Utility of Jatropha, Karanja and Vegetable Oils as a Biodiesel – A Review

Keshav Raj[1], Prof. Rajeev Singh Chouhan[2]
[1]Keshav Raj, Department of Mechanical Engineering, LNCT, Bhopal (M.P), India
[2] Prof. Rajeev Singh Chouhan, Department of Mechanical Engineering, LNCT, Bhopal (M.P), India
Email

* Corresponding Author: Keshav Raj

Abstract: This paper studies the biodiesel's key advantages that are its portability and ready availability. It is non-toxic, biodegradable, and ecologically friendly, has a high flash point, and may be mixed with diesel due to similar properties. Jatropha oil can be used in cooking, lubrication, paint binders and lighting lamps. This oil is used as a herbal medicine in skin diseases. Karanja is a medium size tree; easy to grow and becomes an adult in four to five years. It can survive in heat, drought, salinity and frost conditions. When vegetable oil is used as a fuel in a diesel engine, there are no serious issues. Most vegetable oils have limited technological application in their original forms because of their specific chemical and physical properties. To enhance their commercial application, vegetable oils are often modified using four different methods; hydrogenation, interesterification, fractionation and blending. Numerous advantages of biodiesel have also been discussed in this paper.
Keywords: *Biodiesel, Jatropha, Karanja, Vegetable oil*

I. INTRODUCTION

The environment is greatly polluted by emissions such as carbon monoxide (CO), CO2, NOx, SOx, unburnt or partially burnt hydrocarbons (HC) and particulate from transport vehicles. The chief contributors to urban air pollution and major source of greenhouse gases are fossil fuels, and they are considered to be the major cause of global warming. India imports petroleum products at an annual cost of approximately $50 billion in foreign exchange. In view of this high demand/cost of fossil fuels associated with higher emissions, it is necessary to find a suitable alternative to diesel oil. Replacing just 5% of petroleum fuel by biofuel could enable India to save $2.5 billion per year in foreign exchange. Exhaustive literature work on the use of vegetable oils and their blends in diesel engine applications has been published by various researchers. Various non-edible oils, such as jatropha, honge, honne, rubber seed, mahua, hazelnut kernel, waste cooking and cotton seed oils, are investigated for their suitability to diesel engine fuels.**[1]**

Biodiesel's key advantages are its portability and ready availability. It is non-toxic, biodegradable, and ecologically friendly, has a high flash point, and may be mixed with diesel due to similar properties. When vegetable oil is used as a fuel in a diesel engine, there are no serious issues. The transesterification procedure has proven to be one of the most effective ways to accomplish this. Various vegetable oils can be used to make biodiesel. Edible oil is in high demand as a food source. The use of non-edible oils will help to tackle the problem of fuel shortages while also reducing the demand for edible oils. Biodiesel is one of the most important alternative sources for diesel fuel, and it may be manufactured from a range of non-edible plants. **[2]** Biodiesel production from non-edible oil feedstocks can address the challenges of food vs. fuel, as well as environmental and economic concerns about edible vegetables. They can also be planted along trains, roads, and irrigation canals, as well as on farmers' field boundaries, fallow fields, and public land. Various oils derived from non-edible crop seeds or kernels could be used as biodiesel feedstocks. jatropha, karanja, and other non-edible oil plants are essential. The oils of jatropha and karanja are the most commonly utilised feedstocks in biodiesel production. Edible oils are not produced in sufficient quantities in many countries to suit human needs, so they must be imported. As a result, biodiesel made from edible oils is substantially more expensive than petrodiesel. India is an intriguing case study in biodiesel generation from edible vegetable oils, where roughly 46% of the required amounts for domestic needs are imported. **[2]**

Jatropha oil can be used in cooking, lubricantion, paint binders and lighting lamps. This oil is used as a herbal medicine in skin diseases. The higher density, viscosity and lower calorific value of jatropha oil prevent the use of it directly in conventional diesel engine. Mechanical presses can extract jatropha oil from these seeds. Produced jatropha biodiesel from jatropha oil can be used in diesel engines and oil burners with oil pretreatment. Manual and simple methods of oil extraction from seeds are presently of less use. The oil can be extracted from jatropha seeds by Sundhara and Komet oil expellers. The screw press produced higher oil yield with acceptable physical properties. Screw press was used to produce the oil from cooked seeds and it is very efficient because of its higher yield. The high extraction temperature has an effect on the free fatty acid percentage of the extracted oil. **[3]**

The general processing of biodiesel from Jatropha curcas oil involves three major steps, namely seed drying, oil extraction, and transesterification (the processing of pure vegetable oil into biodiesel). There are also other minor steps that are considered significant, such as the cleaning of the seeds, dehulling, and post-harvest storage. The conventional technique for recovering oils from Jatropha seeds is through the use of a mechanical screw press machine. However, a large proportion of the oil is retained in the kernel, which requires more effective ways to extract the residual oil. The most notable extraction techniques include ultrasound-assisted systems, enzyme extraction, and the utilization of catalytic materials. The catalyst materials are chemicals that enhance the process of transesterification. The extraction method is closely related to the cost of mass biodiesel production in a biorefinery plant **[4]**

Jatropha curcas Planting Challenges in Malaysia

Jatropha curcas is a highly promising crop for biodiesel production, although supportive innovative technologies are required for planting, harvesting, and oil extraction. Furthermore, mechanized crop operations are limited, and hence Malaysia needs to import the knowledge and machines from other countries such as India. Other notable challenges of Jatropha production are the poor seed yield, low impute crop, and pest and disease vulnerability. Although it is a promising crop for biodiesel production, the unavailability of a high-yielding cultivar is a major failure factor **[5].**

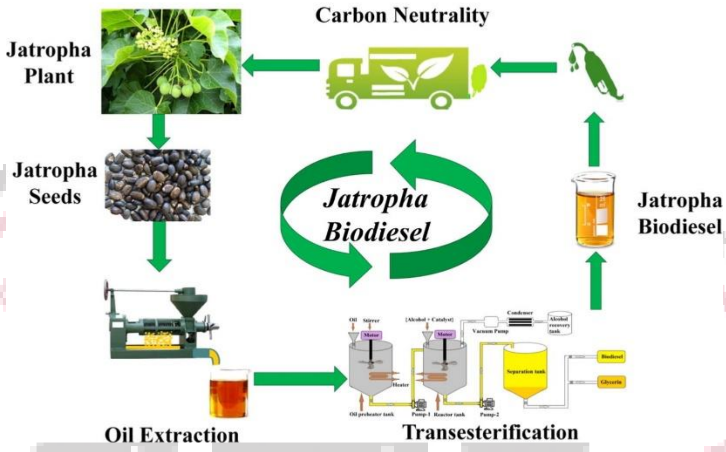

Fig.1 Jatropha oil [6]

Karanja as a potential feedstock

Karanja is also called Pongamia Pinnata. It is a medium size tree; easy to grow and becomes an adult in four to five years. It can survive in heat, drought, salinity and frost conditions. It is a monotypic genus grows abundantly along coasts, riverbanks and reclaims marginal lands but it requires full overhead light in early stages. In India, it found from Himalayan foothills to Kanyakumari. At many places, its seeds remain unused. Karanja fruits have viability period of one year; seeds number varies between 9–90 kg per tree. Karanja pods are elliptical in shape and contain a single seed. Pods are 2–3 cm wide and 3–6 cm long with thick walled. Karanja seeds are brown and 10–20 mm long. Karanja Seed has 27–39% of the oil. The presence of toxic di-ketone pongamol and Karanjin in Karanja oil makes it non-edible oil. Around 10,000 t of Karanja seeds are annually trading in Tamilnadu, Kerala, Karnataka, Maharashtra and Andhra Pradesh.**[7]**

Fig.2 Karanja

Vegetable oils for diesel engine

Vegetable oils are renewable and environment-friendly fuel for diesel engine. Rudolf Diesel had tested peanut oil before 100 years in a diesel engine. However, vegetable oils did not use in diesel engine due to the availability of cheaper petroleum fuel (diesel) for CI engines **[7].**

Oils and fats are used for cooking and frying as well as in food formulations. Most vegetable oils have limited technological application in their original forms because of their specific chemical and physical properties. To enhance their commercial application, vegetable oils are often modified using four different methods; hydrogenation, interesterification, fractionation and blending. Hydrogenation of vegetable oils to obtain oils/fats with improved texture and oxidative stability has been used for a long time. Hydrogen gas and nickel as a catalyst saturate some double bonds in the unsaturated fatty acids. Unfortunately, during hydrogenation some double bonds can be isomerized and converted from cis state to trans state.

Trans fatty acids are known to have negative effects on health and can cause different diseases. Interesterification is an alternative process to hydrogenation. Fatty acids are redistributed in the triacylglycerol structure during this process and no saturation or isomerization occurs. However, this process needs special equipment and is more expensive. Fractionation is a process in which some fats/oils are separated into two fractions with different melting and textural properties. This process is often used for some fats/oil such as palm oil or tallow. Fractionation can be an independent process or can be used as a pretreatment prior to hydrogenation, interesterification or blending.**[8]**

II. LITERATURE REVIEW

Aboubakar Gomna et. al. (2019)[9] With the possible depletion of oil resources and environmental considerations, vegetable oils are considered with great interest in high-temperature applications especially for solar plants. Many parameters affect vegetable oil stability, namely temperature, oxygen, moisture, duration of exposure to heat, etc. Conventional markers such as peroxide or free fatty acids do not always reliably indicate oil quality at high temperature. Evaluating the content of other degradation products such as polymers provides a better estimate. Reducing exposure to oxygen limits oil degradation. Vegetable oils have proven to be a favourable alternative to mineral oils in some applications, and several vegetable oils are commercially available. Their current use in solar cookers gives a good overview of their potential. Several reasons advocate for the use of vegetable oils in concentrating solar power plants: they are renewable resources, environmentally friendly, non-hazardous, highly available and less flammable products. Moreover, their thermophysical properties are similar, if not better, than those of thermal oils commonly used in solar plants. Despite these advantages, vegetable oils face some challenges, as for example their low oxidation stability. If the major challenge of using vegetable oils at high temperatures is their oxidation stability, the numerous environmental, economic and technological advantages make them innovative fluids for high temperature applications, particularly for solar applications.
Kumar A, et. al. (2016)[10] Oils of plant origin have been predominantly used for food-based applications. Plant oils not only represent a non-polluting renewable resource but also provide a wide diversity in fatty acids (FAs) composition with diverse applications. Besides being edible, they are now increasingly being used in industrial applications such as paints, lubricants, soaps, biofuels etc. In addition, plants can be engineered to produce fatty acids which are nutritionally beneficial to human health. Thus these oils have potential to 1) substitute ever increasing demand of non –renewable petroleum sources for industrial application and 2) also spare the marine life by providing an alternative source to nutritionally and medically important long chain polyunsaturated fatty acids or 'Fish oil'. The biochemical pathways producing storage oils in plants have been extensively characterized, but the factors regulating fatty acid synthesis and controlling total oil content in oilseed crops are still poorly understood. Thus understanding of plant lipid metabolism is fundamental to its manipulation and increased production. This review on oils discusses fatty acids of nutritional and industrial importance, and approaches for achieving future designer vegetable oil for both edible and non-edible uses. The review will discuss the success and bottlenecks in efficient production of novel FAs in non-native plants using genetic engineering as a tool.
Uppar, R, et. al. (2022)[11] Lubrication is a procedure that involves the use of a chemical called lubricant to reduce wear on surfaces that are in relative motion with each other. It aids in the transmission of pressure created between opposing surfaces. Lubricants serve as anti-friction agents. They allow for flat-level operations by retaining superior machine functionality and reducing the likelihood of recurring breakdowns. In today's world, the price of crude oil is rising in tandem with the depletion of reservoirs (oil). As a result, protecting a pollution-free environment is a major responsibility. The focus of current research is on creating and using an ecologically friendly lubricant made from renewable resources. This paper discusses the preparation, characteristics, characterization advantages, and uses of vegetable oil-based non-edible lubricants. Chemical changes are required since vegetable oil-based lubricants have lower thermal and oxidative stability. The article explores the required chemical modification approaches for improving the properties of bio-lubricants. The characterization of bio-lubricants has been elaborately discussed, highlighting the major pros and cons. The drawbacks and also future scope of the bio-lubricants have been highlighted.
Nde DB, et. al. (2020)[12] Most seed oils are edible while some are used generally as raw material for soap production, chocolate, margarine, and recently in biodiesel formulations as potential candidates capable of replacing fossil fuels which are costly and destructive to the environment. Oilseeds are a green and major reservoir which when properly exploited can be used sustainably for the production of chemicals at both the laboratory and industrial scales. Oil extraction is one of the most critical steps in seed oil processing because it determines the quality and quantity of oil extracted. Optimization of the extraction conditions for each extraction method enhances yield and quality meanwhile a carefully chosen optimization process equally has the potential of saving time and heat requirements with an associated consequence on cost reduction of the entire process. In this review, the techniques used to optimize oil extraction from plant materials which can be consulted by stakeholders in the field are brought to focus and the merits and demerits of these methods highlighted. Additionally, different types of optimization techniques used for various processes including modeling and the software employed in the optimization processes are discussed. Finally, the quality of the oil as affected by the methods of extraction and the optimization process used are also presented.
Danov, S, et. al. (2017)[13] The present critical review reports the recent progress of the last 15 years in the selective epoxidation of vegetable oils and their derivatives, in particular unsaturated fatty acids (UFAs) and fatty acid methyl esters (FAMEs). Epoxidized vegetable oils (EVOs) have drawn much attention in recent years in the chemical industry since they are environmentally friendly, biodegradable, renewable, highly available and non-toxic. Four major types of catalysts are used to produce epoxidized fatty acid compounds: homogeneous, heterogeneous, polyoxometalates and lipases. EVOs are

currently produced in industry by a homogeneous catalytic conventional epoxidation process, in which the unsaturated oils are converted with percarboxylic acids, such as peracetic or performic acid. However, this method suffers from several drawbacks such as (1) relatively low selectivity for epoxides due to oxirane ring opening, (2) corrosion problems caused by the strong acids in an oxidizing environment, etc. Thus, in view of the principles of green chemistry, the development of new catalytic systems for the selective epoxidation of vegetable oils and their derivatives is an actual task. Furthermore, in our opinion, epoxidized fatty acids and epoxidized fatty acid methyl esters can be a promising substitute for EVOs because the starting materials for their production have a lower viscosity and higher reactivity, which will significantly increase the productivity of the epoxidation process. In this work, we tried to determine the prospects of using the main catalytic methods in industry to obtain epoxidized fatty acid compounds.

Maryom Dabi, et. al. (2019)[14] Vegetable oils have been identified as the promising alternative source to replace fossil based fuel in the compression ignition (CI) engine. It is renewable and possesses characteristics that is similar to that of the diesel. Biodiesel, transesterifiedform of vegetable oil (VO), is now being commercially used in CI engines. However, biodiesel production from VO involves use of alcohols and chemicals which results the need of skilled labor and investment for its production. In view of this, many studies are also being carried out on the direct use of VO in the engine. The direct use of VO oil in engine is as good as that of the diesel. The superior quality of diesel however makes it better performance in engine as compared to the vegetable oil. Preheating and blending of VO are found to be the most common solution to overcome its inferior properties. The use of preheated and blended VO is found to improve the engine overall performance. This paper is focused exclusively on the one-to-one basis of study pertaining to the effect of neat, preheated and blended vegetable oils on diesel engine performance and emission through supplementation of illustrative figures from the various experimental studies.

Puneet Verma, et. al.(2020)[15] The rising pollution levels resulting from vehicular emissions and limited reserves of petroleum based fuels have left mankind in pursuit of alternatives to diesel. There have been stringent regulations generated by authorities around the world regarding vehicular emissions from internal combustion engines. To this end, researchers have been exploring different sources of alternative fuels such as biodiesel produced from non-edible oil sources such as Karanja, Jatropha accompanied by the alcohol fuels, methanol, ethanol, butanol and propanol. This work has experimentally investigated the impacts of various blends of Karanja biodiesel with a chain of fewer alcohols (ethanol, 2-propanol, methanol, 1-butanol and 1-pentanol) to identify the potential of higher alcohols in the production of biodiesel and application to the diesel engine. The results showed that the brake thermal efficiency was decreased by 3.3%, while an increased brake specific fuel consumption was recorded for KOPnE20 by 11.75% compared to the mineral diesel fuel, which could be attributed to the higher calorific values of the respective fuels. The emission results indicated that the carbon dioxide emission increased by 32.25% while the nitrogen of oxide emission decreased by 6.72% for KOPnE20 compared to the diesel fuel at full load condition.

Abhijeet D. Sangle et. al. (2016)[16] Biodiesel has become a key source as a substitution fuel and is making its place as a key future renewable energy source. As an alternative fuel for diesel engines, it is becoming increasingly important due to diminishing petroleum reserves and the environmental consequences of exhaust gases from petroleum-fuelled engines Rapid growth in industrialization of developing countries is resulting in increasing demand for new & ecofriendly energy sources. Depletion of petroleum resources has led to the search for alternative fuel which is renewable, biodegradable and easily available. To satisfy this demand biodiesel derived from different plants oils is comparatively better option. Vegetable oils can be used directly or blended with diesel to fuel diesel (CI) engines. Conversion of vegetable oils into fatty acid methyl ester by trans-esterification is the most convenient method of transforming vegetable oil to biodiesel. The proportional blends of Karanja and Caster can be used in existing Compression ignition engines without any modifications.

III. ADVANTAGES OF BIODIESEL

1) Biodiesel is non-toxic and also safe to transport from one point to another owing to its relative high flash point.
2) Provision of foreign exchange earners. The availability and abundance of feedstock oil seeds in specific areas have created job opportunities for local farmers in creating more plantations of the feedstocks and increasing the production for foreign exchange.
3) Diesel engines have proved to be more efficient than petrol engines in term of energy conversion and power output.
4) The efficiency of engine shelf-life can now be prolonged while reducing the costs of procurement of early replacement.
5) Biodiesel are clean burning fuels. The combustion of biodiesel in IC engines reduce the release and impact of GHG. Literature studies suggest that the combustion of biodiesel reduces GHG by 40%–65% **[17].** Compared to the last 20 years, GHG of major cities with high automobiles usage in the world will be reduced by more than 20% **[18].**
6) Better thermal efficiency from friction reduction as a result of smoother lubricating quality of biodiesel–diesel blends.
7) The raw materials for biodiesel production are organic and easy to source. More biodiesel products can be made available from different plant oil materials and waste oil **[19].**
8) Biodiesel is renewable and does not give rise to global warming due to its closed carbon cycle. Amount of the carbon taken by plants are returned back to the atmosphere. Biodiesel is carbon neutral because it contributes zero emissions to global warming.

In search of a renewable alternative fuel that can suitably replace fossil fuels and the environmental impacts consideration of emissions from petrochemical products, researchers have directed their interests to biomass-derived fuels. This appears to be the logical solution to the environmental concerns, energy security challenges and socioeconomic issues facing the conventional petrol–diesel. According to the records of Web of Science, publications records focusing on development of biofuels and their applications in several areas have increased from 1988 in 2010 to 4061 in 2018, with records to show the spatial distribution all around the globe. One (1) publication was recorded on the use of biodiesel in diesel engine in 1994 while the number has increased over the years gradually to 418 documents from different parts of the world in 2018. The documents by country analysis recovered a total of 2736 peer-reviewed documents related to performance of biodiesel combustion in vehicular diesel engines between 1994 and 2018, with India leading 1339 publications. The distribution of journal publications counts for fifteen leading countries where biodiesel fuel technology is being used as fuel in diesel engines. **[20]**

IV .CONCLUSION

The use of non-edible oils will help to tackle the problem of fuel shortages while also reducing the demand for edible oils. Biodiesel is one of the most important alternative sources for diesel fuel, and it may be manufactured from a range of non-edible plants. Biodiesel production from non-edible oil feedstocks can address the challenges of food vs. fuel, as well as environmental and economic concerns about edible vegetables. They can also be planted along trains, roads, and irrigation canals, as well as on farmers' field boundaries, fallow fields, and public land. Various oils derived from non-edible crop seeds or kernels could be used as biodiesel feedstocks. jatropha, karanja, and other non-edible oil plants are essential. The oils of jatropha and karanja are the most commonly utilised feedstocks in biodiesel production. In search of a renewable alternative fuel that can suitably replace fossil fuels and the environmental impacts consideration of emissions from petrochemical products, researchers have directed their interests to biomass-derived fuels. This appears to be the logical solution to the environmental concerns, energy security challenges and socioeconomic issues facing the conventional petrol–diesel.

REFERENCES:

[1] Ganesh Shirsath, M. S. Tandale, S. V. Khandal, G Suresh, N. R. Banapurmath, V. S. Yaliwal & P. G. Tiwari (2012): Blends of karanja and jatropha biodiesels for diesel engine applications, International Journal of Sustainable Engineering, DOI:10.1080/19397038.2011.652220

[2] Palande, D., Ghuge, N., & Shrivastwa, R. (2022). Comprehensive Review Of Karanja And Jatropha biodiesel Fuelled Diesel Engines. Transdisciplinary Journal of Engineering & Science, 13.

[3] M.S. Gad, A.S. El-Shafay, H.M. Abu Hashish, Assessment of diesel engine performance, emissions and combustion characteristics burning biodiesel blends from jatropha seeds, Process Safety and Environmental Protection, Volume 147, 2021, Pages 518-526, ISSN 0957-5820, https://doi.org/10.1016/j.psep.2020.11.034.

[4] Che Hamzah NH, Khairuddin N, Siddique BM, Hassan MA. Potential of Jatropha curcas L. as Biodiesel Feedstock in Malaysia: A Concise Review. Processes. 2020; 8(7):786. https://doi.org/10.3390/pr8070786

[5] Moniruzzaman, M.; Yaakob, Z.; Shanizuzzaman, M.; Khatun, R.; Islam, A.K.M.A. Jatropha Biofuel Industry: The Challenges; INTECH OPEN: London, UK, 2017. [Google Scholar] [CrossRef][Green Version]

[6] Digambar Singh, Dilip Sharma, S.L. Soni, Chandrapal Singh Inda, Sumit Sharma, Pushpendra Kumar Sharma, Amit Jhalani, A comprehensive review of physicochemical properties, production process, performance and emissions characteristics of 2nd generation biodiesel feedstock: Jatropha curcas, Fuel, Volume 285, 2021, 119110, ISSN 0016-2361, https://doi.org/10.1016/j.fuel.2020.119110.

[7] Patel, R.L., Renewable and Sustainable Energy Reviews (2016), http://dx.doi.org/10.1016/j.rser.2016.12.075

[8] Fataneh Hashempour-Baltork, Mohammadali Torbati, Sodeif Azadmard-Damirchi, Geoffrey P. Savage, Vegetable oil blending: A review of physicochemical, nutritional and health effects, Trends in Food Science & Technology, Volume 57, Part A, 2016, Pages 52-58, ISSN 0924-2244, https://doi.org/10.1016/j.tifs.2016.09.007.

[9] Aboubakar Gomna, Kokouvi Edem N'Tsoukpoe, Nolwenn Le Pierrès, Yézouma Coulibaly, Review of vegetable oils behaviour at high temperature for solar plants: Stability, properties and current applications, Solar Energy Materials and Solar Cells, Volume 200, 2019, 109956, ISSN 0927-0248, https://doi.org/10.1016/j.solmat.2019.109956.

[10] Kumar A, Sharma A, Upadhyaya KC. Vegetable Oil: Nutritional and Industrial Perspective. Curr Genomics. 2016 Jun;17(3):230-40. doi: 10.2174/1389202917666160202220107. PMID: 27252590; PMCID: PMC4869010.

[11] Uppar, R., Dinesha, P. & Kumar, S. A critical review on vegetable oil-based bio-lubricants: preparation, characterization, and challenges. Environ Dev Sustain (2022). https://doi.org/10.1007/s10668-022-02669-w

[12] Nde DB, Foncha AC. Optimization Methods for the Extraction of Vegetable Oils: A Review. Processes. 2020; 8(2):209. https://doi.org/10.3390/pr8020209

[13] Danov, S. M., Kazantsev, O. A., Esipovich, A. L., Belousov, A. S., Rogozhin, A. E., & Kanakov, E. A. (2017). Recent advances in the field of selective epoxidation of vegetable oils and their derivatives: a review and perspective. Catalysis Science & Technology, 7(17), 3659-3675.

[14] Maryom Dabi, Ujjwal K. Saha, Application potential of vegetable oils as alternative to diesel fuels in compression ignition engines: A review, Journal of the Energy Institute, Volume 92, Issue 6, 2019, Pages 1710-1726, ISSN 1743-9671, https://doi.org/10.1016/j.joei.2019.01.003.

[15] Puneet Verma, Gaurav Dwivedi, Arun Kumar Behura, Devendra Kumar Patel, Tikendra Nath Verma, Arivalagan Pugazhendhi, Experimental investigation of diesel engine fuelled with different alkyl esters of Karanja oil, Fuel, Volume 275, 2020, 117920, ISSN 0016-2361, https://doi.org/10.1016/j.fuel.2020.117920.

[16] Abhijeet D. Sangle, Tushar Katratwar, S. S. Deshmukh, Shrikant Baste, 2016, A Review: Biodiesel from Castor & Karanja Oil, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 05, Issue 10 (October 2016), http://dx.doi.org/10.17577/IJERTV5IS100233a

[17] Hanaki, K., & Portugal-Pereira, J. (2018). The effect of biofuel production on greenhouse gas emission reductions. Biofuels and sustainability: holistic perspectives for policy-making, 53-71.

[18] International Energy Agency. (2018). Global Energy & CO2 Status Report the latest trends in energy and emissions.

[19] da Silva, K.R.N., Corazza, M.Z., Raposo, J.L. (2018). Renewable Energy Sources: A Sustainable Strategy for Biodiesel Productions. In: Trindade, M. (eds) Increased Biodiesel Efficiency. Green Energy and Technology. Springer, Cham. https://doi.org/10.1007/978-3-319-73552-8_1

[20] Oyetola Ogunkunle, Noor A. Ahmed, A review of global current scenario of biodiesel adoption and combustion in vehicular diesel engines, Energy Reports, Volume 5, 2019, Pages 1560-1579, ISSN 2352-4847, https://doi.org/10.1016/j.egyr.2019.10.028.