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Assessment of Biodiesel Production Potential and Capacity Analysis Utilizing Animal Fat Waste

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Abstract

New Anthony's Farm, a major chicken producer in Sri Lanka, generates significant wastewater during production. This study aims to find a solution for the sludge produced in their treatment plant. Animal fats, a common waste in various industries, require expensive treatment due to environmental regulations. They mainly consist of triglycerides (90-95%), which are further made up of fatty acids like saturated (SFAs), monounsaturated (MUFAs), and polyunsaturated (PUFAs). Animal fat waste offers valuable opportunities for industrial use, but its improper disposal poses significant environmental threats. Sustainable management and utilization of this waste are crucial to protect the environment and extract valuable resources. First, an FFA (Free Fatty Acids) test was done for the top and bottom animal waste fat samples taken from the fat separation Dissolved Air Floating unit in the wastewater treatment plant in 'Anthony's Farm. The NaOH base with the Phenolphthalein indicator titration method was used for this FFA identification. After that, acid treatment was performed to reduce the FFA value of these samples, 60 ^{0}C hot water washing was done to purify the animal waste fat sample, and biodiesel was produced by transesterification. Direct transesterification was not obtained for the bottom sample, so the resulting liquid layer was centrifuged at 3000 rpm for 15 minutes and trans-esterified. After that, both samples were used to produce bioethanol. There, the top sample was directly used for bioethanol production without pretreatment, and bioethanol was produced using the glycerol layer of the bottom sample. The acid treatment was done with an H_2SO_4 Acid-to-fat ratio of 12:1, Temperature around 64°C, and pH - around 7, and it was reduced the FFA value of the top sample from 20.72% to 12.60%, and the initial FFA value of the bottom sample, which was 3.36%, was reduced to 2.80%. Considering this FFA value, the bottom sample seems to have more potential for biodiesel production. Also, the flash point of the biodiesel produced in this way was measured using the Flashpoint analyser, and it was found to be 55.5 ^{0}C.

Keywords: Animal Fat; Biodiesel; Bioethanol; FFA; Wastewater

1. Introduction

New Anthony's Farm is one of the leading chicken producers in the Sri Lankan market. During production, a significant quantity of waste is produced. The intention of this study is to apply a remedy for the sludge generated in the wastewater treatment plant. Here, the wastewater is first sent through a drum to remove heavy particles, and then the water is sent to the Dissolved Air Floating (DAF). High-pressure air is supplied from the bottom of the DAF. Because of this, the fat in the wastewater collects on top of the container. It is called top sludge. Then this water moves to the aerator tank. The sludge deposited at the bottom is called bottom sludge. At New Anthony's Farm, an average of 6,000 litres of bottom sludge is generated per day. According to the report, an average of 150,000 litres of top sludge is generated per month. The bottom sludge is piled up in coconut plantations until the water is removed, and after the water is removed, the remaining solid is applied to the plants as compost. The top sludge is given to the government for disposal. For this, an amount of 50,000 Sri Lankan rupees per bowser should be given to the government by the company. Also, waste has a great impact on the environment, and this research study presents a solution to these problems.

Animal fats are among the most pertinent wastes that need expensive treatment due to strict environmental requirements. They are commonly found as waste in slaughterhouses, the chicken meat processing industry, and cooking facilities. Animal fats are generally formed of a mixture of triglycerides, proteins, water, and diverse minerals [1]. Triglycerides: about 90–95% of waste animal fat is made up of triglycerides, which constitute the primary constituent. Triglycerides are made up of three fatty acids and a glycerol molecule. The predominant fatty acid composition of waste animal fat is composed of saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs), and polyunsaturated fatty acids (PUFAs). One of the characteristics of SFAs is the absence of double bonds in their carbon chain. At room temperature, they are usually solid and considered less healthful than unsaturated fats. Animal fat waste contains two SFAs: stearic and palmitic acids. MUFAs, or monounsaturated fatty acids, have a single double bond in their carbon chain. They are thought to be healthier than SFAs and are normally liquid at room temperature. Oleic acid is one type of MUFA that can be found in waste animal fat. In their carbon chain, PUFAs have two or more double bonds. They are thought to be the healthiest form of fat, and they are normally liquid at room temperature. Linoleic and linolenic acids are two PUFAs that can be discovered in waste animal fat. Minor Components: Apart from triglycerides, animal waste also includes trace amounts of the following: Phospholipids: Sterols, Free Fatty Acids (FFAs): Fatty acids that are unbound from glycerol are known as FFAs. They are produced when triglycerides break down and can affect the quality of residual animal fat. Water and Minerals: Animal excrement can include traces of salt, calcium, and phosphorus.[2]

Animal fat waste is considered a byproduct, yet it has several uses in the industry, including biodiesel production, animal feed, and soap manufacturing [1]. Animal fat wastes are not directly ingested by humans and are disposed of in the open environment, causing a number of health and environmental issues. To solve these concerns, it is preferable to valorize such wastes in order to extract various valuable goods. The main components of animal fat wastes are triglycerides and free fatty acids, according to a number of reports in the literature. Thus, AFWs such as tallow, lard, and chicken fats are seen to be more practical choices when it comes to producing biodiesel [3]. Due to the large proportion of free fatty acids in animal fat wastes, the biodiesel made from them has a variety of benefits, including fewer emissions and a higher cetane number[3]. Animal fat waste can increase the production efficiency of that environmentally friendly and sustainable good [4].

The waste animal fat generated in Hannwella new anthony’s farm has caused great damage to the environment as well. That is, Anthony’s farm generates an average of 6,000 liters of bottom sludge per day and average of 150,000 liters of top sludge per month. The bottom sludge is piled up in coconut plantation after removing the water, and the top sludge is given to government for disposal. Henceforth, this generated sludge has many adverse effects, and providing an environmentally friendly solution is critically imported. The objective of this research study is to identify the possibility of converting this waste animal fat to valuable fuel product of biodiesel. The FFA values were measured and different pretreatment conditions were studied to gain optimum FFA level for the waste animal fat sludge samples to create suitable condition for biodiesel production.

2. Material and Methodology

2.1 Sample Collection

The animal fats were collected from New chicken meat processing farm. After passing through the rotary screen, wastewater produced from various slaughtering processes and plant washing steps enters the dissolved-air flotation system (DAF). In this stage, solids and oil-grease content are removed from the wastewater. High pressure air is supplied from the bottom of DAF. Because of this, the fat in the wastewater collects on top of the container. It is called top sludge. Then this water moves to the aerator tank. The sludge deposited at the bottom is called bottom sludge. They are used for the production of biodiesel and bioethanol.

2.2 Check FFA amount of WAF

Triglycerides—the primary ingredient in animal fat—are the source of free fatty acids (FFA). An essential metric for assessing the stability and quality of animal fat is its FFA concentration. The fat is more vulnerable to oxidation and rancidity when the FFA level is higher. Several ingredients are mainly used in FFA determination. That is, 0.1M sodium hydroxide (NaOH) solution, Phenolphthalein indicator, 95% ethanol. The 0.1 M NaOH solution acts as a strong base. The acidity of the FFAs is neutralized by the reaction between the NaOH and FFAs in the fat waste solution. Depending on the sample's FFA concentration, this procedure uses a certain quantity of NaOH. In acidic liquids, phenolphthalein is a colourless indicator. As the 0.1 M NaOH solution is added drop by drop to the fat waste solution containing FFAs throughout the titration, the acidic FFAs are gradually neutralized by the NaOH. A little pink tint develops when the solution gets closer to the pH range where phenolphthalein changes color and becomes less acidic. The precise moment at which all of the FFAs have reacted with the NaOH may be clearly identified due to the presence of Phenolphthalein, which ensures precise measurement of the NaOH solution volume employed. We can calculate the FFA content of the animal fat waste using this volume, the known molarity of the NaOH solution, and other factors. Phenolphthalein is an essential component of the FFA test as an indicator because it allows for precise quantification of free fatty acids in animal fat waste as well as the provision of a distinct visual signal at the neutralization endpoint. Samples of animal fat are frequently intractable in solutions containing water. With its potent solvent properties, 95% ethanol is able to dissolve fat and all of its constituents, including free fatty acids (FFAs), from the solid waste sample. This facilitates the transfer and manipulation of the analytes more easily during the testing procedure. Ethanol is mixed with the recovered FFAs and other fat components to create a homogeneous solution. This is necessary to provide an accurate titration because it prevents the analytes from sticking to the glassware and ensures that they are spread equally. This might affects the measured quantity of the NaOH solution used for neutralization.

2.2.1 0.1M NaOH solution preparation

0.4 grams of NaOH pellets were meticulously weighed on an analytical balance. The pellets were dissolved in distilled water in a sterile 100 ml beaker. The solution was carefully stirred with a magnetic stirrer to ensure uniform mixing.

2.2.2 Titration

The sample was titrated using a 0.1M NaOH solution until a steady pink coloring was obtained. Subsequently, the amount of NaOH consumed was calculated.

2.2.3 Calculation of FFA % of waste animal fat

Amount of moles in 5g of sample = (amount of substance)/(volume of one liter) x Consumption value

FFA mass = Amount of moles in 5g of sample X Molarity of Fatty Acid

FFA% = (FFA Mass)/(Sample Weight) X 100%

2.2.4 Pretreatment of WAF - Acid treatment of WAF (Esterification)

The sample was evaporated on a hotplate inside a fume hood to remove moisture.

The next step was an acid treatment with a 12:1 acid-to-fat ratio utilizing a 3.36% FFA solution.

Methanol and H2SO4 requirements were computed.

A combination of methanol and the H2SO4 catalyst was prepared in a different container. Due to the high FFA level, the molar ratio of alcohol to fat was much larger than the stoichiometric ratio for transesterification. (12:1) to ensure complete mixing; the melted waste animal fat was combined with the methanol-catalyst combination gradually and stirred. While stirring gently, the mixture was heated. Esterification is the process that changed FFAs into esters. The temperature was kept below 64°C, which is the boiling point of methanol. A pH meter was used to periodically check the mixture's pH. Stirring and heating were continued until the pH stabilized at a value close to neutral (about 7), signifying the FFAs' conversion to esters. The mixture was given time to settle and cool. Two different layers were formed as the esters separated from the glycerol, acid, and other contaminants.

The lower layer, containing the glycerol and impurities, was carefully removed, leaving the upper layer with the esterified animal fat. Finally, the remaining upper layer was washed with hot water.

2.3 Transesterification of WAF

The transesterification requires mainly alcohol and a catalyst. It is possible to utilize ethanol or methanol. One possible catalyst is KOH or NaOH. In this study, KOH was employed as a transesterification catalyst and methanol as the alcohol supply. Despite being widely accessible and efficient, methanol must be handled carefully due to its flammability and toxicity. KOH is a strong base. It is also a powerful catalyst that increases biodiesel yield.

Following the esterification process, the remaining weight of the esterified animal fat was measured. The amount of fat moles was then calculated based on the measured weight.

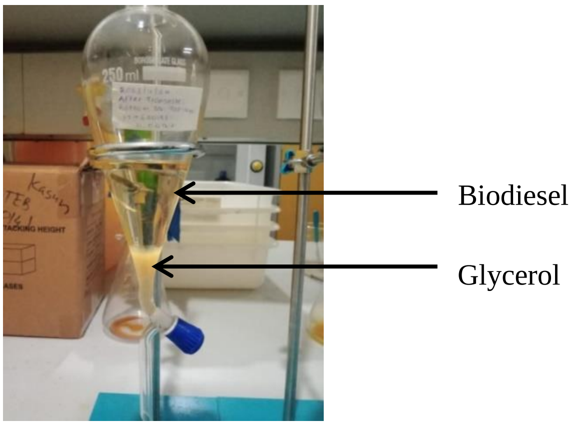

Figure 8. Trans-esterified WAF

The necessary amount of methanol was calculated by multiplying the mole count by the molarity of methanol, taking into account the fat mole count and the alcohol-to-fat ratio of 6:1. To calculate the necessary amount of KOH catalyst, one present by weight of the leftover animal fat was used. The weighed methanol sample was thoroughly mixed with the KOH catalyst using a magnetic stirrer. While the weighed animal fat sample was continuously stirred, the mixed methanol-catalyst mixture was slowly added. The contents were allowed to settle, and the two distinct layers - the top layer of biodiesel and the bottom layer of glycerol - were separated. After removing the glycerol, the methyl ester was washed twice with a 1:1 volume of water for one hour to remove any excess methanol.

3. Result and Discussion

The waste animal fat generated in Hannwella new Anthony's farm has caused great damage to the environment as well. That is, Anthony's farm generates an average of 6,000 liters of bottom sludge per day and average of 150,000 litters of top sludge per month. The bottom sludge is piled up in coconut plantation after removing the water, and the top sludge is given to government for disposal. But since this generated sludge has many adverse effects, an environmentally friendly solution was studied was studied for the production of biodiesel and bioethanol.

In order to produce biodiesel, the FFA value of the sample used should be less than 2 – 2.5. The reason is, the fat is more vulnerable to oxidation and rancidity when the FFA level is higher.

The two waste animal fat (WAF) samples obtained from chicken meat processing Farm were separately tested for FFA. Here, the FFA value of the top sample was calculated as 20.72%. This value is a big obstacle for biodiesel production and therefore an acid treatment was done to reduce the value. After acid treatment, it was possible to reduce the FFA value of the top sample to 12.6%. In this way, an FFA test was also conducted for the bottom sample. Its initial FFA value was 3.36% and after acid treatment it was reduced to 2.8%.

According to these values, it was possible to identify the bottom sample as the most appropriate sample for biodiesel production.

Table 5. FFA amount of both samples

Sample	Initial FFA	FFA of After Acid Treatment
Top Sample	20.72%	12.6%
Bottom Sample	3.36%	2.8 %

The yield of biodiesel produced from these top and bottom samples are shown in the table below. Accordingly, it seems that bottom sample has more potential for biodiesel production.

Table 6. Produced biodiesel volume

Sample	Sample volume	Biodiesel volume	Biodiesel Yield
Top	200 ml	55.35 ml	27.68 %
Bottom	45 ml	13.26 ml	29.47 %

200ml of top sample was taken and transesterified after acid treatment. Accordingly, the amount of biodiesel produced was 27.68% as a percentage. A yield of 29.47% was obtained by transesterification for the liquid layer obtained after taking 45ml from the bottom sample and centrifuging it. Accordingly, considering the yield, it was possible to identify the bottom sample as the most suitable sample for biodiesel production.

The kinematic viscosity of the 55.35 ml biodiesel sample obtained two days after transesterification of the acid treated top sample. The kinematic viscosity was 0.99mm^2/s and the density were 1.02 g/cm^3 at a temperature of 40^{0}C. The conductivity value of this biodiesel sample was 12.26.

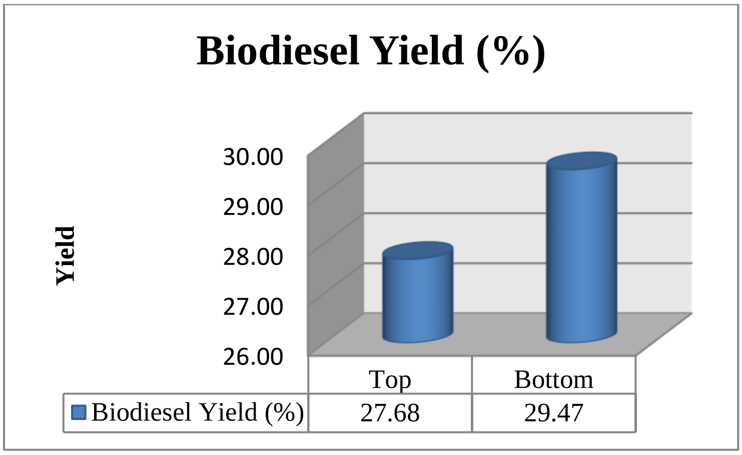

Figure 9. Biodiesel Yield

Although acid treated, biodiesel was not produced by the bottom sample. The reason for this was assumed to be the high number of impurities contained in it. After that, 45ml of the bottom sample was centrifuged. Thus, two solid and liquid layers were obtained separately and biodiesel was produced by the liquid layer. The kinematic viscosity of this biodiesel sample was 1.02mm^2/s and density were 0.97 g/cm^3 at 40^{0}C.

The flash point of the produced biodiesel sample was 55.5 ^{0}C. It took 8 minutes and 56 seconds to get these readings.

Table 7. Properties of biodiesel

Sample	Kinematic Viscosity (mm^2/s)	Density (g/cm^3)	Temperature (^{0}C)	Conductivity	pH	Flash Point (^{0}C)
Bottom Sample (Centrifuged)	1.0162	0.9725	40			55.5
Top Sample	0.9927	1.0192	40	12.26	7.39	

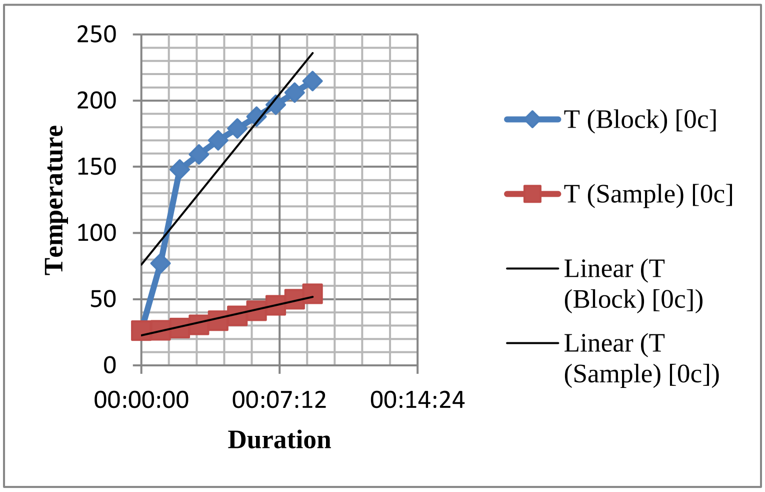

Figure 10. Flash point of biodiesel

Bioethanol was produced using this top and bottom samples. Urea and yeast were used there. Urea was used because it is a nutrient rich in nitrogen It affects the growth and multiplication of yeast. In the production of ethanol, ethanol was produced by adding urea and yeast in different ratios. Accordingly, the following graphs are described using numbers according to the ratio of urea and yeast added for ease of study.

The percentage of ethanol in sample number 3 and 4 was almost the same and the kinematic viscosity and density values were also the same. Here sample numbers 01, 02 and 03 are pure top sample and sample 04 is the bottom layer after trans-esterification of the bottom sample. That is, the glycerol layer.

4. Conclusions

Significant wastewater was produced during production at New Anthony's Farm, a prominent chicken breeder in Sri Lanka. This study aims to resolve the sludge generated in their treatment facility. Environmental rules necessitate the costly treatment of animal fats, a byproduct commonly found in numerous businesses. The FFA-rich waste animal fat was treated with a methanol-sulfuric acid mixture at a molar ratio of 12:1. The reaction temperature was maintained below 64°C to prevent methanol evaporation, and pH level kept near 7. The top sample's FFA value decreased from 20.72% to 12.60% by acid treatment, while the bottom sample's initial FFA value of 3.36% was lowered to 2.80%. This FFA value suggests that the bottom sample may have more biodiesel production potential. Furthermore, it was discovered that the biodiesel made in this manner has a flash point of 55.5 ^{0}C.

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