Rohituka Feedstock : Its Applicability In CRDI VCR Diesel Engine

Dr. Manjunath S H[1], Manju R B[2,3], Pradeep K V[4], Dr. Girisha K B[5]
[1]Professor and Head, Department of Mechanical Engineering, BGS Institute of Technology, ACU, B G Nagara, Karnataka, India-571448 hodme@bgsit.ac.in
[2]Research Scholar, Department of Mechanical Engineering, BGS Institute of Technology, ACU, B G Nagara, Karnataka, India-571448
[3]Department of Mechanical Engineering, Government Polytechnic, Belur, Karnataka, India rmanjubgowda@gmail.com
[4]Department of Automobile Engineering, Smt. L. V. Govt Polytechnic, Hassan, Karnataka, India-573201 pradeepkvijay@gmail.com
[5]Professor, Department of Mechanical Engineering, BGS Institute of Technology, ACU, B G Nagara, Karnataka, India-571448 girish.kn03@gmail.com

Abstract
Due to limited availability of crude oil, many countries across the world are moving towards alternative fuels derived from renewable sources and bio-fuels produced usingfats derived from vegetables, plants, land and aquatic animals. In addition to supplying energy for transportation system, these fuels also help in reducing the pollution. In order to reduce the demand and dependency of crude oil, bio-fuels are the best alternative for petroleum. The main aim of this paper is to provide researchers, chemical engineers, pollution policy makers and lastly automobile industry considerable information related to the AmooraRohitukaseed based bio-fuel. Towards this end, the paper discusses fuel removing techniques and bio-fuel production methods. Also, the performance and exhaust characteristics of Amoora Rohituka Methyl Esters (ARME) blends with diesel in VCR CRDI engine for different loads are discussed towards the end. Akin to the findings of many researchers, this article too finds that the bio-fuel emits lesser pollutants as compared to fossil fuel and that Amoora Rohituka bio-fuels are the best alternate fuel blends for C I engine to overcome dependency on fossil fuels as well as to overcome environmental issues.
Keywords: *Amoora Rohituka seeds: Transesterification; Amoora Rohituka methyl ester; Biodiesel; CI engine.*

Abbreviations:
VCR- variable compression ratio
CRDI-common rail direct injection
CI-compression ignition
ARO- Amoora Rohituka oil
ARME- Amoora Rohituka methyl ester
ARME 5%+D95%- Amoora Rohituka Biodiesel 5% +Diesel 95%
ARME 10%+D90%- Amoora Rohituka Biodiesel 10% +Diesel 90%
ARME 15%+D85%- Amoora Rohituka Biodiesel 15% +Diesel 85%
ARME 20%+D80%- Amoora Rohituka Biodiesel 20% +Diesel 80%
HC-Hydrocarbon
CO-Carbon Monoxide
NO-Nitrous oxide
O2-Oxygen
ARO-Amoora Rohituka oil

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 16s,2025
https://theaspd.com/index.php

1. INTRODUCTION

Owing to its high widespread availability, thermal efficiency, robust construction andreliability,Automobile sector normally uses engines powered by diesel fossil fuel. In addition to the automobile sector, power generation, agricultural forms, and construction fields are also major end users of diesel engine and fossil diesel fuel. However, production of soot or particulate matter which contains unburned hydrocarbon, carbon (carbon monoxide and carbon dioxide), small amount of metallic residues and NOx emissions due to lack of complete combustion which cause ozone depletion, global warming, photochemical smog, acidification, deforestation and also dangerous to human beings and animals[1-5].The conditions like availability/supply, cost of crude oil in terms of foreign exchange and to conquer the effects of fossil fuel on our globe are obviously perceptible to find out the alternate fuels [6-7]. Presently, more importance is being given to alternate fuels due to their cost-effectiveness and eco-friendly nature.These alternate fuels are derived from various food crops and edible oils (1stgeneration), energy crops/plant seeds or non-edible oils (2nd generation), micro-algae and electricity (3rd and 4th generation) [8-10].First generation bio-fuels directly compete with food supply system and also require large quantity of water to cultivate. To overcome these disadvantages, researchers are trying to find out alternative sources for first generation biofuel [13-14]. The use of non-edible seed oils, micro-algae, animal fats have not only decreased the fuel price but also resulted in improved performance and lower exhausts compared to diesel fuel [15]. In addition to these, non-edible oils are readily available, biodegradable, renewable, and fragrant and contain lesser sulfur content. Whereas elevated viscosity, lower volatility and unsaturated fatty acid chain reactivity are some disadvantages [15-16]. Currently, the entire world is moving towards electricity or battery vehicles from both SI and CI engine operated vehicles. The main intention of this changeover is to reduce or eliminate harmful emissions from IC engines. But mineral oil, coal and natural gas are the foremost resources to produce 64% electricity of the world, and this leads to comparatively more emissions than conventional engines. Along with this, since a typical natural raw material is used to manufacture Li-ion batteries, raw material cost, manufacturing cost, disposal of battery after use, user acceptance, charging units and mainly safety are other challenges related to possible changeover from internal combustion engine to electric vehicle [17]. Quicker development, high oil percentage and growth in all-weather circumstances are some advantages of algae. Conversely, to grow the algae, a large amount of water, carbon dioxide, reactors and distillation units are needed. In addition to these, oil withdrawal from algae demands hefty energy and financial resources [22].Some researchers focused on use of waste cooking oil as bio-diesel in diesel engines. [8-10]. However, alternate fuels are not newer ones, Dr. Rudolph Diesel, who discovered the diesel engine, used peanut based edible oil as a substitute for diesel for the CI engine at the World Fair, Paris in1900 [11,12]. Also, the process of transesterification was discovered by G. Chavanne in the year 1937 at the University of Brussels, Belgium and patented his journal "Procedure for the transformation of vegetable oils for their uses as Fuels"[18].Second generation biofuel possesses many advantages. These bio-fuels are obtained from seeds of trees/plants containing 30 to 50% oils. Cultivation of trees increases the oxygen content in the environment, prevents soil erosion, and overcomes deforestation shown in Fig. 1. Plant seeds are most suitable for the production of biofuel in every 75 plants in environment [15].

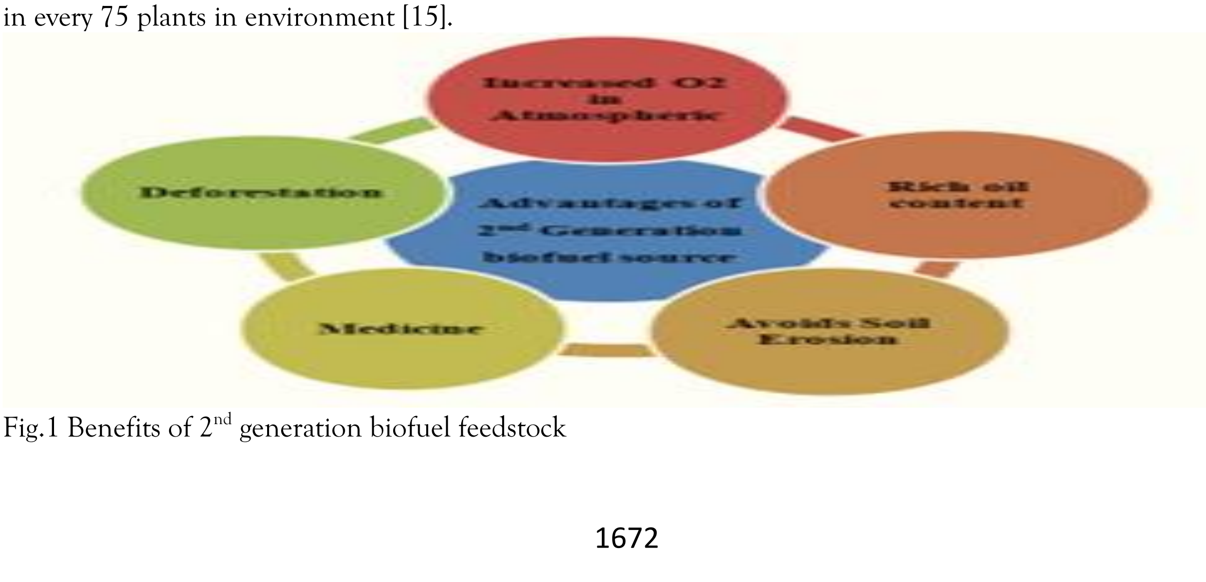

Fig.1 Benefits of 2nd generation biofuel feedstock

Aman et al.[18] conducted an experiment to know the effect of spirulina biodiesel blends on performance characteristics of diesel engine. The load on the engine varied from 25% to 100% at intervals of 25%, with speed being kept constant. Attained energy and exergy efficiency of 33.55% and 31.48% for diesel and for spirulina biodiesel blends (20, 80 and 100%) at 100% load were between 31.89 - 33.02% and 29.5–30.77%, correspondingly. Also emission of CO2 and NOx were lessening by 8.74% and 28.09% for spirulina biodiesel (100%) at all loading conditions. Varun Goel et al. [19] prepared biodiesel from non-edible feedstock Jasminum officinale flowers and examined performance parameter for different Jasminum officinale blends (25, 50, 75 and 100%). They got increased fuel consumption and reduced BTE for all tested fuel blends under all loading conditions. In addition, CO and HC emissions were slightly lesser than neat diesel fuel. However, NOx emissions were higher than diesel fuel for all tested fuels. Similar results were obtained byPriyankesh Kumar et al. [20] for lemon grass biodiesel for different blends. S. Pitchaiah et al. [21] derived biodiesel from Bael fruit seed, used up to 20% blend with diesel fuel in DI CI engine at a constant speed of 1500 rpm and four different loads. They found that at 25% load, fuel consumption was 0.933045 kg/kwhr and 0.862 kg/kW hr for B20D80 fuel and neat diesel respectively. In addition, BTE of Bael biodiesel blends does not reach the expected level as that of diesel fuel. Addisu Frinjo Emma et al.[22] synthesized biodiesel from coffee husk, prepared various blends of Coffee husk oil methyl ester (B-10, B-20, B-30, B-40, B-50, B-80) with diesel fuel and investigated the performance, combustion and emission characteristics of a naturally aspirated, water-cooled, vertical cylinder, D I Kirloskar TV1 diesel engine. In their study they obtained BTE for B-10, 20 and 30% are 29.1%, 29% and 28.4% correspondingly; values that were nearer to that of neat diesel fuel (29.7%) at full load. But BTE of B-40, B-50 and B-80 are lesser than other blends and neat diesel fuel. Furthermore, fuel consumption of all blends showed that increasing rate than the diesel. Similar results were obtained by S.B Arun et al. [23] for Bombax ceiba methyl ester blends. Additionally, exhausts such as CO and HC were comparatively lesser and NOx was more than that of diesel fuel at all load. Rajayokkiam Manimaran et al. [24] reported that they have produced methyl ester from bio-waste of Trichosanthescucumerina seed, and blended it with diesel. The prepared blends such as TCSB20, TCSB40, TCSB60 and TCSB100 exhibit slightly effective performance in diesel engine and all tested blends showed lesser CO and HC emissions related to fossil diesel fuel. A. Saravanan et al. [25] carried out an experiment in variable compression ratio diesel engine (VCRDE) for different loading conditions at a constant speed of 1500rpm with a blend of Rapeseed biodiesel andMahua biodiesel called RM (Rapeseed and Mahua in equal volume). They achieved slightly lesser thermal efficiency than diesel fuel but the emissions such as CO, HC and smoke were 20.66%, 8.56% and 6.9% lesser than diesel fuel at full load condition.

Ankur Nalgundwaret al. [26] conducted an experiment in a single cylinder DI diesel engine at different loads by using blends of palm and jatropha biodiesel in the ratio of 10% (5%+5%), 20% (10%+10%) and 30% (15%+15%) with diesel. The brake power of B10 increased with 4.65% compared to neat diesel fuel and CO emissions for B10, B20 and B30 were 7.1%, 17.7% and 14.5% lesser than the diesel fuel: but NOx emissions were slightly more for B10 and B20 when compared to diesel fuel. Mohamed Khalaf et al. [27] used a single cylinder four stroke,4.5 kW diesel engine to analyze the performance and emission characteristics of Jatropha and Castor biodiesel (B20) and achieveddecreased CO and CO2 exhausts of 10% and 22% respectively, but raised NO emissions up to 8 % as compared to diesel. Surya Dharma et al. [28] derived a biodiesel from two different feedstocks namely Jatropha Curcas and Ceiba Pentandra oil (50-50 volume), chemically converted into biodiesel. They used B10, B20, B30, B40 and B50 of JC biodiesel in a single-cylinder direct injection diesel engine and achieved closer engine performance (B10) and reduced CO2 emissions as well as smoke opacity, but noted increased NO and CO emissions compared to diesel fuel. Akshay Jain et al. [29] prepared a biodiesel from 50% Water Hyacinth Biodiesel and 50% Mesua Ferrea Biodiesel as a main blend. In addition to this, Hydrogen was used to boost the combustion phenomena in a modified single cylinder CI engine to run for WHMF biodiesel with hydrogen. Addition of hydrogen to the blend increases the thermal efficiency but for blend it was lesser than diesel fuel.CO and HC emissions of blend with hydrogen and blend without hydrogen were less than that of diesel fuel.

AphanamixisPolystachya (Wall.) R. Parker tree, commonly known as Amoora Rohituka, Mullu Muthala, Rohithaca, and Harin Hara is actually native to tropical China. They are also found in Bhutan, Malaysia, Sri Lanka, Myanmar, Papua, Thailand, Indonesia, Philippines New Guinea and India. In India, the trees are distributed in Andhra Pradesh, Odisha, Kerala, Tamil Nadu and Karnataka (Chikkamagaluru, Mysuru, Udupi, Uttara Kannada and Hassan).The flowering is alar or terminal raceme and are longer than leaves. Every inflorescence contains around 35-50 fruits, each fruit contains pearl shaped seeds (0.9 - 1.27cm in diameter) and weighs about 0.7 to 0.9g. Every tree produces almost 8-10 kg seeds per year [30]. The percentage of oil content in Amoora Rohituka seeds is 42.85.

2. MATERIALS AND METHODOLOGY

2.1 Materials

Amoora Rohituka seeds were collected from Smt. L. V. Government Polytechnic campus and Biofuel Park, Hassan. These seeds were sun-dried separately for about 4 days to eliminate the moisture content present in it. Chemicals such as Hydrogen sulfate (H2SO4), Methyl alcohol (CH3OH), Lye (NaOH) and Phenolphthaleinwere collected and used for chemical conversion process in Biofuel Park, Madenur, Hassan, Karnataka.

2.2 Extraction of Oil and its physico-chemical properties

Once the seeds were ready, a mechanical expeller was used to extract the oil from AmooraRohituka seeds. This process was conducted at biofuel Park, Madenur, Karnataka, India. The quantity of oil content can be calculated from the Eq. (1).

$$\text{Oil extracted}(\%) = \frac{\text{Pure oil obtained}}{\text{Seeds used to crush}} \text{ X } 100 - - - - - (1)$$

Nearly 4.0 kg pure oil from 10 kg of Amoora Rohituka seeds were obtained. The physico-chemical properties like viscosity, density, flash and heating valuesof the extracted oils (ARO), AR methyl ester's, diesel, diesel with 5%, 10%, 15% and 20% were evaluated as per ASTM standards in Adi Chunchanagiri University, BGS Negara, Mandya, Karnataka.

2.3 Production technique of AR Biodiesel

In the current study, free fatty acid (FFA) of AR oil was calculated as per the technique stated in the literature [66]. The FFA content of ARO was 3.5%. Therefore, ARO required acid (esterification) followed by base catalyst (transesterification) chemical treatment. This chemical conversion process was carried out in biofuel park, Madenur, Hassan, Karnataka, India.

$$\text{FFA} = \frac{28.2 \text{ X Normality of NaoH X Titration value}}{\text{Weight of the oil}} - - - - - (2)$$

2.3.1 Esterification technique (Phase I): Measured quantity of ARO was taken in a 500ml flat bottomed three necked flaskfitted with a condenser at its centre neck. Based on the ARO quantity, chemical combination such as 15% methanol and 0.5% sulfuric acid was added. Themixture was then heated at 65°C for about 60 min at a constant speed of 600rpm. Once the process was completed, the entire mixture was transferred into a funnel to separate excess methanol and sulfuric acid. It was observed that methanol and sulfuric acid had settled in the upper layer, andesterified oil settled at the lower layer. This esterified oil was collected in a container and used for transesterification technique (phase II). The FFA content of collected esterified oil was again checked and obtained 0.9% (w/w). The yield of esterified oil was achieved 91.50%, determined through Eq. (3).

$$\text{Yield (\%)} = \frac{\text{Initial FFA} - \text{Final FFA}}{\text{Initial FFA}} \text{X}100 - - - - - (3)$$

2.3.2 Trans-esterification technique (Phase I I):

Subsequent to Esterification technique, the measured quantity of esterified oil was used as a key matter in transesterification process. The esterified AR oil was combined with a measured quantity of methanol and base catalyst NaOH in a three necked flat bottomed flask used in the esterification phase apparatus. The reaction was carried for about 1hr, reaction temperature was maintained as 65 C at a speed of 600rpm. To receive the AR methyl ester, the mixture was permitted to settle at least 12hours in a separating funnel to make separation of methyl-ester at the top layer and the glycerol at the bottom layer. The obtained AR methyl ester was again heated to remove excess methanol present in it. Biodiesel was washed with hot water to remove the traces of methanol and catalyst. The yield of AR biodiesel was achieved 85% determined through Eq. (4).

$$\text{MCARME yield}(\%) = \frac{\text{Achieved quantity of MCARME}}{\text{Used Quantity of esterified MCARO}} - - - - - - (4)$$

2.4 Physical, chemical properties of ARME

The applicability of derived in CI engine is based on its physico-chemical properties, evaluated as per ASTM (American Society for Testing and Materials) standards. Usually density, kinematic viscosity, heating value, and flash point are the significant properties of bio-fuel and its blends. These properties have significant function in estimating the performance of CI engine [23], as tabulated in table no (1).

Table.1. Physical and chemical properties of AR bio-diesel

Properties	Diesel	ARME	ARME	5	10	15	20
Density	835.9	865	880.1	837.5	838.5	840.8	843.8
Viscosity	2.475	4.66	4.69	2.39	2.55	2.65	2.84
Calorific Value	45.6	38.2	39.5	44.8	43.9	44.6	44.4
Cetane number	48	54	Nd	Nd	Nd	Nd	Nd
Flash point	47.5	155	121.5	48	48.5	49.5	48.5

2.5 Experimental Diesel engine test rig:

The experiments were conducted using aKirloskar 4-stroke, single cylinder water cooled CRDI VCR engine with a compression ratio of 17.5:1 at 1500 rpm. Fig. 2 and 3 represent the actual and line diagram of the engine test rig with gasanalyzer. The engine specifications are tabulated in Table 2. The pollutants from experimental diesel engine like Hydro-Carbon (HC), Carbon oxide (CO), and oxides of nitrogen (NOx) were calculated using AVL 5 gas analyzer. The experiments were conducted by changing the loads such as 0%, 25%, 50%, and 75% and100% at a constant speed. Initially, the engine was run with diesel to achieve constant operational condition. Once the engine reached the stable condition, blends of and diesel were used to record the outcome of engine. The experimentation was carried out without modification of engine with pure diesel, diesel with 5% (B5), 10% (B10), 15% (B15) and 20% (B20).

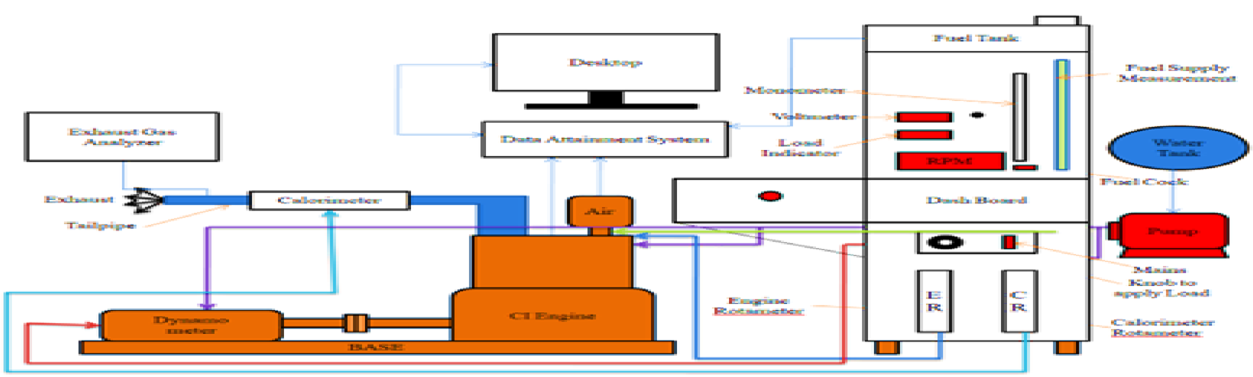

Fig.2. Schematic illustration of the investigational engine setup with gas analyzer

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 16s,2025
https://theaspd.com/index.php

Fig.3. Investigational engine setup with gas analyzer

Table.2. Engine specification utilized in the present study

Type of the engine	CRDI VCR Single cylinder four stroke water cooled
Stroke and bore	110 mm and 87.5mm
Power	3.5kw
Speed	1500rpm
Compression ratio	12-18
Dynamometer	Eddy current, water cooled with loading unit
ECU	Nira i7r

3. RESULTS

3.1 Brake thermal efficiency (B_{Th}):

The amount of chemical energy present in fuel (heat) is extracted as work is brake thermal efficiency. The combustion quality of any fuel can be measured from Brake thermal efficiency. Figure. 4 illustrates the B_{Th} for diesel and different biodiesel blends. From the figure.1, it can be seen that BTh for B0, ARME5, ARME10, ARME15 and ARME20 is at 100% load are 31.6%, 29.5%, 28.7%,25.9% and 25.3% respectively. The reduction in brake thermal efficiency in biodiesel blends as observed from figure.1 is due to its lower heating value and higher viscosity. These parameters lead to poor atomization and vaporization hence achieve reduced combustion phenomena. Brake thermal efficiency for ARME5 is nearer to that of diesel fuel matched with ARME10, ARME15 and ARME20. This result is similar to the research performed by Yuvarajan Devarajan et.al [31]. using Sterculia foetidabiodiesel blends in a four-stroke single-cylinder diesel engine.

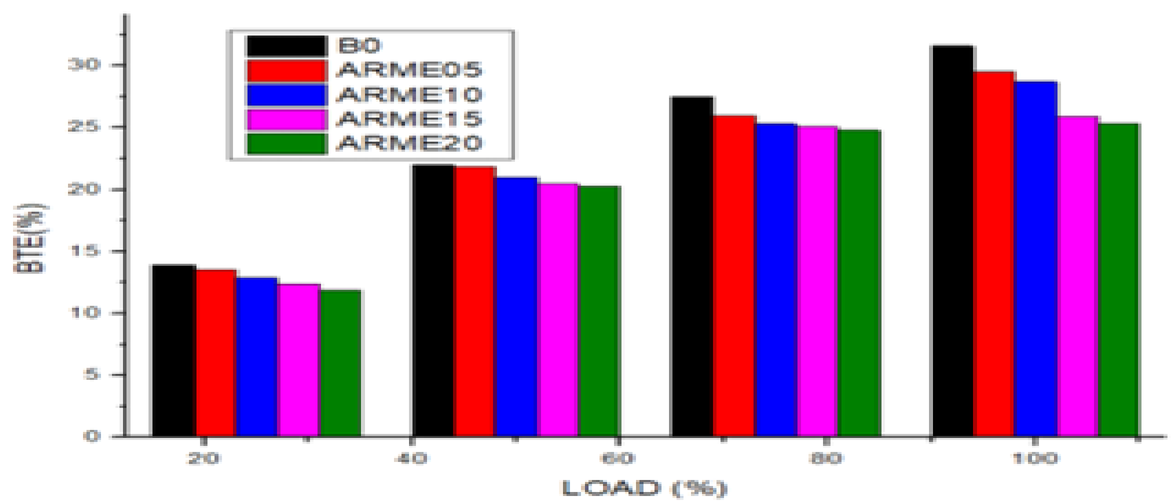

Fig.4.Variation in BTE with different loading condition.

3.2 Brake specific fuel consumption (Bsfc)

Figure.5 illustrates the brake specific fuel consumption versus load of diesel and different biodiesel blends with different loads. As the load increases, BSFC of B0, ARME5, ARME10, ARME15 and ARME20 reduces, it is due to presence of air in the combustion chamber. However, BSFC of ARME5, ARME10, ARME15 and ARME20 are more than the B0. Due to the presence of additional oxygen content in the biodiesel and lower heating values, high viscosity and density. Usually at higher loads all fuel shows the smaller BSFC because of increased combustion efficiency and in-cylinder pressure. Form the figure it is observed that BSFC at 100% load for B0, ARME5, ARME10, ARME15 and ARME20 are, 0.19,0.24,0.26,0.29 and 0.30kg/kW-h respectively.

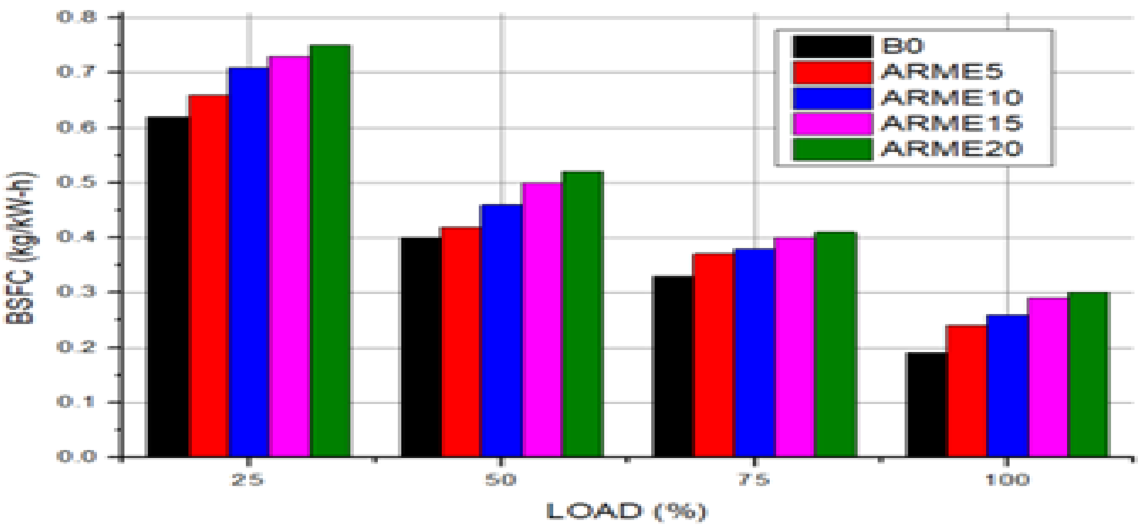

Fig.5.Variation in BSFC with different loading condition.

3.3 Exhaust emission characteristics:

Diesel engine exhausts are harmful to all living beings. Diesel engine exhausts are harmful to all living creatures like human beings and animals. So it is important to determine the exhaust characteristics of B0, ARME5, ARME10, ARME15 and ARME20 to conclude whether diesel fuel emits more exhaust or biodiesel blends. In the current research work carbon monoxide (CO), Un-burnt hydrocarbon(UBHC) and nitrous oxides(NOx) were characterized for B0, ARME5, ARME10, ARME15 and ARME20 at 0%, 25%, 50%, 75% and100% load.

3.3.1 CO emissions

Figure.6 depicts the CO emissions for B0 and different blends for different loads. From the figure it was clear that the CO emissions for ARME5, ARME10, ARME15 and ARME20 were appreciably lesser than the B0. The reduction in CO emission due to presence of additional oxygen content in the biodiesel blends which also improves the atomization in combustion phase and does complete combustion. The CO emission were lesser for ARME5, ARME10, ARME15 and ARME20 as matched with B0.

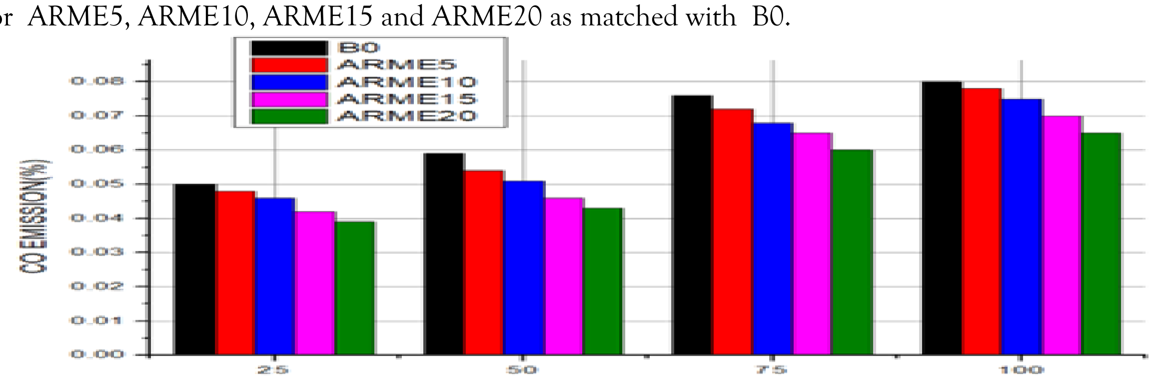

Fig.6.Variation in CO emission with different loading condition.

Figure.7. illustrates the emission of NO for all tested fuels at 25% to 100% loads in an interval of 25% for 1500 rpm. From the figure it was observed that NO emissions for all the tested blends are higher than the neat diesel fuel for all loading conditions. The main reason for higher NO emissions is the presence of extra oxygen in biofuel and in-cylinder temperature, density of the ARME is higher than neat diesel fuel which injects the higher quantity of fuel into the combustion chamber.The NO emissions at 100% load, for all blends are observed as 784ppm ,790 ppm,790 ppm and 810 ppm for ARME5, ARME10, ARME15 and ARME20 respectively and 768 ppm for B0. The NOx emission for B0 is lesser than all tested blends.

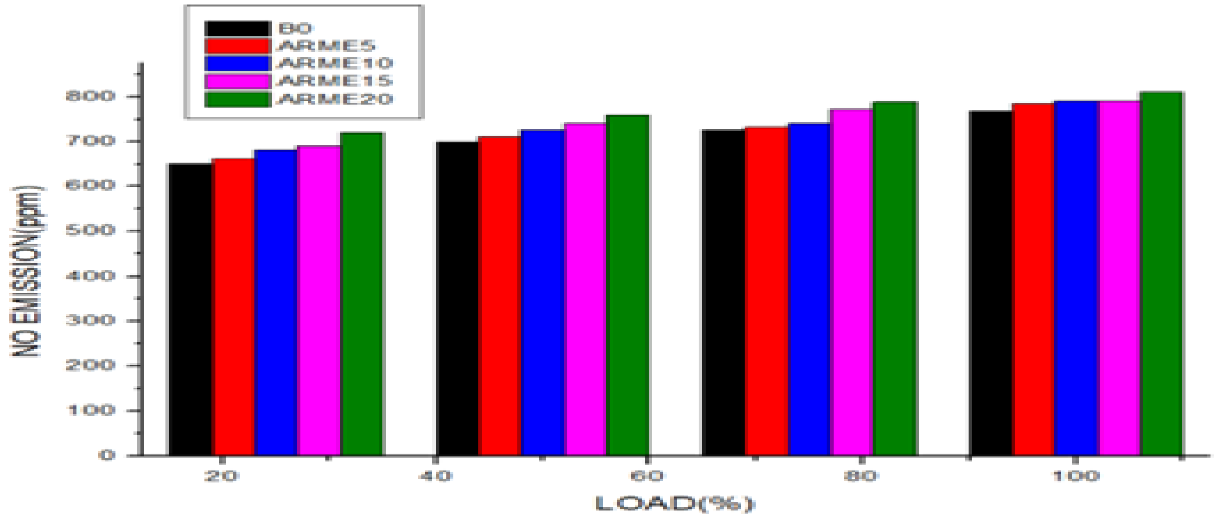

Fig.7.Variation in NO emission with different loading condition.

3.3.3 HC emissions

Figure.8 describes the differences in unburned hydrocarbon emissions for all tested blends and diesel at different loading conditions of constant engine speed. From the figure, decrease trend of HC emissions for all the blends was observed as compared to B0. This reduction is due the lower heating value of blends than neat diesel fuel which directs to boost the more biodiesel at similar loading conditions. In addition to this, presence of extra oxygen in the biodiesel improves the combustion quality. At 100% loading condition, the emissions for ARME5, ARME10, ARME15 and ARME20 are 54 ppm, 51 ppm, 48 ppm and 40 ppm respectively and 58 ppm for B0.

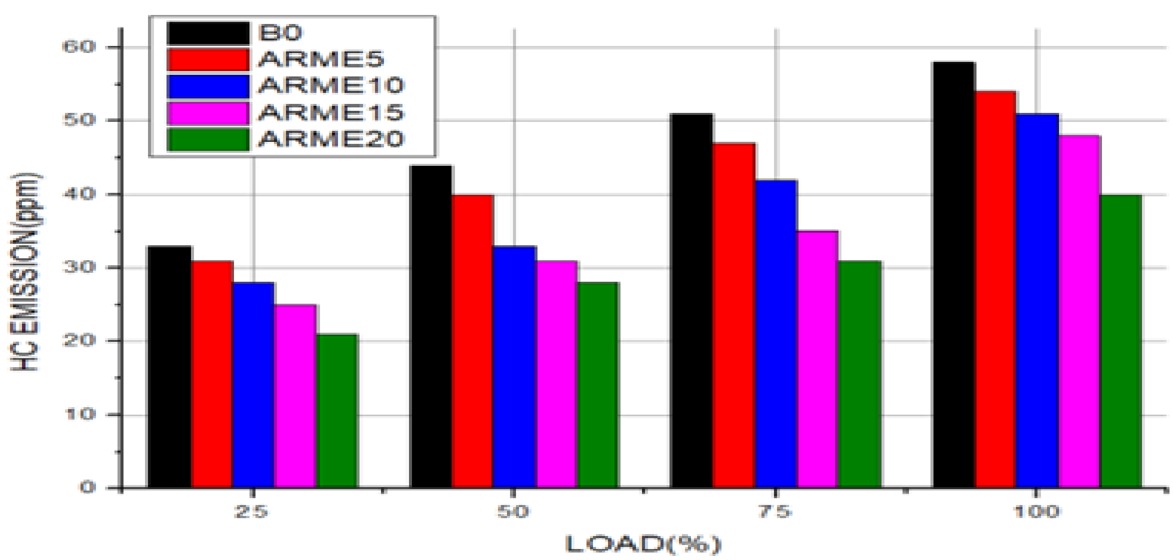

Fig.8.Variation in NO emission with different loading condition.

4. CONCLUSION

In this study, AmooraRohituka seeds were effectively synthesized as AmooraRohituka methyl ester through a homogeneous catalyst. The physical-chemical properties of synthesized methyl ester were evaluated as per ASTM standards and compared with neat diesel. Additionally, performance and tail pipe emissions of neat diesel and MCARME neat diesel blends were examined usingan unmodified 4-stroke 1-cylinder VCR CRDI diesel engine. The results were compared with neat diesel fuel. The followingexperimentaloutcomeswerediscerned from the present examination:

- Methyl ester was successfully converted from oil rich feed-stock: Amoora Rohituka seed, synthesized 800ml of ARME from 1 liter ARO .
- Significantreduction in CO emission and HC emission from all blends was noted at all loading conditions. The reduction in emissions will have a positive effect on atmosphere.
- The study also demonstrates a minor increase in NO emission due to presence of additional oxygen in MCAR methyl ester.
- The presence of extra oxygen content and lower calorific value of MCAR methyl ester results in extra consumption of biodiesel.
- In spite ofhaving lower BTE and increased BSFC, biodiesel has environmental advantages such as increase in plantation area, raising the quantity and quality of oxygen in environment and provision of raw materials for householduse.
- Addition of small quantity of biodiesel to diesel fuel in diesel engine will help reduce the import quantity of crude oil, thereby benefitting a nation's economy.

REFERENCE

1.Pitchaporn Oungpakornkaew, Characterization of biodiesel and soot contamination on four-ball wear mechanisms using electron microscopy and confocal laser scanning microscopy, Wear 458-459 (2020) 203407, https://doi.org/10.1016/j.wear.2020.203407

2. Manoj Babu, Analysis of performance, emission, combustion and endoscopic visualization of micro-arc oxidation piston coated SI engine fuelled with low carbon biofuel blends, Fuel 285 (2021) 119189, https://doi.org/10.1016/j.fuel.2020.119189

3. Dhinesh. B, A study on performance, combustion and emission behaviour of diesel engine powered by novel nano nerium oleander biofuel, Journal of Cleaner Production Volume 196, 20 September 2018, Pages 74-83, https://doi.org/10.1016/j.jclepro.2018.06.002

A. Sanjid, Impact of palm, mustard, waste cooking oil and Calophylluminophyllum biofuels on performance and emission of CI engine, Renewable and Sustainable Energy Reviews 27 (2013) 664–682, https://doi.org/10.1016/j.rser.2013.07.059

4. R. Sathish Kumar, Bio-fuel Production from Martyniaannua L. Seeds Using Slow Pyrolysis Reactor and Its Effects on Diesel Engine Performance, Combustion and Emission Characteristics, Energy, Volume 217, 15 February 2021, 119327, https://doi.org/10.1016/j.energy.2020.119327

5. S. Aravind, Experimental investigation of Lawsoniainermis L. biofuel as fuel in a diesel engine, Materials Today: Proceedings Volume 37, Part 2, 2021, Pages 1734-1738, https://doi.org/10.1016/j.matpr.2020.07.355 A.C.Drenth , Compression ignition engine performance and emission evaluation of industrial oilseed biofuel feedstocks camelina, carinata, and pennycress across three fuel pathways, Fuel 136 (2014) 143–155, https://doi.org/10.1016/j.fuel.2014.07.048

6. S. Prasanna Raj Yadava, Fundamental droplet evaporation and engine application studies of an alternate fuel produced from waste transformer oil, Fuel 259 (2020) 116253, https://doi.org/10.1016/j.fuel.2019.116253

7. Sangita Mahapatra , Potential of tire pyrolysis oil as an alternate fuel for diesel engines: A review, Journal of the Energy Institute 96 (2021) 205e221, https://doi.org/10.1016/j.joei.2021.03.002

8. Federico Millo, Effects of different biofuels blends on performance and emissions of an automotive diesel engine, Fuel Volume 159, 1 November 2015, Pages 614-627, https://doi.org/10.1016/j.fuel.2015.06.096

9. amir Bashir, Recent development of advanced processing technologies for biodiesel production: A critical review, Fuel Processing TechnologyVolume 227, March 2022, 107120, https://doi.org/10.1016/j.fuproc.2021.107120

10. M. Mulyatuna, Production of non-food feedstock based biodiesel using acid-base bifunctional heterogeneous catalysts: A review, Fuel Volume 314, 15 April 2022, 122749, https://doi.org/10.1016/j.fuel.2021.122749

11. H. HaziratulMardhiaha, A review on latest developments and future prospects of heterogeneous catalyst in biodiesel production from non-edible oils, Renewable and Sustainable Energy Reviews 67 (2017) 1225-1236, https://doi.org/10.1016/j.rser.2016.09.036

12. Kiran Raj Bukkarapu, A critical review on available models to predict engine fuel properties of biodiesel, Renewable and Sustainable Energy Reviews Volume 155, March 2022, 111925, https://doi.org/10.1016/j.rser.2021.111925

13. Biswarup Mondal, Optimizing algal biodiesel production from a novel reactive distillation based unit: Reducing CO2 emission and cost, Chemical Engineering and Processing - Process Intensification1 76 (2022), 108948, https://doi.org/10.1016/j.cep.2022.108948
14. H. Haziratul Mardhiaha , A review on latest developments and future prospects of heterogeneous catalyst in biodiesel production from non-edible oils, Renewable and Sustainable Energy reviews Volume 67, January 2017, Pages 1225-1236 https://doi.org/10.1016/j.rser.2016.09.036
15. https://biodiesel.ku.edu/history-0
16. Aman Singh Rajpoot, Sustainability analysis of spirulina biodiesel and their blends on a diesel engine with energy, exergy and emission (3E's) parameters, Fuel Volume 349, 1 October 2023, 128637, https://doi.org/10.1016/j.fuel.2023.128637
17. Mohammed Iyad Ali Alzubaidi , Study on the performance and emissions of compression ignition engine powered by diesel and biodiesel blends, International Journal of Thermofluids, Volume 24, November 2024, 100869, https://doi.org/10.1016/j.ijft.2024.100869
18. Varun Goel, The preparation and optimization of novel jasminum officinale biodiesel blends performance in CI engine: An experimental study, Energy Volume 261, Part B, 15 December 2022, 125263, https://doi.org/10.1016/j.energy.2022.125263
19. Priyankesh Kumar, Effect of synthesized lemongrass biodiesel on the performance and emission characteristics of a CI engine, Sustainable Energy Technologies and Assessments Volume 57, June 2023, 103221, https://doi.org/10.1016/j.seta.2023.103221
20. S. Pitchaiah, Prediction and performance optimisation of a DI CI engine fuelled diesel–Bael biodiesel blends with DMC additive using RSM and ANN: Energy and exergy analysis, Energy Conversion and Management, Volume 292, 15 September 2023, 117386, https://doi.org/10.1016/j.enconman.2023.117386
21. Addisu Frinjo Emma, Extraction and characterization of coffee husk biodiesel and investigation of its effect on performance, combustion, and emission characteristics in a diesel engine, Energy Conversion and Management: X Volume 14, May 2022, 100214, https://doi.org/10.1016/j.ecmx.2022.100214
22. S.B Arun, Green synthesis of copper oxide nanoparticles using the Bombax ceiba plant: Biodiesel production and nano-additive to investigate diesel engine performance-emission characteristics, Energy Volume 274, 1 July 2023, 127345, https://doi.org/10.1016/j.energy.2023.127345
23. Rajayokkiam Manimaran, Biodegradable waste-derived biodiesel as a potential green fuel: Optimization of production process and its application in diesel engine
24. Industrial Crops and Products Volume 192, February 2023, 116078, https://doi.org/10.1016/j.indcrop.2022.116078
25. J. Kakati, Production of biodiesel from Amari (Amoora Wallichii King) tree seeds using optimum process parameters and its characterization, Energy Conversion and anagement Volume 135, 1 March 2017, Pages 281-290, https://doi.org/10.1016/j.enconman.2016.12.087
26. Simangsa Boro , Biodiesel production using areca nut (Areca catechu L.) leaf ash-2CO3 catalyst via transesterification from an oil blend of three different feedstocks, Sustainable Chemistry for the Environment Volume 8, December 2024, 100164, https://doi.org/10.1016/j.scenv.2024.100164A. Saravanan, Performance and emission characteristics of variable compression ratio CI engine fueled with dual biodiesel blends of Rapeseed and Mahua, Fuel Volume 263, 1 March 2020, 116751, https://doi.org/10.1016/j.fuel.2019.116751
27. Ankur Nalgundwar, Comparison of performance and emissions characteristics of DI CI engine fueled with dual biodiesel blends of palm and jatropha, Fuel Volume 173, 1 June 2016, Pages 172-179, https://doi.org/10.1016/j.fuel.2016.01.022
28. Mohamed Khalaf, A comparative study of diesel engine fueled by Jatropha and Castor biodiesel: Performance, emissions, and sustainability assessment, Process Safety and Environmental Protection Volume 188, August 2024, Pages 453-466, https://doi.org/10.1016/j.psep.2024.05.137
29. Surya Dharma, Experimental study and prediction of the performance and exhaust emissions of mixed Jatropha curcas-Ceiba pentandra biodiesel blends in diesel engine using artificial neural networks, Journal of Cleaner Production Volume 164, 15 October 2017, Pages 618-633, https://doi.org/10.1016/j.jclepro.2017.06.065
30. Akshay Jain, Impact of the operational parameters of a dual fuel engine operating on a blend of Water Hyacinth biodiesel and Mesua ferrea biodiesel with hydrogen–A clean development mechanism, International Journal of Hydrogen Energy Volume 66, 13 May 2024, Pages 689-702, https://doi.org/10.1016/j.ijhydene.2024.03.111
31. Nageeb A, Magnolia champaca (L.) Baill. ex Pierre (Magnoliaceae): A first report and a new record in the Arabian Peninsula (Yemen), Journal of the Saudi Society of Agricultural Sciences, 20(2021) 243-247, https://doi.org/10.1016/j.jssas.2021.02.003
32. Siddalingappa R Hotti, Biodiesel production and fuel properties from non-edible champaca (micheliachampaca) seed oil for use in diesel engine, Journal of Thermal Engineering, Yildiz Technical University Press, Istanbul, Turkey, Vol. 1, No. 1, pp. 330-336, January, 2015. https://doi.org/10.18186/jte.67160
33. K.M. Hosamani, Renewable energy sources from Micheliachampaca and Garcinia indica seed oils: A rich source of oil, Biomass And Bioenergy 33 (2009) 267–270, https://doi.org/10.1016/j.biombioe.2008.05.010

34. Suraj CK, Investigation of biodiesel production methods by altering free fatty acid content in vegetable oils. Biofuels 2017. https://doi.org/10.1080/17597269.2017.1378993.
35. H.R. Amriya Tasneem, Performance and Wear Debris Characteristics of Karanja Biodiesel and Biolubricant as a Substitute in a Compression Ignition Engine , Fuel 319(2022) 123870, https://doi.org/10.1016/j.fuel.2022.123870
36. Suresh Vellaiyan, Bauhinia racemose seeds as novel feedstock for biodiesel: Process parameters optimisation, characterisation, and its combustion performance and emission characteristics assessment with water emulsion, Process Safety and Environmental Protection, https://doi.org/10.1016/j.psep.2023.05.099
37. Yuvarajan Devarajan, Utilization of sterculia foetida oil as a sustainable feedstock for biodiesel production: optimization, performance and emission analysis, Results in Engineering Volume 24, December 2024, 103196, https://doi.org/10.1016/j.rineng.2024.103196
38. Ajith Damodaran, Investigating the combined effects of hydrogen-enriched second-generation biodiesel blends derived from Colza and Margosa oils in dual-fuel compression ignition engine, International Journal of Hydrogen Energy, https://doi.org/10.1016/j.ijhydene.2024.12.347
39. Lekidelu Asrat Ayalew, Valorization of indigenous Millettiaferruginea seed oil for biodiesel production: parametric optimization, physicochemical characterization, engine performance and emission characteristics, Heliyon 8(2022) e11601, https://doi.org/10.1016/j.heliyon.2022.e11601
40. Rajendra Kukana, Performance, combustion and emission characteristics of a diesel engine using composite biodiesel from waste cooking oil - Hibiscus Cannabinus oil, Journal of Cleaner Production 372 (2022) 133503, https://doi.org/10.1016/j.jclepro.2022.133503
41. Aisha F. Fareed, Investigation of waste cooking and castor biodiesel blends effects on diesel engine performance, emissions, and combustion characteristics, Case Studies in Thermal Engineering Volume 60, August 2024, 104721 https://doi.org/10.1016/j.csite.2024.104721
42. Ahmet Uyumaz, Experimental investigation on the combustion, performance and exhaust emission characteristics of poppy oil biodiesel-diesel dual fuel combustion in a CI engine, Fuel 280 (2020) 118588 https://doi.org/10.1016/j.fuel.2020.118588
43. Murat Kadir Yesilyurt, A detailed investigation on the performance, combustion, and exhaust emission characteristics of a diesel engine running on the blend of diesel fuel, biodiesel and 1-heptanol (C7 alcohol) as a next-generation higher alcohol, Fuel 275 (2020) 117893 https://doi.org/10.1016/j.fuel.2020.117893
44. Anh Tuan Hoang, A feasible and promising approach for diesel engine fuelled with a blend of biodiesel and low-viscosity Cinnamon oil: A comprehensive analysis of performance, combustion, and exergy , Journal of Cleaner Production 401(2023) 136682 https://doi.org/10.1016/j.jclepro.2023.136682
45. Ala'a K. Al-Bawwat, Extraction and characterization of Cucumis melon seeds (Muskmelon seed oil) biodiesel and studying its blends impact on performance, combustion, and emission characteristics in an internal combustion engine, Energy Conversion and Management: X Volume 23, July 2024, 100637 https://doi.org/10.1016/j.ecmx.2024.100637
46. Mandeep Singh, Performance, emission and combustion characteristics of multi-cylinder CRDI engine fueled with argemone biodiesel/diesel blends, Fuel 265 (2020) 117024 https://doi.org/10.1016/j.fuel.2020.117024
47. Arun Teja Doppalapudi, Experimental investigation on diesel engine performance, combustion, and emissions characteristics with Tucuma and Ungurahui biodiesel blends, Fuel Volume 371, Part B, 1 September 2024, 132161 https://doi.org/10.1016/j.fuel.2024.132161