A REVIEW ON BIODIESEL-ETHANOL BLENDS AS SUSTAINABLE ALTERNATIVES TO DIESEL FUEL

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ABSTRACT

The search for cleaner, renewable energy sources is imperative due to the rising global energy demand and environmental issues related to fossil fuels. The possibility of biodiesel-ethanol blends as environmentally friendly substitutes for conventional diesel fuel is examined in this study. Air pollution and greenhouse gas emissions can be significantly reduced by using biodiesel, which is made from renewable resources like vegetable and animal fats. A bio-based alcohol called ethanol improves biodiesel by decreasing harmful emissions and increasing combustion efficiency. The disadvantages of each fuel are lessened by combining them, offering a workable and environmentally friendly diesel alternative. The study examines the body of research on biodiesel-ethanol blends' stability, engine performance, and environmental effects. Important research shows how well these blends work to lower emissions and enhance engine performance. The stability of biodiesel-ethanol blends is also examined in the study, with a focus on the contribution of additives and surfactants to blend stability. CeO_2 nanoparticles and other advanced additions have demonstrated potential in enhancing combustion and lowering emissions. To sum up, mixes of biodiesel and ethanol present a practical and sustainable substitute for conventional diesel fuel. By lowering dangerous pollutants and enhancing engine performance, they have a major positive impact on the environment. Future research should focus on optimizing blend ratios, enhancing fuel stability, and exploring the use of advanced additives to maximize the potential of biodiesel-ethanol blends as a cleaner and more efficient fuel source.

Keywords: Biodiesel, Ethanol, Renewable Energy, Emission Reduction and Engine Performance

1. INTRODUCTION

The need for cleaner, renewable energy sources has increased due to the world's growing energy consumption and the environmental problems caused by burning fossil fuels. Diesel is a major component in compression ignition (CI) engines, which are vital for transportation and agriculture. Nonetheless, burning diesel greatly increases air pollution and greenhouse gas (GHG) emissions. A viable substitute is biodiesel, which is made from renewable resources like vegetable and animal fats. By improving combustion and lowering toxic emissions, ethanol, a bio-based alcohol, enhances biodiesel. By combining these two fuels, the drawbacks of each are addressed, providing a potentially practical and sustainable substitute for traditional diesel. Second-generation biodiesel mixed with water and nanoparticles was studied by Kumar and Raheman (2022) examined second-generation biodiesel that has been mixed with nanoparticles and water. This method demonstrated the potential of biodiesel as a clean fuel substitute by dramatically increasing thermal efficiency and lowering hazardous emissions (Production_characteriz). Ghadge and Raheman (2021) Demonstrated the high yield and compliance of mahua biodiesel with international standards, emphasizing the role of optimized production processes in achieving high-quality biodiesel.

2.0 REVIEW OF LITERATURE

This section reviews existing research on the use of biodiesel-ethanol blends as substitutes for diesel fuel. The focus is on fuel stability, engine performance, and environmental impact.

2.1 Alcohol and Biodiesel Blends as Fuels

Kirik (1981) emphasized that using alcohol as motor fuel is feasible. Diesel-ethanol blends were found effective, with ethanol vaporization improving power but requiring modifications for optimal engine performance. Goering et al. (1983) Studied ethanol-diesel blends in high-speed diesel engines. Blends reduced petroleum use by 20-37%, though power output decreased under lighter loads due to ethanol's lower calorific value. Eklund et al. (1984) Explored various techniques for using alcohol in diesel engines. Ethanol reduced kinematic viscosity but decreased thermal efficiency when blended above 20%. Shropshire and Bashford (1984) Compared single and multi-nozzle systems for ethanol fumigation. Multi-nozzle systems distributed ethanol more effectively, optimizing engine performance.The effect of ethanol proof on engine performance was examined by Goering and Schrader (1988). Because of the higher water content, lower ethanol percentages resulted in somewhat lower power but higher fuel consumption. Blends of ethanol and diesel improve combustion;however, stabilization is necessary to avoid phase separation, according to Goering et al. (1983). Ajav (1997) found that biodiesel-ethanol mixes reduced CO and particle emissions while slightly increasing NOx emissions. Chandra (2003) Noted that surfactants like ethyl acetate improve the stability of ethanol-biodiesel blends.

2.2 Emissions and Engine Characteristics

According to Hansen et al. (1989), ethanol in diesel improves thermal efficiency at higher loads by increasing ignition delay while lowering smoke emissions. The potential of biofuels to lessen reliance on foreign oil, increase energy security, and lessen environmental effect was highlighted by Peterson et al. (1995). Blends of ethanol and diesel have been shown to cut CO and NOx emissions by up to 20% without the need for engine changes (Ajav, 1997). Ozer and associates (2000) demonstrated that, particularly at higher injection pressures, ethanol can decrease CO and soot emissions while increasing NOx. Btungchul (2008) Observed reductions in CO and PM emissions but noted increased NOx when using biodiesel-ethanol-diesel blends in a common rail diesel engine. Peterson et al. (1995) Highlighted biodiesel's potential to reduce dependence on fossil fuels and associated GHG emissions. Yilmaz and Vigil (2021) Found that alcohol additives lower NOx emissions but may increase CO and HC under certain operating conditions.

2.3 Stability and Additives

Fernando et al. (2004) emphasized how biodiesel stabilizes ethanol-diesel mixtures at different temperatures by acting as an amphiphile. Although its necessity rises with lower ethanol proofs, Chandra (2003) found that ethyl acetate enhances blend stability even when used with aqueous ethanol. Kwanchareon et al. (2006) Investigated phase behavior in diesel-biodiesel-ethanol blends, finding that biodiesel's cetane value compensates for ethanol's low cetane number. Shi et al. (2008) Used catalysts to reduce NOx in ethanol-biodiesel-diesel blends. Results indicated improved emissions but required additional after-treatment technologies for CO and HC control. According to Fernando et al. (2004), biodiesel can effectively stabilize ethanol-diesel blends by increasing their miscibility and lowering their propensity for phase separation. By adding CeO_2 nanoparticles and surfactants to biodiesel blends, Kumar and Raheman (2022) were able to significantly lower CO, HC, and NOx emissions while increasing combustion efficiency. Raheman, H., and S. K. Patidar (2023). An artificial intelligence (AI) method to enhance the performance and fuel qualities of straight Karanja oil with nanographene added and manufactured with ideal dispersion characteristics. biofuels. The paper notes that plant-based oils and biodiesel-diesel blends have gained attention for their ability to enhance engine performance and reduce exhaust emissions cost-effectively by improving combustion processes. including fuel preheating, blending with diesel and alcohols, among others. Among these, preheating crude vegetable oils has proven to be the simplest and most effective method for reducing their high viscosity (Sonar et al., 2015; Prasad & Rambabu, 2015; Pradhan et al., 2014).

2.4 Biodiesel Production and Engine Performance

Transesterification is essential for lowering the viscosity of biodiesel, according to Rodjanakid (2005). Diesel and refined palm oil biodiesel both showed similar engine performance. Das (2010) demonstrated that biodiesel blends maintained similar power output while increasing thermal efficiency. Kumar (2011) showed how microwave-assisted transesterification greatly shortened the time needed to produce biodiesel, increasing its viability as a fuel. Ethanol's oxygenation increases combustion efficiency, as shown by Goering et al. (1983) and Hansen et al. (1989). However, combining ethanol with diesel poses difficulties, such as phase separation. Research by Fernando and colleagues (2004) emphasized the amphiphilic qualities of biodiesel, which aid in stabilizing mixtures of ethanol and diesel. Hansen and associates (1989) Higher ethanol concentrations were shown to improve brake thermal efficiency, which was ascribed to improved combustion. Raheman and Kumar (2022) highlighted the function of cutting-edge additives in maximizing engine performance by observing increased brake thermal efficiency and decreased brake-specific energy consumption with blends enhanced by nanoparticles. Transesterification, dilution, micro-emulsion, pyrolysis, catalytic and reactive distillation, microwave technology, and the superfluid method are some of the different processes used to transform vegetable oils into ones that are acceptable for use in diesel engines. Research like that conducted by Murray et al. (2021), Bharadwaj et al. (2020), Sai Bharadwaj et al. (2019), and Syafiuddin et al. (2020)Describe these techniques and how well they work to improve fuel efficiency and lessen environmental effects. Because of its advantages for sustainability and the environment, biodiesel has drawn a lot of interest as a substitute for traditional petro-diesel. Emulsified diesel-biodiesel-ethanol (D-B-E) blends are one type of biodiesel blend that has been studied for its ability to enhance compression ignition (CI) engines' combustion characteristics. Vasanthaseelan et al. (2016) conducted an experimental analysis of emulsified D-B-E blends' combustion performance, concentrating on the fuel extender's stability and oxygen concentration. Through ternary analysis of 66 emulsified fuel samples at different ratios, the study found that the blends D30-CBD30-E40 and D40-CBD40-E20 demonstrated enhanced combustion properties and stability. The combustion analysis, which included in-cylinder pressure, net heat release rate, and rate of pressure rise, showed promising results with a low deviation (8-9%) when compared to the zero-dimensional thermodynamic model developed in MATLAB. Additionally, the D30-CBD30-E40 emulsified blend exhibited superior combustibility compared to the D40-CBD40-E20 blend, owing to the enhanced micro-explosion of ethanol during combustion. These findings highlight the potential of emulsified biodiesel-diesel-ethanol blends for improving engine performance while maintaining combustion stability. In several studies, the brake thermal efficiency (BTE) of preheated vegetable oils, such as Jatropha, Karanja, and fennel seed oil, has been reported to be higher compared to their unheated forms due to improved fuel atomization and better air-fuel mixing. However, preheating has been shown to increase NOx emissions, as the higher combustion temperatures favor their formation. The BTE of both unheated and preheated straight vegetable oils has been reported to be significantly lower than that of diesel due to their lower heating values, as discussed in several studies by Agarwal and Rajamanoharan (2009), Hazar et al. (2019), Agarwal et al. (2016), Jain et al. (2017), Misra and Murthy (2010), and Soudagar et al. (2018).

2.5 Environmental Impact of Biofuels

Researchers like Shi et al. (2008) discovered that mixtures of biodiesel and ethanol greatly lower emissions of carbon monoxide (CO) and particulate matter (PM). However, in some circumstances, the blends might raise emissions of nitrogen oxides (NOx). According to

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Srivastava (2005), biodiesel has the ability to lower particulate matter and greenhouse gas emissions, hence improving air quality. Jatropha was highlighted by Parawira (2010) as a sustainable biodiesel source that necessitates effective processing and lifecycle assessments to guarantee environmental advantages. Lokesh (2011) suggested substitute crops to alleviate land-use issues in the manufacture of biodiesel, such as microalgae and castor. The performance and emission characteristics of a compression ignition (CI) engine running on blends of diesel, trans esterified rapeseed methyl ester (RME), and n-butanol are examined by Kumar, Prasad, and Raju (2020). The experiment incorporated n-butanol in amounts ranging from 6% to 12% by volume and evaluated different biodiesel blends at different ratios, specifically 10/90 and 20/80. The engine was tested at a rated speed of 1500 rpm and a compression ratio of 17.5:1, under varying loads from 25% to 100%.The findings demonstrated that although the addition of n-butanol resulted in a modest rise in brake-specific fuel consumption (BSFC), the engine's emissions performance improved. As the fraction of n-butanol rose, the levels of carbon monoxide (CO), nitrogen oxides (NOx), and opacity dropped. Higher n-butanol content, however, resulted in a small increase in hydrocarbon (HC) emissions. The blends R10B12 and R20B12 performed the best overall among the studied samples in terms of lowering emissions without sacrificing engine efficiency. According to this study, adding n-butanol to biodiesel blends can improve emissions and engine efficiency, making it a practical option for cleaner fuel substitutes in CI engines.

2.6 Combined Insights

Although NOx emissions may increase, studies regularly demonstrate that biodiesel-ethanol blends have positive environmental effects, such as reduced CO and particle emissions. Biodiesel improves blend stability by increasing ethanol's miscibility with diesel. Long-term stability is still difficult to achieve, though, and calls for sophisticated surfactants or additions. Diesel and biodiesel-ethanol mixes work similarly in engines, with very little differences in power output and fuel consumption. Compared to traditional fuels, nanoparticles enable an earlier start of combustion due to the enhanced energy transfer rate in the combustion chamber, which lowers the peak cylinder temperature and pressure. This phenomenon enhances the probability of reducing NOx emissions. Metal nano-oxides have gained significant attention in fuel science due to their potential to improve combustion and mitigate harmful air pollutants. However, the emission of metal oxide particles from the engine's exhaust system has raised concerns about health risks, including respiratory problems, lung infections, and skin allergies (Soudagar *et al.,* 2018).

2.7 The reviewed literature highlights the growing interest in biodiesel-ethanol blends as substitutes for diesel, particularly in reducing harmful emissions and enhancing engine performance Key findings:

Research indicates that the introduction of additives like n-butanol enhances engine performance, especially in terms of combustion efficiency, in biodiesel-ethanol blends. Trans esterified rapeseed methyl ester (RME) and diesel blends improved in CO, NOx, and opacity emissions while retaining engine efficiency when n-butanol was added. However, greater n-butanol concentrations were associated with somewhat increased brake-specific fuel consumption (BSFC) (Kumar, Prasad, & Raju, 2020). Biodiesel-ethanol blends have been shown to significantly reduce CO and particulate matter (PM) emissions, contributing to cleaner air quality. However, there is an observed increase in NOx emissions at higher engine loads or with higher ethanol content in the blend (Shi et al., 2008; Yilmaz & Vigil, 2021). Supporting the environmental advantages of biofuel, the usage of biodiesel has also been connected to a decrease in greenhouse gas (GHG) emissions (Srivastava, 2005). For biodiesel-ethanol blends, stability is still a major concern because phase separation can happen if the right surfactants or additives aren't used. By increasing miscibility and decreasing phase separation, biodiesel's amphiphilic qualities aid in stabilizing these blends (Fernando et al., 2004; Chandra, 2003). In biodiesel blends, advanced additions like nanoparticles (such CeO_2) have demonstrated promise in enhancing combustion and lowering emissions (Kumar & Raheman, 2022). Blends of biodiesel and ethanol can lower some emissions, such as CO and particulate matter, although they have varying effects on NOx emissions. Although there is evidence that preheating vegetable oils or adding certain additives might lower NOx, it is still difficult to strike a compromise between NOx emissions and combustion efficiency (Kumar, 2011; Soudagar et al., 2018). Numerous studies stress that in order to fully profit from biodiesel-ethanol blends without sacrificing engine power output, engine modifications are required, such as modifying injection pressures and optimizing blend ratios (Ajav, 1997; Goering et al., 1983). Although issues with engine optimization, pollution control, and long-term fuel stability still require further study and development, these results highlight the potential of biodiesel-ethanol blends as competitive substitutes for traditional diesel.

2.8 Future research suggestions

Blend Ratio Optimization: To strike the optimal balance between engine performance, fuel efficiency, and pollution reductions, more study should concentrate on maximizing the blends' ethanol and biodiesel ratios. This involves investigating various forms of ethanol and biodiesel sources.

Sophisticated Additives: Examine how to improve the performance and stability of biodiesel-ethanol blends by utilizing sophisticated additives like surfactants and nanoparticles. Research could examine how different additions affect emission characteristics and combustion efficiency.

Engine Modifications: Studies on engine modifications that maximize the utilization of mixtures of biodiesel and ethanol should be undertaken. To increase efficiency and lower emissions, this entails modifying timing, injection pressures, and other engine settings.

Long-Term Stability: Analyze the mixes of biodiesel and ethanol's long-term stability under various storage circumstances. In order to avoid phase separation and deterioration, this research may help determine the appropriate handling and storage procedures for these mixtures.

Lifetime Assessment: To analyze the overall environmental impact of biodiesel-ethanol mixes, including greenhouse gas emissions, energy consumption, and resource use, conduct thorough lifetime evaluations. This will make it easier to assess how sustainable various mixtures are in comparison to conventional diesel.

Economic Feasibility: Examine if mass production and use of biodiesel-ethanol mixes are economically feasible. This include assessing the price of raw materials, manufacturing procedures, and possible effects on the market.

Policy and Regulation: Examine how policies and regulations might encourage the use of mixtures of biodiesel and ethanol. The creation of guidelines and rewards to promote the use of these sustainable fuels could be the subject of future research.

Population Awareness and Acceptance: Research how the general population views and accepts blends of ethanol and biodiesel. Designing successful communication tactics to encourage the use of these alternative fuels can be aided by an understanding of customer attitudes and habits.

Comparative Research: To identify the most efficient and environmentally friendly choices for various applications, compare biodiesel-ethanol blends with other alternative fuels including hydrogen, electric, and natural gas.

3.0 CONCLUSIONS

The study on biodiesel-ethanol blends as sustainable alternatives to diesel fuel highlights the potential of these blends to address the environmental and performance challenges associated with traditional diesel fuel. The research emphasizes the need for cleaner, renewable energy sources due to the growing energy consumption and environmental issues caused by fossil fuels.The findings indicate that biodiesel, derived from renewable resources such as vegetable and animal fats, can significantly reduce air pollution and greenhouse gas emissions when used as a substitute for diesel. Ethanol, a bio-based alcohol, enhances biodiesel by improving combustion and reducing toxic emissions. The combination of biodiesel and ethanol addresses the drawbacks of each fuel, providing a practical and sustainable alternative to traditional diesel.Key studies reviewed in the paper demonstrate the effectiveness of biodiesel-ethanol blends in improving engine performance and reducing emissions. For instance, Kumar and Raheman (2022) showed that second-generation biodiesel mixed with nanoparticles and water significantly increased thermal efficiency and reduced hazardous emissionsThe literature review also underscores the importance of fuel stability, engine performance, and environmental impact when using biodiesel-ethanol blends. Studies by Goering et al. (1983) and Hansen et al. (1989) demonstrated that ethanol-diesel blends reduce petroleum use and improve thermal efficiency, though they may require engine modifications for optimal performanceThe research further explores the stability of biodiesel-ethanol blends, with Fernando et al. (2004) and Chandra (2003) emphasizing the role of surfactants and additives in enhancing blend stability. Advanced additives like CeO_2 nanoparticles have shown promise in improving combustion and reducing emissions, as highlighted by Kumar and Raheman (2022). In conclusion, biodiesel-ethanol blends offer a viable and sustainable alternative to traditional diesel fuel. They provide significant environmental benefits by reducing harmful emissions and improving engine performance. Future research should focus on optimizing blend ratios, enhancing fuel stability, and exploring the use of advanced additives to maximize the potential of biodiesel-ethanol blends as a cleaner and more efficient fuel source.

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