

ORIGINAL RESEARCH ARTICLE

Utilization of Chicken Waste as a Low-Cost Feedstock for Biodiesel Production: Optimization Strategies and Feasibility Analysis

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ABSTRACT

This study sought the best conditions for producing Biodiesel from chicken waste, an inexpensive feedstock. 5.20 mg KOH / g-oil was the acid value of the chicken waste. For improved biodiesel yield during the transesterification process, sulfuric acid pretreatment was required since acid concentrations above 1.0 mg KOH/g resulted in higher catalyst utilization during the biodiesel manufacturing process. Extracted oil underwent characterization to assess its suitability for transesterification. The optimized transesterification process employed a 6:1 methanol-to-oil ratio, 1% KOH catalyst, and a reaction temperature of 60°C for 2 hours. The resulting Biodiesel achieved an impressive 85% yield and exhibited properties consistent with ASTM standards, including acid value (0.15 mg KOH/g), saponification value (153 mg KOH/g), kinematic viscosity (4.32 mm²/s), specific gravity (0.886), flash point (168°C), and cetane number (62.6). According to the findings, the chicken waste characteristics met the specifications for oil required to produce Biodiesel. The study concluded that chicken waste could be utilized as an economically benign feedstock for the production of Biodiesel, as well as the resultant catalyst could potentially be employed in industries as bio-base.

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INTRODUCTION

Energy consumption is predicted to rise dramatically over the next few years owing to industrialization and population growth (Ejelonu and Emegha, 2022; Emegha et al., 2022). In order to enhance energy competitiveness and diversify the energy portfolio, there is a need to explore clean, sustainable, and cost-effective energy sources, particularly in developing countries (Abeshi et al., 2023). Petroleum has been consistently expensive in recent years (Ejelonu and Emegha, 2022). An alternative fuel supply as a replacement for gasoline is required to diversify the energy mix and reduce excessive cost expenditures (Emegha, 2024). For the current global energy demand, biofuels constitute a significant option. Various organic materials, including starch, oil seeds, cellulose, animal fats, Biodiesel, bioethanol, and biogas, have been produced (Kumar and Jain, 2018). The resource used in first-generation biofuels has some drawbacks compared to food applications (Montagene et al., 2013). Investigations on exploiting inedible raw materials for manufacturing Biodiesel have been driven by the problem of employing organic resources as food or raw material for biofuel production (Montagene et al.,

2013). In addition to being a renewable and biodegradable fuel, Biodiesel also contains more oxygen than petroleum-based diesel. Additionally, using Biodiesel significantly reduces emissions of CO₂, CO, polyaromatics, sulfur, hydrocarbons, smoke, and noise to the ecosystem (Kumar and Jain, 2018).

Waste oils, animal fats, and vegetable oils are the most often utilized raw materials in biodiesel production (Aworanti et al., 2019; Udeh, 2017). Palm oil (Chinglenthoinba et al., 2020), soybean oil (Kim et al., 2010), cottonseed oil (Joshi et al., 2012), and sunflower oil (Ahmad et al., 2010) are among the most often utilized clean vegetable oils as feedstocks for biodiesel synthesis. However, employing edible vegetable oil sources increases production costs while directly competing with the human food supply. To progress the biodiesel industry, it is critical to create economical, abundant, and high-quality feedstock from waste byproducts (Kumar and Jain, 2018; Bianchi et al., 2010).

Utilizing less valuable non-edible organic material or extremely acidic waste materials has been gaining prominence as a solution to this issue (Hasan and Venkata

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Ratnam, 2022). Future biofuel production will have the greatest potential with various wastes, byproducts, and species that do not directly help humans economically (Zhang and Zhang, 2012). Great potential exists for making Biodiesel from non-edible oils. It has been investigated whether chicken waste could be used as a feedstock for biodiesel manufacturing. According to Ciobanu et al. (2019), chicken fat comprises 63.9% - 73.5% unsaturated fatty acids, most of which are palmitic, stearic, linoleic, and oleic. It also includes 26.5% to 30.3% saturated fat (Gugule et al., 2011). However, numerous studies have explored methods for reducing the high production costs and improving the quantity and quality of biodiesel fuel derived from non-edible organic material using a homogeneous catalyst (Purandaradas et al., 2018).

Nevertheless, there has been limited focus on identifying the potential optimal levels of process variables for the economic optimization of chicken waste. This study aims to explore the use of chicken waste as a cost-effective feedstock for biodiesel production. It evaluates the catalyst loading, methanol to oil ratio, and reaction time on biodiesel yield, along with comparing the produced Biodiesel with ASTM standards.

MATERIALS AND METHODS

The experimental equipment utilized in this study comprises a water bath, gloves, a separating funnel, a digital weight balance, a hot plate with a magnetic stirrer, various sizes of conical and Erlenmeyer flasks, beakers, rotary evaporator, an analytical balance, thermometer, and pipettes.

Reagents

Reagents used in this study include chicken waste (fat), methanol, potassium hydroxide, water, and phenolphthalein. All reagents used are of analytical grades.

Collection of chicken Waste and Extraction of fat/ oil

Fresh chicken waste was collected from Ughelli, Delta State, Nigeria slaughterhouses. The waste contains chicken skin, fat, and a few other tissues. They were thoroughly cleansed and gathered in a container before being transferred to the laboratory. The wastes were melted above 100 °C and filtered to eliminate suspended particles. This procedure liberated the liquid fat and separated it from the fat waste. The extracted oil (30 g) was weighed using an electronic balance and stored in a clean container.

Before using a feedstock to manufacture Biodiesel, the oil must be characterized to establish its quality. For example, high acid and free fatty acids (FFA) reduce biodiesel output. The characterization data helps establish if the oil

must be further pretreated in the laboratory. Thus, characterizations were performed for the following parameters: (i) acid value (ASTM D664) and (ii) saponification value (ASTM D5558).

Transesterification

7.0 g of methanol and 0.4 g of dissolved potassium hydroxide were mixed to make methoxide. This mixture was repeatedly stirred until the potassium hydroxide had been dissolved. Following that, 30 grams of heated chicken oil were weighed. The chicken waste (oil) was then added to the methoxide solution and gently agitated for three hours at 600 °C and 300 rpm. After the reaction time, the mixture was allowed to sit in the separating funnel for an hour to separate the Biodiesel from the glycerol (Figure 1). Two distinct layers were formed; the upper layer was the Biodiesel (methyl ester), and the lower layer was a mixture of methanol, glycerol (byproduct), catalyst, and impurities. The lower layer was drained into a waste container. Following that, the Biodiesel was collected and further purified. The Biodiesel was initially treated with 75 mL of a diluted solution of HCl (0.2%) before being repeatedly rinsed with the same volume of distilled water to ensure that all salts, acids, and bases were fully eliminated.

After washing, the Biodiesel was heated to 90 °C to remove any remaining water (Figure 2). The produced Biodiesel underwent additional testing to see whether it met the American Society of Testing and Materials (ASTM) criteria for fuel-like characteristics. Therefore, the transesterification process yielded 85% biodiesel.

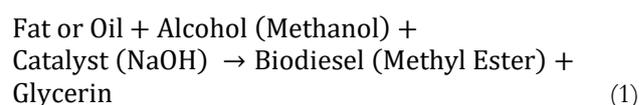


Figure 1: The Produced Biodiesel after Transesterification process undergoing separation

RESULT AND DISCUSSION



Figure 2: The Produced Biodiesel after the washing process

Characterization of Biodiesel Produced from Chicken Waste

Viscosity

The Biodiesel's viscosity was tested using a viscometer according to ASTM D445. The sample was left in a thermostat-heated water bath until it reached the equilibrium temperature of 40 °C. The viscometer tip was placed in the sample after preserving the equilibrium temperature, and the controller reading was obtained. Kinematic viscosity was computed after the dynamic viscosity was measured.

Specific Gravity

Specific Gravity (ASTM D7042): The specific gravity of the Biodiesel was determined using a pycnometer according to ASTM D7042. A pre-weighed pycnometer was filled with 1mL of sample and weighed again. The specific gravity was calculated by dividing the sample's mass by the pycnometer's volume.

Flash point

An apparatus known as the Pensky Martin was employed to establish the flash point according to the ASTM D93 standard. 30 ml of the substance was gathered in the equipment's cup and then chilled with a water bath while continuously stirred. At each decrease of 1°C, the sample vapor was brought into contact with a flame. The flash point represents the temperature at which ignition occurs momentarily.

Cetane number

The cetane rating of the Biodiesel produced was assessed in accordance with the ASTM D613 standard procedure. A mixture of the sample and a known cetane-rated fuel was ignited in an engine, and the ignition delay duration was recorded. The cetane number was then determined by comparing this delay to that of a reference fuel.

The results of the acid values and saponification numbers for chicken waste extraction are presented in Table 1. The table shows that the acid value was 5.20 mg KOH/g. The optimal acid value for generating Biodiesel is less than 1.0 mgKOH/g. Due to the fact that acid concentrations above 1.0 mgKOH/g result in increased catalyst usage during the biodiesel production process, pretreatment is necessary for better biodiesel yield during the transesterification process (Hasan and Venkata Ratnam, 2022). As a result, more catalysts will be needed, which will cost more. The extracted oil underwent additional processing to improve its suitability for biodiesel synthesis by lowering the acid value from 5.20 mg KOH/g to 0.12 mg KOH.

Furthermore, the saponification value of the poultry waste oil was recorded as 168.65 in Table 1. Extracting oil with a high saponification value increases fatty acid concentration, making it highly suitable for biodiesel production. When the oil has a high saponification value, this likely means that there are more triglycerides present, which can be transesterified into Biodiesel. Said, a higher saponification value indicates a higher biodiesel yield. However, the 168.65 mgKOH/g saponification value reported in this study is within the permitted range for biodiesel synthesis. Getahun and Gabiyye, 2013 have reported a similar value.

Table 1: Results for extracted Chicken oil from Chicken Waste

Parameter	Before Pretreatment	After Pretreatment
Acid Value (mg KOH/g oil)	5.2	0.12
Saponification Value (mg KOH/g oil)	168.65	153

Physicochemical properties of Chicken waste used for transesterification experiment

Flash point

The plot in Figure 3 shows the flash point of the Biodiesel produced from chicken waste. Flashpoints are crucial in evaluating fuel quality, representing the lowest temperature at which the fuel can ignite when exposed to an ignition source. The fuel's flash point impacts the safety measures that must be taken during transportation, storage, and handling. According to ASTM specifications, the flash point for acceptable fuels should range from 140 to 150 °C. As a result, the Biodiesel made from waste chicken fat in this study has a flash point (168 °C) that is exceedingly safe to handle and store, making chicken waste biodiesel a better option in terms of safety. The value obtained in this study is slightly lower than the values reported by Hasan and Venkata Ratnam, 2022 and

Olutoye et al. 2016. The difference may result from the nature of the catalyst and alcohol used in the synthetic process.

Kinematic Viscosity

Figure 4 illustrates the viscosity of the generated Biodiesel in relation to the ASTM standard. The study revealed that the viscosity of the produced Biodiesel (4.32) was compliant with the ASTM standards, which specify a range of 1.9 to 6.0. Similar values from chicken fat and other feedstocks have been reported in the literature (Aworanti et al., 2019; Purandaradas et al., 2018). However, the viscosity of oil is a crucial factor in determining an engine's performance. If the viscosity becomes too high, it can result in various problems for the engine, such as excessive deposits, clogged injectors, sticky piston rings, and difficulties when starting the engine (Hasan and Venkata Ratnam, 2022; Sun et al., 2014).

Additionally, high viscosity causes pollution and significantly contributes to a number of ailments caused by exposure to air. Conversely, low-viscosity diesel fuels typically have poor lubrication, which causes the injection pumps to wear out more quickly. The Biodiesel made from chicken fat in this investigation demonstrated a viscosity that fell within the ASTM-established limit.

Cetane Number

The cetane number, also known as the cetane rating, is a method for assessing the effectiveness of diesel fuel. A higher number indicates better combustion in a vehicle's engine. Like the octane rating for gasoline, it serves as an

indicator of fuel quality. Using the appropriate sources, it is important to note that a higher cetane number indicates better ignition quality in diesel fuel (Sokoto et al., 2011). The high cetane number of 62.6 (Figure 5) of the biodiesels produced from used chicken fat feedstocks is a crucial fuel characteristic for diesel engines. It impacts engine starting ability, emissions, combustion noise, and peak cylinder pressure. A high cetane value ensures long engine life, quiet combustion, and reliable cold starting. Animal fats include highly saturated fatty acids, which create a high cetane number and values above 60 (Getahun and Gabiyye, 2013). According to Sun et al. (2014), petroleum-based diesel fuel normally has a cetane number of 40 to 44, but Biodiesel derived from vegetable and animal oils typically has a cetane number of 48 to 52.

Density (Specific gravity)

The fatty acid composition significantly impacts the specific gravity of Biodiesel, causing it to be denser than water. With a Density or Specific gravity of 0.88 for the produced Biodiesel, which is within the ASTM standard specification of 0.86-0.90, Biodiesel made from chicken waste is of good quality and hence more advisable. A similar density value (0.8326) was also reported by Hasan and Venkata Ratnam (2022). For diesel fuel injection systems, specific gravity is a crucial characteristic. Another reason why it must have reasonable limits is to provide ideal air-to-fuel ratios for complicated combustion. In addition, the energy capacity of Biodiesel is augmented by its high density, leading to better fuel economy and greater engine performance in vehicles.

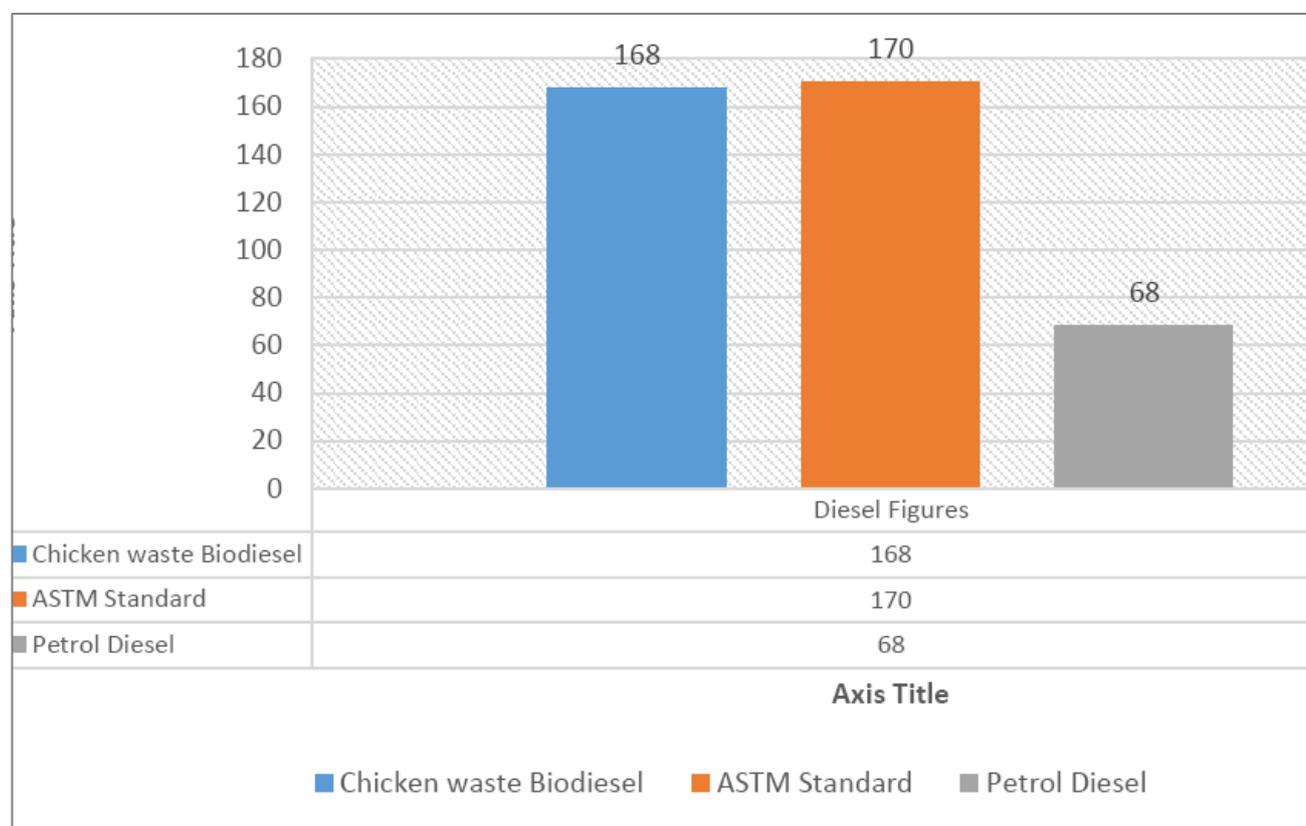


Figure 3: the difference between flash points of Chicken waste biodiesel compared to Petrol diesel and ASTM standard.

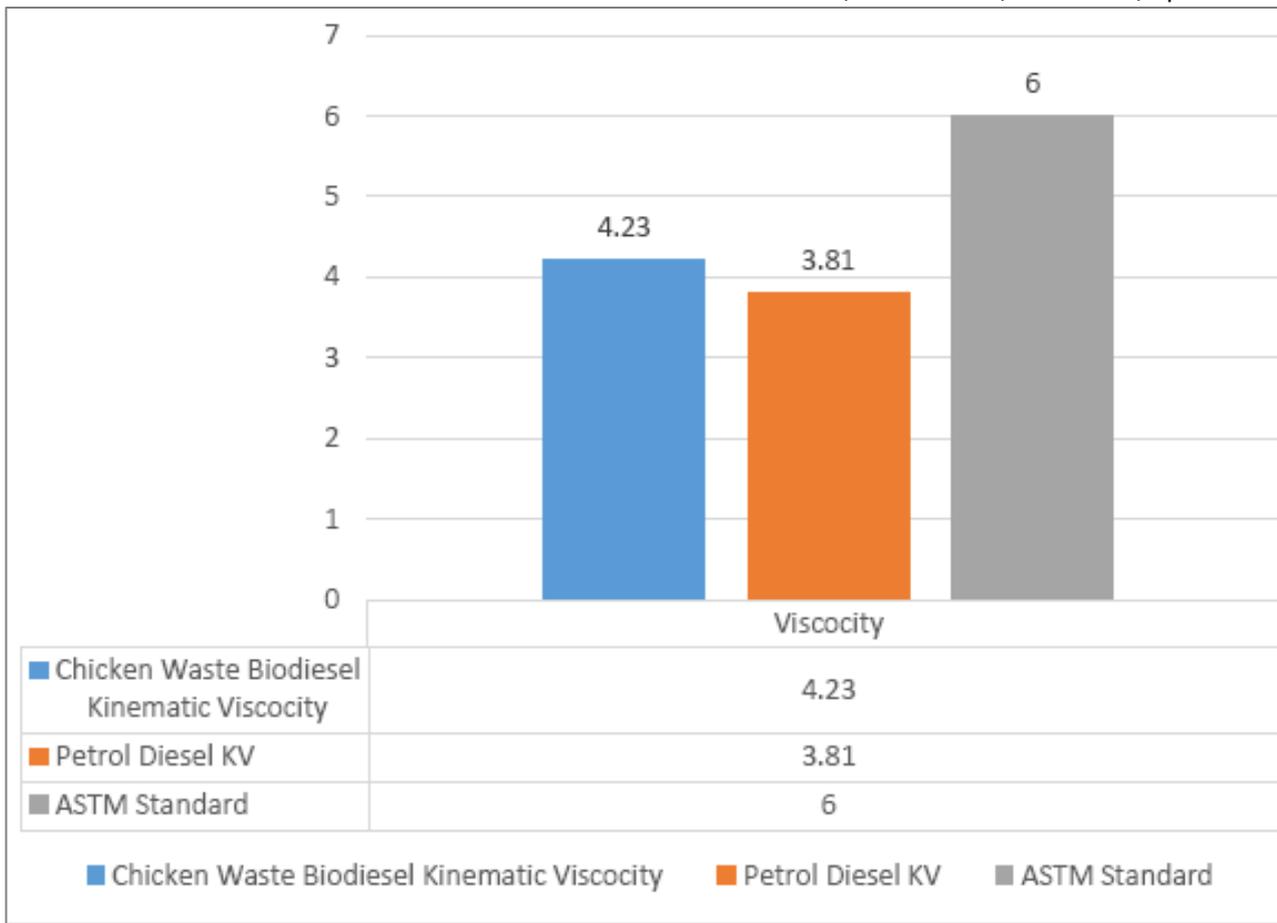


Figure 4: The Kinematic viscosity of the Produced Chicken waste biodiesel

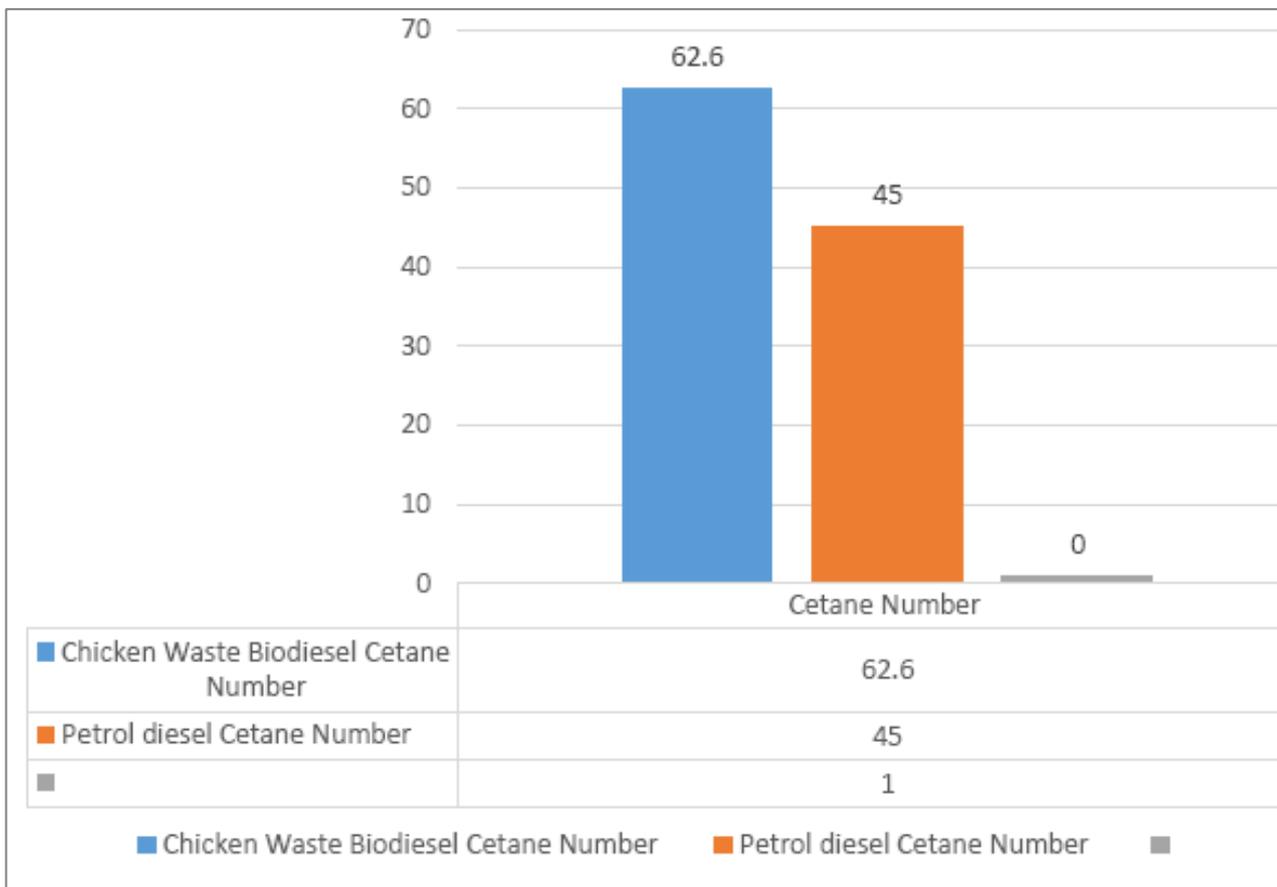


Figure 5: The cetane number of the Produced Chicken waste biodiesel

CONCLUSION

The use of potassium hydroxide on Sulfuric acid (KOH/H₂SO₄) as a catalyst for producing Biodiesel from chicken waste has been examined. The identified physical and chemical characteristics of chicken waste indicate it to be a promising substitute raw material for biodiesel production. The most favorable operating parameters included a 1:6 ratio of oil to methanol, a catalyst loading of 1.0%, a reaction temperature of 60 °C, and a reaction time of 2 hours, resulting in an 85.0% yield. The fuel properties of the produced methyl ester from chicken waste under these optimized conditions met the ASTM standard specifications. Furthermore, the catalyst exhibited excellent performance and could be conveniently separated from the product mixture. However, with a flash point value of 168, kinematic viscosity of 4.23, cetane number of 62.6, and density of 0.886. Therefore, Chicken waste shows potential as a valuable raw material for biodiesel production, and the use of (KOH/H₂SO₄) as a catalyst is promising for producing methyl esters through homogeneous catalytic transesterification under specific reaction conditions.

Future research should emphasize the need for a comprehensive techno-economic evaluation to determine the benefits of using chicken waste to produce Biodiesel on a larger operational level. This may include analyzing cost-effectiveness, energy efficiency, and environmental implications when scaling up the production process. Additionally, it could entail investigating innovative technologies that can enhance the conversion of chicken waste into Biodiesel. Furthermore, research might explore sustainable supply chain models and policy structures to encourage the widespread utilization of chicken waste as important source material for biodiesel production to promote a more sustainable and circular bioeconomy.

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