Journal of Engineering Research

Volume 6 | Issue 1 Article 5

2022

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Medhat Elkelawy

Vol. 6, No. 1 – 2022 Journal of Engineering Research (ERJ)

Biodiesel as an Alternative Fuel in Terms of Production, Emission, Combustion Characteristics for Industrial Burners: a Review

Medhat Elkelawy[1*], Hagar Alm-Eldin Bastawissi[1], Ali Kamel Abdel-Rahman[2], Ahmed Abou-elyaziedAbdelhafez[3], and Saad Mostafa El malla[4]

[1*]*Ph.D. Professor, Mechanical Power Engineering Department, Faculty of Engineering, Tanta University*
[2]*Ph.D. Professor, Mechanical Power Engineering Department, Faculty of Engineering, Assuit University*
[3]*Ph.D. professor, Faculty of Agriculture, Ain Shams University*
[4]*Sugar Technology Research Institute, Assuit University*
Emails: medhatelkelawy@f-eng.tanta.edu.eg

Abstract- This review summaries several studies on the emission and performance characteristics of biodiesel, as well as the various proportions of diesel blended with biodiesel, in an oil burner in terms of the specific fuel type that can be used, types of emissions such as NOx, CO, soot, and CO2, and other operating conditions that can be used to improve the performance of the biodiesel burner system. A brief description of the production of biodiesel, as well as its physical and chemical properties, is presented at the outset. Biodiesel has emerged as the most promising replacement diesel fuel. Because of its renewable origin, the availability of current production technology, biodegradability, high combustion efficiency, the potential for sustainability, economic viability, environmental friendliness, and chemical and physical qualities identical to regular diesel oil. The experimental setup used in various investigations and their results related to performance and emissions with respect to biodiesel and different mixing ratios of it with diesel, as well as methods for maximizing the benefit of it in the combustion applications of industrial burners, have been presented in brief to a large number of studies. The emission and performance characteristics of a biodiesel burner system demonstrated unequivocally that biodiesel fuel may be a viable renewable alternative energy source for a burner system.

Keywords: ***biodiesel, emissions, physical and chemical properties, combustion, and performance characteristics***.

I. INTRODUCTION

Fossil fuels such as petroleum, coal, and natural gas are still being the largest and most important role in energy production, but the problem is that fossil fuels are limited and that excessive continuous use has caused the depletion of fuel stock, additionally problems affecting the environment from fuel use. All this was a necessary reason to use alternative clean fuels from natural materials such as biodiesel. Biodiesel is considered as one of the potential liquid alternative fuels for diesel engines and industrial burners derived from organic oils and fats. Rudolph Diesel experimented with vegetable oil as a fuel for his engine more than a century ago [1]. In 1900 in Paris, the French company Otto demonstrated a diesel engine running on peanut oil. However, due to the widespread availability and low prices of fossil fuels, interest in producing vegetable oil-based fuels has waned. Despite this, several countries are interested in using vegetable oil to power internal combustion engines. In 1937, the Belgian scientist Georges Chavane patented the "Procedure for converting vegetable oils for use as fuel", which introduced the hydrolysis (chemical disintegration) method of breaking down triglyceride molecules (oil and fat) by substituting ethanol or methanol for the glycerol component. Brazilian scientist Expedito Parente developed the industry's first biodiesel production process. In 1989, it was the first of its kind in the world a biodiesel plant was commissioned on an industrial scale in Asperhofen, Austria to produce biodiesel from rapeseed. The united states started commercial operations (Pacific Biodiesel, Maui, Hawaii) in 1996 to process waste grease into biodiesel [2]. According to the organization for economic cooperation and development and the UN's Food and agriculture organization, Biodiesel production increased from 3.9 billion liters in 2005 to 18.1 billion liters in 2010 and is expected to surpass 41.4 billion liters by 2025. [3].

Biodiesel (Fatty Acid Methyl Esters) is a monoalkyl ester of long-chain fatty acids produced from a renewable source such as edible and non-edible vegetable oils, animal fat, and waste cooking oils by the transesterification process. Vegetable oils are composed of triglycerides, which are tri-esters consisting of three long hydrocarbon chains (fatty acids molecules) which may have up to three double bonds in each chain, with each chain also containing an ester group (RCO2R′). By treating these compounds through transesterification, Triglycerides are degraded into smaller alkyl esters [4].

In the transesterification process, the original molecular structure of triglycerides is changed to produce biodiesel by reacting triglycerides with an alcohol (such as ethanol or methanol) in the presence of a catalyst (such as sodium hydroxide) at an elevated temperature (~ 100 ° C). The transesterification process produces biodiesel for methyl ester (if methanol is used) and bio ethyl ester (if ethanol is used) as well as a glycerol product that can later be used in food, medical, pharmaceutical, or cosmetic products [5]. The goal of the conversion transesterification process is to reduce the viscosity of the oil. The reaction with alcohol takes place in many consecutive, reversible reactions, and in this process, the fatty acids of vegetable oil exchange are placed with the (OH) groups of the alcohol producing glycerol and methyl, ethyl, or butyl ester depending on the type of alcohol used. The general equation of transesterification reaction requires 3 mol of alcohol and 1 mol of triglyceride to give 3 mol of fatty acid esters and 1 mol of glycerin, as shown in equation 1.

$$\begin{array}{lllll} CH_2 \cdot OOC \cdot R_1 & & R_1 \cdot COO \cdot R' & CH \cdot OH & \\ I & & & I & \\ CH \cdot OOC \cdot R_2 \ + & 3R'OH \xrightleftharpoons{Catalyst} & R_2 \cdot COO \cdot R' \ + & CH \cdot OH & (1) \\ I & & & I & \\ CH_2 \cdot OOC \cdot R_3 & & R_3 \cdot COO \cdot R' & CH.OH & \\ \text{Triglyceride} & \text{Alcohol} & \text{Fatty acid esters} & \text{Glycerol} & \end{array}$$

R′ is the alcohol alkyl chain, and R1, R2, and R3 are the hydrocarbon chains of fatty acids. The reaction mechanism of transesterification of triglyceride is converted to diglyceride, monoglyceride, and finally glycerol as shown in equation 2 [6].

$$\begin{array}{llll} \text{Triglyceride} + R'OH & = \text{Diglyceride} & + RCOOR' & \\ \text{Diglceride} + R'OH & = \text{Monoglyceride} & + RCOOR' & (2) \\ \text{Monoglyceride} + R'OH & = \text{Glycerol} & + RCOOR' & \end{array}$$

Vegetable oils have enough oxygen in addition to hydrogen, which may make combustion easier. Saturated and unsaturated monoalkyl esters with carbon chains of 15-20 atoms or longer make up biodiesel [7].

II. Waste oil biodiesel

Biofuels derived from waste provide great potential for reducing harmful gas emissions, producing energy using it in combustion processes, disposal of waste that affects the environment, as well as it requires less energy to produce because the raw material for fuel already exists. This effectively increases the value of energy return on investment (ROI) of many waste-derived biofuels such as waste oil biodiesel. Waste cooking oil is reused cooking oil utilized in restaurants, the food industry, and households. Triglycerides are the main constituents of fresh vegetables oil and Waste cooking oil which contains usually more free fatty acids and water and fewer triglycerides. Pretreatment of waste oil by transesterification takes place with reacted methanol in the presence of sodium hydroxide to produce biodiesel. One of the main obstacles in the commercialization of biodiesel production from vegetable oils is the high manufacturing cost, which is due to the high cost of virgin vegetable oil.

Waste cooking oil is an important key component in lowering biodiesel production costs up to 60-90% [8]. Food consumption around the world produces significant amounts of waste cooking oils and fats, which are discarded in harmful ways in many regions of the world. Waste cooking oil is characterized by its availability and low cost. Therefore, it is an economical choice for biodiesel. One of its disadvantages is that this oil contains many unwanted compounds such as polymers free fats acid (FFA) and many other chemicals that are formed during Frying, and all this needs preliminary treatment so as not to affect the esterification reactions [9]. Waste cooking oils have a heating value (41.8 MJ/kg) at a similar level as that of fuel oil (43.0 MJ/kg). Therefore, the use of waste oils as an energy source has become a feasible and experimental option to reduce the intensive dependence on fossil fuels.

III. Production of biodiesel

Biodiesel can be made from vegetable oil or waste cooking oil in a variety of ways, which can be grouped into three categories: (a) homogeneous transesterification, (b) heterogonous transesterification, and (c) non-catalytic transesterification [8]. A multitude of factors influences biodiesel production and conversion, including raw oil, alcohol, molar ratio, catalyst, reaction temperature, time duration, Rate, and stirring mode.

Ahn et al. [10] carried out the transesterification in two-steps reaction process to make biodiesel, a two-step transesterification procedure is used. Fresh methanol and catalyst were used to make biodiesel in a batch reactor using this method. The glyceride phase is separated after each stage. At lower temperatures, the methyl ester and glyceride form two phases with little mutual solubility. The transesterification yield is approximately 99%. M. Elkelawy et al. [11] studied the production of biodiesel from a mixture of sunflower and soybean oils using a catalyzed transesterification by (NaOH) and methanol and the effect of biodiesel and diesel blended on performance and emission characterized of diesel engine, the result showed that the biodiesel yield approximately 93.5% and matches with the property of diesel fuel according to ASTM and also blending diesel and biodiesel enhance the performance and emission of engine.

Cvengro and Povaz [12] studied the production of biodiesel from rapeseed oil using two stages of low-temperature transesterification of cold-pressed rapeseed oil with methanol at temperature up to 70 ℃. The catalyst (NaOH) is used with methanol. Shieh et al.[13] they investigated transesterification of soybean oil by methanol and catalyzed enzyme mild to produce biodiesel and studied the effects on reaction time, temperature, enzyme amount, the molar ratio of methanol to soybean oil. Singh et al [14] studied transesterification process of biodiesel production from non-edible by a heterogeneous catalyst (CaO) for the transesterification reaction of Jatropha biodiesel. At a catalyst concentration of 5 wt% and a methanol to oil molar ratio of 12:1, the heterogeneous transesterification yielded 81.6 percen. . Borges and Daz[15] developed a packed-bed catalytic reactor in a recirculation system to use potassium-loaded pumice material (K-Pumice) as the heterogeneous catalyst in the transesterification reaction of sunflower oil and waste oil for biodiesel production. The value of the biodiesel content was determined, and it was found to be 99.5 percent.

Both batch and continuous industrial processes are used to convert vegetable oils or waste cooking oil into biodiesel. Depending on the type of catalyst utilized in the homogeneous transesterification reaction, the process can be divided into three systems: alkali, acid, and enzyme [9]. The traditional method for producing biodiesel is transesterification with alkali catalysts. The reaction happens in a multi-phase reactor where vegetable oils or waste cooking oil react with alcohol, in presence of an alkaline catalyst, to form fatty acid esters and glycerol as shown in figure 1.

The typical biodiesel production process of alkaline homogeneous transesterification can be described as sequential steps as follows: -

- The first step, 1% alkaline catalyst (NaOH) on a mass basis of the crude oil was utilized with methanol to the molar ratio of 6:1 [16] [17] and was pre-mixed with methanol by a mechanical stirrer to create sodium methoxide and water.

- In the second step, this mixture was then put to a reacting tank to be mixed with vegetable oils or waste cooking oil using a mechanical homogenizer to undergo a transesterification reaction. Because methanol has a boiling point of 63 °C, the transesterification process's reaction temperature was adjusted at 65:70 °C to prevent methanol vaporization during the biodiesel production process. The transesterification process reaction took 60 minutes to complete.
- In the third step, the mixture was separated into two layers, biodiesel, and glycerol, by centrifuging or keeping it motionless by the difference in density between these two compounds.
- The fourth step involves washing the biodiesel that has exited the transesterification reactor with water to neutralize the catalyst and convert any remaining soaps into free fatty acids.
- In the five-step procedure, finally, the washed methyl ester product is dried to reduce the water content to an acceptable level for biodiesel required standards[18] [19].

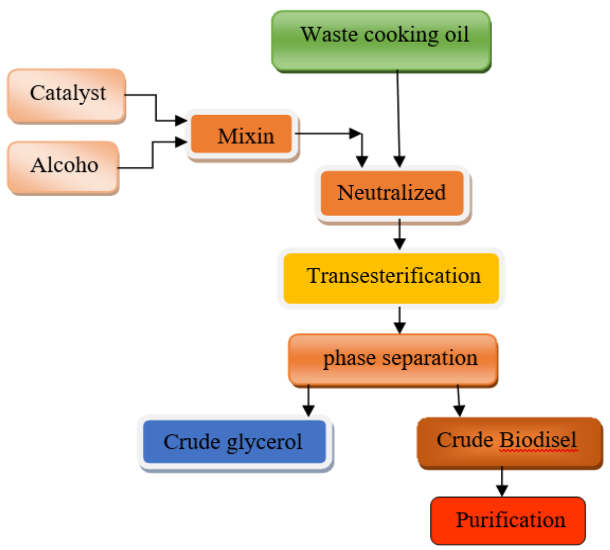

Fig. 1. Flow chart of biodiesel transesterification

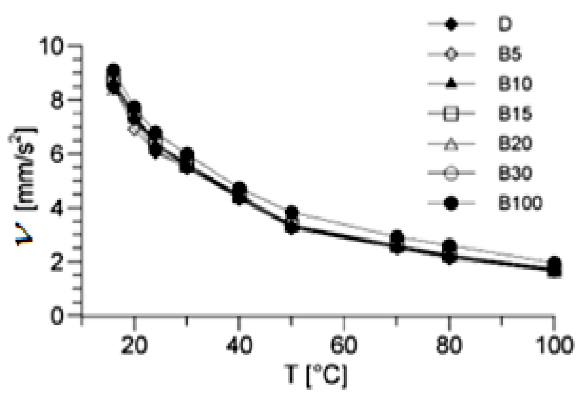

Fig. 2. Variation of blend kinematic viscosity as a function of temperature [21]

IV. Physical and Chemical Properties

The physical and chemical properties of biodiesel fuel and its blends with diesel fuel are different from diesel fuel because of the dissimilar chemical composition of the fuel and have a significant influence on a combustion process compared with conventional diesel fuel. Viscosity, specific gravity, density, speed of sound, and compressibility are the major thermodynamic properties of biodiesel fuel and its blends with diesel fuel have a noticeable effect on the fuel spray atomization and evaporation characteristics. Without any adjustments, biodiesel can be used pure or blended in an industrial burner.

However, the chemical differences between biodiesel (a mixture of mono-alkyl esters of saturated and unsaturated long-chain fatty acids) and standard diesel fuels (a mixture of paraffinic, naphthenic and aromatic hydrocarbons) affect burner performance and pollutant emissions. It's critical to understand the fundamental features of biodiesel–diesel mixes. Some of these features are necessary as input data for burner combustion models and flames that are predictive and diagnostic. It is also critical to determine whether the fuel produced by the blending operation matches the diesel fuel specification guidelines. [20].

V. Kumbhar et al [21] used statistical analysis to find a link between critical biodiesel parameters (cetane number, density, viscosity, heating value) and fatty acid compositions in nine different forms of biodiesel derived from edible oil, non-edible oil, waste oil, and animal oil. The models constructed for cetane quantity and density were highly statistical. Predictive models for kinematic viscosity and heating value, on the other hand, were ineffective; however, the error between experimental and predicted values for heating value was sufficiently small.

As demonstrated in Figures 2 and 3 [21] different biodiesel blends with diesel have varied density and kinematic viscosity values. B0 denotes diesel fuel, whereas B100 denotes pure biodiesel. B5 is a 5 percent biodiesel/95 percent diesel blend, whereas B20 is a 20 percent biodiesel/80 percent diesel blend. Tat and Van Gerpen [22] examined The density of diesel and biodiesel blends. The results revealed that the soybean oil biodiesel–diesel mixes had a linear specific gravity–temperature relationship, similar to pure diesel fuels.

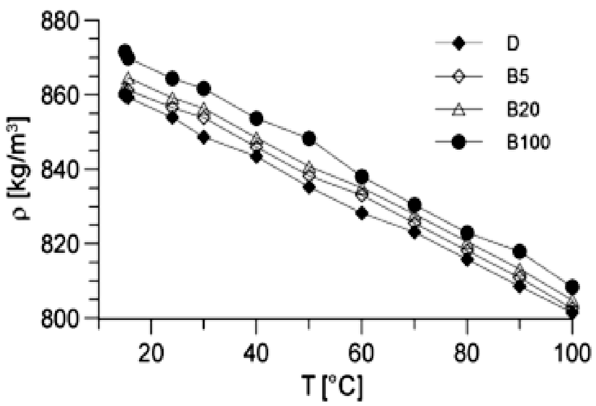

Fig. 3. Variation of blend density as a function of temperature [21]

Biodiesel is made up of mono-alkyl esters of fatty acids in its chemical structure. Biodiesel has a specific gravity of 0.873–0.884, the kinematic viscosity of 3.8–4.8 mm $/s^2$, the cetane number of 50–62, cloud point of 4–14 1 $^{\circ}C$, and flash point of 110–190 1 $^{\circ}C$. It has an energy density (high heating value) of 38–45 MJ/kg, which is roughly 90% that of petrol diesel [2]. Biodiesel has a lower carbon and hydrogen composition than diesel fuel due to its high oxygen concentration (usually 11%), resulting in a mass-energy content that is around 10% lower. volumetric energy of biodiesel content is only roughly 5–6% lower than petroleum diesel due to its higher fuel density [23].

There are many studies on the physical and chemical properties of Biodiesel and understanding the characteristics and performance of combustion and the impact on emissions when using biodiesel in combustion equipment. Yoon et al. [24] investigated the fuel properties of conventional diesel, neat biodiesel, and their blends with varied blending ratios at various temperature ranges, and the resulting measurements of the biodiesel and its blends were compared to the properties of conventional diesel. They discovered that the specific gravity of biodiesel fuel increased with increasing biodiesel blending ratio and progressively dropped as fuel temperature increased linearly. Furthermore, as the biodiesel blending ratio increases, the density values increase linearly. With increasing fuel temperature and decreasing blending ratio, all viscosities of blends, diesel, and biodiesel declined linearly. Anand et al [25] proposed methodologies for predicting the absolute viscosity of vegetable oils and biodiesel, Based on their fatty acid composition and temperature. Their estimates of viscosity are critical for understanding spray and combustion processes in engines.

R. Payri et al [26] studied the effects of temperature and high pressures on three thermophysical properties: speed of sound, compressibility, and density of Three fuel samples. They found that low-pressure biodiesel had a higher speed of sound and could affect the performance of combustion and density values increased with pressure and decreased with temperature. For all the fuels the bulk modulus increased linearly with pressure and increased with density. J.M. Paton and C.J. Schaschke [27] studied the viscosity properties of biodiesels produced from waste cooking oil and vegetable oil Under high pressure. They discovered that the viscosity of the biodiesel samples studied increased with pressure as a result of the compression of the molecules, which inhibited their mobility.

Dzida and Prusakiewicz [28] studied the physicochemical properties of petroleum diesel oil and biodiesel fuel, such as density, isentropic bulk modulus, heat capacity, and isobaric thermal expansion.

V. Biodiesel uses in an industrial burner

Biodiesel fuels in oil burners are an appealing alternative fuel for both industrial and residential uses. Biodiesel can be used in diesel engines and industrial liquid burners as a pure fuel or as a blend with diesel fuel without significant modifications due to having properties like those of petroleum fuels that allow them to be mixed with it [23]. The general function of a burner is to maintain a consistent operation and an appropriate flame pattern under a specified set of operating conditions. Different burner settings are required for maximum performance when using biodiesels, which might vary in composition and purity depending on the feedstock. The atomization and air-fuel mixing rate, for example, can change the fuel density and viscosity. It's easier to inject, atomize, and combine low viscosity fuel with air. As a result, the spray angle will be affected by viscosity [29]. Biodiesel combustion in an industrial burner is practical and produces similar outcomes to diesel combustion in terms of pollution levels, combustion efficiency, and greenhouse gas reduction [30] [31]. The following are the primary benefits of biodiesel, whether pure or blended:

- Biodiesel is considered a renewable fuel because it is derived from a natural source such as vegetable oils or animal fats.
- No modifications or minor modifications to the industrial burner or diesel engine are required to use.
- Inhibits the formation of sulfur dioxide (SO2) and emissions of carbon dioxide.
- Because of its low Sulphur concentration and low aromaticity, it reduces HC and PM throughout the combustion process.
- The existence of substances containing oxygen.
- Biodiesel is a flammable fuel due to its comparatively high cetane number in comparison to regular diesel fuel and because it is an oxidizing fuel.
- Biodiesel features superior lubricants.
- It has a higher flash point than petroleum diesel. Biodiesel has high oxygen content and a flashpoint above 160°C.

The use of biodiesel and mixtures with diesel in industrial burner requires adjusting the fuel rate of biodiesel to be injected to conserve thermal energy because the thermal energy of biodiesel is lower than that of diesel. Also, the airflow is generally lower than that of diesel because it contains biodiesel oxygenates. San José et al [32] carried out an experimental investigation on the performance of combustion and emission characteristic use of biodiesel and diesel mixtures for heating purposes. They observed that the performance of the mixtures requires an adjustment of the fuel parameters since when burning biodiesel; the airflow must be reduced, to contain biodiesel oxygen. In addition, as fuel pressure rises, combustion air must be increased. This is because when the pressure rises, the fuel flow and therefore the required airflow increase. CO2 fossil fuel emissions were observed to reduce when biodiesel is added to diesel and Emissions of sulfur dioxide are reduced because of the increase in the proportion of biodiesel in the fuel.

Macor and Pavanello [33] carried out an experiment on the performance and emissions of a pure biodiesel-fueled fire-tube boiler. When compared to diesel fuel oil, the results showed a reduction in CO and PM emissions and an increase in formaldehyde. Both fuels had relatively low volatile organic compounds (VOCs). Ghorbani et al [34] investigated combustion of B5, B10, B20, B50, B80, and B100 with petroleum diesel over wide input air flows at two energy levels in an experimental boiler. The data demonstrate that while diesel efficiency is slightly better than that of biodiesel at higher levels of energy, biodiesels are more efficient at lower levels. Biodiesel and other blends, except B10, emit less pollutant CO, SO2, and CO2 than diesel. B10 produced less CO_2, NOX, and SO_2 than diesel, but produced more SO_2. The results showed that burning biodiesel reduces NOx levels in flue gases at the second energy level.

Amirnordin et al [35] tested the combustion performance and emission of industrial burner-fueled diesel and biodiesel and blend of diesel and biodiesel. The results showed that biodiesel reduces CO, CO_2, and particulate matter emissions while increasing NOx emission they also showed an increase in exhaust gas temperature as the proportion of biodiesel increased from B0 to B40. Hosseini et al. [36] examined the effect of equivalency ratio on flame temperature and emission parameters of an industrial oil burner using various percentages of biodiesel and gas oil. They found that increasing the percentages of biodiesel in the blends reduces flame temperature, CO, and CO_2 emissions while increasing NOx emissions in comparison with the case of gas oil. Ghassan et all [37] investigated the combustion performance and emissions of biodiesel in comparison to the baseline diesel fuel in a water-cooled furnace with an A/F ratio for the two fuels at two energy input levels.

They discovered that at lower energy rates, biodiesel burned more efficiently with higher combustion efficiency; at higher energy rates, biodiesel combustion performance deteriorates compared to diesel fuel due to its high viscosity, low density, and low volatility; and in terms of emissions, biodiesel emitted fewer pollutants at both energy levels across the entire range of A/F ratio considered.

Abdul Malik et al [38] investigated the performance and emissions of conventional diesel and biodiesel fuel mixes at three different equivalency ratios utilizing a standard solid spray fuel nozzle and an open-ended combustion chamber. At all equivalence ratios, they discovered that biodiesel fuel blends combust at a lower temperature and emit less pollution than regular diesel fuel. Furthermore, increasing biodiesel fuel content in conventional diesel fuel mixes reduced combustor wall temperature and emission concentration.

S. Lee et al [39] investigated the combustion performance and emission characteristics of a blend containing 20% soybean methyl ester fuel blended with diesel fuel in a residential-scale hot water boiler equipped with an oil burner. The results showed that the normal combustion performance of a 20% biodiesel blend is comparable to diesel fuel, and the NOx emissions from the 20% biodiesel blend and diesel fuel are similar, with a reduction in PM emission concentrations and soot and an increase in CO emissions when compared to diesel fuel. Mantari et al [40] were studied the numerical and experimental performance of the oil burning system using different blends of biodiesel, and they found that the temperature and emissions decrease when the percentage of biodiesel in the blends increases. The B5 mixture showed the best performance, followed by B10, B15, and finally B20. This is true for both the numerical and empirical approaches.

Abdul Rahim [41] investigated the combustion characteristics and emissions of 75 percent diesel fuel and 25% biodiesel fuel blends made from various plant oil feedstocks, such as jatropha, palm, and coconut oils, using three different angles of swirl in the liquid fuel burner, ranging from lean to rich mixtures. The results show that when the swirling flow was increased, the emissions of carbon monoxide (CO), unburned hydrocarbon (UHC), and soot were greatly reduced. For all types of biodiesel fuels, 25 percent biodiesel and 75 percent diesel blends yielded decreased carbon monoxide (CO), unburned hydrocarbon (UHC), and soot emissions. When comparing pure diesel fuel combustion to biodiesel blend fuel combustion, NOx emissions were slightly higher for all types of biodiesel fuels. Motamedifar and Shirneshan [42] carried out an experiment on the effects of air swirling with different swirl air vane angles on pollutant emissions and the performance of a burner fueled with diesel-biodiesel-ethanol blends. The result shows that Swirl air vane angle and Biodiesel-included fuel blends have an impact on combustion performance, CO, HC, NOx, and CO_2 emissions.

Mohamad et al [43] investigated how four different air swirlers with 45°, 50°, 60°, and 70° vane angles and varying equivalent ratios affected the combustion performance and emissions of an oil burner system using palm oil biodiesel. They found that increasing the number of swirlers reduced NOx emissions by a significant amount for all equivalent ratio values. They also discovered that increasing the swirler number reduces carbon monoxide emissions while keeping the equivalent ratio constant, but that the concentration of carbon monoxide emissions increases as the equivalence ratio rises.

Mohan et al [44] investigated Biodiesel obtained from waste cooking oil and its blends with diesel in terms of spray and combustion development. they found that in comparison to B20 and diesel fuels, B100 has higher spray tip penetration and velocity but narrower spray angles due to its high viscosity and big momentum. Kunlanit et al [45] studied spray created by a small industrial burner by model dimensionless mass-based drop diameter distribution data at the local position, they found the mean diameters of the diesel and biodiesel drop-size distributions are similar, but their evaporation times are dramatically different.

Lambosi et al [46] used an air-assisted fuel atomizing burner to test the influence of nozzle angle on mixture formation, combustion characteristics, and emission when utilizing blends of biodiesel and diesel. They found that the nozzle angles employed were 450 and 500 degrees. In comparison to nozzle 500, the results demonstrate that nozzle 450 produces lower spray penetration but a higher spray angle and spray area. On flame development, the results were identical. Carbon Monoxide (CO) and Hydrocarbon (HC) emissions were significantly reduced when a nozzle with a 450-degree angle was used instead of a 500-degree angle. Because of the increased viscosity of the fuel, high biodiesel concentration in fuel blends can produce significant spray penetration and area. On the other hand, it has the opposite effect on flame formation. The higher concentration of biodiesel leads to higher exhaust temperature and emission, while lower the CO emission was recorded.

Yatsufusa et al [47] experimented by adding water to a redesigned burner injector that produced less PM and NOx at high loads. Fuel and water are quickly combined by atomizing air in the injector's small mixing chamber, and three fluids consisting of fuel, water, and air are injected into the burner's flame stabilizer. They discovered that at high load, the injector emits less emission. At a high load, a larger amount of water is added, resulting in lower PM and NOx emissions. In whole-load conditions, adding water by using water-emulsified fuel results in greater CO emissions. In low-load conditions, however, injecting water using the internally rapid mixing injector produces less CO emissions.

Pourhoseini and Ghodrat, [48] studied the influence of an Al2O3 nano fuel addition on the flame, radiation, temperature, and pollutant emissions parameters of an oil burner using a blend of 20% biodiesel with diesel. They found that Al2O3 nanoparticles improve the flame's brightness, IR, and total radiation heat transfer. Higher nanoparticle concentrations resulted in a significant increase in the radiation heat flux. However, increase CO emissions. NOx emissions are reduced by 11% when nano fuel is used. S. Gan and H. K. Ng [49] investigated antioxidants' capacity to reduce emissions from the combustion of palm oil methyl ester blends with diesel in a non-pressurized, water-cooled combustion chamber utilizing a liquid fuel burner. Several antioxidant additives, including butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and tert-butyl hydroquinone (TBHQ), were dissolved in varying amounts in B10 and B20 gasoline mixes for testing. Their findings revealed that whereas BHA and TBHQ both reduced the quantity of nitric oxide (NO) produced, adding BHT to both fuel mixtures increased the amount of NO created during combustion. Carbon monoxide (CO) levels were found to be lower when BHA was added to B10 and B20, however, BHT and TBHQ were proven to increase CO generation at all test points. This simple technique has been shown to be an efficient pollution management strategy that is more cost-effective than other existing technologies when the additive type and quantity are correctly selected for application to various biodiesel blends.

H. Kurji et al [50] investigated the performance of a swirl burner using various CO2/CH4 mixtures with diesel or biodiesel produced from frying oil. Comparisons between the mixes were done at various equivalency ratios. They discovered that using biodiesel and CO2/CH4 blend mixtures resulted in lower CO and CO2 production. IN all conditions, the biodiesel/CO2/CH4 blends indicated a considerable reduction in NOx of up to 50%. CO2/CH4/biodiesel blends have often provided the cleanest profiles with the best flame stability.

VI. Conclusion and Final Remarks

The previous researchers' production, combustion characteristics and emission were discussed in this study.
The following is a summary of the findings:

- Biodiesel is one of the most environmentally friendly fuels available, according to a review of biodiesel burner system emission and performance characteristics, and as industries expand, biodiesel will continue to play an increasingly important role in environmental protection and as a substitute for fossil fuels.
- Biodiesel minimizes the amount of unburned hydrocarbons, carbon monoxide, and sulfur dioxide emissions released into the environment by burning longer and more thoroughly due to its higher oxygen content.
- The emission and performance characteristics of a biodiesel burner system clearly showed that this type of alternative fuel might be a viable renewable alternative energy source for a burner system. The physical and chemical features of biodiesel can have a significant impact on the combustion process, impacting burner performance and emissions.
- Biodiesel has the potential to be as efficient as diesel fuel while producing fewer pollutants. Furthermore, biodiesel can be utilized in industrial burners without requiring any modifications. It can also be combined with petroleum diesel in any ratio to create biodiesel blends.
- The biodiesel burner system encompasses a wide range of parametric studies on combustion control methods for burner systems to reduce emissions by managing mixture formation and additives.

Acknowledgments

This work was implemented in the Internal Combustion Engines Laboratory, Faculty of Engineering, and Tanta University, Egypt with full funding from the Research Fund Administration at Tanta University under the number of **tu: 02-19-01**.

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