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Production and Characterization of Biodiesel from Tamarind Seed Via Transesterification

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ABSTRACT

In this present study, the conversion of tamarind seed into biodiesel was performed via transesterification process. The purpose of this study also included examining the impact of several reaction circumstances including methanol-to-oil ratio, catalyst quantity, and reaction time on biodiesel yields, as well as identifying optimal conditions for maximum yield. The physico-chemical properties of the produced biodiesel were examined and compared with conventional diesel and biodiesel to evaluate its viability as an alternative fuel. The methodology employed a two-step process: initially, the extraction of vegetable oil followed by transesterification to convert the extracted vegetable oil into biodiesel. Vegetable oil was extracted using a pressure-based liquid extraction apparatus. Before extraction, the seeds were typically heated at 40°C for 15-20 minutes to ensure optimal extraction conditions. The extracted vegetable oil then underwent transesterification at 55°C for 1-1.5 hours using various methanol-to-oil ratios and KOH as a catalyst. A maximum biodiesel yield of 83% was attained using a 6:1 methanol-to-vegetable oil molar ratio, 0.3g of KOH catalyst (1.5% of vegetable oil), and a reaction duration of 1.5 hours at 55°C. The produced biodiesel demonstrated a density of 855.2-943.1 kg/m^3, a viscosity of 4.9-5.4 cSt, a flash point between 149-155°C, and a cetane number between 66-68. The gross calorific value of the biodiesel was found to be between 27-29 MJ/kg, which was slightly lower than that of diesel (42-46 MJ/kg). These findings suggest that biodiesel produced from tamarind seed represents a viable alternative fuel option or a potential blend with conventional fuels.

Keywords: Biodiesel, Transesterification, Tamarind seed, Biomass, Alternative fuel

1. Introduction

The world is currently going through an unprecedented energy crisis, which has made it clear how important it is to find long-term solutions and new ways of doing things. Natural gas, coal, and oil are examples of fossil fuels, which account for 80-85% of the world's primary production of energy. Many studies have predicted that these resources will ultimately be depleted as time progresses as they are finite [1]. Moreover, petroleum fuel is becoming increasingly scarce due to high consumption rates, and the combustion of fossil fuels results in the release of significant quantities of greenhouse gases, which in turn contribute to ecosystem imbalances [2]. As the energy crisis is intensifying, researchers are amplifying their endeavors to create technologies that can extract energy and valuable by-products from both biodegradable and non-biodegradable solid wastes including biomass, agricultural waste, municipal solid waste, industrial waste, rubber, tires, and plastics, thereby promoting a more sustainable and resource-efficient future [3-5].

Biodiesel constitutes a viable alternative renewable energy source that can diminish reliance on fossil fuels while being less detrimental to the environment. These resources are significant because of their renewability, extensive availability, biodegradability, non-toxicity, and ecological sustainability. The high viscosity of vegetable oil precludes its direct usage in compression ignition engines. The transesterification process is the predominant technique utilized to generate biodiesel from vegetable oil by diminishing its viscosity [6]. Carbon monoxide and carbon dioxide emissions are greatly reduced by 50% and 78%, respectively, when biodiesel is used [7]. A variety of biomass sources including inedible seeds like neem, jatropha, mahua, karanja, rubber seed, and castor can be used for the production of biodiesel [8-9]. Tamarind seed also represents a significant resource for biodiesel manufacturing. Each tamarind seed constitutes 40-44% of the total weight of the tamarind fruit [10]. The tamarind seeds consist of 12-20% fiber, 50-55% carbohydrates, 20% tannins, and 4.5-16.2% oil content [11]. Bangladesh yearly produces approximately 12,000 tons of tamarind [12]. Numerous studies have looked into different ways to make biodiesel from a variety of materials such as animal tallow, microalgae, non-edible vegetable oils, leftover frying oils, and edible vegetable oils [13-15]. Kumbhar et al. [11] illustrated the manufacture of biodiesel from tamarind seeds, highlighting its superior combustion characteristics. They emphasized its potential as an alternative fuel with reduced greenhouse gas emissions and improved environmental sustainability relative to traditional fuels. Raju et al. [16] examined the combustion, emission, and performance attributes of biodiesel produced from tamarind seeds using transesterification. They assessed several biodiesel and diesel mixes in a four-stroke compression ignition diesel engine to analyze engine performance under diverse load circumstances. Mushtaq et al. [17] employed the Soxhlet extraction method to extract tamarind seed oil and utilized High Vacuum Fractional Distillation for its fractionation. The researchers examined the qualities and benefits of biodiesel, using various catalytic techniques such as acid, base, and enzyme catalysis for transesterification. The

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research evaluated the impact of these catalysts on biodiesel synthesis from both unfractionated and fractionated tamarind seeds.

This project aims to produce biodiesel from tamarind seeds through the transesterification process and identify the optimal conditions for maximizing product yield. Evaluation of the biodiesel's physico-chemical properties and a comparison with those of traditional diesel are the additional goals of the study. By doing so, this paper seeks to evaluate the feasibility of manufacturing biodiesel from this non-edible feedstock as a substitute for traditional diesel fuel.

2. Methodology

2.1 Feedstocks preparation

This study utilized tamarind seeds as feed material and bought from the local market. The seeds were first cleaned using a detergent with water to get rid of stones, mud, and sand from the seed body. After washing, the seeds were sun-dried to eliminate excess moisture. Once thoroughly dried, the seeds were grounded into small fragments which increased the surface area of the seeds and facilitated the vegetable oil extraction process.

2.2 Experimental procedure

The production of biodiesel from tamarind seeds involves two main steps: the extraction of vegetable oil from the seeds and the conversion of the extracted vegetable oil into biodiesel. A pressure-based liquid extraction machine was employed for the vegetable oil extraction as this technique maintains the properties of the seed oil and the byproduct. Before pressing, seeds were typically heated at 40°C for 15-20 minutes to ensure optimal conditions for maximum vegetable oil yield, preserve oil stability, and diminish gum saturation in the oil.

Table 1 Experimental conditions for biodiesel production

Alcohol-to-vegetable oil ratio	Catalyst quantity (g)	Reaction time (hour)	Reaction temperature (°C)
3:1	0.1	1	
6:1	0.16	1.5	55
8:1	0.3	2	
10:1	0.4	2.5	

To convert the extracted vegetable oil into biodiesel transesterification process was utilized. The reaction was conducted at 55°C using a hotbox oven where the vegetable oil was forcefully agitated with a methanol-KOH solution in a conical flax. The reaction temperature of 55°C was chosen as methanol has a boiling point of 65°C and a higher temperature could lead to a reduction in biodiesel yield. After every minute the conical flax was shaken to enhance the reaction rate. The reaction continued for 1-1.5 hours while maintaining the temperature. Following this, the mixture was allowed to settle for 24 hours. This settling process resulted in biodiesel floating on top and glycerin accumulating at the bottom of the separator. Both the biodiesel and glycerin were carefully separated. To assess the impact of alcohol-to-vegetable oil ratio, catalyst quantity, and reaction time on biodiesel yield each variable was evaluated independently as detailed in Table 1. Fig. 1. shows (a) the formation of two layers in the separator and (b) the biodiesel obtained after separation. Warm water, constituting around 10 percent of biodiesel was combined with biodiesel to eliminate residual free glycerin, methanol, catalyst, and soap. The mixture was then heated to 55°C for drying and allowed to settle for an additional 24 hours. This washing process was typically repeated until no soap was detected in the wash water.

(a) (b)

Fig.1 (a) Formation of two layers in the separator (b) Biodiesel obtained after separation.

2.3 Product analysis procedure

To evaluate the quality and suitability of the produced biodiesel for various applications its characterization of its properties is essential. The physico-chemical properties include density, cetane number, flash point, viscosity, and gross calorific value (GCV) measured following standard ASTM test methods. The density, and cetane number of the biodiesel were assessed using ERASPEC Fuel Analyzer-ES10. The kinematic viscosity of the biodiesel was determined using an Ostwald viscometer. The flash point, defined as the minimum temperature at which a liquid can momentarily ignite without a sustaining fire when exposed to an external flame was determined using Flash Point (Closed) Pensky-Martens AIM 509 apparatus. Finally, the calorific value indicating the energy or heat generated during the combustion of biodiesel was measured using the GDY-1C Oxygen Bomb Calorimeter.

3. Results and Discussion

3.1 Effect of alcohol-to-vegetable oil ratio on biodiesel production

To analyze the effect of the alcohol-to-vegetable oil ratio on biodiesel yield, tests were conducted at a constant temperature of 55°C using 30ml of vegetable oil, 4.5 g of KOH catalyst, and a reaction time of 1.5 hours. Fig. 2 illustrates the biodiesel yields corresponding to various alcohol-to-vegetable oil ratios. Fig. 2 demonstrates that biodiesel production escalated significantly with the methanol-to-vegetable oil ratio reaching a peak yield of 83% at a ratio of 6:1. However, beyond this ratio, further increases in the methanol-to-oil ratio did not result in a significant boost in biodiesel yield. Therefore, it is not economically viable to use a ratio greater than 6:1. This phenomenon is attributed to excess methanol, which leads to increased glycerol production but does not significantly enhance biodiesel yield [18-20]. This increased glycerol production further complicates the separation process and increases overall expenses.

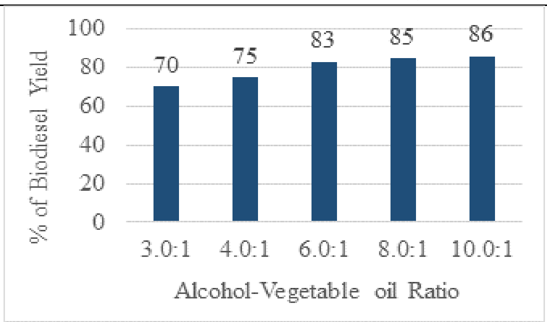

Fig.2 Biodiesel yield for different alcohol-to-vegetable oil ratios.

3.2 Effect of catalyst on biodiesel production

To evaluate the impact of different catalyst amounts on biodiesel yield, a transesterification reaction was performed at a constant temperature of 55°C, using 20 ml of vegetable oil and a reaction time of 1.5 hours with varying catalyst quantities. Fig. 3 illustrates the biodiesel production corresponding to different catalysts amounts. As the quantity of catalyst increased production of biodiesel similarly rose achieving a maximum yield of 83% with 0.3g of catalyst which represented 1.5% of the vegetable oil. However, further increase in catalyst amount had a negative effect as excess catalyst resulted in the formation of a soapy substance which decreased the overall biodiesel yield [19-21].

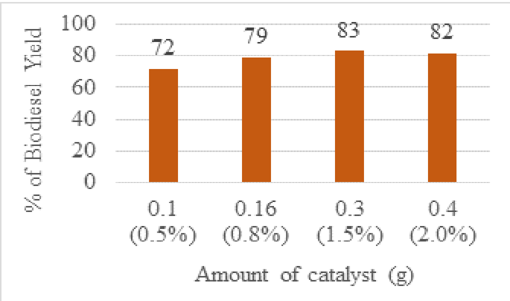

Fig.3 Biodiesel yield for different amounts of catalyst.

3.2 Effect of reaction time on biodiesel production

To investigate the influence of reaction time on the output of the product, transesterification reactions were conducted at a constant temperature of 55℃ with a 6:1 methanol-to-vegetable oil ratio and 0.3g of catalyst in 20 ml of vegetable oil. Fig. 4 shows the biodiesel yield for different reaction times. As the reaction period extended, the production of biodiesel correspondingly rose achieving an ideal yield of 83% at 1.5 hours. However, extending the reaction time beyond 1.5 hours resulted in only a minimal increase in production. Within 1.5 hours, nearly all the vegetable oil was converted into biodiesel, leaving the residue with minimal chemical reactivity [19-21].

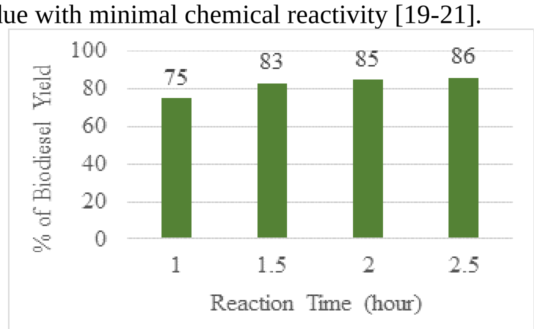

Fig.4 Biodiesel yielded for different reaction time

3.3 Property of produced biodiesel

The biodiesel derived from the transesterification of tamarind seed oil was characterized to identify its quality and suitability for various applications by measuring properties including density, flash point, kinematic viscosity, cetane number, and calorific value. The physico-chemical properties of produced biodiesel and its comparison with diesel fuel and standard values of biodiesel are presented in Table 2:

Table 2 Comparison of properties of produced biodiesel with diesel fuel and standard values of biodiesel.

Properties	Tamarind seed biodiesel	Diesel	Biodiesel (ASTM D6751)
Density (kg/m^3)	855.2-943.1	820-860	880
Kinematic Viscosity (cSt)	4.9-5.4	2-4.5	1.9-6
Flash Point (°C)	149-155	50-95	130 (min)
Cetane Number	66-68	55	47 (min)
Calorific Value (MJ/kg)	27-29	42-46	37-41

The density of produced biodiesel ranged from 855.2-943.1 kg/m^3, while the density of commercial diesel fuel was between 820-860 kg/m^3 and the standard biodiesel value is 880 kg/m^3. The higher density of the produced biodiesel can be attributed to its fatty acid composition, molar mass, water content, purity, and temperature. The kinematic viscosity of the biodiesel was between 4.9-5.4 cSt respectively at 40°C, which was notably higher than diesel fuel (2-4.5 cSt at 40°C) but was within the range of biodiesel standard value range of 1.9-6 cst. This higher viscosity is because of the larger chemical structure and molecular mass of biodiesel. The viscosity of biodiesel can fluctuate considerably affected by the feedstock quality, processing conditions, and the effectiveness of low-boiling component extraction [22]. The flash point of diesel fuel typically ranges from 50-95°C and ASTM 6751 specifies a minimum flash point of 130°C for biodiesel. In this study, the flash point for the produced biodiesel was between 149-155°C. This relatively high flash point can be attributed to the unrefined biodiesel composed of various components with a wide distillation range indicating a need for further refinement for more accurate determination. The cetane number of the produced biodiesel was measured at 66-68, higher than that of regular diesel (55). According to ASTM D6751, the minimum cetane number for biodiesel is 47. A higher cetane number indicates a greater concentration of oxygen resulting in a shorter ignition delay period and enhanced combustion efficiency, making it a suitable alternative fuel. However, despite these promising properties, the calorific value or energy content of the produced biodiesel was between 27-29 MJ/kg, which was considerably lower than that of diesel (42-46 MJ/kg) [23]. This reduced energy content is primarily due to the presence of higher oxygenated compounds in the biodiesel.

4. Conclusions

Emphasizing the renewable and eco-friendly potential of biomass as an energy source, this research aimed at producing biodiesel from tamarind seeds through transesterification, while evaluating its properties and investigating factors affecting biodiesel yield. The utilization of biomass also aids in mitigating environmental issues associated with indiscriminate dumping and incineration. Vegetable oil was extracted using a pressure-based liquid extraction apparatus, with the seeds heated at 40°C for 15-20 minutes. The extracted vegetable oil was subsequently converted to biodiesel via a transesterification process. The optimal conditions were identified to be a methanol-to-vegetable oil ratio of 6:1, a catalyst quantity of 0.3g (1.5% of vegetable oil), and a reaction time of 1.5 hours at 55°C, resulting in a maximum yield of 83% biodiesel. The produced biodiesel exhibited moderate physicochemical properties. Specifically, the calorific value of produced biodiesel ranged from 27-29 MJ/kg. These findings suggest that the produced biodiesel can be used as a low-grade fuel or be blended with conventional fuels.

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References

[1] B. Sundén, "Chapter 1 - Introduction and background," in *Hydrogen, batteries and fuel cells*, Academic Press, pp. 1-13, 2019.

[2] P. Winch and R. Stepnitz, "Peak oil and health in low- and middle-income countries: impacts and potential responses," *American journal of public health,* vol. 101, no. 9, pp. 1607-1614, 2011.

[3] M. H. Ali and M. N. A. Moral, "Pyrolytic fuel extraction from tire and tube: Analysis of parameters on product yield," *Case Studies in Chemical and Environmental Engineering,* vol. 6, no. 100273, 2022.

[4] M. A. Kader, M. R. Islam, M. S. Hossain and H. Haniu, "Development of a pilot scale pyrolysis plant for production of liquid fuel from waste tire," *Mechanical Engineering Research Journal,* vol. 9, no. 2013, pp. 54-59, 2015.

[5] S. A. Jourabchi, S. Gan and H. K. Ng, "Pyrolysis of Jatropha curcas pressed cake for bio-oil production in a fixed-bed system," *Energy Conversion and Management,* vol. 78, pp. 518-526, 2014.

[6] F. Ma and M. A. Hanna, "Biodiesel production: a review," *Bioresource technology,* vol. 70, no. 1, pp. 1-15, 1999.

[7] J. Sheehan, T. Dunahay, J. Benemann and P. Roessler, "Look back at the US department of energy's aquatic species program: biodiesel from algae; close-out report," National Renewable Energy Lab. (NREL), Golden, CO (United States), 1998.

[8] A. Demirbas, "Potential resources of non-edible oils for biodiesel," *Energy Sources, Part B,* vol. 4, no. 3, pp. 310-314, 2009.

[9] M. Gui, K. Lee and S. Bhatia, "Feasibility of edible oil vs. non-edible oil vs. waste edible oil as biodiesel feedstock," *Energy,* vol. 33, no. 11, pp. 1646-1653, 2008.

[10] K. El-Siddig, K. Tamarind: Tamarindus Indica L. Vol. 1. Crops for the Future, Southampton: Southampton Centre for Underutilized Crops, 2006.

[11] V. Kumbhar, A. Pandey, A. Varghese and S. Wanjari, "An overview of production, properties and prospects of tamarind seed oil biodiesel as an engine fuel," *International Journal of Ambient Energy,* vol. 43, no. 1, pp. 3356-3364, 2022.

[12] M. Parveen, M. R. Islam and H. Haniu, "Thermal decomposition behavior study of two agricultural solid wastes for production of bio-fuels by pyrolysis technology," *Journal of Thermal Science and Technology,* vol. 6, no. 1, pp. 132-139, 2011.

[13] R. Maceiras, M. Vega, C. Costa, P. Ramos and M. Márquez, "Effect of methanol content on enzymatic production of biodiesel from waste frying oil," *Fuel,* vol. 88, no. 11, pp. 2130-2134, 2009.

[14] J. B. Rossel, "Animal Carcass Fats, Oils and Fats Series," Leatherhead Publishing: Leatherhead, Vol. 2, p. 14, 2001.

[15] D. Kalita, "Hydrocarbon plant—New source of energy for future," *Renewable and Sustainable Energy Reviews,* vol. 12, no. 2, pp. 455-471, 2008.

[16] V. D. Raju, P. S. Kishore and K. Yamini, "Experimental studies on four stroke diesel engines fuelled with tamarind seed oil as potential alternate fuel for sustainable green environment," *European Journal of Sustainable development research,* vol. 2, no. 1, p. 10, 2018.

[17] A. Mushtaq, M. A. Hanif, M. Zahid, U. Rashid, Z. Mushtaq, M. Zubair, B. R. Moser and F. A. Alharthi, "Production and evaluation of fractionated Tamarind seed oil methyl esters as a new source of biodiesel," *Energies,* vol. 14, no. 21, p. 7148, 2021.

[18] A. Gashaw and A. Lakachew, "Production of biodiesel from non-edible oil and its properties," *International Journal of Science, Environment and Technology,* vol. 3, no. 4, pp. 1544-1562, 2014.

[19] A. A. Elgharbawy, "Transesterification reaction conditions and low-quality feedstock treatment processes for biodiesel production-A review," *Journal of Petroleum and Mining Engineering,* vol. 23, no. 1, pp. 89-94, 2021.

[20] J. Mondal and A. N. M. M. Rahman, "Production and Characterization of Biodiesel from Linseed Using NaOH Catalyst," *Available at SSRN 4857814,* 2024.

[21] M. Danish, P. kale, T. Ahmad, M. Ayoub, B. Geremew and S. Adeloju, "Conversion of flaxseed oil into biodiesel using KOH catalyst: Optimization and characterization dataset," *Data in brief,* vol. 29, p. 105225, 2020.

[22] A. E. Pütün, E. Apaydın and E. Pütün, "Rice straw as a bio-oil source via pyrolysis and steam pyrolysis," *Energy,* vol. 29, no. 12-15, pp. 2171-2180, 2004.

[23] M. H. Ali, M. Mashud, M. R. Rubel, R. H. Ahmad, "Biodiesel from Neem Oil as an Alternative Fuel for Diesel Engine," Procedia Engineering, vol. 56, pp. 625-630, 2013.

NOMENCLATURE

°C : Degree Celsius
GCV: Gross calorific value
ml : Milliliter
g : Gram
cSt : Centistokes
KOH: Potassium hydroxide