



Biodiesel Production from Human Faeces via Soxhlet Extraction with Hexane and Transesterification Reaction

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Authors' contributions

This work was carried out in collaboration between both authors. Author WI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author DO managed the analyses of the study and literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Oil/lipid was extracted from a primary sewage sludge by soxhlet extraction using n-hexane as the solvent. The extracted oil was then converted to biodiesel using transesterification process. The physicochemical properties of the oil/lipids and biodiesel were then determined and compared with literature for lipids and biodiesel parameters, whether they are consistent.

A percentage yield of 18.27 % was obtained for lipids extraction from primary sewage sludge, while for biodiesel production from the extracted lipids, a 66.7% was obtained.

Physicochemical parameters of both lipids and biodiesel obtained, gave values consistent with ASTM standardize, thereby suggesting that primary sludge of human excreta is a veritable/good source for the production of biodiesel, as an alternative source of fuel/energy.

Keywords: *Lipid; biodiesel; primary sewage sludge; base-catalyzed transesterification process; characterization.*

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1. INTRODUCTION

Fossil fuel is account for a major source of global energy consumption. However, the use of fossil fuel as a source of energy has its limitation. One of such limitations is its depletion overtime. Therefore, the need to explore alternative sources of new and renewable energy such as hydro, biomass (better sources of energy), wind, solar, geothermal, hydrogen and nuclear is of vital importance. Alternative renewable fuels have the potential to solve many of the current social problems and concerns, ranging from air pollution, global warming to other environmental improvements and sustainability issues [1]. To deploy other sources of fuels for a sustainable development in the economy of Nigeria and beyond, important factors such as its production process, feasibility, economic viability, environmental friendliness, level of availability should be put in place [2].

First generation biodiesel has been produced by using virgin vegetable oils as feedstock, including soybean oil in the USA, rapeseed in Argentina, sunflower oil in Europe, palm oil in south-east Asia (particularly in Malaysia and Indonesia) and coconut oil in the Philippines [3]. However, the use of vegetable oils for first and second generation biodiesel is still of great concern as their use may limit the availability of farmland and vegetable oil inventories, resulting in a high sensitivity of prices, and at the same time, contributing to a fuel versus food controversy that requires a deep technical-economic-political analysis of non-food feedstock availability for biodiesel production. In this regard, waste lipids and waste materials containing high amounts of lipids may be of interest as feedstock for biodiesel production [3]. The available volume of waste lipids seems to be limited, implying that the use of this type of feedstock is incapable of supporting increased commercial production of biodiesel fuels. This therefore necessitates exploring alternative feedstock for biodiesel production, that are more readily available in large quantities and at low cost [3].

Municipal sewage sludge has the potential to provide sufficient and high energy feedstock for biodiesel production in the future. Sewage sludge can be a viable source of lipid for biodiesel production. This is the waste formed from the treatment of waste water. These waste water treatment plant produces primary and secondary sludge. This sludge consists of a variety of organic matter and microorganisms [4]. Lipids

extracted from this sewage could become a source of cheap and readily available feedstock for biodiesel production [5].

This research study investigates the possibility of producing biodiesel from sewage sludge as a potential feedstock, given that humans excretes faeces regularly, and other lipid-containing wastes are also found in Sewage Sludge and also reliable as organic substances like lipids are found in it. This research is also basically focused on how best the production of biodiesel can be carried out from Sewage Sludge. Owing to the fact that over the years, biodiesel has been produced from common sources such as Vegetable Oils, Animal fats, Plant seeds etc., there is the need to focus on other viable sources.

This study looks into the characterization of the lipid extract from primary sewage sludge obtained from a Waste Water Treatment Plant (WWTP) in Lagos State, Nigeria and the economic viability of producing biodiesel by base catalyzed-transesterification process.

2. MATERIALS AND METHODS

2.1 Pretreatment of Sewage Sludge

Municipal sewage sludge comes from waste water treatment plant. Water is a hindrance for oil extraction, so collected sludge was dewatered as well as the removal of pathogens. Sludge samples were collected from waste water treatment plant.

Primary sludge is produced through the mechanical wastewater treatment process. The sludge amassing at the bottom of the primary sedimentation basin is also called primary sludge. The composition of this sludge depends on the characteristics of the catchment area. Primary sludge consists of organic matters, as faeces, vegetables, fruits, textiles, paper etc.

2.2 Sample Collection

The sample collection for primary sewage sludge was carried out in a sewage sludge treatment plant, which consists of a skimmer used for removing solids with a density less than water containing high load of floating grease, flocculator which is used to increase settling in the primary or settling tank and an aerator used for aerating or supplying air by an aerobic digester to the raw sludge (Sampling Procedures

and Protocols for the National Sewage Sludge Survey, 1988). The sewage sludge treatment plant comprises of a unit tank and is specifically designed to treat domestic sewage and other biodegradable waste and comprises of three treatment stages with a UV disinfection unit and a final effluent pump station of which the flow is from the inlet to the outlet by gravity.

2.3 Sample Drying

After the primary sludge was collected from the sewage sludge treatment plant into a 10 litres keg, the primary sludge was then poured into a big tray and sun dried for 6 hours before air drying. The sample was constantly air dried for 7 days to ensure proper drying of the sample.

2.4 Particle Reduction of the Sludge Sample

The dried primary sludge was reduced in particles by using a pestle and mortar where it was pounded until the big particles of the dried sewage sludge reduces to granules. After then, an industrial blender was used to reduce the particle size of the sewage sludge to finer particle size in order for the sludge to undergo a highly efficient soxhlet extraction.

2.5 Extraction and Characterization

Soxhlet extractor was used in extracting the lipid (oil) from the blended sewage sludge. The sample was placed in the thimble, which is a compartment of the soxhlet apparatus and the round bottom flask was then half filled with n-hexane and heat was applied to the round bottom flask from a heating mantle. Heat supplied from the heating mantle increased the temperature of the solvent (n- hexane) in the flat bottom flask and a condenser cooled the vapour back to its liquid state, which fills the thimble containing the sample until it gets to the point where it refluxes and goes back to the flat bottom flask [6,7,8]. Moreover, some physicochemical properties of the lipid extract were determined.

2.6 Esterification

The extracted quantity of the lipid was esterified by reacting the lipid with 104.41 ml of methanol in the presence of 2.32 ml concentrated sulphuric acid as an acid catalyst at a temperature of 60°C supply of heat. This process was carried out due to the high FFA of the lipid [6,7].

2.7 Base-Catalyzed Transesterification

The esterified oil was then transesterified by preparing a methoxide solution which was carried out by dissolving 1% NaOH of the weight in mass of the lipid (which is $1/100 \times 79.402 \text{ g} = 0.79402 \text{ g}$) in 20% methanol of the weight in mass of the lipid (which is $20/100 \times 79.402 \text{ g} = 15.9 \text{ ml}$) and was heated at a steady temperature of 60°C for an hour with constant stirring of the mixture using a hot plate magnetic stirrer.

2.8 Physicochemical Characterization of the Biodiesel

After the reaction process, the mixture was transferred into a separating funnel, allowed to settle and cooled, while the separation of the two phases (methyl ester phase and glycerin phase as upper and lower phase respectively) took place [9]. Physicochemical properties of the biodiesel were then carried out.

3. RESULTS AND DISCUSSION

The results for the determination of the physicochemical properties of the extracted lipid (oil) from the sewage sludge is presented in Table 1, while Table 2 gives the physicochemical properties of the biodiesel produced thereafter with ASTM standard.

Table 1. Comparative results for the physicochemical properties of the extracted lipid/oil

Parameters	Extracted oil
Colour	Brownish black
Smell	Pungent odour
Percentage yield (%)	18.27
pH	10.81
Density (g/ml)	0.841
Specific gravity	0.841
Viscosity (mm ² /Sec)	41.02
Acid value (mg.NaOH/g)	3.96
FFA (%)	1.98
Saponification value (mg.NaOH/g)	113.98

The percentage yield of oil obtained from the sewage sludge using n-hexane as the extracting solvent was 18.27% [10,5]. Although, this value is low, but given that human faeces is readily available, it therefore has a good potential to be a sufficient source of lipid required for production of biodiesel in commercial quantity [5].

Viscosity is a measurement of internal friction. It is an essential property which affects atomization of fuel and mixing of air and fuel in the combustion chamber. The viscosity of the extracted oil was 41.02 mm²/Sec. This value is relatively lower compared to other sources of lipids from communities like Hebbala, and Vrishabavati in Bangalore with viscosity parameter being 42.2 mm²/Sec [11].

After three esterification processes to reduce the acid value and FFA, 3.96 mgNaOH/g and 1.98% were obtained respectively. This low value will enhance the use of this oil for biodiesel production. The Free Fatty Acid result is also lower when compared to the *Hyptus spicigera* seed oil which has a FFA of 3.50% [12]. This is also an indication that the primary sewage sludge has a better storage quality when compared to that of Sheanut butter oil.

Saponification value which refers to the number of milligrams of sodium hydroxide required to saponify 1 g of fat under the conditions specified. The value of 113.98 mgNaOH/g obtained in this work is lower than that of Shea butter with a value of 183.1 mgNaOH/g, castor oil 26.78 mgNaOH/g, of castor seed oil, 125.081 mgNaOH/g, of jatropa oil, and 199.5 mgNaOH/g of cotton seed oil [10]. The low saponification value suggests the onset of oxidation [13]; and shows that the lipid has few long-chain molecules (Free Fatty Acids) per fixed mass.

Other physicochemical parameters for the extracted oil are fairly similar to other known viable oil for biodiesel production [3].

However, results from Table 2 gives the different physicochemical properties of the biodiesel produced in comparison with the ASTM standards. The biodiesel gave a brownish black colour, being different from the regular colours seen by other biodiesel produced from different

sources like garlic, light yellow and a characteristic pungent smell was also observed [4]. This slight variation could arise from the fact that primary sewage sludge was used as a feedstock, which possesses similar characteristic properties.

The percentage yield was 66.66%, this is higher when compared to other sources of biodiesel.

The pH value of the biodiesel was 7.97 which showed that the biodiesel is slightly alkaline.

The result for density at 15°C and specific gravity was 0.87 Kg/l and 0.87 respectively. This value obtained falls within the limit specified for biodiesel fuel (with ASTM D1298/4052 and D1298 respectively with range between 0.86-0.89 kg/l and 0.89 max).

The acid value analyses carried out on the biodiesel was found to be 0.45 mgNaOH/g. The result indicates that the sample oil used for the production of biodiesel contains less fatty acid and the biodiesel contains very little or no fatty acid in it.

From the results presented in Table 2, the viscosity and kinematic viscosity of the biodiesel was 5.247 mm²/Sec and 6.24 mm²/Sec respectively. These values are consistent with the conventional biodiesel standard and are slightly higher than the petroleum diesel. The 40°C reference point is a parameter required by the biodiesel and petroleum diesel standards. This implies that the biodiesel obtained from the sewage sludge could satisfy the fluidity requirement of an alternative biodiesel and can reduce wear and tear in a biodiesel engine.

The sulphated ash content present in the biodiesel from the result was 0.018%. This low value is consistent with the quality of biodiesel.

Table 2. Physicochemical properties of biodiesel produced from extracted lipid/oil

Parameters	ASTM method	Limits	Units	Results
Percentage yield	-	-	%	66.66
Ph	-	-	-	7.97
Density, 15°C	D1298	0.860-0.890	Kg/m ³	870
Acid value	D664	0.50 max	mgNaOH/g	0.45
Viscosity	D445	3.5-5.0	mm ² /Sec	4.698
Flash point	D93	130 min	°C	159
Cetane number	D613	47 min	-	50.4

The flash point was 159°C that there was no excess methanol contained in the product after purification. If the flash point were to be below 159°C, the fuel will be flammable and more dangerous to handle and store, as a result, it will affect engine seals and corrode metal components. This result is higher than the petroleum diesel standard range of 60-80°C [14].

The cloud point of the biodiesel from the result showed that for the biodiesel to form a cloud of wax crystals, it has to cool down to -5°C under conditions prescribed in the ASTM D6751 fuel standard test method compared to the fuel standard of petroleum according to ASTM D975.

The pour point temperature result obtained was 9°C and showed the low temperature operation of the fuel. It also shows the temperature at which the amount of wax out of solution is sufficient to get the fuel and thus, this is the lowest temperature at which the fuel can flow compared to that of the petroleum diesel (ASTM D975) standard range which is lower.

The result observed for the copper strip corrosion test showed that the strip was free from the corrosion which confirms that the biodiesel was free from acids based on the strip that was compared to the tested method of ASTM standards.

Other physicochemical parameters are within the values obtained in other literature and the limits for biodiesel standards.

4. CONCLUSION

Comparing the physicochemical data obtained with the ASTM standard test method, it can be inferred that the primary sewage sludge can be a viable and cheap feedstock for biodiesel production. The biodiesel produced can be used as a blend to the petroleum diesel and also in other relevant applications. The percentage yield for both lipids from sewage sludge and biodiesel from the lipids shows promising alternative to petroleum diesel for the nearest future.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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