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Impact of Process Parameters on Biodiesel Yield Produced from Corn Stalk Using $MgFe_2O^4$ as Nano-Catalysts

ATOWON, A. D.[1], OKIRI, E.U[2], EDEDET, M, O.[3], UGBONG E. A[4]
[1, 2, 3, 4]*Department of Wood Products Engineering, Faculty of Engineering, University of Cross River State, Calabar, Nigeria.*

Abstract- ***The effect of key process parameters on biodiesel production from corn stalk oil using $MgFe_2O_4$ nano-catalyst was systematically investigated. The results revealed a significant influence of these parameters on both transesterification efficiency and the physicochemical properties of the resulting biodiesel. The optimum reaction conditions that yielded the highest biodiesel conversion (79.54% v/v) were identified as follows: 4% catalyst concentration (w/w), 150 minutes reaction time, reaction temperature of 60 °C, methanol-to-oil molar ratio of 12:1, and agitation speed of 303 rpm. Comprehensive fuel characterization under these optimum conditions yielded the following results: density of 0.927 g·mL^{-1}, kinematic viscosity of 32.985 mm^2·s^{-1}, flash point of 247 °C, fire point of 257 °C, cloud point of 19.4 °C, saponification value of 220.10 mg KOH·kg^{-1}, acid value of 0.5049 mg KOH·kg^{-1}, molecular weight of 755.76 g·mol^{-1}, aniline point in the range of 45–52 °C, diesel index between 31.82 and 41.16, and gross calorific value ranging from 16–18 MJ·kg^{-1}. All measured parameters were within the acceptable limits specified by EN 14214, ASTM D6751, and relevant API standards for biodiesel fuels. Furthermore, the characterization of biodiesel blends demonstrated their suitability for use in stationary engines, with performance metrics closely matching those of conventional diesel. These findings confirm the potential of corn stalk-derived biodiesel as a viable and sustainable alternative to fossil diesel, with the added benefit of reducing emissions of SO_2, CO_2, and NO_x, thereby contributing to environmental protection and improved air quality.***

Keywords: Nano-Catalyst; Tran-Esterification; Biofuel Characterization, Biodiesel Yield

I. INTRODUCTION

The global ecosystem faces significant challenges due to the continuous release of harmful and toxic emissions into the atmosphere from the burning of fossil fuels to power combustion engines. This has led to increased emissions of toxic gases such as SO_2, CO_2, and NO_x worldwide (Dash & Lingfa, 2018; Kusdiana & Saka, 2004; Agbede, 2012; Kazi et al., 2019; Gholami et al., 2020). The use of fossil fuels in combustion engines contributes substantially to climate change and the rise of climate-associated diseases across the globe. Despite the presence of substantial fossil fuel reserves (Ogbu et al., 2018; Keera et al., 2018), incomplete combustion in industrial regions has aggravated environmental pollution through the release of black soot and other particulates, which react with air and water molecules to worsen air quality (Kumar et al., 2011; Owolabi et al., 2011; Laskar et al., 2018). Reports from NASA and the BP Statistical Review of World Energy revealed a significant reduction in CO_2 emissions during the COVID-19 pandemic due to lockdown measures, with emissions falling by approximately 9.6%, compared to the usual 60–78% emission levels during full industrial operation (Montefri & Obbard, 2020; BP, 2021). The transportation sector is the largest consumer of fossil fuels globally, making it a key driver of greenhouse gas emissions. Consequently, many countries are under pressure to transition toward cleaner and more sustainable energy sources. According to BP (2021), fossil fuels still account for about 84% of global energy consumption, underscoring the urgent need for eco-friendly, renewable, locally available energy alternatives that support environmental sustainability and economic growth. Biodiesel has emerged as a viable alternative to fossil fuels (Pikula et al., 2020; Rafaat, 2010; Yousef et al., 2013). Derived from vegetable oils, biodiesel production addresses the challenges of high viscosity and low volatility through the transesterification process, which reduces the viscosity of bio-oil. Transesterification remains the most widely adopted method for biodiesel production, enabling the conversion of triglycerides in vegetable

oil into fatty acid methyl esters (biodiesel) by reaction with alcohol (Ogbu et al., 2018; Satya Lakshmi, 2020). Both homogeneous and heterogeneous catalysts have been employed to accelerate transesterification. Recent studies highlight the benefits of nanocatalysts, which offer advantages such as reusability, easy separation, enhanced reaction rates, dual-functionality, and a high surface area (Yasar, 2019; Pawar et al., 2021). Research interest in nanocatalyst-based biodiesel production has grown significantly, with recent studies reporting successful biodiesel synthesis from Jatropha seed oil (Atowon & Ita, 2024). However, limited research has focused on the use of corn stalk-derived oil for biodiesel production using $MgFe_2O_4$ nanocatalysts. The present study aims to produce biodiesel from corn stalk oil via a nanocatalyst-assisted transesterification process. The work focuses on characterizing the nanocatalyst and oil feedstock, optimizing process parameters, and determining biodiesel yield to evaluate the feasibility of corn stalk as a sustainable biofuel source.

II. MATERIAL AND METHODS

2.1 Corn Stalk, collection and preparation.

Corn stalk (CS) was locally sourced from Obubra, Cross River State, Nigeria. The core stalk, considered agricultural waste after harvesting, was collected and milled to a particle size of 150 mm. The milled sample was oven-dried for 24 hours at 60 °C to regulate its moisture content. The dried corn stalk sample was then homogenized using a homogenizer. A 100 g portion of the homogenized CS was introduced into a 250 mL boiling flask, to which 100 mL of distilled water was added. Crude bio-oil extraction was carried out using a distillation process. The boiling flask was mounted on a heating mantle and heated to 200 °C (392 °F). As the mixture boiled, steam rose gradually, condensed in the condenser, and the volatile oil was collected in a conical flask. The crude corn stalk oil was then transferred into a separating funnel. To further purify the oil, 10 mL of n-hexane was added. The mixture was separated by distillation, during which the n-hexane was distilled off, leaving behind the extracted bio-oil in the conical flask.

2.2 Proximate and bio-oil characterization.

The crude bio-oil extracted from corn stalk was characterized through proximate and ultimate analyses. Key properties evaluated included moisture content, density, viscosity, acid value, iodine value, saponification value, refractive index, and flash point.

2.2.1 Moisture content was determined in accordance with ASTM D6751. A known quantity of the sample was weighed into a pre-weighed petri dish. The dish containing the sample was then placed in a hot-air oven and dried for 1 hour at a controlled temperature of 105 °C using the oven-dry method. After drying, the sample was immediately transferred to a desiccator to cool to room temperature before reweighing. The percentage moisture content was calculated using Equation 1..

$$\% \, a = -\frac{b}{v} \times (100) \quad (1)$$

2.2.2 Density Determination

The weight of an empty density bottle (50 mL capacity) was first recorded. Then, 50 mL of the corn stalk extract was poured into the bottle, and the combined weight was measured. The net weight of the extract was obtained by subtracting the weight of the empty bottle from the filled bottle. The density of the corn stalk bio-oil was then calculated as the ratio of the weight of the bio-oil to its known volume (50 mL), as expressed in Equation 2.

$$h = \frac{wt}{v} \quad (2)$$

2.2.3 Viscosity Determination

The viscosity of the crude extract was determined according to ASTM-IP 350 using a viscometer. A 5 mL sample of the crude extract was carefully introduced into the viscometer using a micropipette. The flow time of the sample from the upper meniscus to the lower meniscus was measured in seconds at a constant temperature of 40 °C. The viscosity was then calculated using Equation 3.

$$ct \ (mm^2s\text{-}1) \quad (3)$$

Hence, c is express as Viscosity constant given as 0.4891 and t is the time take of flow of extract of corn stalk from the upper to lower meniscus.

2.2.4 Acid Value Determination

The acid value of the crude extract was determined according to ASTM D6751. Approximately 0.5 g of the test sample was introduced into a conical flask,

followed by 20 mL of ethanol. Three drops of phenolphthalein indicator were added, and the solution was titrated with 0.5 g KOH solution under constant agitation until a pink endpoint appeared and persisted for 30 seconds. The volume of titrant used at the endpoint was recorded, and the acid value was calculated using Equation 4.

$$\text{Acid value} = \frac{(v)\text{KOH}(5.61)}{\text{wt}} \quad (4)$$

2.2. 5. Iodine Value Determination

The iodine value (IV), defined as the number of grams of iodine absorbed by 100 g of biodiesel, was determined in accordance with ASTM D5554. Approximately 0.5 g of the corn stalk sample was mixed with 5 mL of chloroform in a flask, followed by the addition of 25 mL of Wijs solution. The mixture was shaken vigorously, sealed tightly, and kept in the dark for 30 minutes. After the reaction period, 20 mL of 10% KI solution and 150 mL of deionized water were added. The mixture turned red, after which 5 mL of 5% starch solution was introduced as an indicator, causing the solution to turn blue-black. The mixture was then titrated with 0.1 N sodium thiosulfate until the solution became colorless, indicating the endpoint. The iodine value was calculated using Equation 5.

$$\text{IV} = \frac{(12.69)(v1-v2)\text{normality of titrant}}{\text{wt}} \quad (5)$$

2.2. 6Saponification Value Determination

The saponification value (SV) represents the amount of potassium hydroxide (KOH) required to completely hydrolyze 1 g of biodiesel. The procedure was carried out following the method described by Boerlage (1994) and adopted by Effiom (2023). Approximately 0.5 g of the test sample was weighed into a conical flask, and 50 mL of 0.5 N ethanolic KOH solution was added. The mixture was refluxed to ensure complete saponification of the sample. After refluxing, the unreacted KOH was titrated with 0.5 N hydrochloric acid (HCl) using three drops of phenolphthalein indicator.The saponification value was calculated using Equation 6.

$$\text{Sv} = \frac{(\text{tv})(\text{HCl})(56.1)}{(\text{wt})} \quad (6)$$

2.2.7 Refractive Index (RI) Determination

The refractive index (RI) is defined as the ratio of the speed of light in a vacuum to its speed in the biodiesel sample. The RI was measured using a digital tabletop refractometer. The instrument was first calibrated to zero using distilled water. Subsequently, a small amount of the biodiesel sample was placed on the glass prism, and the refractive index value was recorded using the RI function on the device.

2.3 Transesterification and biodiesel characterization

Transesterification Reaction

The transesterification reaction was carried out to produce methyl esters (biodiesel). A 500 mL, three-neck, round-bottom glass reactor was used for the process. Approximately 0.5 g of $MgFe_2O_4$ nanocatalyst was introduced into 1000 mL of corn stalk extract. The reactor was placed on a heating mantle equipped with electromagnetic stirring, which activated the stir bar upon switching on.The mixture was gently heated to 60 °C, which is below the boiling point of methanol, to produce methoxide. The catalyst dissolved completely within 160 minutes. The resulting methoxide was then introduced into the flask containing the extracted oil and stirred thoroughly.The reaction mixture was subsequently transferred into a 1000 mL separating funnel and allowed to stand under gravity for 24 hours to facilitate phase separation. The pH of the biodiesel layer was measured, and the crude glycerol was removed through the separating funnel tap. The methyl ester (biodiesel) was then subjected to drying by heating at 105 °C, which is above the boiling point of water, to remove residual moisture. The biodiesel was finally cooled to room temperature and stored for further analysis

2.3.1 Biodiesel characterization

Characterization of Biodiesel

The biodiesel was characterized to evaluate its combustibility properties, including cetane index, flash point, fire point, specific gravity, cloud point, and anisidine value.

Cetane index and cetane number

Cetane Index and Number

The cetane index and number are numerical values that indicate the ignition quality of a fuel (Keera et al., 2018). A higher cetane index enhances the efficiency of fuel utilization in standard diesel engines. The cetane index was evaluated in accordance with ASTM

D4737, following the method adopted by Boerlage (1994), as expressed in Eq. 7.

$$CI = \frac{AP(C) \times API\ Gravity}{10} \quad (7)$$

Flash Point

The flash point of biodiesel is the temperature at which the vapor pressure of the liquid produces sufficient flammable vapor to ignite momentarily. It was determined according to ASTM D93 using an automated Pensky–Martens closed-cup apparatus. The biodiesel samples were gradually heated to 60 °C until the vapors ignited.

Gravity

Gravity of biodiesel was derived, based on the American Petroleum Institute (API). Thus gravity of bio was determined from the value of the specific gravity of the product and was obtained with Eq. 8

$$API = (141.5/\text{Specific gravity at } 60^0F) \quad (8)$$

Cloud point and pour point

The cloud point is the temperature at which the clarity of biodiesel changes due to the formation of wax crystals. A sample of biodiesel was poured into a medium-sized test tube, stored in a refrigerator, and monitored until cloudiness appeared. The procedure followed the method adopted by Aawar et al. (2010) and Ayetor et al. (2015).Similarly, the pour point is the lowest temperature at which the biodiesel solidifies and ceases to flow. It was determined using a mercury-in-glass thermometer.

Anisidine Value

The anisidine value is a measure of the amount of aldehydes present in biodiesel, indicating secondary oxidation products that affect fuel stability. The method described by Konethe (2010), as adopted by Effiom (2023), was used for this determination.

2.4 Impact of Process Parameters on Biodiesel Yield

The effect of key process parameters—nano-catalyst concentration (wt.%), reaction temperature (°C), reaction time (h), methanol-to-bio-oil molar ratio, and agitation speed (rpm)—was evaluated to determine their influence on biodiesel yield. Each parameter was varied within its study range while the others were kept constant to isolate its effect. The primary response measured was the volume of biodiesel produced.

2.4.1 Effect of Nano-Catalyst Concentration

The effect of nano-catalyst concentration on biodiesel yield was studied by varying the catalyst loading at 1, 2, 3, 4, 5, and 6 wt.%. The reaction temperature (60 °C), reaction time (180 minutes), methanol-to-bio-oil molar ratio (10:1), and agitation speed (400 rpm) were kept constant.

2.4.2 Effect of Temperature

The influence of temperature on biodiesel yield was investigated at heating intervals of 30, 40, 50, and 60 °C. All other parameters—methanol-to-bio-oil molar ratio (10:1), agitation speed (400 rpm), nano-catalyst concentration (optimal value from Section 2.4.1), and reaction time (optimal value from Section 2.4.3)—were maintained at their constant levels to ensure that only temperature effects were observed.

2.4.3 Effect of Reaction Time

Reaction time was varied at 40, 80, 120, and 160 minutes to study its impact on biodiesel yield. Other parameters were kept constant: temperature at 60 °C, methanol-to-bio-oil molar ratio at 10:1, agitation speed at 400 rpm, and the optimal nano-catalyst concentration identified in Section 2.4.1.

2.4.4 Effect of Methanol-to-Bio-Oil Molar Ratio

The methanol-to-bio-oil molar ratio was varied at 4:1, 6:1, 8:1, 10:1, and 12:1, following the methodology of Keera et al. (2018) and Effiom (2023). The agitation speed (400 rpm), nano-catalyst concentration (optimal value), reaction time (optimal value), and temperature (optimal value) were kept constant as determined in Sections 2.4.1–2.4.3 to observe the isolated effect of molar ratio.

III. RESULTS AND DISCUSSIONS

3.1 Results of Proximate Analyses of Corn Stalk Oil

The proximate analysis was carried out to characterize the feedstock parameters and assess the intrinsic properties of the bio-oil. Table 1 presents the proximate values of biodiesel derived from corn stalk oil. The acid value obtained from the analysis is a key indicator of oil quality, as it reflects the ease with which the feedstock can be utilized for bio-oil production. A higher acid value signifies an increased concentration of free fatty acids, which may necessitate pretreatment prior to transesterification. Moreover, prolonged exposure to elevated temperatures and light can accelerate oxidation, leading to an increase in the acid value (Sarkar et al., 2012; Effiom, 2023).Similarly, the peroxide value serves as an important measure of oxidative deterioration in bio-oil (Marchetti et al., 2007; Atowon & Ita, 2024). In this study, the peroxide value was found to be within the acceptable range of 1.0–5.0 meq O_2/kg, signifying good oxidative stability and minimal degradation (Onukwuli et al., 2016). Additionally, the moisture content of the biodiesel produced from corn stalk oil was below 8.0%, which falls within the recommended quality standards. This finding aligns with the results reported by Effiom (2023) and Atowon and Ita (2024), who employed $CoMgFe_2O_4$ nanocatalysts to achieve comparable reductions in moisture content.

Table:1 Bio-oil characterization

S/n	Parameters evaluated	Values
1	Moisture (%)	4.24
2	Density(g/ml)	0.927
3	Viscosity at 400C(mm^2s-1)	32.983
4	Ash content	11.8
5	Acid value (mgKOH/kg)	0.5049
6	Iodine value (mg/100g)	18.30
7	Refractive index at 29^0C	1.4554
8	Flash point (^{0}C)	247
9	Fire point (^{0}C)	257
10	Cloud point (^{0}C)	19.40
11	Oil yield (%)	18.7
12	Peroxide Value (meq/kg)	0.88
13	Saponification (mgKOH/kg)	220.10
14	Molecule weight(g/mol)	755.76

The saponification value determined in this study reflects the extent of triglyceride hydrolysis in the presence of ethanolic alkali. Together, the saponification value, acid value, and cloud point provide critical insights into the elemental composition, ester content, and molecular weight of the oil. The ester content is particularly important, as it indicates the potential of the triglycerides to be converted into methyl esters — a key step in biodiesel production. Furthermore, knowledge of the oil's molecular weight is essential for accurately determining the stoichiometric amount of methanol required for efficient transesterification.

3.2 Impact of process parameters on the biodiesel yield using nano-catalyst

3.2.1 Impact of Nano-Catalyst Concentration on Bio-Oil Yield

The nano-catalyst is a critical parameter in the transesterification process, as it significantly enhances the reaction rate. In this study, the concentration of $MgFe_2O_4$ nano-catalyst was varied at 1%, 2%, 3%, 4%, and 5% (w/w), while other process parameters, such as reaction temperature, methanol-to-oil molar ratio, and reaction time, were maintained constant. The maximum biodiesel yield achieved was 75.55% by volume, which was lower than the yield reported by Effiom (2023) but higher than that obtained by Atowon and Ita (2024) for Jatropha curcas using $CoMgFe_2O_4$ as a nano-catalyst. Biodiesel yield increased progressively as catalyst concentration rose from 1% to 4%, after which a slight decline was observed at 5%. Figure 1 displayed the nano-catalyst concentration on bio-oil yield. This reduction at higher concentrations suggests that excessive nano-catalyst loading can result in product adsorption and mass transfer limitations, ultimately hindering conversion

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efficiency (Keera et al., 2019; Effiom, 2023; Atowon & Ita, 2024).

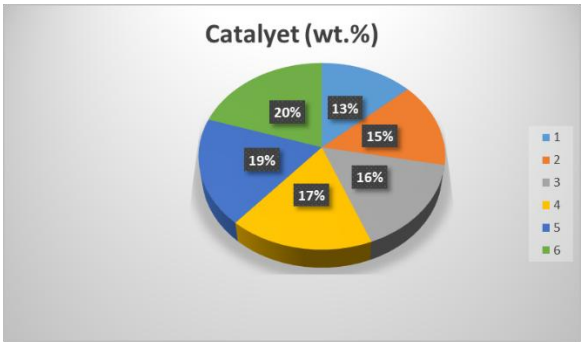

Figure 1. nano-catalyst and bio-oil yield

3.2.2 Impact of Temperature on Biodiesel Yield

In this study, the methanol-to-oil molar ratio (10:1), catalyst concentration (3 wt%), reaction time (150 minutes), and agitation speed (250 rpm) were kept constant, while the reaction temperature was varied between 35 °C and 70 °C. Biodiesel production commenced at 30 °C, but optimal biodiesel yield from corn stalk oil was achieved at 65 °C, with a maximum yield by volume recorded at this temperature. At 70 °C, a noticeable reduction in biodiesel yield was observed. This decline was attributed to the volatilization and partial evaporation of methanol at elevated temperatures, which disrupts the transesterification process. Additionally, excessive temperature promotes side reactions such as saponification, which consumes free fatty acids and reduces biodiesel yield. The results confirm that 65 °C is the temperature at which sufficient activation energy for transesterification is achieved, beyond which efficiency decreases (Ayetar et al., 2015; Yasar, 2019).

3.2.3 Impact of Reaction Time on Yield

Reaction time was systematically varied from 30 to 150 minutes, while catalyst concentration, reaction temperature, and methanol-to-oil molar ratio were held constant. Biodiesel yield exhibited a progressive increase with reaction time, attaining a maximum of 79.50% (v/v) at 150 minutes. Extending the reaction beyond this duration resulted in no statistically significant improvement in yield, indicating that the system had approached reaction equilibrium under the specified operating conditions.

3.2.4 Impact of Methanol-to-Oil Molar Ratio on Yield

The methanol-to-oil molar ratio plays a critical role in biodiesel production. Four different ratios (6:1, 8:1, 10:1, and 12:1) were evaluated under constant reaction conditions: temperature (65 °C), time (150 minutes), and catalyst concentration (3 wt%). The biodiesel yield increased with higher molar ratios, achieving a maximum yield of 78.54% by volume at 12:1. Although Ayetar et al. (2015) reported 6:1 as the optimal molar ratio for biodiesel production, the present study indicates that a higher methanol ratio is necessary for corn stalk oil to drive the reaction to completion. However, excessive methanol beyond the optimal level may complicate product separation and increase processing cost. Other proximate parameters such as moisture content, fatty acid profile, and nano-catalyst modification technique were also identified as potential factors affecting biodiesel yield. In some cases, the bio-oil exhibited poor miscibility with methanol, leading to phase separation where the denser oil layer settled at the bottom while methanol remained afloat, potentially reducing reaction efficiency.

3.4 Characterization of the biodiesel blends

The biodiesel produced from the corn stalk bio-oil was blends into five difference blends ($B_{10,}$ $B_{20.}$ $B3_{0,}$ B_{40} and B_{100}) and diesel (D_{100}); the blends evaluation, characterized proximate properties of the biodiesel derivative of corn stalk.

3.4.1 Density

Density is a critical parameter that influences fuel injection, atomization, and combustion efficiency in compression ignition engines. The density values obtained for the biodiesel and its blends ranged between 0.850 and 0.900 $kg \cdot m^{-3}$, aligning with EN 14214 specifications. The slightly higher density of biodiesel relative to petroleum diesel provides a marginal advantage by improving volumetric efficiency. Consequently, the time required for the fuel to travel from the injection pump to the injector is reduced, partially compensating for the lower calorific value of biodiesel (Effiom, 2023; Brondani et al., 2015).

3.4.2 Flash Point

The flash point represents the lowest temperature at which fuel vapors ignite momentarily in the presence of an ignition source, whereas the fire point denotes the minimum temperature required for continuous combustion under the same conditions. The flash point of the biodiesel and its blends in this study ranged from 96 °C to 141 °C, fully compliant with EN 14214 and ANP biodiesel specifications. The relatively higher flash point of biodiesel compared to fossil diesel indicates safer handling, storage, and transportation.

3.4.3 Kinematic Viscosity

Kinematic viscosity describes the resistance of a liquid to flow under the influence of gravity and directly affects fuel atomization during injection. In this study, kinematic viscosity values ranged from 5.31 $mm^2 \cdot s^{-1}$ to 7.83 $mm^2 \cdot s^{-1}$. According to ANP specifications, the recommended kinematic viscosity is approximately 6.00 $mm^2 \cdot s^{-1}$. The B30 and B40 blends, as well as neat biodiesel (B100), exceeded the upper limit, suggesting reduced atomization efficiency and potentially incomplete combustion. Conversely, D100 and B20 exhibited viscosities within the acceptable range, resulting in superior atomization and more efficient combustion. Reduced viscosity generally promotes improved atomization, which enhances combustion efficiency and lowers fuel consumption.

3.4.4 Cloud Point

Cloud point is the temperature at which wax crystals first appear, causing the fuel to become visibly cloudy and potentially impairing flow at low temperatures. The cloud point values recorded for the biodiesel and blends ranged between 4.13 °C and 6.50 °C. These results indicate that biodiesel exhibits reduced cold-flow properties compared to conventional diesel, which must be considered for applications in colder climates. Although cloud point primarily influences operability in low-temperature environments, its relationship with pour point and flash point is essential for evaluating overall fuel handling and storage performance.

3.4.5 Aniline Point

The aniline point is a key parameter used to assess the aromaticity of fuels. In this study, biodiesel exhibited a lower aniline point compared to petroleum diesel, indicating a relatively higher aromatic hydrocarbon content. Fuels with lower aniline points generally mix more readily with other aromatic-rich fuels, thereby improving blending compatibility. The aniline point of the biodiesel blends ranged between 45 °C and 52 °C, which is consistent with reported values for biodiesel from lignocellulosic feedstocks. The parameter is also indicative of the carbon-to-hydrogen ratio per unit volume of fuel, making it useful in predicting combustion characteristics and sooting tendencies.

3.4.6 Diesel Index

The diesel index is an empirical measure of the ignition quality of fuel and is typically used as an alternative to cetane number determination (Owolabi et al., 2013; Effiom, 2023). In this study, the biodiesel exhibited a slightly lower diesel index than petroleum diesel, suggesting comparatively delayed ignition under identical conditions. Blends with lower biodiesel proportions demonstrated higher ignition quality, with diesel index values ranging from 31.82 to 41.16. These findings deviate slightly from those reported by Effiom (2023), which may be attributed to differences in feedstock composition, catalyst efficiency, or process optimization.

3.4.7 Cetane Number

Cetane number is a critical parameter used to evaluate the suitability of fuel for combustion in compression-ignition (CI) engines. A higher cetane number is generally associated with shorter ignition delays and more efficient combustion. In this study, pure biodiesel (B100) exhibited a lower cetane number compared to petroleum diesel (D100), resulting in slightly longer ignition delays. Furthermore, the cetane number of the fuel blends decreased progressively with increasing biodiesel content, consistent with previously reported trends for biomass-derived biodiesel.

3.4.8 Gross Calorific Value

Gross calorific value (GCV), also referred to as the higher heating value (HHV), represents the total amount of heat released when a unit quantity of fuel is completely combusted under standard conditions (Owolabi et al., 2011; Effiom, 2023). In this study, biodiesel (B100) exhibited a GCV of 8032.63 $kcal \cdot kg^{-1}$, which was higher than that of petroleum diesel (D100) at 7373.62 $kcal \cdot kg^{-1}$. The observed variation in GCV is consistent with literature reports (Yasar, 2019), confirming that biodiesel derived from corn stalk oil possesses favorable energy density characteristics that make it a promising renewable substitute for conventional diesel.

CONCLUSION

This study successfully investigated the production of biodiesel from corn stalk oil via transesterification using $MgFe_2O_4$ as a nano-catalyst. Key process parameters—including catalyst concentration, methanol-to-oil molar ratio, reaction time, and temperature—were systematically evaluated to determine their influence on biodiesel yield. The results demonstrated that these parameters exert a significant effect on the overall transesterification efficiency, with optimum conditions yielding a maximum biodiesel conversion of 79.50% (v/v).

Comprehensive fuel characterization was performed in accordance with EN 14214, ASTM D6751, and ANP specifications. Critical properties—including density, flash point, fire point, aniline point, cloud and pour point, kinematic viscosity, cetane number, diesel index, and gross calorific value—were analyzed for pure biodiesel (B100) and its blends (B10, B20, B30, and B40) relative to petroleum diesel (D100). The findings indicate that B100 exhibited fuel properties comparable to standard diesel, with slight deviations in viscosity and cold-flow characteristics. Blends containing lower biodiesel fractions (B10 and B20) were more closely aligned with the reference fuel, demonstrating superior ignition quality and combustion performance. The results further confirmed that biodiesel derived from corn stalk oil has potential as a sustainable alternative to fossil diesel. Its use could significantly reduce emissions of harmful pollutants such as SO_2, CO_2, and NO_x, contributing to improved air quality and environmental protection. Therefore, corn stalk biodiesel presents a viable pathway toward cleaner energy production, enhanced energy security, and reduced dependence on non-renewable petroleum resources.

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