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Estimated Fuel Properties of Luffa Aegyptiaca as a Possible Feedstock for Biodiesel Production

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Abstract

The world's expanding human population and rising standard of living result in a rise in energy consumption. Since fossil fuel reserves are mostly exploited to fulfil the expanding energy demand, this makes it more difficult to get energy. Due to the non-renewable nature of fossil fuel resources and the possibility of energy supply issues occurring as a result of globalization, access to energy becomes challenging at this point. However, switching to alternative and environmentally beneficial fuel sources is now a need because of the harm that their widespread usage has caused to the environment and the diminishing resources that are being used up. The loofah seed Luffa Aegyptiaca, which is grown mostly in Turkey's Hatay region, is discussed in this paper. Fatty acids in the oil produced from Luffa aegyptiaca seeds were identified by analysis. Oleic and linoleic acids were found to be the primary fatty acids controlling the combustion characteristics of biodiesel fuel. These acids were found to be, respectively, 97.8318 and 129.1163. Using the Biodiesel Analyzer v1.2, the physicochemical characteristics of biodiesel fuel were identified. It was determined that biodiesel fuel made from Luffa aegyptiaca seed might be used as a substitute for diesel fuel.

Keywords: Biodiesel, Alternative fuel, Luffa aegyptiaca, Fatty acid

Luffa Aegyptiaca'nın Potansiyel Biodizel Üretimi İçin Olası Bir Hammadde Olarak Tahmini Yakıt Özellikleri

Öz

Dünya genelindeki artan insan nüfusu, yükselen yaşam standartlarıyla birleştiğinde enerji taleplerini arttırmaktadır. Bu durum, fosil yakıt rezervlerinin çoğunlukla yükselen enerji talebini karşılamak için kullanılmasına bağlı olarak enerji erişimini zorlaştırmaktadır. Fosil yakıt kaynaklarının yenilenebilir olmayan doğası ve küreselleşme ile ortaya çıkan enerji arzı sorunları potansiyeli nedeniyle enerjiye erişim bu aşamada zorlaşmaktadır. Öte yandan, yaygın kullanımları sonucunda çevreye verilen zararlar ve her geçen gün azalan kaynakların tükenmesi göz önüne alındığında, alternatif ve ekolojik dostu yakıt kaynaklarına geçiş yapmak günümüzde kaçınılmaz hale gelmiştir. Bu çalışmada, özellikle Türkiye'nin

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Hatay bölgesinde yetiştirilen Luffa Aegyptiaca adı verilen loofah tohumu ele alınmaktadır. Luffa Aegyptiaca tohumları kullanılarak elde edilen yağ analiz edilmiş ve yağ asitleri belirlenmiştir. Biyodizel yakıtın yakıt özelliklerini etkileyen başlıca yağ asitleri oleik ve linoleik asit olarak belirlenmiştir. Bu asitler sırasıyla 97.8318 ve 129.1163 olarak belirlenmiştir. Biyodizel yakıtın fizikokimyasal özellikleri Biodiesel Analyzer v1.2 kullanılarak belirlenmiştir. Luffa aegyptiaca tohumu biyodizel yakıtın, dizel yakıtla karıştırıldığında potansiyel bir yakıt kaynağı olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Biyodizel, alternatif yakıt, Luffa aegyptiaca, Yağ asidi

1. INTRODUCTION

In the rapidly industrializing world, the need for energy is increasing rapidly and a large part of the need is obtained from fossil fuels. The projections have shown that oil, the primary source of energy, is being depleted day by day. In addition to the depletion of petroleum-derived fuels, environmental problems have increased considerably in the globalizing world and researchers have turned to alternative fuel research that can replace oil and reduce environmental concerns. Alternative fuels are defined under the Energy Policy Act as alcohols (such as ethanol), natural gas and liquefied fuels generated from natural gas, liquefied petroleum gas (LPG), coal-derived liquid fuels (CTL), hydrogen (H2), and biodiesel (B100) [1]. Among these alternative biofuels, biodiesel has been the subject of research for decades. Biodiesel has attracted the attention of researchers worldwide due to its significant advantages over fossil fuels such as its renewable nature, biodegradability, non-toxicity, and high flash points. Biodiesel exhibits an environmentally friendly feature with a decrease in greenhouse gas emissions. Biodiesel shows a better combustion emission profile by producing much less carbon monoxide, sulfur dioxide and unburned hydrocarbons than petroleum-based diesel fuel without the need for any modification when used in diesel engines. For decades, numerous scientists have been working on the synthesis of biodiesel and its use in internal combustion engines based on the observed benefits.

Çelikten and Arslan investigated the biodiesel obtained from canola and soybean oil methyl ester in their study. They concluded that canola methyl ester gives the lowest smoke and CO emissions. However, in their comparison, they concluded that the NOx value of standard diesel fuel is lower than that of canola and soy methyl ester [2]. Şimşek and Çolak found that soot emissions were reduced while HC emissions rose as a result of their analysis of biodiesel fuel. Looking at the study's specifics, it can be observed that adding propanol to biodiesel fuel can erase some of its drawbacks and minimize NOx emissions [3]. İçgür and Koçak investigated the methyl ester of hazelnut oil. The study compared conventional diesel and hazelnut oil biodiesel. They found that these two fuels have fairly similar power and specific fuel consumption ratings. Additionally, they discovered that methyl ester of hazelnut oil emits less CO, NOx, and soot than regular diesel. So they concluded that methyl ester of hazelnut oil would be an alternate fuel source [4].

However, oil seeds used as feedstock are the biggest obstacle to the synthesis of this biofuel. Because the use of so-called edible oils which is in the human food chain, such as palm oil, sunflower oil, coconut oil, soybean oil and cottonseed oil, has a negative impact on food prices, which are already high. To eliminate this negativity, the use of oils that are not suitable for human consumption (non-edible) as raw materials is the best way to be followed.

Scientists evaluated many non-edible oils such as: The performance, combustion, and emission characteristics of a DICI engine running on a dual biodiesel mix made from the plant's Jatropha curcas, Pongamia pinnata, Mahua, and Azadirachta indica were examined by Sayyed et. al. The physio-chemical properties were found to be within acceptable limits. These engines are less efficient thermally, mechanically, and volumetrically than pure diesel engines, have higher exhaust gas temperatures, and need more energy specifically for the brakes. The effects of clean and blended diesel on CO, CO_2, HC, and NOx exhaust emissions were investigated and compared. The largest CO reduction was shown by Blend D90 + JB5 + NB5 (46.91%). In comparison to plain diesel, all of the mixes under consideration produce higher CO2 emissions [5].

Kibazohi and Sangwan conducted studies on Aleurites moluccana, Croton megalocarpus, Jatropha curcas, Moringa oleifera, and Pachira glabra. All five varieties were found to have acceptable oil yields of between 3 and 12.5 tons per hectare per year with a range of 20 to 33% weight-for-weight oil contents. C. megalocarpus has the highest potential to generate 1.8 t of vegetable oil per hectare per year, followed by M. oleifera, J. curcas (1 t/ha.y), A. moluccana, and P. glabra, according to the results of the multi-criteria decision analysis. For the purpose of producing biofuel in Africa and other regions, the analysis emphasizes the need for additional research on C. megalocarpus and M. oleifera [6].

As a brand-new non-edible feedstock for the base-catalyzed transesterification of ethanol to make biodiesel, bitter almond oil was put to the test by Emaad et al. a significant raw material with a maximum yield of 42.0 weight percent for the production of biodiesel. The fuel properties of the biodiesel were within the allowable limits specified by the regulations. It was shown to be an appropriate feedstock for producing biodiesel, and bitter almond oil [7].

Fadhil et. al. studied the wild mustard Brassica juncea L seeds by extracting oil from them to obtain a yield of 34.0% w/w and transesterify via KOH-catalyzed methanol. The qualities of the as-produced biodiesel were checked in accordance with ASTM D6751 regular test protocols, and it was found that they satisfied the typical requirements for biodiesel. The usual approach was proven to be less effective, time-saving, and advantageous than co-solvent methanolysis since it needed more perfect circumstances to complete the conversion [8].

The high-free fatty acid oils were transformed into their mono-esters using a two-step trans-esterification procedure developed by Perumal and Mahendradas. The free fatty acid content of the oil is first reduced by acid-catalyzed esterification to less than 1.9% and then converted into mono-esters and glycerol by alkaline-catalyzed trans-esterification. The produced biodiesel is similar to petroleum-based fuel in many ways [9].

Sterculia foetida oil and used cooking oil (SWO) were blended in a 1:1 ratio by Kavitha and Murugavelh, and the effects on the qualities of the biodiesel were investigated. Plackett-Burman design was used to assess the effects of process variables and operating parameters such as sample quantity, methanol volume, hexane volume, sulphuric acid, temperature, and time. The largest amounts of linolenic acid (20.9%) and palmitic acid (18.3%) were detected by GCMS and utilized the blended oil achieved a high output of biodiesel that was higher than 95%. the high yield of biodiesel produced by the trials using this blended oil was over 95% [10].

Tabebuia Rosea seed oil was investigated by Sirigeri et. al. as a viable alternative for utilizing biodiesel since it can be grown in a variety of climates, produces a lot of fruit, and is inexpensive. To create Tabebuia Rosea oil methyl ester, the crude oil was transesterified by using sodium methoxide as a catalyst (TOME). Physicochemical characteristics were used to evaluate the quality of the TOME/biodiesel produced. Analysis showed that the evaluated parameters were within the standards of biodiesel. It was concluded that T. Rosea seed oil is a suitable feedstock [11].

To create biodiesel using the transesterification process, Kshirsagar and Anand investigated oil from Alexandrian laurel which has a higher percentage of free fatty acids. By adopting the TOP degumming technique, the high FFA (20.2%) was reduced to 12.9%. The refined kernel oil was esterified using ortho-phosphoric acid. Using methanol as an analytical solvent and NaOH as an alkaline catalyst, transesterification was carried out. According to the study, the most crucial control parameter for achieving the best methyl ester synthesis was CC. The most effective treatment formula produced 97.14% biodiesel. Since biodiesel's fuel characteristics fall within the ASTM

D6751 and EN 14214 standards, it may be used as a viable substitute for diesel fuel for the long-term carbon cycle [12].

The goal of Vázquez et. al. was to determine the type of castor oil plant that might be grown in Tlaltenango. Physicochemical chemical characteristics of both oil and biodiesel were determined, and three distinct variations were found; the "green stem with wax, ashen fruit" variety had the highest oil content (51.7 ± 5.6%), and the highest transesterification reaction yield (61.44 ± 0.44%). Except for the viscosity and moisture, the produced biodiesel complies with the standards, so blending with diesel is advised [13].

Yatish et. Al. analyze the transesterification of seed oils from Garcinia gummi-gutta, Terminalia belerica, and Aegle marmelos using a catalyst made of sodium phosphate. GC analysis was used to evaluate the oils. Additionally, multiple ratios of biodiesel and conventional diesel were blended, and each blend's fuel characteristics-including density, flash point, and kinematic viscosity-were assessed and compared to conventional diesel [14].

Yadav et al. used a magnetic stirrer technology and ultrasonic transesterification to produce biodiesel from Nerium oleander oil. Comparisons were made between the biodiesel produced with the magnetic stirrer and the ultrasonic approach in terms of percentage yield and physicochemical properties. The ultrasonic transesterification process yielded oleander biodiesel with a maximum yield of 97% by weight and outstanding physiochemical characteristics. It may be concluded that the ultrasonic approach is the most effective process for converting raw oleander oil into biodiesel [15].

A. Abdulvahitoglu studied the oil derived from Turkish cherry kernels. The oil was characterized using gas chromatography (GC), and the free fatty acids were computed. The anticipated outcomes demonstrated that Prunus avium seed oil is an effective substitute for biodiesel [16].

Analyzing Bay Laurel oil's viability as a substitute fuel for diesel engines was the goal of Abdulvahitoglu A. This article examines the fuel quality of pure bay laurel oil. According to the results, BLO appears to have a low CN, high densities and viscosities, as well as a high FFA. [17].

Turkey is located in a geography with 4 climates and large plant diversity, so there are many possible opportunities for finding suitable feedstock. In addition to the previous studies in the literature, this study aimed to work with Luffa Aegyptiaca, a seed that has not been studied before. The main purpose of this study is to characterize oil obtained by using Luffa Aegyptiaca seeds and evaluate the gained oil for possible biodiesel production as a different feedstock.

2. MATERIAL AND METHOD

Within the scope of the study, the Luffa Aegyptiaca seed oil shown in Figure 1 was discussed. This plant was first grown in the geography of India. Over time, the loofah plant has spread widely throughout the world, including the Mediterranean coastline of Central and South America, Northeastern Australia, Asia, Africa, and Europe. In our country, in the Aegean and Southeastern Anatolia regions, especially in the Mediterranean region, people are grown in their gardens for personal needs [18]. Luffa Aegyptiaca has a very rapid development and growth process. The vines formed by the branching of this plant can exceed 10 meters in length. Also, Luffa Aegyptiaca is a taproot plant that forms many lateral roots. However, Luffa Aegyptiaca roots cannot go very deep into the soil [19]. Regarding our country, Hatay, which is situated in the Mediterranean area, stands out in terms of Luffa Aegyptiaca cultivation [18].

Figure 1. Luffa Aegyptiaca (20).

The Luffa Aegyptiaca seeds were pressed in cold press (Figure 2) to gain oil

Figure 2. Karaerler NF 80 cold-press machine

Figure 3. Luffa Aegyptiaca Oil sample.

Figure 3 shows the Luffa Aegyptiaca oil sample. To determine the % oil in the seed, the Luffa Aegyptiaca seeds (Figure 4) were ground into powder as shown in Figure 5.

Figure 4. Luffa Aegyptiaca seeds

Figure 5. Luffa Aegyptiaca grounded seeds.

Three different samples were prepared from powdered Luffa Aegyptiaca seeds. In the Soxhlet apparatus seen in Figure 6, 150 ml of hexane was used for each sample. The gained samples are used for oil content calculation.

Figure 6. Soxhlet apparatus used for extracting oil.

There are many important factors in determining the character of biodiesel fuel. These factors are cetane number, density, cloud point, viscosity, cold flow properties etc. are listed as. The oil obtained from Luffa Aegyptiaca seeds was analyzed using the Biodiesel Analyzer V1.2 [21] to assess its fuel characteristics and reveal its composition. Thus, necessary data for fuel values were obtained. In obtaining these data, the following formulas were used in the program.

Iodine (IV) and saponification (SV) values and Cetane Number (CN).

$$SV = \sum (560 \times N)/M \quad (1)$$

$$IV = \sum (254 \times D \times N)/M \quad (2)$$

where,

M: Fatty ester's molecular weight, N: (%)FA ester in oil samples, D: The total number of double bonds

$$CN = 46.3 + (5.458/SV) - (0.225 \times IV) \quad (3)$$

$$DU = MUFA + (2 \times PUFA) \quad (4)$$

where,

DU stands for unsaturation degree, Monounsaturated FA% is referred to as MUFA, and Polyunsaturated FA% is referred to.

Allylic position equivalents (APE) and equivalents of bis-allylic positions (BAPE)

$$APE = \sum(apn \times Acn) \quad (5)$$

$$BAPE = \sum(bpn \times Acn) \quad (6)$$

where,

an: amount of equivalent allylic positions
Acn: Fatty acid proportion in the mixture.
b_{pn}: number of Bis-allylic position equivalents

The following formulas were used to calculate the oxidation stability (OS) of biodiesel.

$$OS = (117.9295/(C_{18:2} + C_{18:3}) + 2.5905) \quad (7)$$

The ability of biodiesel fuel to flow coldly is one of its crucial characteristics. Cold Filter Plugging Point (CFPP), Cloud Point (CP), and Pour Point (PP) are the three cold flow properties that were anticipated, respectively.

LCSF denotes the long-chain saturated factor

$$LCSF = (0.1 \times C_{16}) + (0.5 \times C_{18}) + (1 \times C_{20}) + (1.5 \times C_{22}) + (2 \times C_{24}) \quad (8)$$

$$CFPP = (3.1417 \times LCSF) - 16.477 \quad (9)$$

$$CP = (0.526 \times C_{16}) - 4.992 \quad (10)$$

$$PP = (0.571 \times C_{16}) - 12.24 \quad (11)$$

The kinematic viscosity at 40 °C was computed as:

$$\ln(v) = \sum Ni(-12.503 + 2.496 \times \ln Mwi) - 0.178 \times Di \quad (12)$$

where,

M_{wi} is the molecular weight of the supplied Fatty acid, Ni is its percentage, and Di is the number of double bonds.

The following equation estimates the density of biodiesel at 20°.

$$\rho = \sum Ni(0.8463 + (4.9/(Mwi)) + 0.118 \times Di \quad (13)$$

The estimated higher heating value (HHV) is as follows:

$$HHV = \sum Ni(46.19 - (1794/Mwi - 0.21 \times Di) \quad (14)$$

The formula below was utilized to estimate Flashpoint:

$$FP\ (°C) = 205.226 + 0.083xp - 1.727xs - 0.5717xo - 0.3557xLI - 0.467xLN - 0.2287xE \quad (15)$$

Where the x denotes for mass fraction, and the mass fractions for palmitic acid x_p, stearic acid x_s , oleic acid x_o , linoleic acid x_{LI} , linolenic acid x_{LN} , erucic acid x_E [16].

3. RESULTS AND DISCUSSION

The oil obtained from the seed of Luffa Aegyptiaca was analyzed by gas chromatography. The results obtained from this spectrum are shown in Table 1.

Table 1. Profile of fatty acids in Luffa Aegyptiaca seed.

Fatty Acid	*% W*	*Fatty Acid*	*% W*
Caprylic (C8:0)	0.009	Linoleic (C18:2)	43.85
Myristic (C14:0)	0.082	Linolenic (C18:3)	0.141
Palmitic (C16:0)	13.79	Gadoleic (C20:1)	0.495
Palmitoleic (C16:1)	0.103	Behenic (C22:0)	0.122
Margaric (C17:0)	0.152	Erucoic (C22:1)	0.026
Stearic (C18:0)	7.898	Tricosanoic (C23:0)	0.063
Oleic (C18:1)	33.00		

The main fatty acids in Luffa Aegyptiaca seed oil are 43.85% Linoleic acid, 33.00% Oleic acid, 13.79% Palmitic acid and 7.90% Stearic acid by weight, respectively. Due to their large percentage values, linoleic and oleic acids are the principal fatty acids that have an impact on the characteristics of Luffa Aegyptiaca biodiesel [16]. The chromatography spectrum is shown in Figure 7.

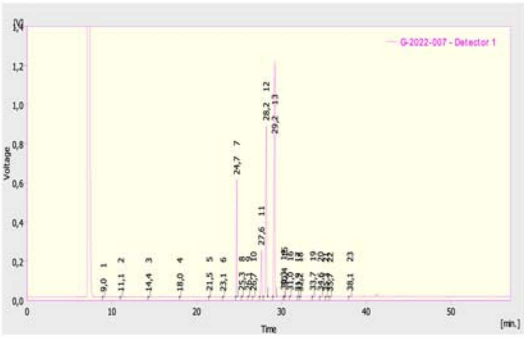

Figure 7. GS result of Luffa Aegyptiaca seed

Based on the fatty acid profile, Luffa Aegyptiaca biodiesel's fuel qualities were predicted using Biodiesel Analyzer Software V1.2. Table 2 gives the basic fuel properties of biodiesel.

Table 2. Estimated physicochemical properties of biodiesel made from Luffa Aegyptiaca oil

Property	*Diesel (EN 590)*	*Biodiesel (EN 14214)*	*LAB*
Oxidation Stability	25 g/m^3 max	8 hrs min	5.27
Cetane Number	51	51	48.71
Cold Filter Plugging Point	Depends on the region and climate	Depends on the region and climate	0.83
Iodine Value	-	120^1g log/100g	110.00
Cloud Point	Depends on the region and climate	Depends on the region and climate	2.26
Degree of Unsaturation	-	-	121.58
Kinematic Viscosity (mm^2/s)	2.0-4.5	3.5-5.0	1.32
Higher Heating Value (HHV)	-	-	39.35
Density (kg/m^3)	820-845	860-900	870
Saponification Value	-	-	200.93

The overall molecular mass of the oil's glycerides, which is inversely related to the saponification value, was calculated as 200.93 for LAB. The heating value, a measurement of the fuel's energy per unit mass, for the Luffa Aegyptiaca biodiesel was found to be 39.35 (LAB). This value is within the limits of EN 14214 [22].

Mass per unit volume is defined as density. This value was measured as 870 kg/m^3 for LAB (23). This value is within the standard limits. Viscosity is the resistance of the liquid to flow. This value was measured as 1.32 mm^2/s for LAB. It is lower than the limit values for biodiesel. However, lower viscosity values can be advantageous as they are favourable for improving the atomization of fuel spray [23].

The cloud point refers to the temperature at which liquid fuel starts to appear cloudy [9]. This value is not given for biodiesel standards. However, in cold climate conditions, it is required to be below zero for biodiesel to be suitable. For LAB, this value is measured as 2.26 and it can create a disadvantage. The CFPP is the temperature at which, under a specific set of conditions, fuel cannot pass through a conventional filter [24]. For LAB, this value is 0.83.

Biodiesel instability results from unsaturation in the biodiesel ester molecule; this is known as oxidation stability. The oxidation stability was predicted as 5.7 for LAB. This may cause biodiesel to be easily affected by air oxidation under long-term storage conditions.

The fuel-air mixture's ability to self-ignite is one of the essential aspects of an internal combustion engine. It is the CN of the fuel that determines the ignition delay [25]. For LAB, this value is 48.71, which is very close to the biodiesel standard. If the CN of the fuel is high, it means that the fuel ignites quickly and on its own. In this case, however, fuel with a low cetane number has a considerable ignition delay.

Biodiesel fuel's oxidation resistance is determined by its iodine value. If the fuel has a high iodine value, it can easily be oxidized when it comes into contact with air [25]. The iodine value of LAB is 110, which is less than the maximum iodine value specified for biodiesel in the standard EN 14214. The obtained Luffa Aegyptiaca seed oil was subjected to further analysis in order the obtain the FFA value which is directly related to the biodiesel production method. FFA results are shown in Table 3.

Table 3. The free fatty acid analysis result [26]

Analysis	Analysis Method	Analysis Result
Percent Free Acid (As %Oleic Acid)	*TGK 2014/53*	2.41

The FFA value must be less than 1% to employ the transesterification technique to produce biodiesel, thus the results show that Luffa aegyptiaca needs more processing to lower the FFA value, which is 2.41% [26].

4. CONCLUSION

In terms of energy resources, many nations in the world, particularly developing nations, rely on external sources. Each nation has now realized how crucial it is to fulfil its own energy needs in light of the pandemic conditions that occurred at the beginning of 2020, the war situations that emerged as a result of the political tensions between the countries, and the rise in fossil fuel costs. While every effort in this direction is valuable, one of the things that need to be taken into account to stop the climate disaster is getting the fuel that will be utilized from environmentally and naturally friendly sources.

The most crucial factor to take into account when assessing the long-term viability of biodiesel is sustainability in addition to environmental effects. Accelerating the transition to biodiesel will benefit the economy, the environment, car engines, and our independence from foreign oil. However, only a little amount of biodiesel is produced because the material used to make it is a component of the food chain. Therefore, non-edible oils should be used to produce biodiesel.

It will be more advantageous to make biodiesel from Luffa aegyptiaca seeds as they won't be consumed by humans.

i. GC analysis results were used to identify the fatty acids. The fuel characteristics of biodiesel were evaluated using the amounts of oleic, linoleic, palmitic, mystic, and stearic acid
ii. The density of LAB100 is within the standards of EN14214.
iii. Cold flow properties are promising but in its pure form, it can be easily said that it is not suitable for cold climates. Blending diesel and biodiesel will have positive effects on the cold filter plugging point and pour point and will lead to reducing obstacles to a manageable level.
iv. Cetane number is 4,49 % less according to the standards which leads to more ignition delay time.
v. The viscosity value is 34% below the standard of diesel.

This analysis predicts that the biodiesel made from Luffa aegyptiaca oil will be a substantial alternative fuel and will be useful when utilized in a blended form.

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