Production of biodiesel from Aegle marmelos correa seed oil for fuel cell application

Vinoth Thangarasu, Anand Ramanathan*
Department of Mechanical Engineering, National Institute of Technology, Tiruchirappalli-620 015, India.
*Corresponding Author. Tel: (0431) 2503423, Fax: (0431) 2503423, E-mail: anandachu@nitt.edu

Abstract. Energy acting an important role in the development of any country. In an emerging country like India, energy plays an important role to fulfill the energy demand by the industry as well as society. Each year there is an increase in demand for energy. Currently, most of the demand for energy is filled with a petrol-based product that creates the problem of sustainable supply of energy and increasing problems like, pollution, global warming, etc. The huge quantities of energy require a huge amount of fuel, spending this huge amount of fuel across the world have adverse effects on the environment which cannot be altered after damage being done. Energy production from fossil fuel is the main reason for environmental degradation which effects on human health, disturbs the ecological equilibrium and biotic diversity. There is a requirement of the alternate and renewable source to tackle the energy demand as well as keeping a safe environment. Bioenergy productions from biofuels have emerged as one of the most popular sources. The biofuels are a promising, renewable and eco-friendly source of energy that can replace fossil. To avoid the effects of growing energy demand on the environment, human life in near future and satisfy present energy demand, these biofuels have the potential to provide energy services with almost zero emissions of air pollutants and greenhouse gases. This paper aims at emphasizing the production of biodiesel from Aegle marmelos Correa seed oil. Maximum biodiesel yield of 95% was obtained using a potassium hydroxide catalyst. Physical and chemical properties of biodiesel were determined as per American Society for Testing Method D6751 standards. It can be concluded that biodiesel produced from Aegle marmelos Correa seed oil can be another energy source to substitute the petroleum diesel fuel. Further, AMC biodiesel can be a promising source to produce hydrogen for fuel cell application.

Keywords: Aegle Marmelos Correa Seed; Oil extraction; Acetone; Heptane; Design Expert; Biodiesel production; Fuel Cell.

1. Introduction
Because of the expanding vitality request and contamination issues created by the utilization of fossil fuels, it is essential to create elective energizes and additionally renewable vitality source. As an alternative fuel, biodiesel is turning out to be progressively imperative because of decreasing petroleum holds and antagonistic ecological results of fumes gasses from fossil fuel fuelled engines [1,2].

Our over-dependence on fossil fuel, increasing oil demand and monetary value, environmental problems caused by fossil fuels stimulated the search of a new alternative to fossil fuels. The emission of CO, unburned hydrocarbons, the particulate matter gets reduced by the biodiesel from edible oil, non-edible oil, animal fats algae, etc. compared to fossil fuels [3,4]. Biodiesel is an Eco-friendly and renewable fuel that can be utilized as an alternative to petroleum diesel due to the increasing energy demand [5].
Renewable energy is a source of energy which is not diminishing with human consumption, which is collected from natural resources like wind, sunlight, tide, rain, and biomass. In the areas of electricity generation, air and water heating and transportation, biomass, and geothermal energy played a significant role. Petroleum fuels are formed under the earth’s surface due to entrapped biomass, which is a non-renewable source of energy.

A biofuel is a fuel derived from biomass, which included animal materials, industrial wastes, and algae’s and plant materials. Due to the anaerobic digestion of this biomass, a chemical change takes place on the biomass leads to the production of chemicals which can be used as a fuel. The increase in pollution caused by fossil fuels leads to the searching of new alternative fuels like biofuels are an excellent alternative to petroleum fuels.

The principle feedstock’s for biodiesel is edible oil, non-edible oil, waste cooking oil, animal fats and algae’s, etc. The perspective of the limitation of satisfying oil for human use, the non-edible oils are the promising alternative for the production of biodiesel. In India, unflinching efforts are going on to find a new sustainable energy source. In the northeast part of India, lots of oil-bearing plants are growing, the seeds of these plants are not appropriately utilized [6]. The production of biodiesel from edible has been inconceivable in India since despite everything we depend on different nations for edible oil in order to meet the demand [7].

The cost of the biodiesel feedstocks, the cost of the methanol, by-products of biodiesel production assumes a noteworthy part in the overall economy of the biodiesel production process. At the time of biodiesel production, a considerable amount of biowastes like glycerol, seed cake, seed shell, etc., is generated. Utilization of these by-products is essential for improving the overall economy of the biodiesel production process [8].

Jatropha, Karanja, Neem, Mahua, Rubber are some proven non-edible feedstocks. In order to meet the enormous energy requirement of a country like India, these proven non-edible feedstocks are not sufficient. Here comes the importance of finding new non-edible feedstock for producing biodiesel. Aegle Marmelos Correa is famous for medical uses. The seed is not yet appropriately utilized. The oil from the seed can be used for producing biodiesel.

Biodiesel can be produced by the chemical process such as transesterification of straight vegetable oils or animal fats with alcohol in the bearing of a suitable catalyst [9]. Transesterification is the process of reaction between triglycerides present in the oil with alcohol in the presence of a strong base to form a mixture of alkyl esters with glycerol. The transesterification reaction is a chain reaction in which triglyceride first converted into di-glyceride then into monoglyceride finally it forms a mixture of alkyl esters [10].

Biodiesel is a fuel derived from plant materials which consist of triglycerides. The triglycerides present in the plant material which compelled to react with methanol with a suitable catalyst produce biodiesel. Mainly biodiesel is mono-alkyl esters of free fatty acids. Laura et al., [11] used oil containing high free fatty acid for the synthesis of biodiesel. The properties of biodiesel are almost comparable to that of petroleum diesel, so it named as biodiesel. Biodiesel can be used in diesel engine directly or with some engine modification or as a blend with petroleum diesel. The process of converting triglycerides into biodiesel called transesterification.

Edible oils are the oil, which is used for human consumption. The commonly used edible oils are coconut oil, palm oil, mustard oil, soybean oil, sunflower oil, etc. edible oils are used to produce biodiesel by transesterification method. Biodiesel is, for the most part, arranged from expectedly developed edible oils, for example, rapeseed, soybean, sunflower, and palm along these lines prompting to reduce nourishment versus fuel issue [12]. Around 7% of worldwide vegetable, oil supplies were utilised for biodiesel generation as a part of 2007. Full utilization of consumable oils may bring about other critical issues, for example, starvation in creating nations. The utilization of non-consumable plant oils when contrasted and edible oils are incredibly critical in creating nations on account of the gigantic interest for edible oils as sustenance, and they are costly to be utilised as fuel at present.
Non-edible oil is not used for human consumption. Hundreds of varieties of non-edible seeds are available in the world which is not properly utilizing. Presently, more than 95% of the world biodiesel is delivered from eatable oil, which is effortlessly accessible on an expansive scale from the rural business. Be that as it may, constant and substantial scale generation of biodiesel from eatable oil without appropriate, arranging may bring about adverse effects to the world, for example, consumption of nourishment supply prompting to financial irregularity. A conceivable answer for conquering this issue is to utilize non-eatable oil or waste cooking oil.

In this research, the effect of factors such as solid-liquid proportion and extraction time on Aegle Marmelos Correa seed oil yield were analyzed using Mixture of Simple lattice Design and Optimal Design to optimize the Maceration extraction method. Further, biodiesel was produced from extracted AMC crude oil for fuel cell applications.

2. Materials and methods
Aegle Marmelos Correa fruit is to be collected from Indian Council of Forestry Research and Education, Coimbatore, TamilNadu. Figure 1 shows the photograph view of the fruit and bi-section fruits. Methanol (99.9% purity), phosphoric acid (H₃PO₄ 80%), Hydrochloric acid (HCl, 38%) Sulphuric acid (H₂SO₄, 98%), Sigma Aldrich, Bangalore.

2.1. Oil extraction
Aegle Marmelos Correa, generally known as bael, also vilvam, golden apple and wood apple, is a species of tree native to India, Srilanka, and Bangladesh. It is widely available in Southeast Asia countries like as Pakistan, Burma, Vietnam, and Thailand. Its fruits are utilized in Ayurvedic medicine and leaves of the tree used for Lord Shiva as part of worship. The bael fruit has a smooth wooden shell with green, grey or yellow skin. The maturation of trees takes about 11 months and can reach the size of a bigger grapefruit, and some are much bigger. The shell is very hard that its necessity to bisect with a pestle or hammer. The seed of the fruit is extracted and collected in a container. The preparation of the seeds before an oil extraction step depends on the kind of seed and the required quality of the oil. Initially; the seed is mixed with seed gel and fruit pulp. The seed is soaked in water for 2 hrs. for easy removal of gel, materials stick onto the surface of the seed. After that, the seed is cleaned using a metal strainer. The cleaned seed is dried in sunlight for 24 hours and stored in a plastic container for future use.

The dried seed is crushed into small particles using a household 750 W grinder. The crushed sample was sieved to 0.75 mm particle size and dried in sunlight before extraction. Heptane and acetone are used for the extraction of oil from the seed. Acetone (99%, Boiling range 55.5 – 56.5 °C, CDH) and Heptane (85%, Boiling range 90 – 100 °C, (Loba Chemie). The average particle size is estimated by the average size of the sieves between which the seed particles are caught:
\[ \text{d}_p = \frac{d_{p,\text{max}} + d_{p,\text{min}}}{2} \] (1)

Maceration is carried out using 100 g seed in a 3 neck round bottom flask using 400 ml solvent (acetone: heptane). The flask is kept in a container \( \frac{1}{2} \) filled with water to keep the solvent temperature below the atmospheric temperature in order to reduce the solvent evaporation at the time of stirring. A stirrer rod was introduced into the flask through the top, and the speed of stirring is adjusted to 600 rpm by using a digital rpm indicator and the knob. The experimental setup used for oil extraction is given in figure 2.

![Figure 2. A schematic and photographic view of oil extraction setup](image)

The extracted solvent seed mixture is filtered using a filter paper of Whatman Grade No.44 ashless filter paper by using vacuum filtration. The oil-solvent mixture is poured into a ceramic conical funnel; the filter paper was fitted in the bottom of the funnel. It took a few hours to filter 1 liter of solvent–oil mixture. The top of the funnel is closed at the time of filtration in order to prevent the evaporation of the solvent. Acetone and Heptane were evaporated at 50 °C and 94 °C respectively and collected in flask separately. Pure Aegle Marmelos Correa oil obtained after distillation.

2.2. Biodiesel production

The transesterification process was carried out in a hot plate system. The reactor system consists of 3-neck flat bottom glass type flask and reflux condenser. Initially, 50 g of AMC oil was preheated to 50 °C for 30 min to remove moisture content. Then methanol catalyst solution was prepared by taking a 1:6 molar ratio of oil to methanol and 1 wt% of potassium hydroxide catalyst and mixed thoroughly. After that reaction was carried out with 700 rpm stirring speed for 60 min at 60 °C in a 250 ml glass type flask fitted with a reflux condenser. After completion of the transesterification process, the resultant product was shifted into a separating funnel. After 6 hours of settling time, two distinct layers were formed. Top and bottom layer consist of biodiesel and glycerol respectively. The biodiesel was collected and was washed with hot water at 60 °C to remove the remaining catalyst, methanol, and glycerol.

3. Results and discussion

3.1. Effect of various process parameters on oil extraction

The effect of solid to the liquid ratio on the extraction of AMC oil yield is shown in figure 3. The results indicated that no variation in the AMC oil yield was observed to increase in solid to liquid proportion from 1:4 to 1:6 for all 22 runs. In research work, a variation of solid-liquid ratios showed that insignificant role on the oil yield (figure 3). The result obtained from this design (1:4 solid to liquid ratios) was selected to be included in further Multilevel Categoric Design.
Figure 3. Variation of the oil yields with the different solid-liquid proportion

Figure 4. Variation of extraction time on AMC oil yield

The effect of extraction time on AMC oil yield is shown in figure 4. The maximum yield of oil was achieved in 2.5 h (solid-liquid proportion (1:4), particle size (1.02), Acetone/Heptane (50/50 %, by volume)), but no significant difference was observed between 2.5 h and 4 h for the same solid-liquid proportion, particle size and Acetone/Heptane concentration. The graph showed that there was no substantial benefit to prolonging the duration (more than 2.5 h) of maceration since the solvent has already saturated.

4. Conclusions

Maceration assisted oil extraction from Aegle Marmelos Correa seeds by using Acetone and Heptane (50/50%) solvent mixture exhibited improved oil yield than other solvents. The Acetone/Heptane solvent mixture 50/50 %, by volume, the solid-liquid proportion and of 1:4 and 0.75 mm particle size for 2.5 hours of extraction time gave a maximum oil yield percentage which is 43%. In this study, the results also exhibited the maximum oil yield than another soxhlet method of extraction. The oil gives an optimum conversion of biodiesel of 95% at a temperature of 56 ºC, one wt% of KOH catalyst and 1:9 oil-methanol ratio. The fatty acid composition and physicochemical properties of Aegle Marmelos
Correa biodiesel show that can be used to produce biodiesel. It can conclude that, AMC biodiesel could be a promising alternative source for the hydrogen production through steam reforming process and which will be used for hydrogen fuel cell applications.

5. Scope for future work
Hydrogen production is a crucial development for the future alternative energy system to provide a clean and affordable system energy supply. Currently, interest is increasing in the development of fluid conversion technologies to produce hydrogen from hydrocarbons rich liquid fuels. This option does not involve any additional development cost infrastructure, which could help reduce costs introduction of hydrogen into energy systems. Also, hydrogen can be used in electrochemical fuel cell applications.

References

[1] Murugesan A, Umarani C, Chinnusamy T R, Krishnan M, Subramanian R and Neduzchezhain N 2009 Production and analysis of bio-diesel from non-edible oils-A review Renew. Sustain. Energy Rev. 13 825–34
[2] Saba T, Estephane J, El Khoury B, El Khoury M, Khazma M, El Zakhem H and Aouad S 2016 Biodiesel production from refined sunflower vegetable oil over KOH/ZSM5 catalysts Renew. Energy 90 301–6
[3] Karmakar A, Karmakar S and Mukherjee S 2010 Properties of various plants and animals feedstocks for biodiesel production Bioresour. Technol. 101 7201–10
[4] Kasote D M, Badhe Y S and Hegde M V. 2013 Effect of mechanical press oil extraction processing on quality of linseed oil Ind. Crops Prod.
[5] Jesus A A, Almeida L C, Silva E A, Filho L C, Egues S M S, Franceschi E, Fortuny M, Santos A F, Araujo J, Sousa E M B D and Dariva C 2013 Extraction of palm oil using propane, ethanol and its mixtures as compressed solvent J. Supercrit. Fluids
[6] Canakci M and Van Gerpen J 2001 Biodiesel Production from Oils and Fats with High Free Fatty Acids Trans. Am. Soc. Agric. Eng.
[7] Pourzolfaghar H, Abnisa F, Daud W M A W and Aroua M K 2016 A review of the enzymatic hydroesterification process for biodiesel production Renew. Sustain. Energy Rev.
[8] Ayoola a a, Efeovbokhan V C, Bafuwa O T and David O T 2014 A Search for Alternative Solvent To Hexane During Neem Oil Extraction Int. J. Sci. Technol. 4 66–70
[9] Gratuito M K B, Panyathanmaporn T, Chumnanklang R A, Sirinuntawittaya N and Dutta A 2008 Production of activated carbon from coconut shell: Optimization using response surface methodology Bioresour. Technol.
[10] Buasri A, Kasapbutr B, Panapoy M and Chaiyut N 2012 Biodiesel production from waste cooking palm oil using calcium oxide supported on activated carbon as catalyst in a fixed bed reactor Korean J. Chem. Eng.
[11] Naik M, Meher L C, Naik S N and Das L M 2008 Production of biodiesel from high free fatty acid Karanja (Pongamia pinnata) oil Biomass and Bioenergy
[12] Balat M 2011 Potential alternatives to edible oils for biodiesel production - A review of current work Energy Convers. Manag. 52 1479–92

Acknowledgment
The authors would like to acknowledge the Department of Science and Technology, India for the financial support under Young Scientist Scheme. The authors also like to thank the Director and Head Department of Mechanical, National Institute of Technology, Tiruchirappalli for providing the experimental facility, valuable help, and support.