REPUBLIC OF TURKEY
ADANA ALPARSLAN TÜRKEŞ SCIENCE AND TECHNOLOGY UNIVERSITY

INSTITUTE OF GRADUATE STUDIES
DEPARTMENT OF MECHANICAL ENGINEERING

NUMERICAL INVESTIGATION OF EXHAUST EMISSIONS BY USING VARIOUS BIODIESEL IN A COMPRESSION IGNITION ENGINE

DUYGU DURDU KOÇ
MASTER OF SCIENCE

ADANA 2022

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I hereby declare that all information in this thesis has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all information that is not original to this work.

[Signature]

Duygu Durdu KOÇ

ABSTRACT

NUMERICAL INVESTIGATION OF EXHAUST EMISSIONS BY USING VARIOUS BIODIESEL IN A COMPRESSION IGNITION ENGINE

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September 2022, 73 pages
The increasing human population and developing living standards in the world have led to significant increases in energy use. Meeting a significant part of the energy need from fossil fuels has begun to put these energy sources at risk. This is because fossil fuel reserves are not renewable. It has become a necessity of our age to turn to alternative and environmentally friendly fuel sources when the damage to nature as a result of their use, as well as the decrease of these resources with each passing day, is evaluated. In this study, Luffa Aegyptiaca, known as loofah seed, which is grown especially the in Hatay region in Turkey, is discussed. The oil was obtained using the seeds of Luffa Aegyptiaca. The fatty acids were determined by subjecting the obtained oil to the necessary analyzes and tests. The main fatty acids affecting the fuel properties of biodiesel, oleic acid (C18:1) and Linoleic acid (C18:2), were determined as 97.8318 and 129.1163, respectively. In addition to these two fatty acids, all the free fatty acids determined were evaluated using the Biodiesel Analyzer v1.2 program. Using the Diesel-RK program in line with the data obtained; Compared to Luffa Aegyptiaca biodiesel (LAB100), Soy Methyl Ester (SME100), Canola Methyl Ester (RME100) and standard diesel (DIESEL100). For each fuel; engine power, torque, specific fuel consumption and NOx emission values were analyzed at five different engine speeds (rpm). It has been determined that the value of LAB100 fuel has NOx emissions of only 10% of the emission value of other fuels. As a result of this study, it is shown that LAB100 fuel can be a good alternative to fossil fuel sources by reducing the analyzed FFA value of 2.41% to below 1% by making the necessary procedures.

Key Words: Luffa Aegytiaca, Alternative Fuel, Exhaust Emission, Engine Performance

ÖZET

İÇTEN YANMALI BİR MOTORDA FARKLI BİYODİZELLER KULLANILARAK EGZOZ EMİSYONLARININ SAYISAL İNCELENMESİ

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Eylül 2022, 73 sayfa

Dünyada artan insan nüfusu ile gelişen yaşam standartları, enerji kullanımında önemli artışlara yol açmıştır. Enerji ihtiyacının önemli bir kısmının fosil yakıtlardan karşılanması bu enerji kaynaklarını riske atmaya başlamıştır. Bunun nedeni fosil yakıt rezervlerinin yenilenebilir olmamasıdır. Bu kaynakların her geçen gün azalmasının yanı sıra kullanımları sonucunda doğaya verilen zararlar değerlendirildiğinde alternatif ve çevreci yakıt kaynaklarına yönelmek çağımızın bir gerekliliği haline gelmiştir. Bu çalışmada, Türkiye'de özellikle Hatay bölgesinde yetiştirilen ve lif kabağı tohumu olarak bilinen Luffa Aegyptiaca ele alınmıştır. Yağ, Luffa Aegyptiaca tohumları kullanılarak elde edildi. Elde edilen yağ gerekli analiz ve testlere tabi tutularak yağ asitleri belirlenmiştir. Biyodizelin yakıt özelliklerini etkileyen ana yağ asitleri olan oleik asit (C18:1) ve Linoleik asit (C18:2) sırasıyla 97.8318 ve 129.1163 olarak belirlenmiştir. Bu iki yağ asidine ek olarak belirlenen tüm serbest yağ asitleri Biodiesel Analyzer v1.2 programı kullanılarak değerlendirilmiştir. Elde edilen veriler doğrultusunda Diesel-RK programı kullanılarak; Luffa Aegyptiaca biyodizeli (LAB100), Soya Metil Esteri (SME100), Kanola Metil Esteri (RME100) ve standart dizel (DIESEL100) ile karşılaştırılmıştır. Her bir yakıt için; motor gücü, tork, spesifik yakıt tüketimi ve NOx emisyon değerleri belirlenen beş farklı motor hızında (rpm) analiz edilmiştir. LAB100 yakıtının değerininin diğer yakıtların emisyon değerinin sadece %10 kadar NOx emisyonuna sahip olduğu tespit edilmiştir. Bu çalışmanın sonucunda LAB100 yakıtının analiz edilen %2,41 değerindeki FFA değerinin gerekli işlemler yapılarak %1'in altına düşürülmesi ile fosil yakıt kaynaklarına iyi bir alternatif oluşturabileceğini göstermektedir.

Anahtar Kelimeler: Luffa Aegytiaca, Biyodizel, Alternatif Yakıt, Egzoz Emisyonu, Motor Performansı

to my very dear family…

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

CO	: Carbon Monoxide
CO_2	: Carbon Dioxide
EGR	: Exhaust Gas Recirculation
HC	: Hydrocarbon
LAB	: Luffa Aegyptiaca Biodiesel
NO_x	: Oxides of Nitrogen
RME	: Rapeseed Methil Ester
SFC	: Specific Fuel Consumption
SME	: Soybean Methil Ester
SV	: Saponification Value
IV	: Iodine Value
N	: Percentage of Fatty Acid Ester in the oil sample
M	: Molecular mass of fatty ester
D	: Number of double bonds
CN	: Cetane Number
DU	: Degree of Unsaturation
MUFA	: % monosaturated fatty acids,
PUFA	: % polyunsaturated fatty acids.
apn	: number of allylic position equivalents
Acn	: Amount of Fatty Acid in the mixture
B_{pn}	: number of Bis-allylic position equivalents
OS	: Oxidation stability
LCSF	: Long-chain saturated factor
CFPP	: Cold Filter Plugging Point
CP	: Cold Filter Plugging Point
PP	: Cloud Point
FP	: Flashpoint
x_p	: mass fraction of palmitic acid
x_s	: mass fraction of stearic acid
x_o	: mass fraction of oleic acid

x_{LI}	: mass fraction of linoleic acid
x_E	: mass fraction of erucic acid

1. INTRODUCTION

Owning energy resources and being able to produce energy are the most important signs of development in the period we live in. Today, for technological developments to continue and to continue the opportunities these technological developments offer in our lives, energy must be consumed directly and indirectly (Samani et al. 2020). Therefore, countries have a say in world trade in direct proportion to the amount of energy they have. With the increase in population density in the world with each passing year, the demand for energy resources is also increasing. In this direction, there has been a significant decrease in the fossil resource reserves that mankind has used as an energy source until today. Decreases in fossil-based energy reserves cause crises in this field. Declining reserves; have led human beings to seek new energy sources to meet their needs and maintain their living standards. In addition to this situation, due to global warming, ozone layer depletion, climate change and uncontrollable forest fires, care should be taken to ensure that new energy sources are environmentally friendly. This situation has formed the basis of new research and studies in the automotive sector, which needs energy the most to survive. In the automotive sector; the search for a renewable, clean, environmentally friendly new energy source has revealed biodiesel as an important solution proposal. Biodiesel, which can be obtained from animal, vegetable and waste products as a result of chemical processes, is a liquid fuel type. This type of fuel can be used in diesel engines in pure form or mixed with diesel fuels in certain proportions. This fuel obtained as a result of chemical processes is named differently according to the mixing ratios. a fuel blend B5 of 5% biodiesel and 95% diesel fuel, a fuel blend B20 of 20% biodiesel and 80% diesel oil, a fuel blend B50 of 50% biodiesel and 50% diesel oil A fuel mixture consisting of 100% biodiesel is called B100.

When we look at the history of biodiesel, it is seen that the first studies were made by Rudolf Diesel, who also invented the diesel engine. Although Rudolf diesel prefers to use peanuts as raw materials, nowadays canola, safflower, sunflower, cotton, soybean, and both animal/vegetable waste oils can be used as raw materials for biodiesel. In our country, we see that the first studies on biodiesel were made for its use in agricultural machinery in Atatürk Forest Farm. However, these studies, which have been suspended for a long time, have come to the agenda again since the 2000s, and significant progress has been made in biodiesel production and research studies.

Many raw materials can be used for biodiesel production. Among these are sunflower, safflower, canola, cotton, soy and of course waste oils. When we look at the historical development of biodiesel as old as diesel engines, we see for the first time that Rudolf Diesel obtained fuel from vegetable oils using peanut oil. İn our country, as a result of the search for alternative fuels since the 2000s, biodiesel production and academic studies have increased.

Diesel engines are an internal combustion engine type, and the chemical energy of the fuel is converted directly to mechanical energy with the cylinders. Diesel engines operate according to the principle of self-ignition of fuel sprayed into the air, whose pressure and temperature are raised and the burning process takes place (Küçükşahin, 2008).

In combustion engines, the gases produced by the harmful gases released as a result of the combustion of fuel-air mixtures are exhaust gases. Emission is a term used to describe the air pollution created by a vehicle.

CO (carbon monoxide) is the leading gas that affects exhaust emission values. İt is a type of emission depending on parameters such as CO emission, air-fuel mixture ratio, oxygen amount and engine temperature. CO occurs as a result of incomplete combustion of petroleum-based fuels that do not contain oxygen in their molecular structure (Agarwal, 2007).

NO, NO_2, N_2O, N_2O_3 etc. with the combination of different molecules of nitrogen and oxygen gases. Various gases such as emerge, all of which are called "nitrogen oxides" and are expressed as NOx (Demir, 2009). The emission of nitrogen oxides is created by two mechanisms in the combustion chambers. One of them is Zeldovich and the other is the emission of NO.

$O + N_2 \leftrightarrow NO + N$ (Eq.1)

$N + O_2 \leftrightarrow NO + O$

$N + OH \leftrightarrow NO + H$

Formed in this way and the amount of nitrogen oxide is determined in the first reaction. This mechanism is mostly dependent on temperature and linear oxygen concentration and it is independent of the type of fuel (Küçükşahin, 2008).
In this study, biofuel is discussed to prevent environmental pollution, create an alternative to

existing fossil fuels, to increase the working areas of renewable energy against depleted energy sources. Considering the research and literature reviews conducted in this direction, it has been seen that biofuels can be produced from many different raw materials.

However, the basis of this study, unlike other raw materials in the literature, has not been studied before, Luffa aegyptiaca seed. Luffa aegyptiaca seeds have an oily structure and are grown in many parts of the world, including our country. The oil of the Luffa aegyptiaca seeds obtained in the study was obtained by two different methods and oil analysis studies were carried out. The analyzed oil was simulated and run in the Diesel RK program. The closeness of the obtained values to the real values was compared with the reference value. This study, which is made by considering emission, torque and specific fuel consumption as valuable, it is aimed to produce a renewable alternative fuel from luffa aegyptiaca seed raw material, which has not been studied before and has a high oil content.

1.1.Previous Works

These parameters, which cause environmental pollution and adverse effects on the climate, have become important for the alternative fuel source biodiesel and have been examined by many researchers. Such as Sugözü et al examined B100 biodiesel obtained from sunflower, and a decrease of 25.6% was observed in CO emissions compared to diesel fuel while an increase of NO_x was 9.5%. This increase in NO_x emission is due to the oxygen contained in the sunflower biodiesel content (Sugözü, 2009).

Çelikten and Arslan stated that CO values for pure biodiesel obtained from canola and soy, which were discussed in a similar study, decreased by 17% and 35%, respectively, while NOx values increased by 14% and 26% (Çelikten and Arslan, 2008).

Hanbey and Öztürk observed that the CO value for peanut biodiesel decreased by 35% while a 25% increase in NO_x value was reflected in the experimental results (Hanbey and Öztürk, 2016).

Şimşek and Aydoğan observed that the values handled for pure biodiesel from camelina provide a 55% reduction for CO while an increase in NO_x of 31.32% (Şimşek and Aydoğan, 2016).

Öztürk et al concluded that the addition of oxygen compounds, ethanol and biodiesel, to diesel fuel reduced CO, soot and SO_2 emissions, while slightly increasing NOx emissions. With the addition of ethanol, there was a decrease in power and an increase in specific fuel consumption, while biodiesel blends achieved power and specific fuel consumption values that are very close to diesel fuel (Öztürk, Usta and Can, 2005).

Şimşek stated that a maximum reduction in motor torque of 11% and a maximum of 5% in motor power. It has been demonstrated that there is a decrease in HC, and CO emissions, while there is a 13% increase in NO_x emissions and an 18% improvement in soot emission (Şimşek, 2016).

Ayhan et al determined that when using B10 and B20 mixtures in the engine, the effective power and torque of the engine increased compared to the standard situation, while decreases occurred in the B50 mixture. The maximum increase was achieved in the use of B20 fuel. İt has been determined that in the case of B20 use, there is a significant decrease in HC, CO and Soot emissions, and an increase in NO emissions (Ayhan et al. 2019).

Aksoy et al wrote that maximum engine power was obtained at 3000 / min engine speed for biodiesel and diesel fuels. A 6.27% reduction in engine power compared to diesel fuel was achieved with the use of Biodiesel at 3000 / min engine speed. These reductions are due to the low thermal value and high viscosity of biodiesel. Specific fuel consumption increased by 16.41% on average compared to diesel fuel with the use of biodiesel. Specific fuel consumption increased with the use of biodiesel due to its high density and low thermal value. With the use of biodiesel, CO emissions decreased on average by 23.98%. With the use of biodiesel, NOx emissions increased by an average of 10.61% compared to diesel fuel (Aksoy, Bayrakçeken and Çengelci, 2011).

Haşimoğlu et al concluded that the lower thermal value of biodiesel compared to diesel was the main factor in the changes in engine performance and exhaust emissions. By using biodiesel as a fuel, specific fuel consumption, efficiency and nitrogen oxide emissions have increased, and exhaust gas temperature and smoke darkness have decreased (Haşimoğlu, İçingür and Özsert, 2008).

Öztürk and Bilen determined that the hourly fuel consumption values of the mixture fuel are

8% higher than the diesel fuel values. The average CO_2 emission values of canola oil methyl ester are 4.2% compared to diesel fuel; On the other hand, mixed fuel CO_2 emission values were found to be 2.8% lower than diesel fuel. The average NO_x emission values of canola oil methyl ester are 1.7% compared to the diesel fuel NO_x emission values; İt has been determined that the mixed fuel NO_x emission values are on average 1.2% higher than the diesel fuel NOx emission values. The average smoke darkness values of canola oil methyl ester are 50.2% compared to diesel fuel smoke darkness values; On the other hand, it has been determined that the mixture fuel smoke darkness values are 20,1% lower than diesel fuel (Öztürk and Bilen, 2009).

Abdulvahitoğlu, in his doctoral study in 2009, tried to improve fuel mixtures that can be used in diesel engine vehicles without any changes. In this direction, hydrocarbon was used as an additive to improve the properties of biodiesel, such as density and viscosity, which are bad compared to diesel. Canola biodiesel was mixed with diesel oil at rates between 10% and 50%. Diesel, which is the subject of the study, has a low sulfur content of between 45% and 85%. He prepared 15 different fuel mixtures by using 5% n-hexane, n-heptane and xylene hydrocarbons as additives. When the fuels whose engine performances were measured were examined, it was determined that there was an increase of 0.57% in maximum torque and 1.04% in specific fuel consumption. Despite this, it achieved the most ideal result by increasing the power by 15.31% for the D50RSB40HX10 fuel it prepared within the scope of the study (Abdulvahitoğlu, 2009).

Çelikten and Arslan reported that the highest engine performance was provided by diesel fuel, and then the performances of canola and soy oil methyl esters were listed. The fuel that gave the lowest smoke and CO emission values were the methyl ester of canola oil. However, normal diesel fuel NOx was lower than canola and soy methyl esters (Çelikten and Arslan, 2008).

Şahin concluded that at the maximum torque values obtained from the experimental fuels, the highest value is approximately 59.6 Nm at 1000 rev/min with diesel fuel, while it is approximately 53.8 Nm at 1200 rev/min with B100 fuel. When the maximum power values are considered, the highest value is approximately 10.96 kW at 2100 rev/min with diesel fuel, while it is approximately 10.23 kW at 2000 rev/min with B100 fuel. When looking at the minimum specific fuel consumption values, the lowest value was measured as approximately 231.36 g/kWh at 1000 rev/min with diesel oil, while it was measured as approximately 296.73 g / kWh at 1200 rev/min with B100 fuel (Şahin, 2013).

Behçet and Oral graphed the variation of the engine performance and exhaust emission values of the blended fuels according to the engine speed were graphed. Considering the results obtained as a result of comparing the test fuels with each other, the engine torque, engine power, CO, HC and SO_2 values of the blended fuels (BYME50 and FYME50) decreased, while the specific fuel consumption and NO_x emissions increased. Due to the good combustion properties of mixed fuels and their positive effects on the environment, these fuels can be used as an alternative to diesel fuel without any changes in diesel engines (Behçet and Oral, 2014).

Behçet et al concluded that BYME and APYME fuels have better properties than D2 fuels in terms of exhaust emissions. Biodiesel fuels originating from waste oil can be used as an alternative to diesel fuel due to the lower exhaust emissions (HC and CO) of BYME and APYME compared to diesel fuel, the good combustion properties of fuels and their positive effects on the environment (Behçet, Aydın and Çakmak, 2012).

Çengelci et al reported that carbon deposits have a negative effect on valve seats, especially in injectors. The carbon accumulated in the injectors worsens the injection and atomization of the fuel and negatively affects the quality of the combustion. Vegetable oils, whose viscosity is reduced by various methods, have different effects on the lubricating oil during their burning in the diesel engine. While it was observed that the mixture obtained by thinning slightly reduced the consumption of lubricating oil, it was determined that the oil obtained by pyrolysis and micro-emulsification methods reduced the viscosity of the lubricating oil by slightly thinning it (Çengelci, Bayrakçeken and Aksoy, 2011).

İçingür and Koçak stated that at the moment, power and specific fuel consumption values of hazelnut oil methyl ester and diesel fuel are very close to each other. The emissions of CO, NOx and smoke darkness of hazelnut oil methyl ester and exhaust temperatures were also lower than diesel fuel. As a result, it has been demonstrated that hazelnut oil methyl ester can be a renewable source and a suitable diesel fuel alternative (İçingür and Koçak, 2006).

Şimşek and Çolak observed that CO, NOx and soot emissions tend to decrease, but HC emissions increase. It has been determined that some disadvantages of biodiesel fuel can be eliminated with the addition of propanol in biodiesel, and there is an improvement in NOx emissions in particular (Şimşek and Çolak, 2019).

Sezer stated that BD fuel has efficiency values close to D fuel, it causes a decrease in engine performance and soot-particulate matter (PM) emissions, an increase in nitrogen oxide (NO_x) emissions and fuel consumption. On the other hand, D – BD fuel mixtures, although varying depending on the mixing ratio, generally gave spraying, combustion, performance and emission values between diesel and biodiesel fuels (Sezer, 2016).

Yaşar et al determined that the increase in biodiesel ratio in the mixture caused a decrease in thermal efficiency and an increase in specific fuel consumption (SFC). It has also been found that the addition of alcohol and biodiesel fuel reduces carbon monoxide emissions and increases NO_x and carbon dioxide emissions (Yaşar, Keskin and Yıldızhan, 2016).

Akgül et al investigated the usability of cheap and renewable carbon-based biochar as a catalyst in biodiesel production. The study is detailed with analysis methods such as GC-MS, SEM, and FTIR. The following conclusions were reached in this study, biochar can be used as catalysts, especially catalysts derived by acid activation have the advantage of being used multiple times. With this study, valuable data on the use of both biodiesel and biochar from renewable energy sources were obtained (Akgül, Sözer and Culfa, 2017).

Özsezen and Çanakçi determined that as the biodiesel ratio in the mixture increased, the specific fuel consumption increased and the rotational torque of the engine decreased compared to the PKDY. As a result of the emission analysis, there were improvements in the emissions of unburned hydrocarbon (HC), carbon monoxide (CO) and smoke darkness compared to PKDY, with the proportion of biodiesel in the mixture. However, it has been determined that carbon dioxide (CO2) and nitrogen oxide (NO_x) emissions do not show a stable structure compared to the engine speed (Özsezen and Çanakçı, 2009).

Aydin et al concluded that the use of biodiesel has achieved a 3% increase in brake-specific fuel consumption and a 5% reduction in brake-specific energy consumption compared to diesel fuel. İn addition, a decrease of 17%, 33% and 31% in NO_x, CO and soot emissions compared to diesel fuel, and an increase of 24% in HC emissions were determined, respectively (Aydın, Afşar and Çelik, 2017).

Keskin et al determined that according to the diesel fuel values, the torque and power values of the mixed fuel have decreased by up to 2.99% and 2.94%, respectively. The specific fuel consumption values of the engine with the mixed fuel increased by an average of 7.63%. With the use of mixed fuel, reductions of up to 35.44% in CO emission values and up to 13.27% in smoke emissions were detected. İn addition, there was an increase of up to 13.29% in NO_x emissions (Keskin, Gürü and Altıparmak, 2007)

Wang et al. in their study 2010; discussed the raw materials from Euphorbia lathyris L. (EL), Sapium sebiferum L. (SS) and Jatropha curcas L. (JC). By analyzing these inedible oils, they compared the biodiesel production process and fuel properties. Within the scope of the study, the methyl ester content and yield of these three oils were calculated. The methyl ester value of these three fatty acids was 97.5% and the yield was above '84.0'. When these three biodiesels are compared within themselves, EL biodiesel gave the best results with 59.6 cetane number, 10.4 hours oxidation stability and -11°C cold filter point. On the other hand, dewaxed SS kernel oil (DSSK) biodiesel yielded the lowest results with a cetane number of 40.2 and oxidation stability of 0.8 hours. As a result of the study, they concluded that E. lathyris L. is a highly promising raw material among these three biodiesel raw materials compared (Wang et al. 2011).

In 2012, Wang et al. prepared biodiesel (DSO) from Datura Stramonium L. oil to be used as an alternative fuel source. In their feasibility studies, the oil content obtained from the seed was 21.4% and the fatty acid value was determined as 7.93 mg KOH/g. They also determined their physical and chemical properties according to these values. In the other stage of the study, under the catalyzed reaction conditions, the yield of fatty acid methyl ester was 87% and the weight value of fatty acid methyl ester was found to be 98%. In addition, DSO, whose fuel properties were determined, were compared with Jatropha curcas L. (JC) and beef tallow (BT) biodiesels. As a result of the comparison, they determined that DSO biodiesel had a viscosity of 4.33 mm2/s and a cold flow filter of -5°C and defined it as a promising fuel source (Wang et al.

2012).

Li et al., in their research study in 2011, stated that biodiesel fuel obtained from the oils of inedible woody plants has less damage to the environment and has recently aroused great interest with its low cost. Looking at the details of their study, it is seen that they investigated the enzymatic transesterification of methanol and Pistacia Chinensis seed oil (PCO). Biocatalysts called MI-ROL and AI-ROL were used in the study. These catalysts additionally used macroporous immobilized recombinant Rhizopus oryzae lipases (ROL). In their study, they used Al-ROL in five cycles during the transesterification process. They reported that they did not experience a significant loss in yield during this period. As a result of the cycle they used MI-ROL, they stated that there was a decrease in the efficiency of biodiesel, but it remained above 60% (Li et al. 2012).

Sharma and Singh used the Schleichera triguga plant, which contains an inedible oil, as a raw material in their study in 2009. They conducted tests to check the physical and chemical properties of the oil they obtained from this raw material and whether it is suitable as biodiesel fuel. The fatty acid components in the oil to be used as raw material were determined by the gas chromatography method. With the finding of 21.30 mg Koh/g, they decided to apply transesterification in two stages. Due to the sulfuric acid used as a catalyst, they succeeded in reducing the fatty acid value. Then, the oil was converted to methyl ester by transesterification method with the help of potassium hydroxide (KOH). Affecting the yield of oil; They optimized parameters such as molar ratio, catalyst amount and reaction time. Thus, they obtained oil with 95% efficiency. They showed that the product obtained was within the limit values according to ASTM D 6751 standards determined for biodiesel. In the results of working; They concluded that it was 10:1 for acid esterification and 8:1 for alkaline esterification. They also showed that sulfuric acid (H_2SO_4) 1% (v/H) and potassium hydroxide (KOH) 0.7% (v/v) are the optimum values for the reactions. Finally, it was revealed that 1 hour for acid esterification and 1 hour for alkaline esterification at 50 ± 0.5 °C are the most suitable conditions for biodiesel production. (Sharma and Singh, 2010).

Soo-Young in his study in 2011; to create an alternative to emerging environmental problems and energy crises, discussed biodiesel obtained from inedible vegetable oils. Inedible vegetable oils within the scope of the study; Seven vegetable oils including jatropha, Karanja, Mahua, linseed, rubber seed, cottonseed and neem oils were examined. No modification is required during the use of Jatropha oil in internal combustion engines. For this reason, it has seen an advantage in the use and commercialization of jatropha oil as biodiesel, since it is not used as a food product. In this advantage-based study, he stated that there was a big difference in fuel properties between six different oils compared to jatropha oil. Comparing the seven different biodiesels discussed in this study with diesel, it was concluded that NOx emissions increased and HC, CO and PM emissions decreased. In addition, in his work; He stated that a fuel containing 20% biodiesel and 80% diesel can be operated without any modification or damage to the diesel engine. This will be achieved even if the rate of biodiesel fuel rises to 40%. On the other hand, he reported in his study that biodiesel can replace diesel fuel by up to 10% for the engine to run smoothly without encountering any durability problems (Soo-Young, 2011).

Singh and Singh used Argemone mexicana oil as a raw material in their study in 2008. The methyl ester of the oil was obtained using the transesterification method. However, the Argemone mexicana oil they use; production potentials, the values that will emerge when they are used as a blended fuel, and the economic feasibility results. However, being the first study to obtain the methyl ester of Argemone Mexicana oil increased the originality of the study. The cultivation process of Argemone mexicana seed, the process of obtaining its methyl ester, the process of obtaining oil from the seed, and the transesterification process used for ester production were examined in the context of overlap. Seeds were collected from a selected field within the scope of the study, the oil obtained from the seeds was extracted and their physical and chemical properties were determined. The methyl ester yield of the oil obtained from the collected seeds and, accordingly, the fuel and economic values were determined and compared with the diesel fuels used in the present (Singh and Singh, 2010).

In their study in 2010, Kumar and Sharma stated that scientists are researching obtaining biofuel from non-food raw materials due to a noticeable food shortage and increasing fuel prices around the world. They mentioned that the interest in biodiesel will increase shortly and that especially cooking oil will be used as a raw material. However, they also mentioned that this raw material is not a sustainable resource against increasing needs. Against this situation, they emphasized that the use of biodiesel obtained from inedible oil seeds will provide a significant advantage in meeting the need. They discussed their study on the potential of non-edible oils compared to edible oils on their suitability as biodiesel. In this direction, research studies and analyzes of inedible oil have indicated that it has a great potential to be used as a raw material in biodiesel production. They also provided an overview (Kumar and Sharma, 2011).

Abdulvahitoğlu handled the seeds of prunus avium in her study in 2019 to create an alternative to the decreasing energy resources, meet the energy demand in many countries and sustain development. These seeds, also known as Turkish cherry, are grown in the Pozantı region of the Taurus Mountains. In his study, he primarily obtained oil from the seeds of Prunus avium. The oil obtained was determined by gas chromatography (GC) oil characterization and free fatty acid values. He determined the oleic acid value, which has an important effect on the characterization of biodiesel, as 38.938 and the linoleic acid value as 40.663. After determining all fatty acid values, the biodiesel properties of the oil obtained from Prunus Avium seeds were evaluated using the Biodiesel Analyzer v1.2 program. For the biodiesel, which is the subject of the study; The cetane number was 50.1, the iodine value was 109.878, the kinematic viscosity value was 3.543, the flash point was 160.56, the saponification value was 191.354 and the oxidation stability was 5.468. These values revealed that biodiesel obtained from Prunus Avium core is an important raw material with a promising future (Abdulvahitoğlu, 2019).

The present study mainly focuses on the effects of the use of biodiesel from different sources on exhaust emissions and characterizes the seed oil of Luffa Aegyptiaca as a new possible feedstock for biodiesel production.

2. CHARACTERISTICS OF BIODIESEL

Biodiesel fuels have been the subject of researchers' studies as they provide an alternative to fossil fuels and are environmentally friendly. In this process, first of all, the physical and chemical properties of this fuel type were examined.

2.1. Chemical Specifications of Biodiesel

2.1.1. Chemical Structure of Biodiesel

Biodiesel is expressed in the designation C16-C18 and has a medium-length carbon chain. Biodiesel contains 11% oxygen, and when its calorific value is examined, a result close to diesel is obtained. In addition, biodiesel provides an advantage over standard diesel fuels by being a safe fuel with its high flash point.

2.1.2. Degradability

Since biodiesel fuel is based on animal and vegetable origin, it has the feature of being rapidly and easily degraded in nature. While 40% of standard diesel fuel degrades within 28 days, 95% of biodiesel degrades at the same time.

2.1.3. Toxic Feature

According to the studies, no toxic properties of biodiesel were found. According to the test results on humans, it has been determined that it is less harmful to the skin than 4% soap solution. Although biodiesel does not have any toxic properties, in the use of biodiesel and biodiesel blended fuels; It is recommended to use standard conditions of use applicable to diesel oil.

2.1.4. Storage Conditions

Until the time of use of the biodiesel produced; It should be stored in a dry, clean, dark and not excessively hot environment. With this feature, it is equivalent to diesel. Steel, stainless steel, fluorinated steel or fluorinated polyethylene can be preferred for the storage tank.

2.1.5. Flow and Temperature Feature

For fuels to be used in winter conditions; cloud point, pour point and cold filter clogging point are the features to be considered. The temperature at which the first wax crystal cloud is observed under cold storage conditions is defined as the cloud point. Again, the lowest temperature at which the fuel can show its fluidity in cold weather conditions is called the pour point.

Biodiesel and other diesel fuels with biodiesel blends have higher pour and cloud points than standard diesel fuels. This situation may pose a problem in the use of biodiesel in cold weather conditions (Karaosmanoğlu, Kurt and Özaktaş, 2000).

2.2. Technical Specifications of Biodiesel

The technical features of biodiesel show its usability and quality as a fuel differ from standard diesel fuel. These differences were analyzed and made into an international standard. EN14214 and ASTM D6751 are the most widely used biodiesel standards in Europe. The table below shows the values determined by these standards for biodiesel.

Table 1. General applicable requirements and test methods for biodiesel (EN 14214, 2019).

Feature	Unit	Limits Min.	Max.	Test Method
FAME Content	% (m/m)	96.5	-	EN 14103
Density (15°C)	kg/m3	860	900	EN ISO 3675 EN ISO 12185
Viscosity (40°C)	mm2/s	3.5	5	EN ISO 3104
Flash point	°C	101	-	EN ISO 2719 EN ISO 3679
Sulfur Content	mg/kg	-	10	EN ISO 20846 EN ISO 20884
Carbon Residue (10% distillation residue)	% (m/m)	-	0.3	EN ISO 10370
Cetane Number	-	51	-	EN ISO 5165
SulphatedAsh Content	% (m/m)	-	0.02	ISO 3987
Water Content	mg/kg	-	500	EN ISO 12937
Total Pollution	mg/kg	-	24	EN 12662
Copper strip corrosion (50°C-3 hours)	Degree	Class 1		EN ISO 2160
Oxidation stability (at 110°C)	Hour	6	-	Pr EN 15751 EN 14112
Acid Value	mg KOH/g	-	0.5	EN 14104
Iodine Value	g Iodine t/100g	-	120	EN 14111
Linolenic acid methyl ester	% (m/m)	-	12	EN 14103
Unsaturated methyl esters	% (m/m)	-	-	1
Methanol content	% (m/m)	-	0.2	EN14110
Monoglyceride content	% (m/m)	-	0.8	EN 14105
Diglyceride content	% (m/m)	-	0.2	EN 14105
Triglyceride content	% (m/m)	-	0.2	EN 14105
Free glycerol	% (m/m)	-	0.02	EN 14105 EN 14106
Total glycerol	% (m/m)	-	0.25	EN 14105

When these features are examined; cetane number, viscosity, carbon residue, sulfur content, ash content, flash point, lower flow point, cloud point, and water content.

2.2.1. Cetane Number

One of the most important factors affecting combustion efficiency is ignition delay. Ignition delay is expressed by the cetane number and it is required to be at an appropriate value. Cetane Number (CN) is the value that shows how well the fuel burns inside the engine. After the fuel is injected into the engine during the combustion process, the ignition process is desired. As the cetane number increases, the ignition time decreases and the desired actual combustion phase (diffusion-controlled combustion) increases. Since the ignition delay will cause diesel knock, it is not desired to experience this delay. It is not desired that the cetane number be low, but it is also undesirable for it to be too high. As this will cause the fuel to be ignited close to the injector, the injectors will become extremely hot. Fuel particles inside the overheated ejector will clog the injector. For this reason, the cetane number of diesel fuel should not be higher than 65 to prevent data burning (Çanakçı and Şanlı, 2008). If this value is; Once the mixing ratio is known, the cetane number is calculated as the volume-weighted average and rounded to the nearest whole number.

The longer the chain length that makes up the fuel, the less branching and unsaturation. In this case, the calorific value of the fuel increases. Parallel to this, the viscosity and cetane number increase with the increase in the heating value.

In addition to all these, when the cetane number of biodiesel and diesel is examined; It was concluded that the cetane number of biodiesel is higher. This makes biodiesel more advantageous. Thus, the low combustion efficiency resulting from high viscosity and low thermal efficiency is partially compensated (Sen et al. 2004).

2.2.2. Flash Point

The lowest temperature at which the fuel vapour is formed by temporarily igniting the fuel by approaching the flame is called the flash point (Borat, Balcı and Sürmen, 1992). Flash point: It depends on two basic factors, namely the ignition feature of the fuel and the vapour pressure.

To determine the flash point; In the closed container where the fuel is located, the flame is circulated at a certain temperature without contacting the fuel. In this process, the first temperature at which the transition occurs is the flash point for the fuel. The flash point is the main parameter that determines the safety requirements for the transport and storage of fuel (Kinast, 2003).

2.2.3.Kinematic Viscosity

Kinematic viscosity, which is an important criterion for motor fuels, is defined as the resistance of a liquid to flow at a certain temperature. If the viscosity value resulting from the internal friction of the molecules is low, the liquid is more fluid. Since this value is important for the fuel-air mixture, combustion and injection system for diesel engines, the viscosity of the fuel at $40^{o}C$ is a parameter to be determined.

Viscosity value increases with increasing hydrocarbon chain length. Increasing the number of double bonds in the hydrocarbon decreases the viscosity. The purity rate of biodiesel fuel is one of the important factors affecting viscosity (Tillem, 2005). When a fuel with a high viscosity is injected for combustion, it affects the operating time of the engine as it will affect the burning time of the fuel. In addition to all these, the viscosity of the fuel higher than the desired value can cause soot formation in an engine, insufficient fuel injection and blockages in the injectors (Kinast, 2003).

In line with the standards determined for biodiesel, the viscosity value should be between 3.5-5 mm^2/sec according to EN14214 and between 1.9-6 mm^2/sec according to ASTM. The fact that the viscosity is higher than the determined standard values is due to the inability to complete the transesterification process correctly during the production phase.

2.2.4.Sulphated Ash Content

CO_2, H_2O, hydrocarbons and inorganic substances that come out with the combustion of biodiesel fuel cause ash formation. Ash consisting of inorganic metallic compounds is called sulfated ash. The ash content defines the abrasive and catalyst residues, the number of pollutants, and the amount of soluble metal soaps in the fuel content. Although metallic ash has abrasive properties, it causes damage to cylinder walls and circlips (Sarin, 2019).

The damage caused by the ash resulting from the non-combustion of hydrocarbons differs from the damage caused by metallic ash. Abrasive metal ash can cause significant damage between the piston ring and the cylinder wall (Sarin, 2019).

2.2.5. Sulfur Content

It is one of the important factors for fuels because it has abrasive properties when it comes into contact with steel surfaces. Sulfur in a low-temperature engine; As a result of its accumulation in the exhaust pipes and air silencers, it causes the content of the exhaust gas differs (Ölçüm, 2006).

The waste oil resulting from frying foods with a rich sulfur structure such as onion rings may have a sulfur content of 15 ppm. Similar to this situation, biodiesel obtained from oils with high sulfur content will also contain high sulfur content.

Biodiesel made from pure soybean oil does not contain sulfur as soybean oil does not contain sulfur. Canola, rapeseed, and mustard contain varying amounts of glucosinolates, which are sulfur-containing compounds. Cultivated low in glucosinolate, canola contains sulfur fatty acids. It is the only cooking oil known to contain these compounds, and as a result, canola oil contains between 3 and 25 ppm of sulfur (Gunstone, 2004).

2.2.6. Carbon Residue

One of the most important parameters determining the efficiency of biodiesel fuel is carbon residue. The percentage of the carbon amount formed at high temperatures, which is sufficient in terms of air content, is called carbon residue. In other words, it is the measure of the carbon deposit in the combustion chamber (Hotti, 2015).

Carbon residue indicates deposits and pollution in the combustion chamber. In addition, he points out that soaps are wastes of free fatty acids, glycerides, and catalysts from the transesterification reaction (Barabas and Adrian, 2017).

2.2.7. Pour Point

The lowest temperature at which fuel flows and can still be pumped is defined as the pour point. This feature of biodiesel fuel is independent of the catalyst and reaction conditions that are effective in the production phase. The pour point of biodiesel fuel depends on the amount of saturated fatty acids in the oil from which it is derived. The pour point, which can also be expressed as the freezing point or solidification point, is determined by an increase in viscosity or the crystallization of the wax in the oil. In addition, the fatty acid composition of the structure from which biodiesel is obtained greatly affects the pour point. The freezing point of biodiesel increases with the increase of carbon atoms in the carbon chain. On the contrary, the increase in the double bond in the carbon chain decreases the freezing point. Therefore, biodiesel obtained from oils with high saturated fatty acids will have a high cloud and pour point.

Regardless of the raw material from which it is obtained, biodiesel has a higher cloud and pour point than diesel. Its pour point creates an obstacle to its widespread use, as it makes it difficult to use in countries with cold climates around the world.

2.3. Advantages and Disadvantages of Biodiesel

2.3.1. Advantages Of Biodiesel

Biodiesel has been the subject of many studies as an alternative to existing fossil fuels and many advantages have emerged as a result of these studies. Due to its fatty acid alkyl esters, it is a non-toxic, environmentally friendly and renewable energy source. The biodiesel obtained as a result of the transesterification method can be used in existing diesel engines without the need for any modification or by making very minor changes.

Biodiesel has a higher flash point and ignition rate than other petroleum-based fuels. This has made it easier to store and transport biodiesel. Thus, biodiesel has gained an advantage in terms of safety. In addition, biodiesel releases less CO, S_2O and burnt hydrocarbons to the environment compared to petroleum-based fuels, due to its appropriate combustion emission (Leung and Guo, 2006; Koç,2011).

Biodiesel is a carbon-neutral fuel. This is because; CO_2 is used by plants from which biodiesel is obtained. With this feature, it does not cause CO_2 accumulation in the atmosphere and the resulting greenhouse effect (Öğüt and Oğuz, 2006).

Biodiesel fuel has high lubrication properties. Due to its lubricating feature, engines using biodiesel have a longer life. The cetane number of biodiesel is higher than that of standard diesel fuel. This feature provides a quieter operation of the biodiesel engine.

Considering the biodiesel production processes and its production from quality pure oils, it causes the production cost is higher than the production cost of other petroleum-based fuels (Leung and Guo, 2006). However, the fact that biodiesel can be produced from waste oils and animal fats instead of high-quality pure oils is an important factor in reducing production costs.

Another advantage of using waste oils is that it reduces the amount of environmental waste. In this case, it creates a secondary usage area for agricultural products (Boşbaz, 2008; Cubas et al, 2006).In addition to this advantage, by-products occur during biodiesel production. The pulp of these products can be used in animal husbandry. In addition to this, 40% pure glycerin emerges. Glycerin, one of the import items, can be evaluated and used as medical glycerine.

In addition to all these advantages, biodiesel also has important contributions to the country's economy. It is getting harder for countries that are dependent on foreign energy to reach fossil fuel resources such as oil, which is decreasing day by day. The biodiesel that each region will obtain from its unique products throughout the country will make a significant contribution to the country's economy. Thus, socio-economic developments can be achieved with the creation of new business areas in the rural areas, the increase in oil prices can be stopped, and interstate problems can be solved for oil fields that have been going on for many years.

2.3.2.Disadvantages Of Biodiesel

As with every product that is produced, biodiesel has its advantages as well as disadvantages. However, studies are still ongoing to eliminate these disadvantages. Developing technology will provide a significant benefit in this regard.

These disadvantages can be listed as follows:

- It has a more expensive process than standard diesel fuel production. Despite this, the by-products of biodiesel production and the less damage to the environment reduce this cost.
- It has a certain useful life. After six months after its production, the interaction begins. Chemical additives are used to solve this problem.
- The low calorific value of biodiesel causes power loss for the engine in the combustion process. It causes more nitrogen release in the combustion process compared to diesel fuel. However, this problem can be eliminated by delaying the combustion temperature by 1-3ºC or by using a catalytic converter (Öğüt, Oğuz, Mengeş end Eryılmaz, 2006).
- It has a high viscosity. This is the most important disadvantage. The low freezing points make it difficult to use in countries with cold climates. It is possible to use by mixing diesel fuel as a blend (20% biodiesel can be blended and used as a fuel without problems). However, studies continue for 100% biodiesel.

2.4. Method of Biodiesel Production

Many raw materials can be used as a source of biodiesel. These are vegetable oils, recycled oils from urban and industrial waste, animal fats, and waste vegetable oils.

There are many sources of raw material for biodiesel, as well as many methods for its production. These methods can be listed as microemulsion, pyrolysis, dilution and the most widely used transesterification method.

2.4.1. Microemulsion Method

The process of combining two liquids that do not mix under normal conditions is called microemulsion or amphiphiline. The organic substance used in this method is alcohol. Utilizing this substance, it has become possible to create alternative fuels other than oil. Short-chain aliphatic alcohols such as ethanol and methanol are used as alcohol (Aksoy,2010).

2.4.2. Pyrolysis Method

The process of breaking chemical bonds to form smaller molecules is called the pyrolysis or cracking method. There are two methods for obtaining pyrolysis products from vegetable-based oil. The first of these methods was to break up the vegetable oil in a closed container using the effect of heat. The other method is thermal cracking with ASTM distillation. These methods, which are used to reduce viscosity, are costly. Because it causes high energy consumption (Srivastava and Prasad, 2000).

2.4.3. Dilution Method

The process of thinning the vegetable and waste oils adjusted in certain proportions as a result of mixing them with diesel fuel is called dilution. With this method, the viscosity of the oil is reduced. In addition, it has been seen in the research that the properties of diesel fuel and the properties of the mixture obtained from vegetable oil can be easily mixed due to the high similarity ratio to each other.

2.4.4. Transesterification Method

The most important and most used method, also known as the alcohollysis reaction, is called the transesterification method. In this method, vegetable oil consisting of small molecules reacts with an alcohol catalyst as shown in Figure 1. As a result of the reaction, fatty ester and glycerin are formed.

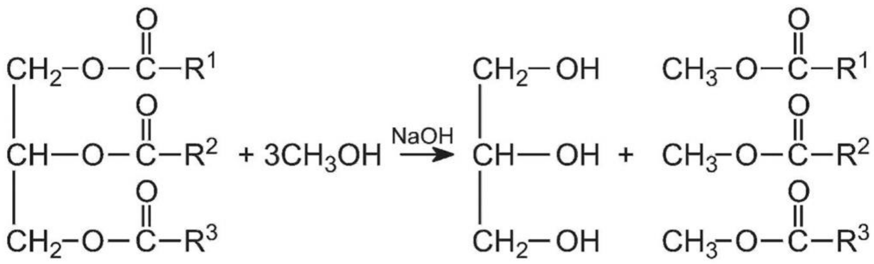


Figure 1. Transesterification reaction (Mutlubaş, 2016).

Reacting the vegetable oil molecules with the catalyst at a certain temperature separates the fatty acids from the triglycerides they are in and enables them to form new esters with alcohols as shown in Figure 2.

With the reaction realized in this method, three moles of ester are formed and one mole of glycerine is obtained. The reaction takes about 8 hours to complete. At the end of this period, the products shown in the diagram below are obtained.

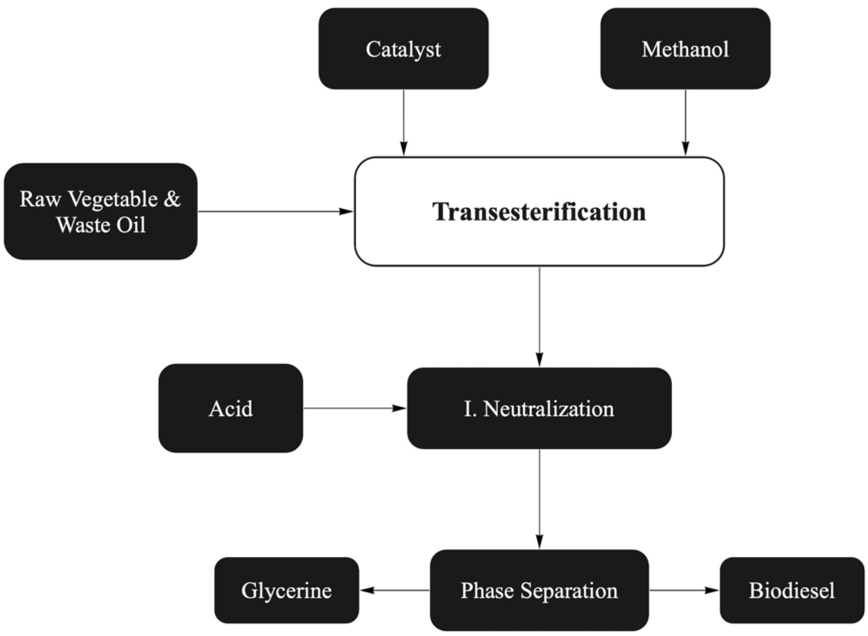


Figure 2. Transesterification flow-chart (Koçar and Demir, 2006).

2.5.Raw Materials Used in Biodiesel Production

Many raw materials can be used in the production of biodiesel fuel, which can be an alternative to the existing diesel fuel. These raw materials; vegetable oils, animal fats, recycled or waste oils, renewable or non-renewable vegetable-based oils, and unsaturated or saturated fatty acids. When choosing vegetable oils; unsaturation, product quality, shelf life and cost are taken into account.

While petroleum-derived fossil reserves are found in certain parts of the world, vegetable-derived oil can be found in almost every region of the world. These oils can be used in biodiesel production. The most used oils in biodiesel production are; canola, sunflower, palm, rapeseed, cottonseed, and soybean. In Table 2, the most used for biodiesel production; are vegetable, non-edible, animal and other oils (Gashaw, Teshita, 2014).

Table 2. Oils are used in biodiesel production (Singh and Singh, 2010).

Vegetable Oils	Non-Edible Oils	Animal Fats	Other Sources
Soybean	Almond	Pig	Bacteria
Rape	Rubber	Essential oils	Algae
canola	Babassu	Animals with wings	Mushrooms
Sunflower	Salmon oil	Fish	Micro Algae
Wheat	Cumaru		
Coconut	Laurel oil		
Sorghum	Jatropha Curcas		
Cotton	Tobacco Seed		
Peanut			
Rice			
linen			
Safflower			
Sesame			
Palm			

2.5.1.Generations of Biodiesel

Biodiesel fuels are divided into different generations according to the studies carried out for many years and the raw material source used. As seen in Figure 3, these generations consist of 5 different contents.

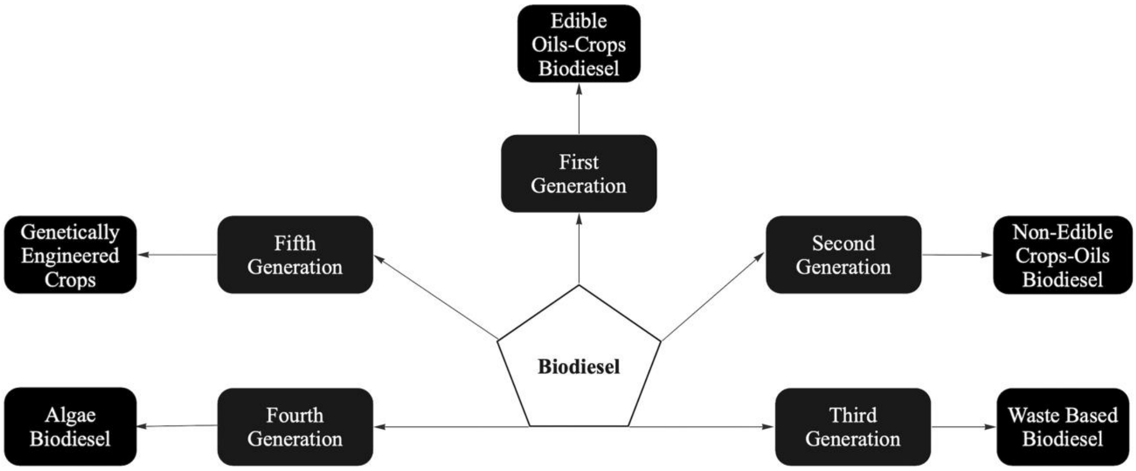


Figure 3. Classification of feedstocks for biodiesel synthesis (Khan et al., 2016).

When we look at the raw material of biodiesel produced worldwide, it is seen that 95% of it is produced from first-generation raw materials. Both agricultural lands and water resources are used in the production of these raw materials. Therefore, it is more suitable to be grown in fertile water-rich areas. However, because the raw material of first-generation biodiesel is also used as a food product, it creates a disadvantage. However, since inedible raw materials are used in the production of second-generation biodiesel, it does not pose a problem in this respect. However, it affects agricultural land and water use. Third-generation biodiesels are waste oils. Waste edible oils and animal and vegetable waste oils are seen as suitable raw materials for producing biodiesel since they are abundant in the market. Since there is no need for land use in third-generation biodiesel raw materials, it is seen as viable, safe and cost-effective. Likewise, fourth and fifth-generation biodiesel have common and inexpensive raw materials with less greenhouse gas impact. (Zulqarnain et al., 2022)

2.5.2.Vegetable Oils

Vegetable oils, which are raw materials for biodiesel, are obtained from the seeds of agricultural products or different fruits. It shows a different structure compared to petroleum-derived fuels. An environmentally friendly and renewable fuel is obtained from this raw material, which can be grown for commercial purposes for biodiesel production. The reason for this is that biodiesel obtained from vegetable oils has a neutral carbon feature. In summary, biodiesel obtained from vegetable oils gives the carbon back to nature during the combustion stage and does not cause extra carbon emissions. However, biodiesel obtained from vegetable oils cannot be used directly like diesel fuels. The main reason for this is viscosity. Viscosity values in biodiesel cause changes in existing diesel engines. The increase in viscosity causes deterioration in the structure of the fuel during combustion and with the increase in the resulting droplet size, complete combustion is prevented (Altınsoy, 2007).

2.53.Animal Fats

In the production of biodiesel, animal fats obtained from tail fat and bones are used as raw materials. At the stage of obtaining fuel, these oils, which are solid under room conditions, are first turned into liquid, and then glycerin is removed from their structure. However, the obtained fuel is not ideal for use in a standard diesel engine (Deniz, 2013).

2.5.4.Waste Oils

Waste cooking oils used in homes and waste oils used in factories can be used as raw materials in biodiesel production. The impurity rates of waste oils and the amount of water they contain are high. Due to this, their oxidation stability is low (Koç, 2011). Its price is lower than biodiesel obtained from edible vegetable oils. Despite this advantage, the viscosity, cold flow properties and carbon residue of the biodiesel obtained from waste oils do not have a good result compared to the biodiesel obtained from pure oils (Guerrero et al. 2018).

2.6.Fuel Properties of Vegetable and Animal Oils

Biodiesel obtained from different vegetable and animal oils can be used as fuel in diesel engines in pure or mixed form.

With the change of mixing ratios, the fuels in different forms can be listed as follows; fossil diesel fuels mixed with pure vegetable oil, methyl esters, methyl ester/ petrodiesel blends and hydrotreated vegetable oil blends. The properties of fuels obtained from some vegetable oils are given in Table 3 (Bart, Palmeri and Cavallaro, 2010).

Table 3. Fuel properties of vegetable oils (Bart, Palmeri and Cavallaro, 2010).

Oil	Kinematic Viscosity (310.8 K için) (mm2/s)	Cetane Number	Heating Value (MJ/kg)	Cloud Point (K)	Pour Point (K)	Flash Point (K)
Corn	34.9	37.6	39.5	271.9	233	550
Cotton	33.5	41.8	39.5	274.7	258	507
Linseed	27.2	34.6	39.3	274.7	258	514
Palm	39.6	42	-	304	-	540

Peanut	39.6	41.8	39.8	285.8	266.3	544
Rapeseed	37	37.6	39.7	269.1	241.3	519
Soybean	32.6	37.9	39.6	269.1	260.8	527
Sunflower	33.9	37.1	39.6	280.2	258	547
Diesel	2.7	47	45.3	258	240	325

2.7.Vegetable Oils in Biodiesel Production

Vegetable oils, waste oils or used oils enter into a chemical reaction with the right catalyst to form biodiesel as a result of esterification. Fat molecules called triglycerides in the vegetable oil structure are composed of fatty acids. These fatty acids form new ester bonds with alcohol during the reaction. In this reaction where new bonds are formed, glycerin emerges as a by-product and is evaluated in a different area for use in the cosmetic industry.

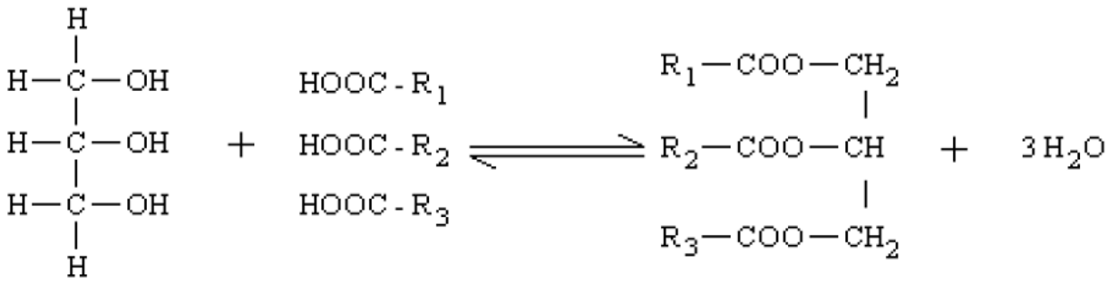
When its chemical structure is examined, it is seen that biodiesel is different from diesel fuels due to the reactions at the production stage. Oxygen makes up about 11% of the weight of biodiesel, which consists of hydrocarbon chains with 16 or 20 carbons. On the other hand, they do not contain sulfur, aromatic hydrocarbons, metals and other petroleum wastes such as biodiesel, and diesel fuels. Heating value, density and viscosity, which are other values that affect efficient combustion, are very close to diesel fuels for biodiesel. In addition to all these, biodiesel provides an advantage over diesel fuel with its higher cetane number, better lubrication and less toxic properties.

The type of oil to be used as a raw material is of great importance to obtain east values and to produce efficient diesel fuel. Because the fatty acids contained in the oil to be used and the amounts of these fatty acids determine the quality of the biodiesel fuel.

2.7.1.Lipids

Fats found in plant and animal tissues containing hydrogen, oxygen and carbon atoms are called organic compounds. In short, esters formed by alcohols with organic acids are called oils. In addition to hydrogen, oxygen and carbon atoms, it also contains phosphorus, sulfur and nitrogen elements. Fatty acids form the basis of oil. The fact that oils do not dissolve in water or dissolve very slightly, on the other hand, is due to their non-polar structure. Although they are hydrophobic, they can dissolve in organic solvents such as acetone, benzene, and ether chloroform.

Fatty acids have the R-COOH structure and are solid or liquid triglycerides formed as a result of esterification with glycerin as shown in Figure 4. Oils in the liquid phase at room temperature are called oils, and oils in the solid phase are called fat.



Glycerin Fatty acids Vegetable oil Water

Figure 4. Esterification of glycerin with 3 fatty acids (Bulut, 2008).

95% of vegetable oils, which are in two different phases as solid and liquid, constitute their weight. The remaining 5% consists of fatty acids, mono and diglycerides, sterols and free fatty acids.

2.7.2.Fatty Acids

It contains many different structures in the oil obtained by pressing or extracting oilseeds. These structures can be listed as oxygen, hydrogen, hydrocarbon, sterols, mono and diglycerides, and fatty acids. For the oil to be consumed by humans, certain properties must be added to the oil. For this, impurities are removed by subjecting the oil to the refining process. These substances, which affect the purity and quality of the oil, are removed from the oil so that it can be consumed.

The refining process consists of four main steps. In the first step; sticky substances in the structure are removed. In the neutralization process, which is the next step; water-insoluble hydrates, phosphacids and free fatty acids are removed. At this stage, soap is formed during processing. Although this soap is removed from the oil, it emerges as a by-product and is used in a different industry. By treating this soap with acid, either acid is obtained. The content of fatty acids also called triglyceride and free fatty acid mixture depends on the refining process. Fatty acids, which are the other important elements that make up the oil with glycerol, exist in different sequences in different oils depending on the groups they are attached to. However, as seen in Figure 5, when looking at the general structure of fatty acids, it is seen that fatty acids have a long chain, aliphatic tail, straight carbon chain and carboxyl group structure.

$$CH3 - (CH_2)_x - \overset{\overset{\displaystyle O}{\|}}{C}\text{-}OH$$

Aliphatic Chain Carboxyl Group

Figure 5. General formula of a fatty acid acid (Karaca and Aytaç, 2017).

Fatty acids differ from each other according to their structure, the type of bond of carbon atoms, the number of carbons in the hydrocarbon chain, and the location and number of double bonds, if any (Tütüncü, 2013). These fatty acids, which have different properties, determine the characteristics of the complex oils in their structure. In the structure of natural oils, fatty acids are divided into two different groups saturated and unsaturated fatty acids according to their content, arrangement and bond type.

2.7.3.Saturated Fatty Acids

Saturated fatty acids with the general formula Cn-H2n-O2 do not contain double bonds in the hydrocarbon chain. Saturated fatty acids, which have a branched structure, are in liquid form at room temperature from 4 carbon atoms to 8 carbon atoms. Fatty acids, which have up to 38 carbons in their structure, can also be called volatile fatty acids because they fly with water vapour. Fatty acids with carbons starting from 8 carbon atoms up to 38 carbon atoms are in the solid phase at room temperature. While the molecular weights of saturated fats increase, their density decreases. On the other hand, there is an increase in viscosity and refractive indices.

The maximum hydrogen bonding to carbons other than the carbon in the carboxyl group is the reason why the fatty acid is called a saturated fatty acid as shown in Figure 6.

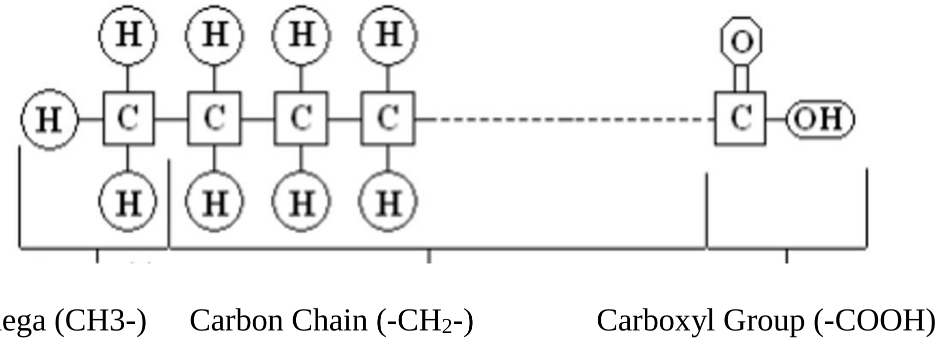


Figure 6. Groups in saturated fatty acid **(**Tütüncü, 2013).

Table 4. Saturated fatty acid (Tütüncü, 2013).

Fatty Acid	**Chemical Formula**	**Carbons and Double Bons**
Butyric Acid	$CH_3(CH_2)_2COOH$	4:0
Caproic Acid	$CH_3(CH_2)_4COOH$	6:0
Caprylic Acid	$CH_3(CH_2)_6COOH$	8:0
Capric Acid	$CH_3(CH_2)_8COOH$	10:0
Lauric Acid	$CH_3(CH_2)_{10}COOH$	12:0
Myristic Acid	$CH_3(CH_2)_{12}COOH$	14:0
Palmitic Acid	$CH_3(CH_2)_{14}COOH$	16:0
Stearic acid	$CH_3(CH_2)_{16}COOH$	18:0
Arachidic Acid	$CH_3(CH_2)_{18}COOH$	20:0
Behenic Acid	$CH_3(CH_2)_{20}COOH$	22:0
Lignoceric Acid	$CH_3(CH_2)_{22}COOH$	24:0

2.7.4.Unsaturated Fatty Acids

Unsaturated fatty acids with the general formula CnH2(n-a)O2 contain one or more double bonds from their hydrocarbon chains. Unsaturated fatty acids differ depending on the structure and position of the double bonds they have. These double bond structures make unsaturated fatty acids more reactive than saturated fatty acids.

In the research, it has been observed that with the increase in the number of double bonds in the hydrocarbon chains of saturated fatty acids, there is an increase in their tendency to isomerization and polymerization reactions. This situation, which depends on the number of double bonds, makes saturated fatty acids more prone to isomerization and polymerization reactions than unsaturated fatty acids (Nas, Gökalp and Ünsal, 2001).

If there is no branching in the chain structure of saturated fatty acids, they contain an even number of carbons. In addition, saturated fatty acids have a higher solubility than unsaturated fatty acids with the same number of carbons. In addition, it was observed that the densities of unsaturated fatty acids were higher than unsaturated fatty acids with the same chain length. Despite this situation, it has been determined that there is no visible difference in vapour pressures and boiling points. When the melting and freezing points are compared, it is seen that these values of unsaturated fatty acids are lower than saturated fatty acids.

Table 5. Unsaturated fatty acid (Tütüncü, 2013).

Fatty Acid	Chemical Formula	Carbons and Double Bons
Caproleic Acid	C_9H_{17}-COOH	10:1
Lauroleic Acid	$C_{11}H_{21}$-COOH	12:1
Myristoleic Acid	$C_{13}H_{25}$-COOH	14:1
Palmitoleic Acid	$C_{15}H_{29}$-COOH	16:1
Oleic Acid	$C_{17}H_{33}$-COOH	18:1
Linoleic Acid	$C_{17}H_{31}$-COOH	18:2

3. FOUR-STROKE INTERNAL COMBUSTION DIESEL ENGINES AND THEIR COMBUSTION EMISSIONS

3.1. Working Principle of Four Stroke Internal Combustion Engines

Engines in which one ta cycle of the piston takes place in four stages are called four-stroke engines. These engines are in the internal combustion engine class. These engines work by converting the chemical energy in the fuel into heat energy at the appropriate pressure and temperature and moving the pistons. four-stroke engines; It is called by this name because it consists of four stages: suction time, compression time, combustion time and exhaust time. Each overshoot of the four-stroke engine is shown in Figure 7.

During the intake stroke, which is the first stage of a four-stroke diesel engine, the piston moves from the top dead centre (TDC) to the bottom dead centre. During this movement, the intake valve opens, there is a volumetric increase with the movement of the piston and a vacuum is created on the piston. At this stage, the air is filled into the cylinder with the help of the intake manifold and the intake valve. Thus, only air is taken into the engine at the time of intake.

At the compression time, the piston moving from the bottom dead centre to the top dead centre starts to compress the air. At this stage, the pressure and temperature increase as the air is compressed. Press. 30-45 bar, the temperature rises to 600 - 900 °C.

The combustion time, on the other hand, is realized as a result of injecting fuel into the air, whose pressure and temperature have increased as a result of the piston approaching the top dead point, with the injectors. As a result of the combustion process, the piston at the top dead point is pushed down with the help of the rising pressure and temperature.

Exhaust time starts when the piston is pushed to the bottom dead centre at the end of the combustion. At this stage, the new cycle must be started and the burned gases in the cylinder must be removed from the engine. For this, the valve opens, the piston starts to move from the bottom dead centre to the top dead centre and the burned gases are sent out from the exhaust valve.

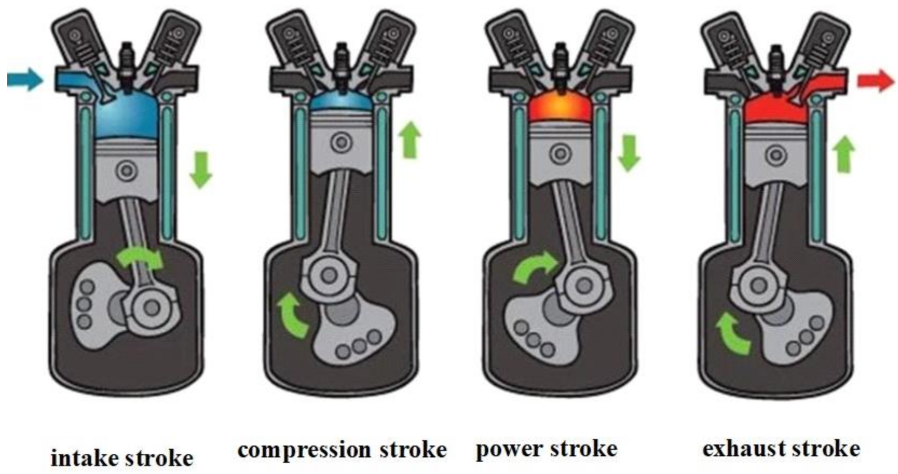


Figure 7. Four-stroke internal combustion diesel engine

3.2. Combustion Emissions for Diesel Engines

In diesel engines, as a result of the chemical reaction of the fuel with oxygen, heat and light and the associated energy are produced by the reaction. When the basic structure of fuel is examined, it is seen that there is a carbon (C) and hydrogen atoms in its molecules.

As a result of the combustion of fuel with air in diesel engines, more than 600 products are released. When these gases are examined, it is seen that 99.2% of them are harmless gases such as water, oxygen, carbon and nitrogen. In the remaining 0.2%, it has been observed that there are gas mixtures that will harm human and environmental health.

Studies have shown that emissions from internal combustion engines have a significant effect on air pollution, especially in metropolitan cities where the population is dense. The beginning emissions that create air pollution; are nitrogen oxide, carbon monoxide, hydrocarbons, sulfur oxide and soot.

3.2.1. Nitrogen Oxide (NO_x)

Nitrogen oxides, which are composed of components of oxygen and nitrogen atoms, are also called nitrogen oxides or nitric oxides. Its general representation is expressed as NO_x. At the time of combustion in the engine, the air sucked from the intake manifold enters the combustion chamber, while most of the nitrogen gas is sent to the atmosphere via the exhaust route. However, a certain part of this nitrogen reacts with oxygen as a result of the effect of high pressure and temperature during combustion, causing the formation of nitrous oxide (NO_x). On the other hand, N_2O, one of the NO_x gases, has a stable structure and is not considered a pollutant.

The amount of nitrogen oxide to be formed in the exhaust gas increases with the increase in oxygen, temperature and pressure entering the cylinders during the combustion process. As a result, combustion becomes inefficient and fuel consumption increases. For this reason, exhaust gas recirculation (EGR) and selective catalytic reduction (SRC) systems have been developed in vehicles. Because nitrogen oxides combine with the water in the atmosphere and cause nitric acid rains. However, it combines with the water vapour in the lungs of all living things that breathe lungs, causing the formation of nitric acid in their bodies (Yamık, 2002).

3.2.2. Carbon monoxide (CO)

Carbon monoxide gas is one of the polluting emissions that occur as a result of incomplete combustion in diesel engines during combustion. The main factor that creates incomplete combustion is the lack of sufficient oxygen at the time of combustion.

Carbon monoxide does not have enough time to form a second reaction and cannot turn into carbon dioxide. For this reason, it is sent to the atmosphere as carbon monoxide from the exhaust. Carbon monoxide sent to the atmosphere over time is oxidized to form carbon dioxide. Colourless, odourless and tasteless carbon monoxide gas becomes toxic when inhaled. Carbon monoxide, which enters the body through the respiratory tract, clings to the haemoglobin in the blood, preventing the blood from carrying oxygen within the body. Carbon monoxide in its low concentration causes headaches and physical slowdowns. Increasing carbon monoxide concentration causes unconsciousness and even death (Keskin, 2005).

3.2.3. Hydrocarbons (HC)

In diesel engines, hydrocarbons are formed as a result of incomplete combustion of the fuel during combustion. The basis of incomplete combustion is low temperature and lack of oxygen. Exhaust gas; contains different kinds of hydrocarbons that have a carcinogenic effect and an irritating effect on the respiratory tract.

Hydrocarbon formation is independent of the speed or load of the engine where combustion takes place. This event varies depending on the geometry of the place where the combustion takes place. In addition, the cooling of the fuel-air mixture on the walls after the combustion process is one of the important factors that increase the formation of hydrocarbons.

Hydrocarbons released into the atmosphere through the exhaust cause the formation of acid rain. In addition, hydrocarbons that react chemically with ultraviolet rays are also effective in the formation of photochemical fog (Keskin, 2005).

3.2.4. Sulfur Oxide (SO_x)

Sulfur oxide formation from exhaust emissions varies depending on the amount of sulfur in the fuel. Sulfur oxide is a colourless gas and has toxic properties. It also has an unpleasant odour.

Sulfur, which reacts with the oxygen in the environment at the time of combustion, also forms sulfur dioxide. The amount of sulfur in the fuel determines the amount of sulfur oxide that will be formed. For this reason, if the amount of sulfur in the fuel is known, the amount of SO_x that will be formed can also be calculated.

The lifetimes of these chemicals, which are sent into the atmosphere with exhaust, vary between 6-10 days. Since SO_x gases in the atmosphere can oxidize and turn into an acid, acid rain can occur (Keskin, 2005).

3.2.5. Soot

The main reasons for the formation of soot are that the fuel withstands environments with low oxygen, oxidation of hydrogen molecules, and removal of carbon molecules from the environment without being oxidized. Soot is also called black smoke.

The formation of soot depends on the air-fuel mixture ratio as well as the type of fuel. Soot formation causes wear on the piston and cylinder. In addition, it causes permanent damage to this area as a result of accumulation on the valve. For this reason, the resulting soot does not only create exhaust emissions but also negatively affects other components, especially the engine (Keskin, 2005).

4. MATERIALS AND METHODS

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, loofah roots cannot go very deep into the soil. Mert M., 2009. Fibre Plants, Nobel Academic Publications, Ankara. 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 raise their gardens for personal needs. When we look at the provincial basis in our country, Hatay comes to the fore in loofah cultivation (Yaman,2017). The effects of different nitrogen doses on yield and some agricultural characteristics of loofah (Yaman, 2017).

With the increase in loofah cultivation, it has been the subject of many studies. As a result of these studies, the powder obtained from the fibres of the loofah can be evaluated as a regulatory drug in the treatment of digestive problems, while the seeds are used in the treatment of asthma, sinusitis and (high) fever (Partap et al 2012).

In this study, loofah was used in the production of biodiesel, unlike in previous studies. The amount of oil it contains, the fact that it has not been the subject of such a study before, and that it can be grown under the conditions of our country are the main reasons for this study.

In this study, first of all, loofah seeds were obtained. The seeds were grown in Hatay, Turkey. Hayat has the feature of being the province where loofah is grown most intensively in our country. Loofah is seen to be valued as a vegetable, as well as grown as an ornamental plant in gardens. The fact that our country is under the influence of the Near East and Mediterranean climate has contributed to its advantage in plant diversity. In this case, the climate of our country provides an advantage in obtaining the loofah and accordingly the loofah seed shown in Figure 8.

Figure 8. Luffa Aegyptiaca seeds

4.1.Obtaining Oil from Luffa Aegyptiaca Seeds

Luffa Aegyptiaca seeds were selected as raw material to be evaluated within the scope of the study. Oil is obtained from this seed grown in Hatay, Turkey, using different methods. Within the scope of this study, two methods of oil extraction, namely cold press machine and soxhlet device, are discussed.

4.1.1.Cold Press Method

Pressing, solvent-assisted oil extraction, supercritical liquid-assisted extraction method, microwave-assisted and ultrasound-assisted extraction methods are generally used in the extraction of oil from oilseeds (Sevindik and Selli, 2017). The most widely used of these methods in recent years is the cold press method, which is obtained completely mechanically and without the use of chemicals (Konuşkan, 2020). According to the Turkish Food Codex Communiqué on Oils Called by the Name of Plants, cold-pressed natural oils are defined as oils suitable for direct consumption and obtained only by mechanical method without heat treatment (Türk Gısa Kondeksi, 2012). The cold pressing method is the only process of extracting the oily components of a plant, such as the fruit, seed or kernel, and pressing the oil without the application of mechanical heat and the use of chemical solvents (Asil and Göktürk, 2020). Cold pressed oils are mainly used in the pharmaceutical and cosmetics industry and on the table (Gürpnar and Geçgel, 2011). Due to its low-temperature processing, the oil's properties such as phenolic content, flavour, aroma and nutritional value remain unchanged (Asil and Göktürk, 2020). The disadvantage of the cold press technique is that the oil yield is low. Since the cold-pressed vegetable material may still contain some oil, the remaining oil can be removed by solvent extraction from the extracted pulp (Duran and Benderli, 2020).

It was decided to extract the oil to be obtained from the luffa aegyptiaca seed selected within the scope of the study using this method. In this direction, first of all, garbage and other unnecessary substances mixed into the seed were cleaned by sorting as seen in Figure 9. This process was carried out to prevent any other substance other than the seed from being included in the process during cold pressing.

Figure 9. Sorting Luffa Aegyptiaca seed

After this process, Karaerler NF 80 cold-pressed press machine shown in Figure 10 was used to turn the luffa aegyptiaca seed into oil.

Figure 10. Cold press machine

Luffa aegyptiaca seeds were ground as shown in Figure 11 and the oil contained in the seed was extracted after pressing.

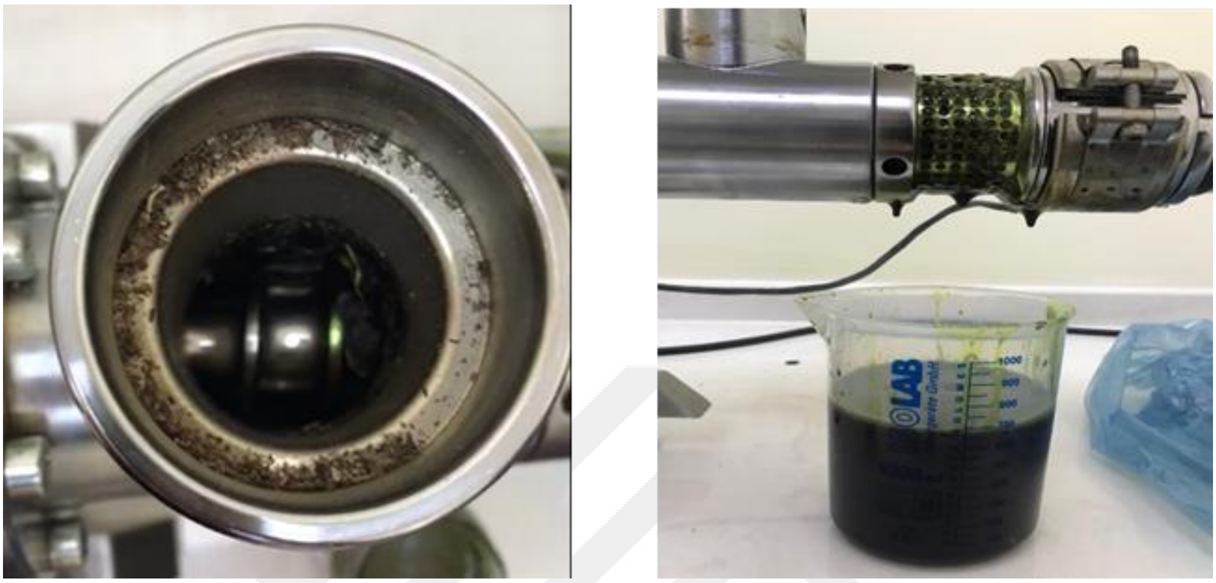


Figure 11. Milling of seeds and obtaining oil

Figure 12. Luffa Aegyptiaca Oil sample

4.1.2.Obtaining Oil with the Soxhlet Device

Although designed to extract oil from a solid test sample, it can be used in any condition where it is difficult to extract a compound from a solid. Usually, the dry test sample is placed in a thimble-shaped extraction tube made of filter paper placed in a Soxhlet extractor (Figure 13). The extractor is fitted with a fluted glass flask containing the solvent (usually diethyl ether or petroleum ether) and a condenser. The solvent is heated and evaporated. The hot vapour of the solvent moves to the condenser condenses and falls on the solid sample. When the thimble containing the extraction tube containing the sample is filled with the condensed solvent, it reaches the level of the bypass arm and a siphon is formed and the solvent empties back into the glass flask. This cycle of condensation, rise, and siphoning is called 'backflow' and it repeats over and over. During each cycle, some of the solids contained in the oil dissolve in the solvent. But once the solvent reaches the heated glass bubble, it stays there, not rejoining the cycle. This is the main advantage of this extraction method, only the pure solvent evaporates and condenses to extract the solid, it is cycled. Therefore, the efficiency of this method applied with the Soxhlet extractor is higher compared to the method of extracting the solid by heating it in a solvent in a glass flask. The solvent remaining at the end of an extraction can be removed by the evaporator, leaving the extracted oil.

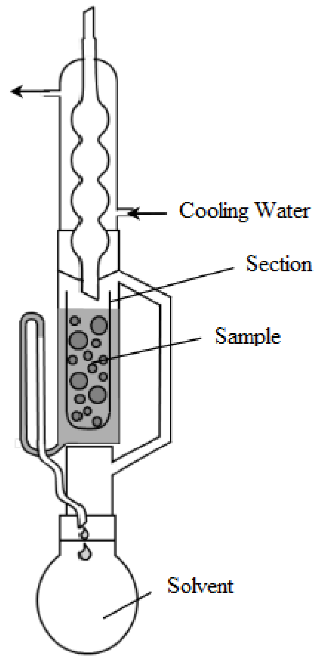


Figure 13. Soxhlet extraction device (Büyüktuncel, 2012).

Another method used to obtain oil from Luffa Aegyptiaca seed within the scope of the study is the soxhlet device. Luffa Aegyptiaca seeds supplied for the process are cleaned of garbage and unnecessary materials. The extracted seeds were pulverized as seen in Figure 14.

Figure 14. Grounded Luffa Aegyptiaca seeds

Three sample tubes were determined for the pulverized Luffa Aegyptiaca seed. To start the necessary process in the Soxhlet device, the powdered Luffa Aegyptiaca seeds were placed in a filter and taken into these sample tubes. Before this process, the weight of each sample tube was measured as shown in Figure 15.

Figure 15. Measurement of sample tubes on a precision balance

After adding the powdered luffa aegyptiaca to the tare tubes, 150 ml of hexane was added to act as the solvent for each tube. The samples shown in Table 6 were placed in the Soxhlet device as shown in Figure 16.

Table 6. Luffa Aegyptiaca Seed Oil Sample Properties

No	Sample Weight (gr)	Hexane (ml)
1	11.8233	150
2	11.5838	150
3	12.4746	150

Figure 16. Samples placed in the automatic soxhlet device

The sample samples obtained are weighed before being processed in the soxhlet device. After the samples are processed in a soxhlet device to extract the oil, they are also weighed. The purpose of the weighing process here is to calculate the amount of oil contained in the powdered luffa aegyptiaca seeds according to their weight ratio.

4.2. Luffa Aegyptiaca Seed Oil Values

Oil was obtained from Luffa Aegyptiaca seeds by two different methods. One of these methods is cold press and the other is the extraction of the oil of the powdered seeds in the soxhlet device. The vegetable oil obtained from Luffa Aegyptiaca in the Soxhlet device was analyzed in Osmaniye Korkut Ata University Central Research Laboratories (OKUMERLAB) to find the free fatty acid (FFA) values.

The oil sample obtained from the Luffa Aegyptiaca seed was mixed with hexane as shown in Figure 17.

Figure 17. Preparation of Luffa Aegyptiaca specimen for GC testing

The sample mixed with hexane is mixed from the Rotofix 32 A centrifuge as shown in Figure 18.

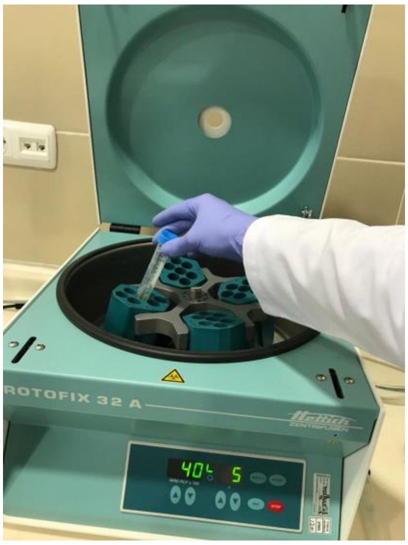


Figure 18. Rotofix 32 A centrifuge device

The oil sample dissolved with hexane is removed from the centrifuge. The oil sample was subjected to Gas Chromatography (GC) test in the YL 6500 device as shown in Figure 19 to separate its chemical components and find out which components it contains and how much of each component it contains.

Figure 19. Gas Chromatography (GC) device

4.3.Prediction of Biodiesel Characterization

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 Biodiesel Analyzer V1.2 program was used to determine the fuel properties of the oil obtained from Luffa Aegyptiaca seeds and to reveal the character of the fuel. Thus, necessary data for fuel values were obtained. In obtaining these data, the following formulas were used in the program.

The cetane number is influenced by iodine and saponification values.

Saponification Value (SV) = $\sum (560 \times N)/M$ (Eq.2)

Iodine Value (IV) = $\sum (254 \times D\ N)/M$ (Eq.3)

where,

M: Molecular mass of fatty ester,

N: percentage of Fatty Acid Ester in the oil sample

D: Number of double bonds

Cetane Number (CN) = $46.3+(5.458/SV) - (0.225 \times IV)$ (Eq.4)

Degree of Unsaturation (DU) = $MUFA + (2 \times PUFA)$ (Eq.5)

where,

MUFA: % monosaturated fatty acids,

PUFA: % polyunsaturated fatty acids.

The oxidation stability of biodiesel was calculated using the given formulas below.

Allylic position equivalents (APE)= $\sum (apn \times Acn)$ (Eq.6)

where,

apn: number of allylic position equivalents

Acn: Amount of Fatty Acid in the mixture. Bis-allylic position equivalents (BAPE)

$BAPE = \sum (bpn \times Acn)$ (Eq.7)

B_{pn}: number of Bis-allylic position equivalents

Oxidation stability (OS) = $(117.9295/(C18{:}2+C18{:}3) + 2.5905)$ (Eq.8)

One of the important properties of biodiesel fuel is its cold flow property. The cold flow properties that are predicted are Cold Filter Plugging Point, Cloud Point, and Pour Point, respectively.

Long-chain saturated factor (LCSF) = $(0.1\times C16) + (0.5\times C18) + (1\times C20) + (1.5\times C22) + (2\times C24)$ (Eq.9)

Cold Filter Plugging Point ($CFPP$) = $(3.1417 \times LCSF) - 16.477$ (Eq.10)

Cloud Point (CP) = $(0.526 \times C16) - 4.992$ (Eq.11)

Pour Point (PP) = $(0.571 \times C16) - 12.24$ (Eq.12)

The kinematic viscosity is estimated at 40 °C as:

$\ln(v) = \sum Ni\,(-12.503 + 2.496 \times \ln Mwi) - 0.178 \times Di$ (Eq.13)

where,

M_{wi} molecular weight of FA, Ni is the percentage of the given FA, Di denotes the number of double bonds. The density of the biodiesel is estimated at 20° with the following equation.

$\rho = \sum Ni(0.8463 + (4.9/(Mwi)) + 0.118 \times Di$ (Eq.14)

A higher heating value is estimated as follows:

$HHV = \sum Ni(46.19 - (1794/Mwi - 0.21 \times Di)$ (Eq.15)

Flashpoint was estimated by using the formula below:

FP (°C) = $205.226 + 0.083xp - 1.727xs - 0.5717xo - 0.3557xLI - 0.467xLN - 0.2287xE$ (Eq.16)

Where,

x_p mass fraction of palmitic acid

x_s mass fraction of stearic acid

x_o mass fraction of oleic acid

x_{LI} mass fraction of linoleic acid

x_E mass fraction of erucic acid (Abdulvahitoğlu, 2019).

4.4.Diesel-RK Software

Diesel RK is a software program that can simulate engine values to measure the engine performance of internal combustion engines with different parameters and different fuel types. In this program, it is possible to simulate and optimize one, two and four-stroke internal combustion engines. Engine types that can be actively operated in the program; DI diesel engines including PCCI, engines running on biofuels, SI gasoline engines, SI gas engines, dual-fuel engines, and opposing piston engines.

Deisel-RK makes fuel consumption estimation and optimization by ensuring that the specified fuel is run in the desired engine type. At the same time, it is possible to see torque values and other moto performances. Other advantages of the program are combustion and emission analysis, EGR analysis and optimization, turbocharger matching and optimization.

As mentioned in the previous section, Diesel-RK must first determine the engine characteristics whose performance will be measured.

The first step is to run the program. After the program is opened, the “Wizard of Designing New Project” is selected. Then, the windows where we will determine the engine properties are opened in order.

As seen in Figure 20, Four-Stroke Cycle and fuel and ignition method DI Diesel were chosen to evaluate the performance within the scope of this study.

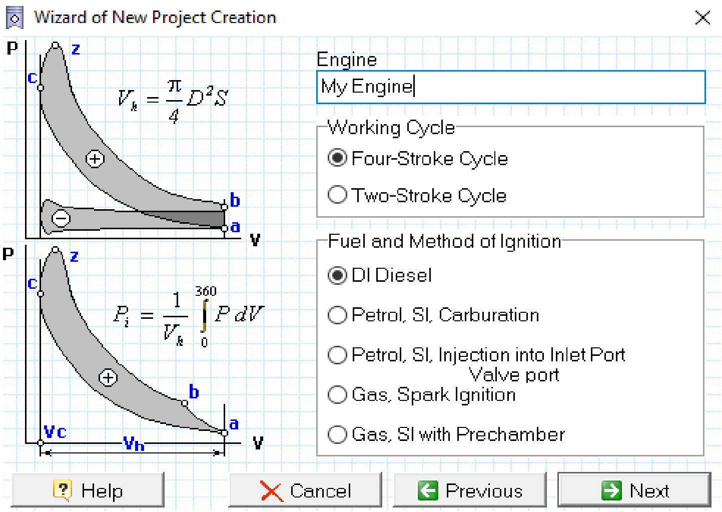


Figure 20. Working cycle, fuel and method of ignition selection screen on Diesel-RK Software

The next window that opens includes the engine type and cooling system. Here, as shown in Figure 21, an In-line, 4-cylinder and liquid-cooled engine was chosen.

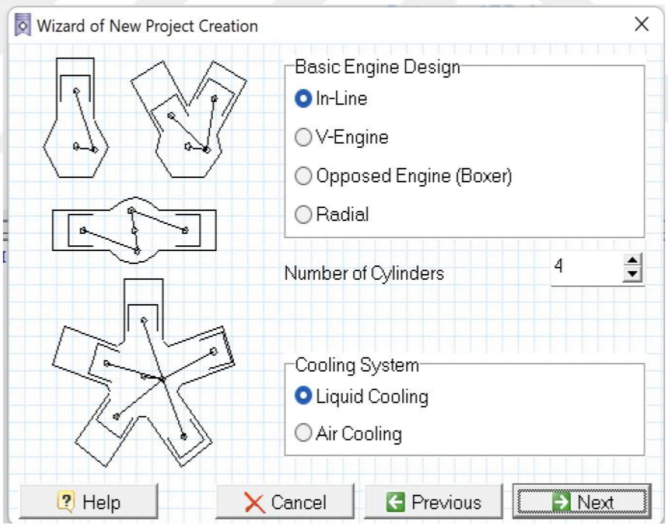


Figure 21. Basic engine design and cooling system selection screen on Diesel-RK Software

As shown in Figure 22, the final values are the parameters at which the engine will operate at sea level. Here, the pressure is 1 bar and the temperature is 288 K.

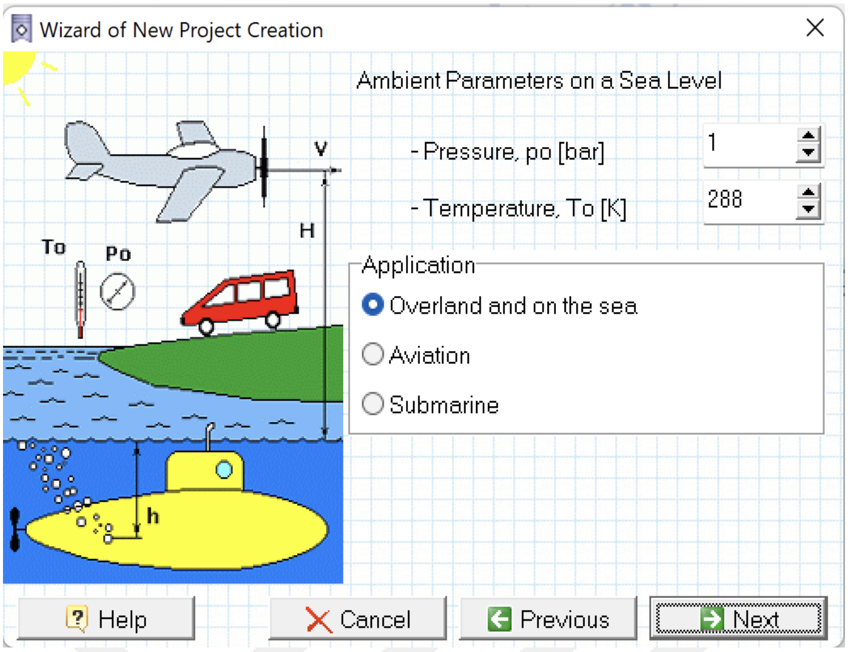


Figure 22. Ambient parameters on sea level selection screen on Diesel-RK Software

In the next step, the cylinder bore is 105 mm, the piston stroke is 110 mm, the nominal engine speed is 1500 rpm and the compression ratio is 15 as shown in Figure 23.

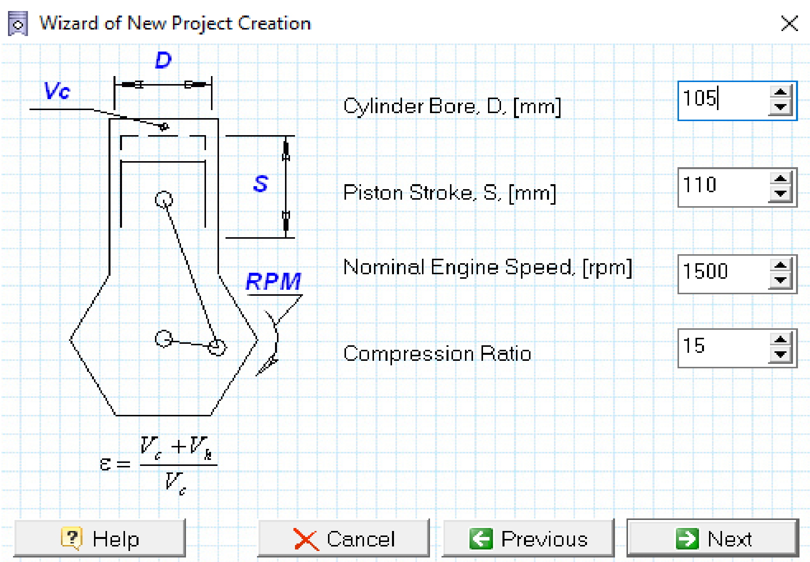


Figure 23. Cylinder bore, piston stroke, nominal engine and compression ratio selection screen on Diesel-RK Software

As shown in Figure 24, in cylinder head design, 4 valves were selected and injection pressure was determined between 800-1000 bar.

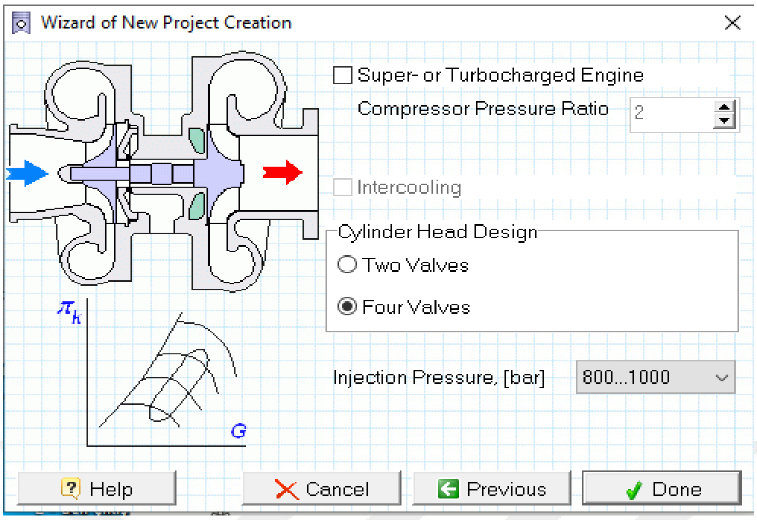


Figure 24. Cylinder head design selection screen on Diesel-RK Software

After these features are displayed, the "Operating Mode" located at the top of the main working screen of the program is opened. From here, as shown in Figure 24; Parameters can be change according to preferences form this stage for example we can decide whether the engine turbocharge or not. Diesel-RK has many fuel types in its library, from diesel to biodiesel, and from gasoline to natural gas. After the fuel type was determined, the engine speed was determined under the operating conditions shown in figure 25. Here, the engine speed was increased by 300 rpm in each step from 1200 rpm to 2400 rpm and operated at 5 different values.

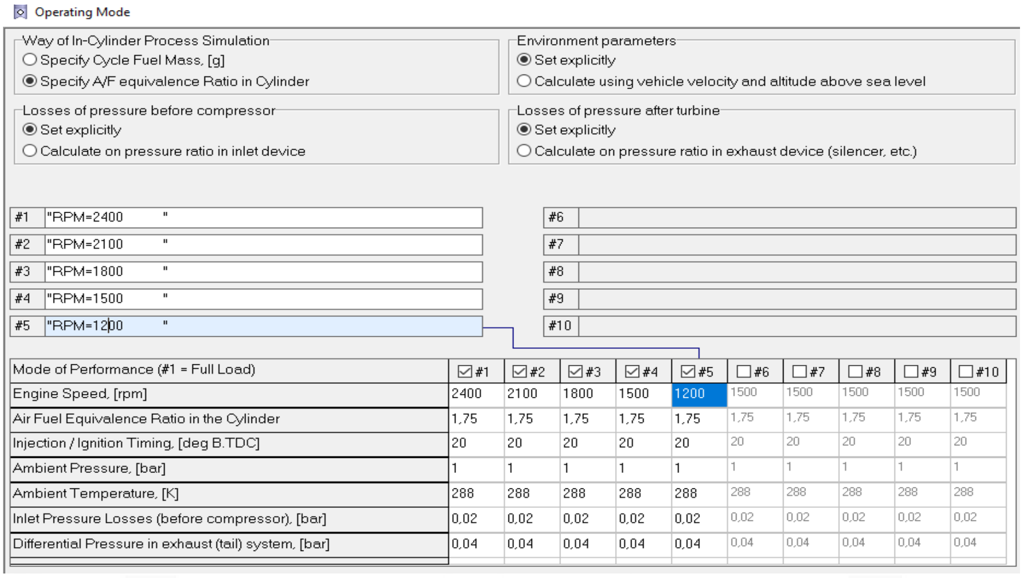


Figure 25. Operating mode selection screen on Diesel-RK Software

In the next step, the program "RUN" is in line with these determined values and by pressing the ICE Simulation button, the performance values are saved in the program memory and the data is drawn from here.

5. RESULTS AND DISCUSSIONS

Fossil fuel reserves are decreasing day by day. When using these fuel sources, greenhouse gases are released into the atmosphere. Greenhouse gases are harmful gases that cause global warming and climate change. For this reason, it is desired that the resources to be used as fuel today will be resources that will reduce or even eliminate the greenhouse gas effect. The content of this study was determined by these targets and it was obtained from Luffa Aegyptiaca seeds as an alternative fuel source and it was analyzed whether this oil would be a suitable source of biodiesel.

In order to calculate % oil ratio of seed the results of oil extracted by soxhalet is used. For this purpose, the measured value before and after the treatment was determined separately for each sample as seen in Table 7. After this process, the amount of oil per unit of product was calculated.

Table 7. % Oil ratio according to samples

Sample	Tare Weight+Oil	Tare Weight	Weighed Amount	% Oil
1	142.9227	141.2857	11.8233	13.85
2	146.5219	144.6724	11.5838	15.97
3	146.453	144.5676	12.4746	15.11

As a result it is concluded that the Luffa Aegyptiaca seed has an average value of 15.98% oil content.

According to the result of the GC test, a gas chromatography spectrum for the Luffa Aegyptiaca seed spectrum was obtained. This spectrum is shown in Figure 26.

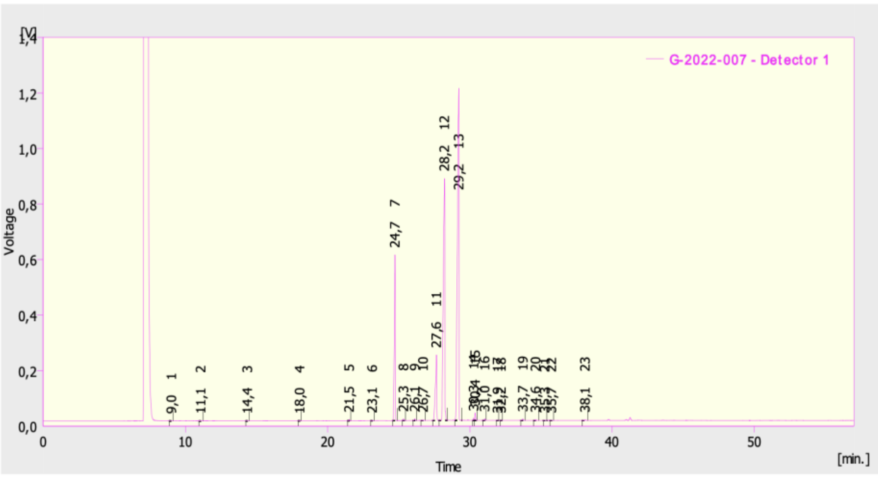


Figure 26. GS result of Luffa Aegyptiaca seed

According to the results obtained from the gas chromatography, the oil obtained from the Luffa Aegyptiaca seed; contains 43.85% linoleic acid, 33% oleic acid, 13.70% palmitic acid, 7.90% stearic acid. These oils, especially these oils, and other oils that affect the biodiesel properties of the oil are shown in Table 8.

Table 8. Fatty acids profile of Luffa Aegyptiaca seed

Fatty Acid Name	Analysis Result	Fatty Acid Name	Analysis Result
Butyric acid (C4:0)	0.003	*Linoleic Acid (C18:2)*	43.85
Caprylic acid (C8:0)	0.009	*Linoleic Acid (C18:3)*	0.141
Decanoic acid (C10:0)	0.008	*Gadoleic/Eicosenoic Acid (C20:1)*	0.495
Dodecanoic acid (C12:0)	0.008	*Linolenoic Acid (C18:3 cis-9,12,15)*	0.109
Myristic acid (C14:0)	0.082	*Heneicosanoic Acid (C21:0)*	0.003
Pentadecanoic acid (C15:0)	0.024	*Eicosadienoic Acid (C20:2 cis-11,14)*	0.004
Palmitic Acid (C16:0)	13.79	*Behenic Acid (C22:0)*	0.122
Palmitoleic Acid (C16:1)	0.103	*Eicosatrienoic Acid (C20:3 cis-8,11,14)*	0.059
Heptadecanoic (C17:0)	0.152	*Erucoic Acid (C22:1 cis-13)*	0.026
Heptadecenoic (C17:1)	0.044	*Eicosatrienoic Acid (C20:3 cis-11,14,17)*	0.007
Stearic Acid (C18:0)	7.898	*Tricosanoic Acid (C23:0)*	0.063
Oleic Acid (C18:1)	33		

Fuel properties were calculated according to the gained spectrum by Biodiesel Analyzer V1.2.

The estimated physicochemical fuel values were given in Table 9.

Table 9. Estimated physicochemical values of Luffa Aegyptiaca biodiesel

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	Location and season dependent	Location and season dependent	0.83
Iodine Value	-	120^1g log/100g	110.00
Cloud Point	Location and season dependent	Location and season dependent	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 density of LAB100 is within the standards of EN14214. Cold flow properties are promising but in its pure form, it can be easily said that it is not suitable for cold climates. On the other hand Catane number is 4,49 % less according to the standards which leads to more ignition delay time. the viscosity value is 34% below the standard of diesel. According the fuel property results LAB is not suitable for using as B100 form but can be used as blend form.

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 10.

Table 10. The free fatty acid analysis result

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

On the other hand for the accuracy of the estimated model a comparison table were prepared by taking the experimental values from literature (Erol, 2016).

The experimental torque values of RME100 and the theoretical RME100 fuels obtained from using Diesel-RK are shown in Table 11 and plotted as in Figure 27.

Table 11. Experimental and theoretical torque values for the RME100

Engine Speed (rpm) / Biodiesel Torque (Nm)	**1100**	**1400**	**1700**	**2000**	**2300**	**2600**	**2900**
RME100 (Experimental)	207.23	211.31	213.29	212.09	202.6	197.44	189.14
RME100 (Theoric)	180.75	199.71	205.66	209.97	211.6	213.41	212.64
Difference (%)	**12.78**	**5.49**	**3.58**	**1.00**	**-4.44**	**-8.09**	**-12.42**

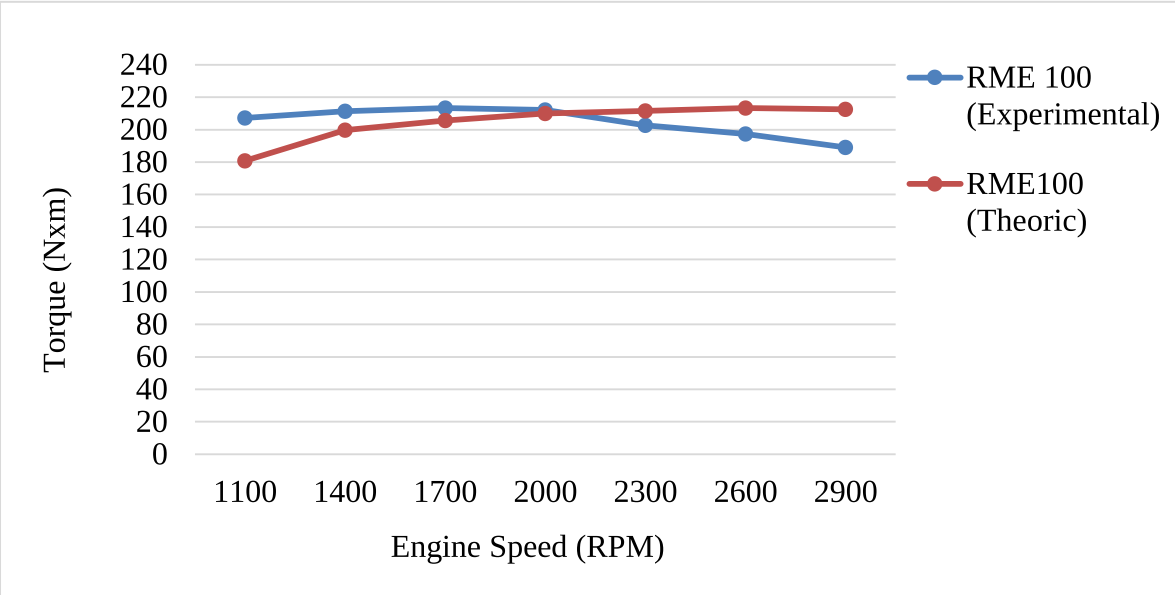


Figure 27. Experimental and theoretical torque graphics for the RME100

The engine power results are shown in Table 12 and Figure 28 (Erol, 2016).

Table 12. Experimental and theoretical engine power values for the RME100

Engine Speed (rpm) / Biodiesel Engine Power (kW)	**1100**	**1400**	**1700**	**2000**	**2300**	**2600**	**2900**
RME100 (Experimental)	23.90	31.00	38.00	44.40	48.80	53.80	57.40
RME100 (Theoric)	20.82	29.28	36.61	43.97	50.96	58.10	64.57
Difference (%)	**12.89**	**5.55**	**3.66**	**0.97**	**-4.43**	**-7.99**	**-12.49**

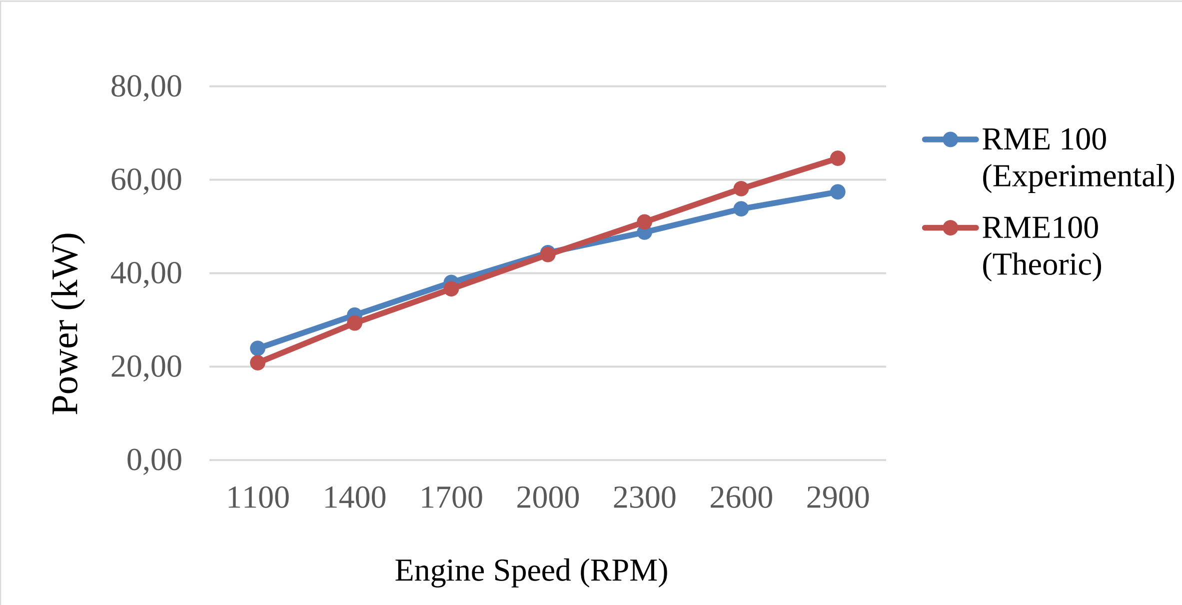


Figure 28. Experimental and theoretical engine power graphics for the RME100

Considering the given values and graphics, it has been observed that there is less than a 10% change in the theoretical and experimental results from 1400 rpm to 3000 rpm. This value is an important indicator of the accuracy of the results obtained for the LAB100, SME100, RME100 and DIESEL compared.

5.1.Engine Power

Engine power, which is a parameter revealed by torque and crankshaft angle, is one of the important factors affecting engine performance. The engine performance of LAB100 fuel, which is considered within the scope of this study, was investigated against RME100, SME100 and DIESEL fuel. As shown in Figure 29, engine performance changes at 5 different values were obtained for each fuel type starting from 900 rpm up to 2700 rpm. When these changes are examined, it has been observed that the four fuel types have similar engine day values at 900 rpm as the starting point and 1200 rpm, which is the next value. While DIESEL and RME100 fuels were parallel to each other at 2100 rpm and 2400 rpm values, it was observed that the engine power of SME100 and LAB100 fuels decreased compared to RME100 and DIESEL fuels.

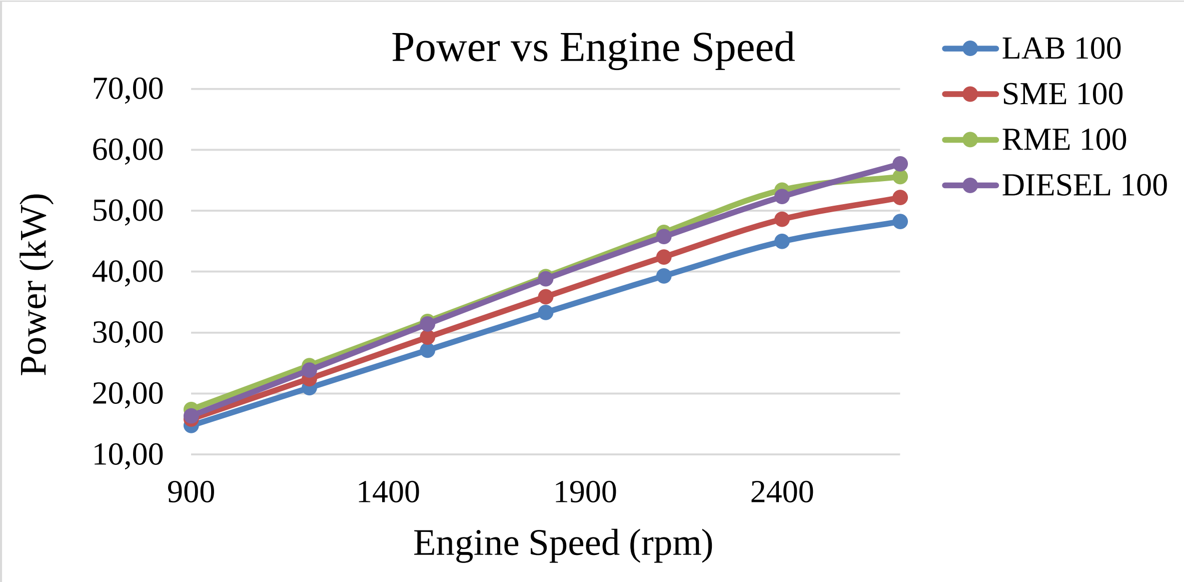


Figure 29. Power vs engine Speed

5.2. Engine Torque

Torque, the general definition of which is turning force, refers to the rotation of the crankshaft per minute for the engine. In the analysis made for torque, which is one of the important parameters affecting engine performance, the results in Figure 30 were obtained. As seen in the graphic, RME and DIESEL are parallel to each other at 5 different rpm values. LAB100 fuel followed the lowest values in torque value comparing the four fuels.

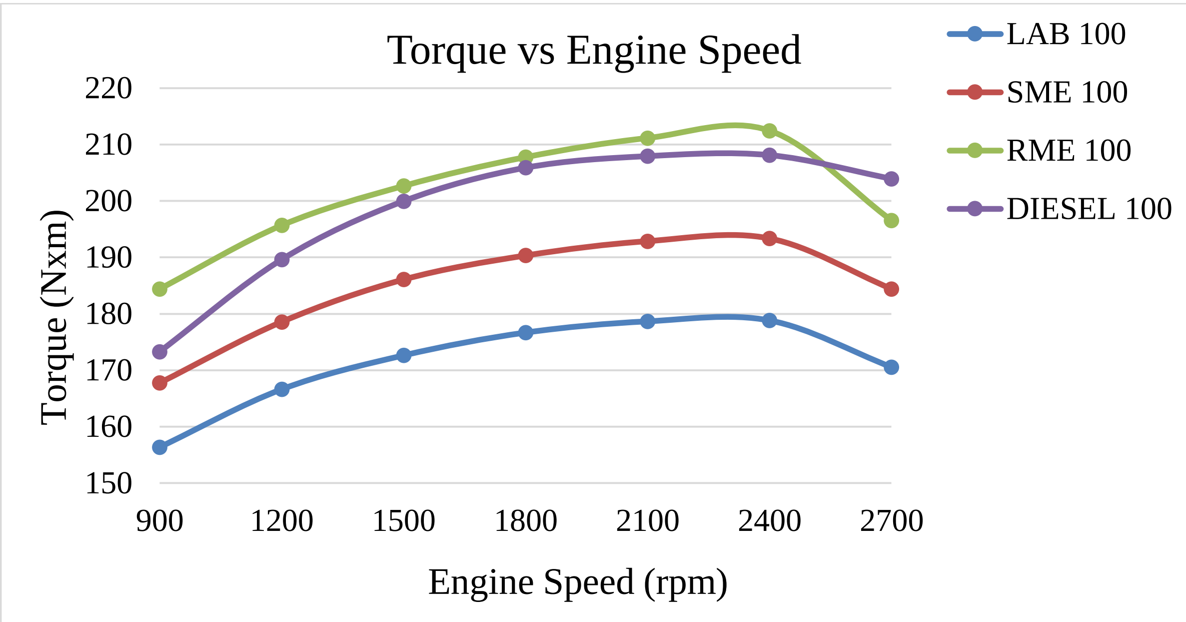


Figure 30. Torque vs Engine Speed

5.3. Specific Fuel Consumption (SFC)

SFC, which depends on the engine design, is the value in grams of fuel the engine consumes per kWh of work under constant operating conditions. SFC values for LAB100, SME100, RME100 and DIESEL compared at engine speeds 900, 1200, 1500, 1800, 2100 and 2400 rpm are shown in Figure 31. The lowest SFC value is DIESEL, followed by RME100 with the second lowest SFC value. LAB100 and SME100 fuels show parallelism in terms of SFC values. Here, the fuel consumption shows the consumption against the work done, and although LAB100 seems to be disadvantageous, it has positive results in terms of creating an alternative to these fuels, as it produces results close to plant-based fuels such as RME100 and SME100

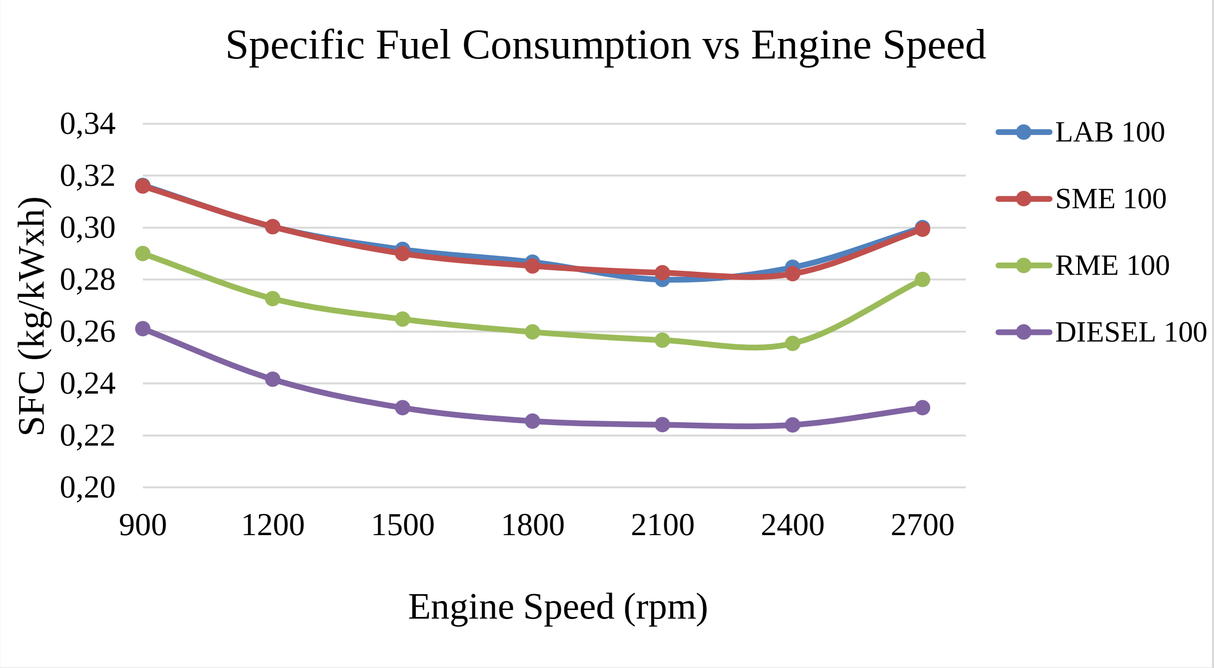


Figure 31. Specific Fuel Consumption vs Engine Speed

5.4.NOx Emission

Structures consisting of oxygen and nitrogen atoms are called NO_x for short. NO_x are gases that are sent to the atmosphere through the exhaust with the effect of high temperature and pressure at the time of combustion. The unstable versions of NO_x have polluting properties. This also harms the environment. The more NO_x in the exhaust gas, the more inefficient this combustion is.

In this study, LAB100 fuel, which is considered an alternative fuel, was compared with RME100, SM100 and DIESEL fuels according to their NOx emission values. The results of these fuels, which are compared at 5 different rpm starting from 900 rpm, are shown in Figure 28. As can be seen in the graph, LAB100 has a significant advantage in NOx emissions against fossil-derived DIESEL flux as shown in Figure 32. In addition, LAB100 seems to have a theoretical advantage over RME100 and SME100, which are alternative biofuels of plant origin, like itself.

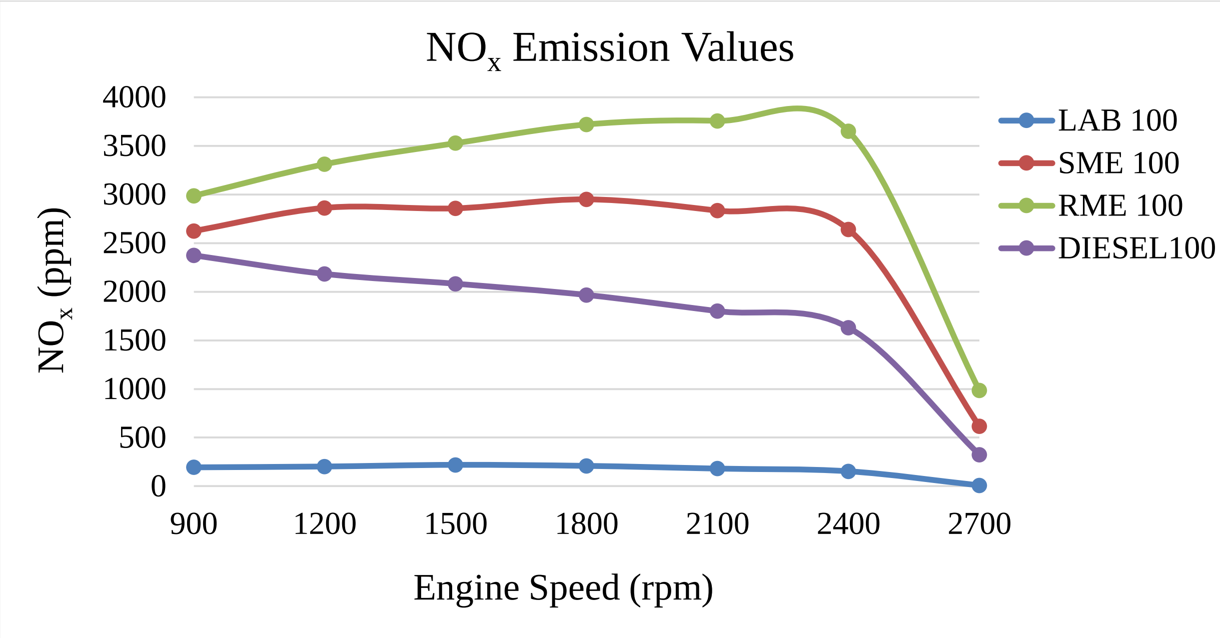


Figure 32. NOx emissions values

5.5. Particulate Matter

The most complex of exhaust emissions is particulate matter. This substance, which contains diluted and cooled exhaust gas, has a filterable feature. It includes solids as well as liquids formed during the dilution process. Particulate matter includes all particles smaller than 40 nm in size.

For this exhaust emission value, which is considered within the scope of the study, the engine was operated at seven different speeds from 900 rpm to 2700 rpm. When the engine started, from 900 rpm to 2400 rpm, LAB100 fuel gave values close to SME100 and RME100 fuels. In addition, better results were obtained for LAB100 compared to DIESEL100 fuel between 900 and 2400 rpm as shown in Figure 33. However, when the engine reaches high revs such as

2700, it has been observed that there is a sudden increase in PM value of LAB100, RME100 and SME100 fuels compared to DIESEL100 fuel.

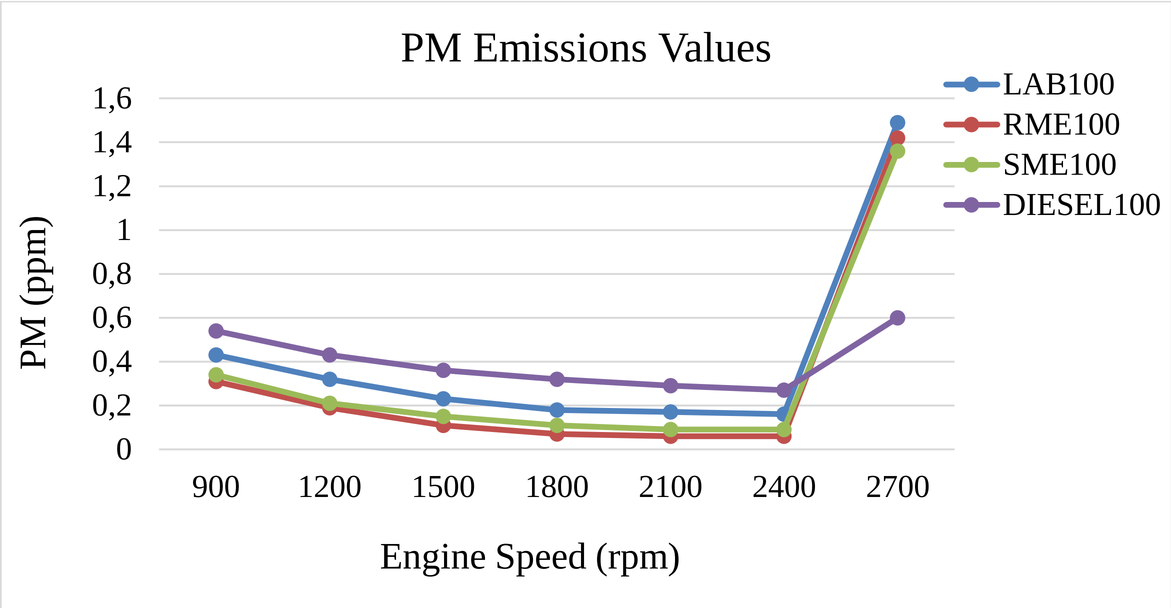


Figure 33. PM emissions values

To make the comparison clearer within the scope of the study, as the engine speed was increased from 900 to 2700 cycles. LAB100 fuel has gained an advantage over both SME100 and RME100 fuels, which are biodiesel, as well as fewer emission values than DIESEL 100. Due to the fact that it causes less NO_x and PM emissions compared to other fuels signals that a more environmentally friendly fuel can be obtained from Luffa Aegyptiaca as a biodiesel feedstock.

5.6. Bosch Smoke Number

Bosch smoke number is defined as the degree of blackening of the filter caused by the exhaust gas. Within the scope of the study, the results obtained by increasing the engine from 900 to 300 revolutions up to 2700 revolutions were evaluated. The LAB100 value gave good results up to 2400, close to SME100 and RME100 fuels. These values show that biodiesel fuels up to 2400 rpm give better results than DIESEL100 fuel as shown in Figure 35. However, as with PM, they reached higher values than DIESEL100 fuel after 2700 rpm. Because PM value and Bosch smoke number value are related to each other.

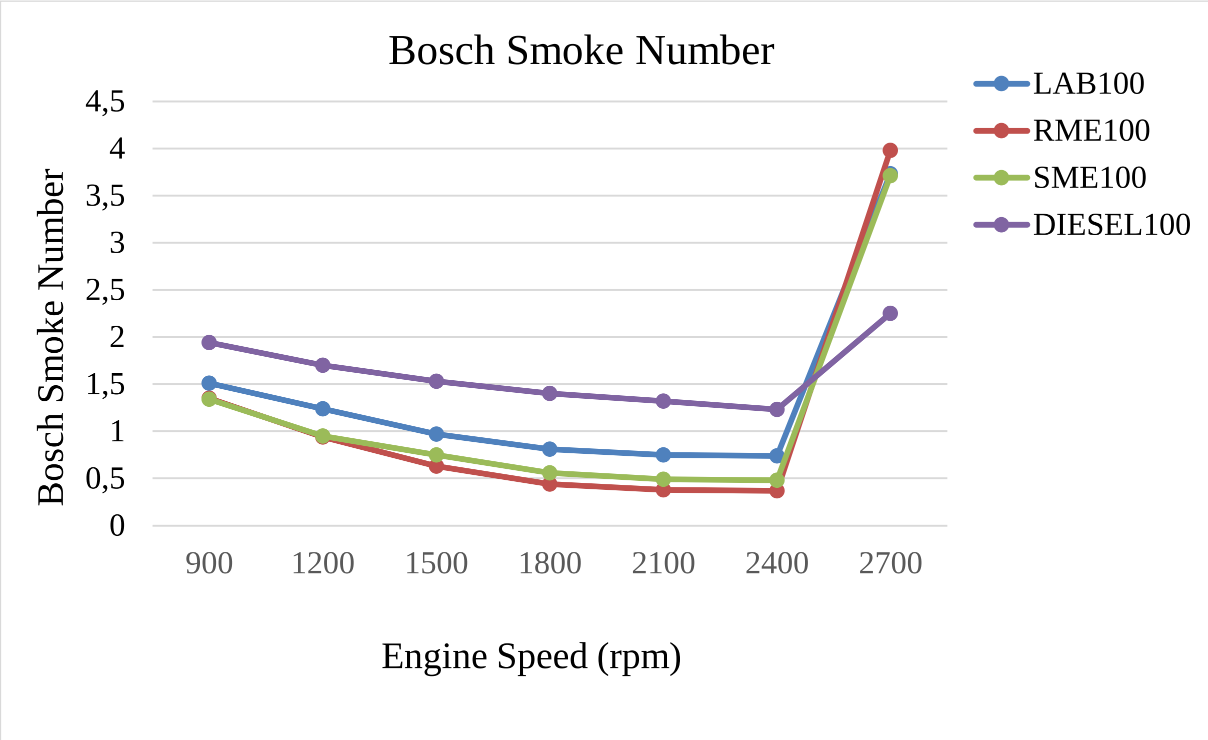


Figure 34. Bosch smoke number emissions values

6. CONCLUSION

With the increase in population in the world; The energy consumption used in these fields, especially in industry, human needs, technology and vehicles, has also increased. Accordingly, in the last 20 years, a significant decrease has been recorded in fossil energy sources, which meet our energy needs the most.

Reductions in the amount of energy have put countries that do not have sufficient resources and are dependent on foreign sources in a disadvantageous position. The race to own oil and energy resources, which dates back to the 1980s, has led to tensions and even wars in world politics, especially in the last 10 years. In addition, the fact that each country is close to itself with the pandemic conditions that emerged in March 2020 has shown once again how important it is for a country to be self-sufficient and to meet its needs.

The Luffa Aegyptiaca seeds discussed in this study were obtained from Hatay and oil was obtained from the seeds obtained by two different methods. One of these methods is the cold pressing method and the other is the method of processing in the soxhlet device by turning it into powder.

The obtained Luffa Aegyptiaca seed oil was subjected to the GC test and according to the results obtained from the gas chromatography, the oil obtained from the Luffa Aegyptiaca seed; contains 43.85% linoleic acid, 33% oleic acid, 13.70% palmitic acid, 7.90% stearic acid.

On the other hand FFA analyzes were made. To use the transesterification method for producing biodiesel the FFA value must be below 1% , hence the report indicates that the Luffa Aegyptiaca needs further process reduce the FFA value which is 2.41%.

After determining the fatty acids content of the Luffa Aegyptiaca oil, biodiesel properties were determined for LAB100 using Biodiesel Analyzer V1.2. These determined values were compared with the biodiesel standard EN14214. The density of LAB100 is within the standards of EN14214. Cold flow properties are promising but in its pure form, it can be easily said that it is not suitable for cold climates. On the other hand Catane number is 4,49 % less according to the standards which leads to more ignition delay time. Above all, the main obstacle is the viscosity it is below the standards which can be cause large fuel drops during injection. According the fuel property results LAB is not suitable for using as B100 form but can be used as blend form.

LAB100, RME100, SME100 and DIESEL fuel properties were used in the Diesel-RK program. In the program, the engine power, torque, specific fuel consumption, particular matter, bosch smoke number, and NO_X emission values of these four fuels were compared at the specified engine speed.

LAB100; although it showed lower performance compared to other fuels in terms of engine power, torque and specific fuel values, it provided a significant advantage over other fuels with the values it showed in NOx emissions. In particular, it has been theoretically determined that DIESEL causes emission of 10% of the NO_X emission value it sends to the atmosphere. It is predicted that the motor power, torque and SFC value can be improved for LAB100 if it is used as blend.

As well as the political dimension of owning and using energy resources, the most important dimension is the environment. Because every source that causes emissions as a result of combustion poses a danger to the environment. These emission sources send greenhouse gases that cause climate change and global warming to the atmosphere. As a result, if the process proceeds in this way, both ecological life and the future of humanity will be in danger. Considering all these conditions, it has become necessary to develop alternative and environmentally friendly fuels in the automotive sector, which needs energy the most. Therefore, by using as a blend with diesel fuel; it is believed that Luffa Aegyptiaca seed oil is a promising candidate for biodiesel production.

7. RECOMMENTATION

In this study, LAB100 is considered an alternative fuel source. The engine performance of LAB100 fuel was measured theoretically. These engine performance and emission values were compared with two different biodiesel and diesel fuels. As a result of the study, LAB100 fuel may be an instrumental fuel, therefore it is necessary to improve the fuel value by making detailed research for future studies.

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CURRICULUM VITAE

APEX
App. 1. Analysis Report

OKÜMERLAB

T.C.
OSMANİYE KORKUT ATA ÜNİVERSİTESİ
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G2022-007
2022/04

Analiz Raporu
Analysis Report

Müşterinin adı *Customer name*	:	
Müşterinin adresi *Customer address*	:	
Talep Numarası *Order No.*	:	G2022-007
Numunenin adı ve tarifi *Name and identity of analysis item*	:	Kabak Lifi Yağı (1 Adet Numune) *Pumpkin Fiber Oil (1 Sample)*
Numunenin kabul tarihi *The date of receipt of analysis item*	:	30.03.2022
Talep edilen Analizler *Analysis request*	:	Yağ Asitleri Kompozisyonu *Fatty Acids Methyl Esters*
Açıklamalar *Remarks*	:	
Analizin yapıldığı tarih *Date of analysis*	:	30.03.2022 - 18.04.2022
Raporun sayfa sayısı *Number of pages of the Report*	:	2

Analiz sonuçları, genişletilmiş ölçüm belirsizlikleri (olması halinde) ve analiz metotları bu sertifikanın tamamlayıcı kısmı olan takip eden sayfalarda verilmiştir.
The analysis results, the uncertainties (if applicable) with confidence probability and analysis methods are given on the following pages which are part of this report.

Mühür/Kaşe Seal	***Yayımlandığı Tarih*** Date	***Analizi Yapan***	***Onaylayan***
OKÜMERLAB	18.04.2022		

Bu rapor, laboratuvarın yazılı izni olmadan kısmen kopyalanıp çoğaltılamaz.
İmzasız raporlar geçersizdir.
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Analysis reports without signature are not valid.

OML.FRM.069/11.04.2022-01 Sayfa *(Page)* **1 / 2**

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Analiz Raporu
Analysis Report

Analizler *Analysis*	**Analiz Yöntemi** *Analysis Method*	**Analiz Sonucu** *Analysis Result*	**Ölçüm Belirsizliği** *Measurement Uncertainty*	**Mevzuat Sınırları** *Legislation Limits*	**Mevzuata Göre Sonuç** *Result by Legislation*
Bütirik asit (C4:0) *Butyric acid (C4:0)*	TGK 2014/53-54	0,003	---	---	---
Kaprilik asit (C8:0) *Caprylic acid (C8:0)*	TGK 2014/53-54	0,009	---	---	---
Dekanoik asit (C10:0) *Decanoic acid (C10:0)*	TGK 2014/53-54	0,008	---	---	---
Dodekanoik asit (C12:0) *Dodecanoic acid (C12:0)*	TGK 2014/53-54	0,008	---	---	---
Miristik asit (C14:0) *Myristic acid (C14:0)*	TGK 2014/53-54	0,082	---	---	---
Pentadekanoik asit (C15:0) *Pentadecanoic acid (C15:0)*	TGK 2014/53-54	0,024	---	---	---
Palmitik Asit (C16:0) *Palmitic Acid (C16:0)*	TGK 2014/53-54	13,79	---	---	---
Palmitoleik Asit (C16:1) *Palmitoleic Acid (C16:1)*	TGK 2014/53-54	0,103	---	---	---
Heptadekanoik/Margarik Asit (C17:0) *Heptadecanoic Margaric Acid (C17:0)*	TGK 2014/53-54	0,152	---	---	---
Heptadesenoik/Margoleik Asit (C17:1) *Heptadecenoic Margoleic Acid (C17:1)*	TGK 2014/53-54	0,044	---	---	---
Stearik Asit (C18:0) *Stearic Acid (C18:0)*	TGK 2014/53-54	7,898	---	---	---
Oleik Asit (C18:1) *Oleic Acid (C18:1)*	TGK 2014/53-54	33,00	---	---	---
Linoleik Asit (C18:2) *Linoleic Acid (C18:2)*	TGK 2014/53-54	43,85	---	---	---
Linolenik Asit (C18:3) *Linoleic Acid (C18:3)*	TGK 2014/53-54	0,141	---	---	---
Gadoleik/Eikosenoik Asit (C20:1) *Gadoleic Eicosenoic Acid (C20:1)*	TGK 2014/53-54	0,495	---	---	---
Linolenoik Asit (C18:3 cis-9,12,15) *Linolenoic Acid (C18:3 cis-9,12,15)*	TGK 2014/53-54	0,109	---	---	---
Heneikosanoik Asit (C21:0) *Heneicosanoic Acid (C21:0)*	TGK 2014/53-54	0,003	---	---	---
Eikosadienoik Asit (C20:2 cis-11,14) *Eicosadienoic Acid (C20:2 cis-11,14)*	TGK 2014/53-54	0,004	---	---	---
Behenik asit (C22:0) *Behenic Acid (C22:0)*	TGK 2014/53-54	0,122	---	---	---
Eikosatrienoik Asit (C20:3 cis-8,11,14) *Eicosatrienoic Acid (C20:3 cis-8,11,14)*	TGK 2014/53-54	0,059	---	---	---
Erükoik Asit (C22:1 cis-13) *Erucoic Acid (C22:1 cis-13)*	TGK 2014/53-54	0,026	---	---	---
Eikosatrienoik Asit (C20:3 cis-11,14,17) *Eicosatrienoic Acid(C20:3 cis-11,14,17)*	TGK 2014/53-54	0,007	---	---	---
Trikosanoik Asit (C23:0) *Tricosanoic Acid (C23:0)*	TGK 2014/53-54	0,063	---	---	---

Değerlendirme
Assessment

Müşteri tarafından uygunluk beyanı talep edilmemiştir. *The conformity declaration was not requested by customer.*

Analiz sonuçları yalnızca analizi yapılan numunelerle ilgilidir. Tablodaki ölçüm belirsizliği değerleri, analiz laboratuvarı tarafından k=2 ve %95 güven aralığında belirlenmiştir.
Analysis results are only relevant to the analyzed samples. The measurement uncertainty values in the table were determined by the analysis laboratory at k=2 and 95% confidence interval.

Bu rapor 2 nüsha olarak düzenlenmiştir.
This report has been issued in 2 copies.

App. 2. FFA Analysis Report

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Analiz Raporu
Analysis Report

Analizler *Analysis*	**Analiz Yöntemi** *Analaysis Method*	**Analiz Sonucu** *Analysis Result*	**Ölçüm Belirsizliği** *Measurement Uncertainty*	**Mevzuat Sınırları** *Legislation Limits*	**Mevzuata Göre Sonuç** *Result by Legislation*
Serbest Asitlik (% Oleik Asit Olarak) *Percent Free Acidity (As % Oleic Acid)*	TGK 2014/53	2,41	---	---	---

Değerlendirme
Assessment

Müşteri tarafından uygunluk beyanı talep edilmemiştir. *The conformity declaration was not requested by customer.*

Analiz sonuçları yalnızca analizi yapılan numunelerle ilgilidir. Tablodaki ölçüm belirsizliği değerleri, analiz laboratuvarı tarafından k=2 ve %95 güven aralığında belirlenmiştir.

Analysis results are only relevant to the analyzed samples. The measurement uncertainty values in the table were determined by the analysis laboratory at k=2 and 95% confidence interval.

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OML.FRM.069/11.04.2022-01 Sayfa *(Page)* **2 / 2**

App. 3. Chromatography

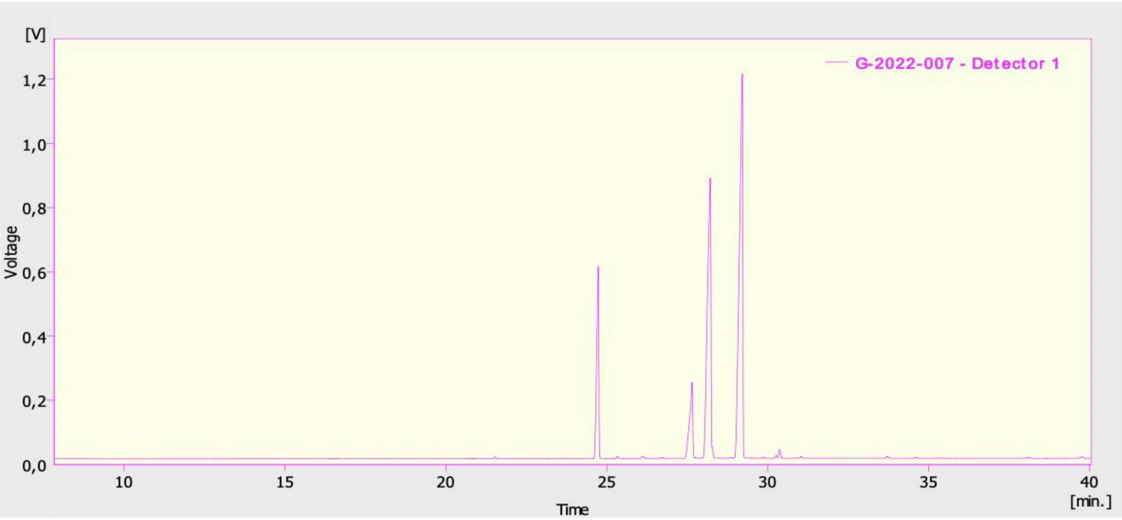
28.02.2022 13:18 Chromatogram C:\YLClarity\WORK1\DATA\G-2022-007.PRM Page 1 of 1

Clarity - Chromatography SW
DataApex 2006
www.dataapex.com

Chromatogram Info:

File Name	: C:\YLClarity\WORK1\DATA\G-2022-007.PRM	File Created	: 11.04.2022 10:46:59
Origin	: Acquired, Acquisition started 11.04.2022 10:49:51	Acquired Date	: 11.04.2022 11:46:58
Project	: C:\YLClarity\Projects\Work1.PRJ	By	: Administrator

Column	:	Detection	:
Mobile Phase	:	Temperature	:
Flow Rate	:	Pressure	:
Note	:		



Result Table (Uncal - G-2022-007 - Detector 1)

Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]	Compound Name
No peak to report						