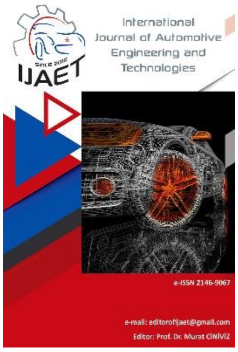
e-ISSN: 2146 - 9067

International Journal of Automotive Engineering and Technologies

journal homepage:

https://dergipark.org.tr/en/pub/ijaet



Original Research Article

Evaluation of Prunus insititia L. Oil: characterization and its potential as a sustainable biodiesel feedstock

Aslı Abdulvahitoğlu [1*], Nurten Cengiz [2]

[1, *]Engineering Faculty, Mechanical Engineering Department, Adana Alparslan Türkeş Science and Technology University, Türkiye.
[2]Engineering Faculty, Food Engineering Department, Adana Alparslan Türkeş Science and Technology University, Türkiye.

ARTICLE INFO

Orcid Numbers
1. 0000-0002-3603-6748
2. 0000-0002-6640-4927

Doi: 10.18245/ijaet.1604765

* Corresponding author
aabdulvahitoglu@atu.edu.tr

Received: Dec 20, 2024
Accepted: Apr 13, 2025
Published: 30 Jun 2025

Published by Editorial Board Members of IJAET

To cite this paper: Abdulvahitoğlu, A, Cengiz, N., Evaluation of prunus insititia l. Oil: characterization and its potential as a sustainable biodiesel feedstock, International Journal of Automotive Engineering and Technologies. 2025, 14 (2), 86 – 98.
http://dx.doi.org/10.18245/ijaet.1604765

ABSTRACT

Long-term development and economic growth are closely related to energy. The economy is negatively impacted by any changes in the energy supply. If the energy is consistent, clean, and of a quality that can satisfy the demands of several sources, supply security can be achieved. Nowadays, biofuels made from biomass provide a variety of choices. For many years, research has been conducted on biofuels that can be transformed into liquid fuel. In this situation, biodiesel—which may be used in place of diesel fuel—becomes essential. To lessen dependency on fossil fuels and edible feedstocks, the core purpose of this assessment is to demonstrate the biodiesel potential of Prunus insititia L. by describing the oil's composition and predicting the fuel's qualities. The predominant fatty acids found in Prunus insititia kernel oil were oleic acid (61.687 %w), linoleic acid (21.405 %w), palmitic acid (5.965 %w), and stearic acid (1.450 %w). The cetane number, flash point, cold flow characteristics, and oxidation stability all fell within the acceptable ranges of EN14214. However, the density and viscosity were computed to be 5.93% and 0.542% lower, respectively, than the standard's minimal values. These results suggest that Prunus insititia kernel L. might be a viable option for producing biodiesel.

Keywords: Prunus insititia L., fatty acid, biodiesel, fuel property, characterization.

1. Introduction

The world's energy need has been increasing not only from industrialization but also from the humankind population. Many predictions were made on fossil fuel resources and predictions showed that resources are depleted. Even though the global energy supply has grown by 2.6 times during the past 47 years, fossil fuels, particularly oil, have remained dominant in the energy mix [1]. On the other hand, it has been a goal to reduce the harmful emissions of fossil fuels both to human health and the environment while meeting the energy need. In this context, renewable alternative fuels have been turned towards and biofuels seem to be a suitable solution for internal combustion engines.

For a long time, biodiesel has been utilized as a diesel fuel substitute. Biodiesel is unique in that cause oil can be obtained from a variety of sources. Biodiesel, a methyl-ester of long-chain fatty acids, is one of these alternative biofuels [2-4]. It is biodegradable and non-toxic [5] has qualities similar to fossil diesel and may be utilized in internal combustion engines without modification. The composition of the oil used as feedstock is related to the overall fuel qualities of biodiesel [6]. Oils may be subdivided into numerous subcategories, such as edible oils (such as soybean, corn, sesame, and palm), inedible oils (such as rubber seed and pongamia), waste frying/recycled oils, animal fats, and macroalgae, all of which can be used to produce biodiesel. [7-10]. For decades, biodiesel has been evaluated as a substitute for diesel fuel. Biodiesel can be produced in four different ways. Processes include thermal cracking, blending, microemulsions, and transesterification [11]. Since it can be used in engines without any changes, biodiesel has long been a powerful alternative fuel in our lives. Many countries have used biodiesel with various regulations they have implemented. According to BP Statistical Review of World Energy 2022, global total biodiesel production in 2021 was 734 thousand barrels of oil equivalent per day, with consumption at 787 thousand barrels of oil equivalent per day [12]. According to a recent FAO analysis, international prices for oilseeds and associated goods have risen dramatically in recent months, reflecting tighter market circumstances. The COVID-19 scenario, as well as meteorological circumstances in South America and Southeast Asia (especially in light of the next La Niña cycle), international trade regulations, mineral oil prices, and the future direction of national biodiesel initiatives, are projected to impact oil crops prices [13]. However, the possibility of a problem related to the food supply in plant-based production has emerged and biodiesel production from non-edible oils has grown in popularity. Many alternatives have been explored in this context such as Jatropha, Karanja, Mahua, Bay laurel, Neem, Eucalyptus, Sisymbrium irio, Linseed, Watermelon seed, Rubber seed, Polanga, Sisymbrium Sophia, Yellow oleander etc [14-16].

In the literature, scientists concentrated on examining alternative feedstocks, performance characteristics, optimal mixes, and additive effects. Dmytryshyn et al. [17] evaluated a variety of feedstocks, such as processed and unprocessed waste frying oil, Canola oil, and green seed oil. The largest yield was reported to be from canola oil. The physicochemical features of canola methyl ester and green seed methyl ester are quite similar to those of petrodiesel fuel. They advocated utilizing a lubricity improver while running with green seed biodiesel to protect the engine because it has a low lubricity feature. Rao et al. [18] used an electrical dynamometer to conduct testing on a single-cylinder, 4-stroke, naturally aspirated air-cooled diesel engine and found that jatropha methyl ester and its blends had a shorter ignition delay, maximum heat release rate, and combustion duration. Apart from NOx, other exhaust pollutants were reduced when biodiesel was used instead of diesel. In a four-cylinder, four-stroke direct injection diesel engine with water cooling, Mbarawa [19] tested clove stem oil and diesel mixtures with a proportion of 25 and 50. There was a modest reduction in power, an increase in SFC, and a drop in bte. The amount of CO and HC emissions in the smoke was dramatically reduced. The amount of NOx emitted rose dramatically, notably in the 50 % mixture. The FA content of a variety of vegetable oil was studied by Ramos et al. [20]. They discovered that increasing the length of the carbon chain and lowering unsaturation, increased cetane number and oxidation stability. Puhan et al. [21] evaluated the methyl ester of linseed oil in a steady state direct injection diesel engine with fuel injection pressures that vary 200, 220 and 240 bar respectively. The optimal injection pressure was discovered to be 240 bar, and thermal efficiency was comparable to diesel at this pressure. CO, HC, and smoke emissions fell; however, NOx emissions rose. Two distinct solvent types (n-hexane and n-heptane) were studied by Abdulvahitoglu and Aydin [22] as additions to enhance the viscosity and cold flow characteristics of rapeseed biodiesel. Blends containing 5% to 10% alkenes were found to have fuel characteristics that were close to the typical limits of diesel fuel standard EN 590, meaning that they may be used directly in diesel engines. Simsek et al [23] stated that Petroselinic acid which is

(68.5% by weight) is an uncommon fatty acid found in coriander (Coriandrum sativum) that has not been identified as a significant component in biodiesel fuels. Methyl ester of Coriandrum sativum seed oil was shown to exhibit exceptional oxidative stability, a distinct fatty acid content, and qualities appropriate for diesel engines, meeting ASTM D6751 and EN 14214 criteria. The effects of FAME content and biodiesel physicochemical qualities on engine performance and emissions are investigated by Ruhul et al. [24]. Blends of Jatropha curcas, Calophyllum inophyllum, and palm biodiesels were studied. In the case of biodiesel blends reduction in brake, power was found. There was a decline in the emissions of Hydrocarbon and Carbon monoxide, on the contrary, NOx emissions inclined. Abdulvahitoglu and Tüccar [5] assessed the suitability of watermelon seed oil biodiesel (WMB) as a fuel for diesel engines. Tests were conducted on different fuel characteristic values. The results of engine performance tests showed that using WMB lowered pollution levels while somewhat lowering the test engine's torque and brake power ratings. The ester of watermelon seed oil is suggested as a feasible substitute fuel additive for diesel fuel due to its ecologically friendly combustion profile. Devarajan and Selvam evaluated Sterculia foetida oil as a sustainable biodiesel feedstock. Using a two-step catalytic process, it achieves a 95.2% conversion rate. Biodiesel blends reduce emissions, including 2.3% CO, 4.1% HC, and 1.9% smoke, highlighting its eco-friendly potential and viability [25]. AlYammahi et al. evaluate Salicornia species as sustainable biodiesel feedstock for hypersaline coastal regions. S. bigelovii showed superior oil content (20.6 wt%) and yield potential (11,442 kg/ha), surpassing traditional feedstocks. Both species met ASTM D6751 and EN 14214 standards, with advanced analyses revealing valuable insights for future breeding. The findings highlight Salicornia's potential as a high-yield, salt-tolerant crop for sustainable energy on marginal lands [26]. Rajesh et al. [27] studied Coconut fatty acid distillate (CFAD) for biodiesel production. Engine tests revealed that the performance of B20 is closer to that of diesel but emits more nitrogen oxide. They concluded that CFAD is a promising source. Phillip and Saini emphasized waste cooking oils (WCOs) and waste animal fats (WAFs) as viable biodiesel feedstocks, highlighting their potential despite challenges. They suggest that trasesterification is the predominant method for biodiesel production [28]. Emmanouilidou et al compared biodiesel from uncooked sunflower oil and waste cooking oils, finding similar properties that meet EN 14214 standards. However, oxidation stability and viscosity were often outside specified limits, highlighting the impact of feedstock type on biodiesel performance [29]. Khan and Long evaluated six non-edible seed oils, revealing oil contents of 17-51%. Biodiesel quality metrics included viscosity (2.9-5.7), density (868-910), cetane number (49-58), and flashpoint (137-187), indicating favorable properties for biodiesel production from these feedstocks [30].

According to data from the Turkish Institute of Standards, there are 5,524,915 diesel-powered vehicles on the road in Turkey, while the number of gasoline-powered vehicles is 4,819,942 [31]. Diesel vehicles accounted for 34.45 percent of all vehicles on the road. Diesel is widely used as a fuel in Turkey's transportation industry. The Turkish economy is heavily influenced by diesel prices. Concerns about the impacts of climate change and exhaust pollutants on human health, as well as the need to reduce costs as an oil-importing country, have pushed biodiesel research to the forefront. The Turkish Energy Market Regulatory Authority, on the other hand, has implemented diesel-biodiesel blending (at a rate of 7%) through a regulation dated 1.1.2018 [31].

A search on the Web of Science Core Collection with "Biodiesel" as the topic and "fuel property" and "fatty acid" as author keywords returns 7,363 results. This indicates extensive research on biodiesel properties, including cetane number, cold filter plugging point, and other fuel characteristics, often emphasizing engine performance and exhaust emissions, as depicted in Figures 1 and 2 below.

Figure 1 illustrates the keywords utilized in the search, emphasizing "Biodiesel," "Fuel properties," and "fatty acid" as the main terms used to access relevant literature.

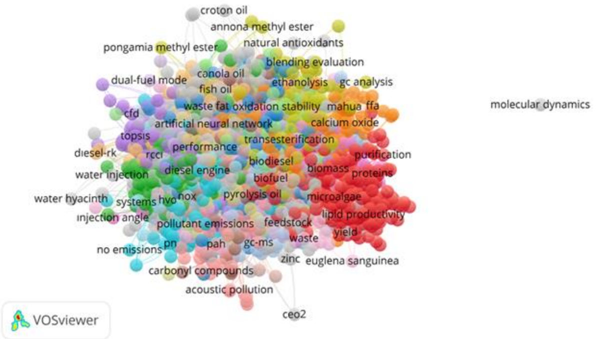


Figure 1. Keywords utilized to access literature (Compiled by the author)

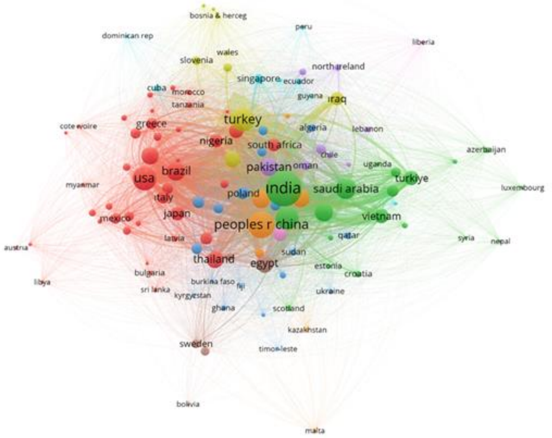


Figure 2 Global interest and spread of scientific efforts (Compiled by the author)

Figure 2 depicts the countries conducting research in this field, illustrating the worldwide interest and spread of scientific efforts related to biodiesel fuel properties.

If biodiesel is to be commercialised as an alternative fuel, it must be produced from non-edible oils. Non-edible oils, which are not part of human nutrition, might be taken into account as a feedstock for biodiesel. According to statistics from 2023, a total of 348,750 tonnes of plums were produced, with roughly 20,000 tonnes wasted and discarded as trash accounting for approximately 5.73 percent of the total production [31]. Within the context of zero waste, plum harvest loss that was not suitable for human consumption was investigated. Therfore to lessen dependency on fossil fuels and edible feedstocks, the core purpose of this assessment is to demonstrate the biodiesel potential of Prunus insititia L. by describing the oil's composition and predicting the fuel's qualities.

2. Material and Methods

Plums cultivated in China, Serbia, Romania, the United States, and Turkey have a global commercial appeal. Although production volumes vary depending on the season and weather conditions, Turkey ranks fifth among plum-cultivating countries [33].

According to 2023 data, 348,750 tonnes of plums were grown in Turkey. The Mediterranean region (which includes the cities of Adana, Mersin, Hatay, Isparta, Burdur, Antalya and Osmaniye) realizes approximately 42 percent of the plum production with 146,161 tonnes [31]. Plum cultivation areas as seen in Figure 3 [34].

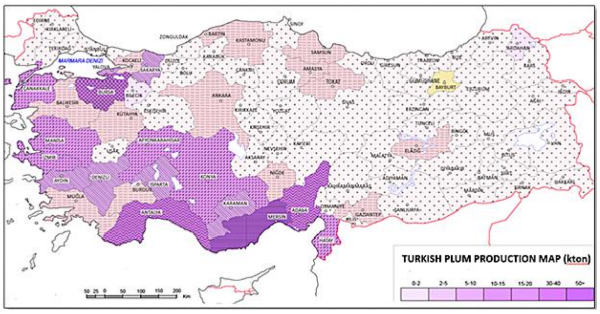


Figure 3. Plum cultivation area of Turkey [34]

Figure 4. Prunus insititia L.

Prunus insititia L. can be cultivated from the Mediterranean coast into Norway in the north and Russia in the northeast stretches. It extends from the west of the Himalayas to the east to Kashmir. This type is consumed as jam and marmalade rather than fresh consumption. Trees are stunted, densely branched, with more or fewer thorns and twigs, depending on the species plum. Flowers open with or after the leaves. Fruits in various shapes, mostly oval, small, bluish-black or amber-yellow, thick cloudy, sweet or sour. Its kernels stick to the meat or split [35]. Figure 4 illustrates Prunus insititia L. samples collected in Pozantı (a town near the Taurus Mountains) in the Mediterranean region. Fatty acid characterization was carried out using GC, and the fatty acid profile was determined.

Prunus insititia L. kernels were prepared (see Figure 5a) by grinding using ground machinery (Figure 5b). The moisture content of the ground kernels (Figure 5c) was found to be 8.47 percent via the Shimadzu moisture analyser (Figure 5d). Soxhlet (Figure 5e) was used to extract the oil.

Figure 5. a- Prunus insititia L. kernels b- Grounding machine c- Grounded kernels d- Moisture analyzer e- Soxhlet device

The Prunus insititia L. kernel oil (PIO) (Fig. 6a) was analyzed by gas chromatography (GC-FID Agilent 7890 A) as seen in Figure 6b.

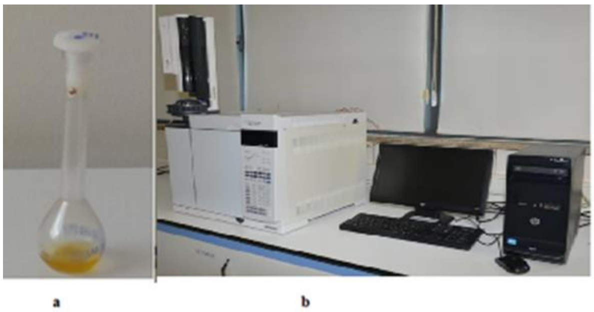


Figure 6 a- Prunus insititia L. kernel oil b- GC-FID

Fatty acids, which typically include carbon atoms between C8 and C24, make up the majority of vegetable oil [36]. The oil contains both saturated and unsaturated fatty acids [37]. Fatty acids, both saturated and unsaturated, have a substantial impact on the physicochemical properties of biodiesel. The process of transesterification of vegetable oil yields biodiesel [38]. Even after the transesterification process, the fatty acid content of vegetable oils does not change [36]. The essential characteristics of biodiesel, such as its density, calorific value, viscosity, and cold flow characteristics, are thus determined by its fatty acids [36].

In order to determine whether the produced biodiesel can be used in a diesel engine without any problems, it is first necessary to determine whether the quality of the fuel is within the range specified in EN14214. For this reason, the Biodiesel analyzer v2.2 program, which uses empirical equations to estimate the fuel parameters of biodiesel from fatty acids, was used [39]. The given calculations were used to determine the estimated biodiesel properties [16, 40].

Cetane number is affected by iodine (IV) and saponification (SV) values.

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

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

hence

M: fatty ester molecular mass,

N: % ester of FA,

D: the total number of double bonds

Saturated fatty acids (SFA), polyunsaturated fatty acids (PUFA), and monounsaturated fatty acids (MUFA) are the three kinds of fatty acids found in oils. Chemically, hydrogen cannot be added to saturated fatty acids since they are already saturated with it. SFA, which only has one connection between carbon atoms, is crucial to the cold flow characteristics of biodiesel [41, 42]. Only one carbon double bond and one hydrogen atom are present in MUFA. This indicates that saturated fatty acids are more stable than this fatty acid. There are many double bonds in PUFA, and extra hydrogen can be added [43].

After the calculation of Saponification and Iodine values the Cetane Number (CN) can be calculated by equation 3.

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

Unsaturation Grade

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

MUFA: monounsaturated FA%,
PUFA: polyunsaturated FA%.

Special indices called Allylic Position Equivalent (APE) and bis-allylic Position Equivalent (BAPE) were created to account for the quantity of allylic or bis-allylic carbons. These indices seem to be more appropriate for evaluating oxidative stability than IV [44]. Chromatographic or spectroscopic techniques like GC or NMR can be used to determine the BAPE and APE indices [45]. Because the relative rate of oxidation of bis-allylic CH2 locations is substantially larger, the BAPE value is particularly relevant for the oxidation of unsaturated fatty molecules [44]. The quantity and location of double bonds affect how quickly autoxidation occurs. Compared to allylic sites, bis-allylic sites are significantly more susceptible to oxidation [46].

The formulas listed below were utilized to determine the oxidation stability of biodiesel.

Equivalents of allylic position

$$APE = \sum ap_n \times A_{cn} \quad (5)$$

ap_n: the overall number of equivalent allylic positions

A_{cn}: FA Content

Equation 6 can be used to calculate bisallylic position equivalents (BAPE).

$$BAPE = \sum (bp_n \times A_{cn}) \quad (6)$$

bp_n: the overall number of Bisallylic positions

Oxidation stability (OS) can be computed using equation 7.

$$OS = (117.9295/(C18{:}2 + C18{:}3) + 2.5905) \quad (7)$$

The most significant disadvantage of using biodiesel as a fuel is its cold flow properties. CFPP, CP, and PP are the cold flow properties predicted [47, 48], in that order.

Saturated long-chain factor (LCSF)

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

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

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

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

At 40 °C, the kinematic viscosity was estimated from Equation 12

$$\ln(v) = \sum N_i(-12.503 + 2.496 \times \ln M_{wi}) - (0.178 \times D_i) \quad (12)$$

with

Mw_i molecular weight of FA, N_i % FA, D_i double bonds quantity, respectively.

Biodiesel density is calculated by using equation 13 (at 20°C)

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

Higher heating value can be calculated by equation 14

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

For flashpoint computation equation 15 is used [49].

$$FP\ (°C) = 205.226 + 0.083x_p - 1.727x_s - 0.5717x_o - 0.3557x_{LI} - 0.467x_{LN} - 0.2287x_E \quad (15)$$

with

x_p (C16:0) ratio; x_s (C18:0) ratio; x_o (C18:1) ratio; x_{LI} (C18:2) ratio; x_{LN} (C18:3) ratio; x_E (C22:1) ratio, respectively.

3. Results and Discussion

Obtained sample of plum oil was subjected to GC testing, and the gas chromatography spectra of Prunus insititia kernel oil are shown in Figure 7.

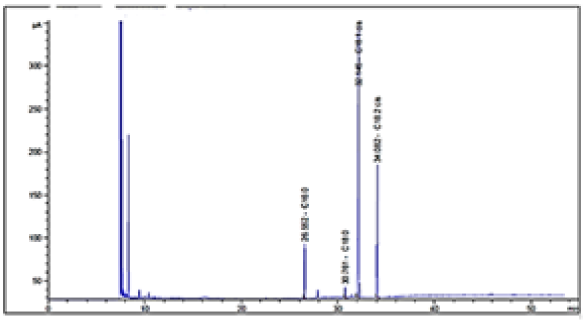


Figure 7. GC result of Purus insititia L kernel oil (PIO)

GC analysis provides detailed information on the hydrocarbons, fatty acid esters, and triglycerides present in the oil, which are crucial for understanding its fuel properties. The X-axis represents time (minutes), while the Y-axis represents signal intensity (pA –

picoampere). The distinct peaks indicate the presence of specific components in the sample. The most prominent peaks correspond to fatty acids. The labeled main fatty acids in the chromatogram are:

First Peak: C16:0 (Palmitic Acid) - 26.552 min. A saturated fatty acid. Increases viscosity and density.May negatively affect cold flow properties but enhances oxidative stability.

Second Peak : C18:0 (Stearic Acid) - 30.761 min. Another saturated fatty acid. Contributes to higher combustion efficiency at elevated temperatures but may reduce fluidity.

Third Peak: C18:1 (Oleic Acid) - 32.145 min A monounsaturated fatty acid. It improves cold flow properties and combustion efficiency.

Fourth Peak: C18:2 (Linoleic Acid) - 34.082 min A polyunsaturated fatty acid. Enhances cold flow characteristics but reduces oxidative stability, potentially leading to polymerization over time.

The fatty acid profile is based on the corresponding data shown in Table 1.

Linoleic acid (21.405 %w), Oleic acid (61.687 %w), Palmitic acid (5.965 %w), and Stearic acid (1.459 %w) were the primary fatty acids found in Prunus insititia L. kernel oil. According to Table 1, the key fatty acids that define the characteristics of the resulting biodiesel are linoleic acid and oleic acid, which have the largest percentage by weight.

Prunus insititia kernel oil biodiesel fuel parameters were predicted using the biodiesel analyzer V2.2. Table 2 gives Saturated Fatty acid (SFA), Bisallylic position equivalents (BAPE), Long-chain saturated factor (LCSF), Allylic position equivalents (APE), and % monosaturated fatty acids (MUFA), % polyunsaturated fatty acids (PUFA).

The estimated physiochemical values of Prunus insititia biodiesel (PIB) are given in Table 3.

Saturated fatty acids (C16:0, C18:0); Increase viscosity, reduce cold flow properties.

Unsaturated fatty acids (C18:1, C18:2); Lower viscosity, improve combustion efficiency.

Polyunsaturated fatty acids (C18:2) → Improve cold flow but may require antioxidant additives for stability.

This GC analysis indicates that the oil sample has a suitable fatty acid profile for biodiesel production:

A balanced ratio of saturated and unsaturated fatty acids.

A higher proportion of unsaturated fatty acids improves cold flow properties.

Oxidative stability may need to be enhanced using antioxidants.

Biodiesel instability is caused by oxidation stability (OS), which is defined as the unsaturation of the biodiesel ester molecule [50]. The biodiesel gets increasingly unstable as the unsaturation of the FA chain increases. As a result, the rate of oxidation is determined by the location and amount of allylic and bis-allylic methylene groups adjacent to the double bond. OS is anticipated to be 8.093 hours, which is within the biodiesel standard range [51].

Total unsaturated fat is measured by the iodine value [50]. PIB has an iodine value of 95.55, which is less than the biodiesel standard's maximum iodine value.

PIB has a saponification value of 184.28, which is inversely linked to the average molecular mass of the glycerides in plum oil [16].

Table 1. Fatty acids (FA) profile of Prunus insititia L. kernel oil

FA	% w	FA	% w
Butyric (C4:0)	0.098±0.00	Hexanoic (C6:0)	0.077±0.00
Caprylic (C8:0)	0.014±0.00	Capric (C10:0)	0.020±0.00
Lauric (C12:0)	0.011±0.00	Myristic (C14:0)	0.067±0.00
Pentadeanoic (C15:0)	0.019±0.00	Palmitic (16:0)	5.965±0.14
Palmitioleic (C16:1)	0.079±0.01	Margaric (C17:0)	0.036±0.00
Stearic (18:0)	1.459±0.06	Oleic (C18:1)	61.687±1.46
Linoleic (18:2)	21.405±1.02	Linolenic (18:3)	0.027±0.00
Eicosenoic (C20:1)	0.099±0.02	Behenic (C22:0)	0.042±0.00
Docosahexaenoic (C22:6)	0.036±0.00	Lignoceric(C24:0)	0.027±0.00
Ervonic (24:1)	0.277±0.03	Ecucic (C22:1)	0.198±0.01

Table 2. Results of predicted values

SFA	MUFA	PUFA	DU	LCSF	APE	BAPE
7.833	62.857	21.468	105.792	1.442	104.730	21.639

Table 3. Estimated physiochemical values of PIB

Value	Diesel (EN 590)*	Biodiesel (EN 14214)*	PIB
Oxidation Stability	25 g/m^3 max	8 hrs min	8.093
Cetane Number	51	51	54.314
Iodine Value max	-	120[1] g lod/100g	95.550
Kinematic Viscosity (mm^2/s)	2.0-4.5	3.5-5.0	3.481
Higher Heating Value (MJ/kg)	-	-	36.420
Density (kg/m^3)	820-845	860-900	809
Saponification Value	-	-	184.936
Flash Point (°C)	55	101	160.083
Pour Point (°C)	-	-	-8.834
Cold Filter Plugging Point (°C)	a	a	-11.947
Cloud Point (°C)	a	a	-1.854

Cetane is affected by iodine and saponification levels. Being a dimensionless descriptor of a diesel fuel's ignition quality CN is very important. CN shows the potential for self-ignition. A high cetane number indicates a rapid self-ignition [50] PIB has an estimated cetane number as 54.314 which is above the Biodiesel standard which means delay time is reduced.

The resistance of one component of a substance moving over another section of the same substance is defined as viscosity. If the viscosity of the fuel is low, leakage will result in a loss of engine power PIB has a calculated viscosity of 3.481 mm^2/s, which is slightly below (0.542%) minimum of the biodiesel regulations. Low-viscosity fuels generally result in better atomization, characterized by smaller droplet sizes and more uniform patterns. This is due to enchanced droplet breakup and reduced droplet aggregation, which are crucial for efficient combustion [52, 53]. Imroved atomization leads to more complete fuel burns, which can enchance combustion efficiency. This is because smaller droplets have a larger surface area relative to their volume, facilitating faster evaporation and more complete mixing with air [54, 55, 56]. Better atomization and more complete combustion can lead to reduced soot and other particulate emissions. This is particularly beneficial in reucing the environmental impact of combustion engines [55,57,58]. While low viscosity improves atomization, it can also lead to issues such as fuel leakage and power loss due to insufficient lubrication and sealing in engine components [53]. Also, the ignition delay period is reduced because low viscosity values promote faster atomization of the fuel spray [50]. The use of low-viscosity fuels can reduce emissions of nitrogen oxides (NOx) and carbon monoxide (CO), contributing to clener combustion processes [54,56].

Density is a key parameter. The energy content per unit volume rises as density rises [59]. The predicted density of PIB is 809 kg/m^3 which is 5.93% below the limits of the EN14214 standard. Hence the density of PIB is low which will cause decreasing in the energy content. Lower fuel density can enchance air-fuel mixing, leading to more uniform combustion and potentially lower emissions. This is supported by studies showing that fuels with lower density can result in better atomization and mixing, which is crucial for efficient combustion and reduced emissions [60,61,62]. Improved mixing from lower density fuels can lead to reductions in emissions such as soot, CO, and hydrocarbons. For instance, better air utilization and mixing can significantly reduce soot and othe emissions in dıesel engines [62,63]. Enhanced mixing due to lower density can also improve combustion efficiency, as seen in studies where optimized mixing led to increased power delivery and reduced specific fuel consumption [63,64]

The projected Higher Heating Value of PIB is 36.420 MJ/kg. PIB has less energy content than diesel fuel. The engine produces less peak power if fuel is used with a lower energy content per litre [38].

The flashpoint of a fuel is the temperature at which it produces enough vapour to generate a flammable combination. For diesel fuel, the temperature should be between 52 and 66 degrees Celsius. Biodiesel's high flashpoint (>150) suggests that it has a minimal risk of catching fire [47]. PIB's flashpoint is anticipated to be 160.083°C, which is greater than the minimum value in EN14214, indicating that PIB is suitable for storage and transportation.

Cold flow properties (Cloud Point, Pour Point and Cold Flow Plugging Point) are very important properties for biodiesel. Decreasing temperatures promote the creation of submicron-scale solid wax crystal nuclei that are undetectable to the naked eye. These crystals develop as the temperature drops more. The temperature at which crystals become visible is known as the cloud point (CP), because they often produce a hazy or foggy suspension. Larger crystals fuse and create huge agglomerates at temperatures below CP causing startup problems [47]. The cloud point of PIB is estimated as -1.854 °C which is not too low for wintertime. The pour point (PP) is the temperature at which crystal aggregation is prevalent enough to prevent fluid from flowing freely [47]. The predicted PP for PIB is -8.834 °C. The lowest temperature at which 20 mL of oil may safely pass through the filter in 60 seconds is known as the Cold Flow Plugging Point (CFPP)[47]. The calculated value of CFPP for PIB is -11.947 °C.

4. Conclusion

Several more countries are currently attempting to reduce their reliance on foreign energy sources. Simultaneously, biofuels have become an absolute necessity due to the environmental and human health consequences of fossil fuel use. A more attainable goal would be to use biodiesel as a raw material from so-called oil. If biodiesel is to be commercialised as an alternative fuel, it must be manufactured from non-edible oils rather than edible oils. Since price rises are to be expected as a result of the withdrawal of food-grade oils, which will jeopardise long-term economic stability.

Alternative feedstocks, such as Prunus insititia L., that were lost and discarded as food waste, would be used at this stage. These wastes, which currently have no economic value, could be used as a new source of raw material for biodiesel production. Prunus insititia L. kernels were analyzed in this study, and the fatty acid content was calculated numerically. Linoleic acid, Oleic acid, Palmitic acid, and Stearic acid were the main fatty acids in Prunus insititia kernel oil. The key fatty acids that determine the characteristics of the resultant biodiesel are Linoleic acid and Oleic acid. And the results are as follows:

- The predicted values of oxidation stability, flash point, cold flow properties, and cetane number were within the limits of EN14214 standards.
- However, the viscosity was calculated as 0.542% and the density 5.93% less than the minimum values in the standard. The density of 0.809 g/cm³ means the biodiesel may have slightly lower energy content than standard diesel. More fuel may be needed to achieve the same power output. Since the density of PIB is low, the oxidative stability and long-term storage durability could decrease. Antioxidant additives can be included to enhance stability. Lower density and better atomization could result in higher combustion temperatures. Result: NO_x emissions may slightly increase. This can be controlled using EGR (Exhaust Gas Recirculation) or catalytic converters.

As a result of these issues, Prunus insititia seed L. appears to be a viable biodiesel feedstock. Prunus insititia kernel oil biodiesel is suggested to be produced experimentally, and engine performance aspects are investigated for future research.

Declaration of Competing Interest

The authors declare that there is no conflict of interest in the study.

CRediT authorship conribution statement

Aslı Abdulvahitoğlu: Conceptualization, Formal Analysis, Methodology, Visualization, Writing - original draft, Writing - review & editing. **Nurten Cengiz**: Investigation, Writing - Original Draft.

5. References

1. World energy 418625c2c9d7/ balance available from https://iea.blob.core.windows.net/assets/23f096ab-5872-4eb0-91c4-World_Energy_Balances_Overview_ 2020_ edition.pdf] accessed 3.6.2021
2. Sakthivel R., Ramesh K., Purnachandran R., Mohamed Shameer P.. A review on the properties, performance and emission aspects of the third generation biodiesels. Renew Sust Energ Rev., 82, pp.2970–2992, 2018. https://doi.org/10.1016/j.rser.2017.10.037
3. Shuit S.H., Tan K. T., Lee K. T. Kamaruddin A. H. Oil palm biomass as a sustainable energy source: A Malaysian case study Author links open overlay panel. Energy., 34(9), pp.1225-1235, 2009. https://doi.org/101016/j.energy.2009.05.008
4. Sugebo, B., Demrew, Z., Feleke, S. Biazen M. Evaluation and characterization of rubber seed oil for biodiesel production. Biomass Conv. Bioref. 2021. https://doi.org/10.1007/s13399-021-01900-4
5. Abdulvahitoğlu A, Tüccar G. Evaluation of watermelon seed biodiesel as an alternative fuel in diesel engines. J Fac Eng Archit Gazi, 32(1), pp.189-194, 2017. https://doi.org/10.17341/gazimmfd.300610
6. Aderibigbe F.A., Mustapha S.I., Adewoye T.L., Mohammed I.A., Gbadegesin A.B., Niyi F.E., Olowu O.I., Soretire A.G., Saka H.B. Qualitative role of heterogenous catalysts in biodiesel production from Jatropha curcas oil. Biofuel Research Journal, 26, pp.1159-1169, 2020. https://doi.org/10.18331/BRJ2020.7.2.4
7. Verma P, Sharma M.P. Review of process parameters for biodiesel production from different feedstocks. Renew Sust Energ Rev., 62, pp.1063–1071, 2016. https://doi.org/10.1016/jrser.2016.04.054
8. Latinas A., Geivanidis S., Faliakis A., Courouclis Y., Samaras Z., Keder A., Krasnoholovets V., Gandzha I., Zabulonov Y., Puhach O., Dmytriyuk M.. Biodiesel production from high FFA feedstocks with a novel chemical multifunctional process intensifier. Biofuel Research Journal, 26, pp.1170-1177, 2020. https://doi.org/10.18331/BRJ2020.7.2.5
9. Avinash A., Mahian O., Hollmann F., Zhang W., Environmentally benign solid catalysts for sustainable biodiesel production: A critical review. Sci Total Environ, 768, pp.144856, 2021. https://doi.org/10.1016/j.scitotenv.2020.144856
10. Cijil B. John, S. Antony Raja, B. Deepanraj, H. C. Ong. Palm stearin biodiesel: preparation, characterization using spectrometric techniques and the assessment of fuel properties Biomass Conv. Bioref., 12, pp.1679–1693, 2022. https://doi.org/10.1007/s13399-020-01265-0
11. Azam M. M., Waris A., Nahar N. M. Prospects and potential of fatty acid methyl esters of some non-traditional seed oils for use as biodiesel in India. Biomass Bioenerg, 29, pp.293–302, 2005. https://doi.org/10.1016j.biombioe.2005.05.001
12. BP stats are available from https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2022-full-report.pdf 18.12.2024.
13. FAO available from http://www.fao.org/3/cb1993en/cb1993en_oilcrops.pdf accessed 3.6.2021.
14. Abdulvahitoğlu A., Evaluation of the fuel quality values of bay laurel (Laurusnobilis L.) oil as a biodiesel feedstock. Biofuels, 9(1), pp. 95-100, 2018. https://doi.org/10.1080/17597269.2016.1257319
15. Al-Samaraae R. R., Atabani A. E., Gediz U., Gopalakrishnan K., Arpa O., Ayanoglu A., Mohammed M.N., Farouk H., Perspective of safflower (Carthamustinctorius) as a potential biodiesel feedstock in Turkey: characterization, engine performance and emissions analyses of butanol–biodiesel–diesel blends, Biofuels, 11 (6), pp.715-731, 2017. https://doi.org/10.1080/17597269.2017.1398956
16. Sahafi S. M., Ahmadibeni A., Talebi A. F., Goli S. A. H., Aghbashlo M., Tabatabaei M. Seed oils of Sisymbriumirio and Sisymbriumsophia as a potential non-edible feedstock for biodiesel production. Biofuels, 12(1), pp.103-111, 2021. https://doi.org/10.1080/17597269.2018.14573

15
17. Dmytryshyn S. L., Dalai A. K., Chaudhari S. T., Mishra H. K., Reaney M. J., Synthesis and characterization of vegetable oil derived esters: evaluation for their diesel additive properties. Bioresource Technol, 92(1), pp.55–64, 2004. https://doi.org/10.1016/jbiortech.2003.07.009
18. Rao G. L. N, Prasad B. D, Sampath S, Rajagopal K., Combustion Analysis of Diesel Engine Fueled with Jatropha Oil Methyl Ester - Diesel Blends, Int J Green Energy, 4(6), pp.645-658, 2007. https://doi.org/10.1080/15435070701665446
19. Mbarawa M., Performance, emission and economic assessment of clove stem oil–diesel blended fuels as alternative fuels for diesel engines. Renew Energ, 33, pp.871–882, 2008. https://doi.org/10.1016/j.renene.2007.06.009
20. Ramos M. J., Fernández C. M., Casas A., Rodríguez L., Pérez A. Influence of fatty acid composition of raw materials on biodiesel properties. Bioresource Technol,100, pp.261–8, 2009. https://doi.org/10.1016/j.biortech.2008.06.039
21. Puhan S., Jegan R., Balasubbramanian K., Nagarajan G., Effect of injection pressure on performance, emission and combustion characteristics of high linolenic linseed oil methyl ester in a DI diesel engine. Renew Energ, 34, pp.1227–1233, 2009. https://doi.org/10.1016/j.renene.2008.10.001
22. Abdulvahitoglu, A., Aydin, K. Performance and exhaust emission characteristics of a CI engine fueled with synthesized fuel blends Energy Education Science and Technology Part A: Energy Science and Research, , 28(2), pp.699–710, 2012.
23. S. Simsek, E. Koç, and A. Öztürk, “Unique fatty acid composition of coriander seed biodiesel”, International Journal of Automotive Engineering and Technologies, vol. 13, no. 3, pp. 114–122, 2024. doi: 10.18245/ijaet.1497824.
24. Ruhul Md. A., Abedin Md. J., Ashrafur Rahman S. M., Bin Haji M. H., Alabdulkarem A., Abul Kalam Md., Shancita I., Impact of fatty acid composition and physicochemical properties of Jatropha and Alexandrian laurel biodiesel blends: An analysis of performance and emission characteristics. J Clean Prod., 133, pp.1181-1189, 2016. https://doi.org/10.1016/j.clepro.2016.06.07
25. Devarajan Y, Selvam D C, Utilization of sterculia foetida oil as a sustainable feedstock for biodiesel production: optimization, performance, and emission analysis, Results in Engineering, Volume 24, 103196, 2024. https://doi.org/10.1016/j.rineng.2024.103196.
26. AlYammahi J., Chelaifa H., Hasan A., Darwish A.S., Lemaoui T., Hernandez H.H., Rios-GalvanA., Salicornia seed oil: A high-yielding and sustainable halophytic feedstock for biodiesel and energy in underutilized hypersaline coastal deserts, Energy Conversion and Management,Volume 318,118914, 2024. https://doi.org/10.1016/j.enconman.2024.118914.
27. Rajesh K., Natarajan M. P., Devan P. K., Ponnuvel S., Coconut fatty acid distillate as novel feedstock for biodiesel production and its characterization as a fuel for diesel engine. Renew Energ,164, pp.1424-1435, 2021. https://doi.org/10.1016/j.renene.2020.10.082
28. Turkstat available from www.turkstat.gov.tr accessed 16.12.2024.
29. Borovalı S. available from www.dunyaenerji.org.tr/wp-content/ uploads /2019/04/ Selcuk Borovali Sunum accessed 3.6.2021.
30. Atlasbig is available from www.atlasbig.com/tr/ulkelerin-erik-uretimi accessed 3.6.2021.
31. Plum cultivation map available from http://cografyaharita.com/haritalarim/4cturkiye-2019-erik-uretim-haritasi.png accessed 3.6.2021.
32. Plum available from https://acikders.ankara.edu.tr/pluginfile.php/112430/modresource/content/0/ER%C4%B0K%20DERS%20NOTU-7.%20HAFTA.pdf accessed 3.6.2021.
33. A.E. Atabani, A.S. Silitonga, Irfan Anjum Badruddin, T.M.I. Mahlia, H.H. Masjuki and S. Mekhilef. “A comprehensive review on biodiesel as an alternative energy resource and its characteristics”, Renewable and Sustainable Energy Reviews, pp. 2070–2093, 2012.
34. Jana Orsavova, Ladislava Misurcova „

Jarmila Vavra Ambrozova , Robert Vicha and Jiri Mlcek, "Fatty acids composition of vegetable oils and its contribution to dietary energy intake and dependence of cardiovascular mortality on dietary intake of fatty acids", International Journal of Molecular Sciences, Vol. 16, pp. 12871-12890, 2015.
35. Gog Adriana, M. Chintoanu, M. Roman, Gabriela Pitl, E. Luca and F. D. Irimie, "Biodiesel as alternative fuel – general aspects", Agricultura – Stiina si practica, no. 3-4 (63-64), 2007.
36. Biodiesel Analyzer available from http://brteam.org/analysis/#id02 "biodiesel Analyzer © Version 2.2" accessed 3.6.2021.
37. Talebi, A.F., Tabatabaei, M., Chisti Y."Biodiesel analyzer©: a user-friendly software for predicting the properties of prospective biodiesel" Biofuel Research Journal 1, 2, pp.55-57, 2014. https://doi.org/10.18331/BRJ2015.1.2.4
38. Arjun B. Chhetri, K. Chris Watts and M. Rafiqul Islam, "Waste cooking oil as an alternate feedstock for biodiesel production", Energies, Vol. 1, pp. 3-18, 2008.
39. Alok Patel, Neha Arora, Juhi Mehtani, Vikas Pruthi and Parul A. Pruthi, "Assessment of fuel properties on the basis of fatty acid profiles of oleaginous yeast for potential biodiesel production", Renewable and Sustainable Energy Reviews, Vol. 77, pp. 604-616, 2017.
40. Nithyananda B S, Prakash G V N, Vinay K B, Mohankrishna S A, Ankegowda N "Investigation on the Effect of Fatty Acids Composition on the Fuel Properties of Biodiesel" E3S Web of Conferences 559, 03001 ICSTCE 2024. https://doi.org/10.1051/e3sconf/202455903001
41. Knothe G,Dunn R O.Dependence of oil stability index of fatty compounds on their structure and concentration and presence of metals.Journal of the American Oil Chemists Society;80(10):1021–6, 2003.
42. Knothe G. Structure indices in FA chemistry. How Relevant Is the Iodine Value? Journal of the American Oil Chemists' Society; 9:847–53, 2002.
43. JPullen, K. Saeed An overview of biodiesel oxidation stability / Renewable and Sustainable Energy Reviews, 16, 5924–5950, 2012.
44. Sarin A, Arora R, Singh N, Sarin R, Malhotra R, Kundu K. Effect of blends of Palm-Jatropha-Pongamia biodiesels on cloud point and pour point. Energy, 34, pp.2016–2021, 2009. https://doi.org/10.1016/j.energy.2009.08.017
45. Senthamilselvi, D., Kalaiselvi, T., Gamma ray mutants of oleaginous microalga Chlorella sp. KM504965 with enhanced biomass and lipid for biofuel production. Biomass Conv. Bioref. 2022. https://doi.org/10.1007/s13399-022-02400-9
46. Agarwal M, Singh K, Chaurasia S. P. Prediction of Biodiesel Properties from Fatty Acid Composition using Linear Regression and ANN Techniques, Indian Chemical Engineering 52, (4), pp.347-361, 2010. https://doi.org/10.1080/00194506.2010.616325
47. Knothe G., Van Gerpen J., Krahl J. "The Biodiesel Handbook" AOCS, ISBN 1-893997-79-0. 2005.
48. Dieselnet available from https://dieselnet.com/tech/fuel_biodiesel_std.php accessed 3.6.2021.
49. van Basshuysen R., Schäfer F. "Internal Combustion Engine Handbook" Basics, Components, Systems, and Perspectives. SAE International.; ISBN 0-7680-1139-6. 2004.