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The Production of Biodiesel from Sewage Sludge using a Mixture of N-Hexane and Diethyl Ether as Extracting Solvents and Transesterificaton Reaction

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ABSTRACT

Lipid was extracted from dried powdered sewage sludge using a soxhlet extractor and a mixture of n–hexane and diethyl ether as extracting solvents in a ratio of 2:1. The extracted lipid was brownish black in color with a pungent smell. The physical parameters showed percentage yield of 0.58%, density of 0.875 g/ml, specific gravity of 0.875 and pH of 8.5 while the chemical parameters revealed an acid value of 2.82 NaOH/g, a free fatty acid of 1.41% and a saponification value of 120.615. The extracted lipid was used in the production of biodiesel by a base transesterification process. The result showed a percentage yield of 14.37%, a density of 0.854 g/ml, an acid value of 0.00, a specific gravity of 0.854 and a pH of 8.5. This showed that the feedstock (primary sewage sludge) would be a promising source for the production of biodiesel.

KEYWORDS: *Biodiesel, primary sewage sludge, diethyl ether, n-hexane*

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INTRODUCTION

With the increase in crude oil prices, the need for the development of economically attractive and alternative fuels has increased. With increased industrialization and urbanization, the over-consumption of the energy could lead to an energy crisis. Nowadays, most of the energy demand is satisfied from fossil fuel sources which are non-renewable and will be run out in the future (Demirabas,2009; Shafiee and Topal,2009]. The energy demand is majorly fulfilled from the conventional energy resources like coal, petroleum and natural gas. To meet the global rising energy demands, more reliable energy source that are not dependent on fossil fuel are needed. Fossil fuels are non-renewable that is, they draw on finite resources that will eventually dwindle, becoming too expensive or too environmentally damaging to retrieve (Barnwal and Sharma, 2005).

As a result of the depleting of fossil fuel resources and the increasing environmental concerns, the use of biodiesel is increasingly sought as a good alternative to replace petroleum diesel. Utilization of renewable energy resources is encouraged to prevent energy scarcity, since the consumption of energy from fossil fuel is increasing every year, while its availability is limited. Biodiesel is one of the prospective renewable energy resources (Abdullah et al, 2013), because there are many species that produce high content of oil either edible or non-edible oil producing plants (Bello and Agge, 2012).

Biodiesel is seen as part of a larger plan to reduce air pollution, carbon emissions, and dependence on fossil fuels. The use of biodiesel results in substantial reduction of unburned carbon monoxide and particulate matter. Biodiesel is an easy alternative fuel and can be produced from renewable sources such as canola or other oil seed crops (Gerpen, 2005). Biodiesel is an eco-friendly, alternative diesel fuel prepared from vegetable oils and animal fats. It is a renewable source of energy and seems to be an ideal solution for global energy demand. The general way to produce biodiesel is by transesterification of vegetable oil with methanol in the presence of either alkaline or strong acid catalysts (Meher et al, 2004). Interestingly, the use of municipal sewage sludge as another source of lipids for the production of biodiesel production has been explored (Sirangala et al., 2014). Municipal sewage sludge can be exploited to obtain lipids, which then becomes a good and high energy feedstock for biodiesel production in the future.

This research paper, examines the possibility of producing biodiesel from sewage sludge by first extracting lipids from sewage sludge obtained from a treatment plant in Udu local government area of Delta State, Nigeria via soxhlet extraction with n-hexane and diethyl ether (2:1) as solvent; and converting the lipids to biodiesel using transesterification reaction.

MATERIALS AND METHODS

Study Site: Solid primary sewage sludge was collected from waste water treatment plant, located in Udu L.G.A, Delta state in Nigeria, a subsidiary of Delta state waste water management office, which was carved out of the erstwhile sewage department of the office of drainage services in the ministry of the environment, Delta State, to oversee waste water management in the state. The office was incorporated into the Delta state water corporation. The creation of the office arose from the need for an institutional reform in wastewater and related matters in Delta state.

Samples collection and preparation: Solid primary sewage sludge collected from waste water treatment plant in Udu, was pretreated using mechanical method and this involves switching off the connection between the sump (A hollow or pit into which liquid drains, such as a cesspool, cesspit or sink) and the aerator for about 12 hours, thereby allowing the primary sewage sludge to settle beneath the sump before collection.

The primary sewage sludge was then collected and dried for 7 days with sun and air. Then particle reduction was carried out using local pestle and mortar. The reduced particles were weighed using the electronic weighing balance.

Reagents: The reagents used were of analytical grade. Some of the reagents were purchased while some were obtained in chemistry department, Federal University of Petroleum Resources, Effurun, PMB 1221, Delta State, Nigeria.

Sample Extraction: The oil from the primary sewage sludge was obtained by soxhlet extraction using a mixture of n-hexane and diethyl ether as extracting solvents in the ratio 2:1. The oil was obtained after the extracting solvents was removed under reduced temperature and pressure, and refluxing at 70^{o}C, using rotary evaporator. The extracted oil was stored in refrigerator/ freezer at 2^{o}C for subsequent physicochemical analyses (Warra et al, 2011).

Physicochemical Analyses of the Extracted Oil: Various physicochemical parameters were carried out on the extracted oil which includes: Percentage yield, colour, pH value, Density, Specific gravity, Saponification value and Acid value/Free fatty acid.

Production of biodiesel: The production process of biodiesel are in two stages. These are the Acid Catalysed Transesterification Process also known as Esterification Process and The Base Catalysed Transesterification process. The acid catalysed transesterification process is performed to reduce the percentage of free fatty acid in the oil, if the acid value is high (Karaosmanoglu, 1996).

In this research work, a base catalysed transesterification process was used. The transesterification of lipid was undertaken by preparing a methoxide solution which was obtained by dissolving 1g of KOH in 20ml methanol in a 50 ml beaker using a magnetic stirrer. The prepared methoxide solution was added to the extracted oil and heated to a temperature of 60^{o}C for an hour using a hot plate magnetic stirrer. After the reaction process, the mixture was transferred into a separating funnel, followed settling and cooling, while the separation of the two phase layer of methyl ester phase (Biodiesel) and glycerin phase (Glycerol) as the upper and lower phase takes place respectively (Gerpen et al, 2004).

Physicochemical Analysis of the produced Biodiesel: The following physicochemical parameters were carried out on the produced biodiesel. These include percentage yield, pH value, density, specific gravity and acid value/free fatty acid.

RESULTS AND DISCUSSION

The experimental result of the physicochemical analyses conducted on the extracted oil is presented in table 1, while those on the produced biodiesel in accordance with the ASTM standard in table 2, respectively.

Table 1: Summary of the Physicochemical analysis on the Extracted oil

Physicochemical Parameters	Results
Colour of oil	Brownish black
Smell	Pungent odour
Percentage yield (%)	0.58
pH	8.50
Density (g/ml)	0.875
Specific gravity	0.875
Acid value (mg KOH/g)	2.82
Saponification value (mg KOH/g)	120.615
FFA (%)	1.41

Table 1 gives the different values of the physiochemical characteristics of the extracted lipid. The extracted oil has a brownish black colour and a pungent smell. A percentage yield of 0.58% was obtained. This yield is substantially lower than that of *Lageneria siceraria* seed oil with a yield of 39.22% (Hassan and Sani, 2007). Although the yield is low, but if sufficient quantity of sewage sludge is extracted, there will also be a corresponding increase in the lipid yield. This implies that sewage sludge can be a veritable source of lipid for biodiesel production. The pH value for the extracted oil was found to be 8.50 which showed that it is slightly alkaline.

The density and specific gravity of the extracted lipid was found to be 0.875g/ml, being lower than water (1.0 g/ml). Density is expressed as the ratio of the mass or weight (g) of a substance to the volume of the substance (ml), while specific gravity is the ratio of the density of a substance to the density of water at 4°C (Bello and Agge, 2012).

The acid value obtained from the extracted oil is 2.82mgKOH/g. This value is smaller when compared with 10.3 mgKOH/g reported for Sheanut butter; and higher in comparison to 2.455mgKOH/g, 1.265mgKOH/g and 0.82mgKOH/g for castor seed oil, jatropha oil and cotton seed oil respectively. The higher the acid value of an extracted oil, the lower its storage quality and vice-versa, therefore suggesting that the extracted oil have better storage quality when compared to that of Sheanut butter oil (Warra, 2011). The free fatty acid value was found to be 1.41% which is lower than the *Hyptusspicigera*seed oil with a value of 3.50% (Ladan, 2010).

The saponification value of the extracted lipid was found to be 120.615mgKOH/g which is smaller than the value of 183.1mgKOH/g for sheabutter oil and 126.728mgKOH/g, 125.081mgKOH/g and 199.95mgKOH/g for castor seed oil, jatropha oil and cotton seed oil respectively, with a potential for soap production (Warra, 2011).This suggests that the extracted oil from the sewage sludge will not be a good for soap production due to its low saponification value (Warra, 2011).

Table 2: Summary of the Physicochemical analysis results on the Biodiesel produced

Physicochemical Parameters	Experimental Results On The Biodiesel	Test Method	ASTM Standard Results Limits D-6751-02
Percentage yield (%)	14.37	-	-
Density at 15°C (kg/ml)	0.854	ASTM D1298	0.860–0.890Kg/ml
Specific gravity	0.854	ASTM D1298/4052	0.89max
pH	8.50	-	-
Acid value (mg KOH/g)	0.00	ASTM D664	0.50 max

Table 2 gives the different values of the physicochemical characteristics of the biodiesel. The percentage yield (%) of the biodiesel produced was found to be 14.37% from calculations. The density of diesel fuel is an important property that affects the fuel injection system. Density of biodiesel at 15°C is the weight of a unit volume of the biodiesel. The biodiesel produced has a density of 0.854kg/ml and a specific gravity of 0.854 which falls slightly below the ASTM standard range at 15°C. The biodiesel showed a pH of 8.50 which is slightly alkaline.

Acid value is a direct measure of the level of free fatty acids that may be present in biodiesel. The acid value of the biodiesel produced was found to be 0.00mg KOH/g. This shows that the biodiesel does not contain any free fatty acid which is in agreement with the conventional biodiesel standard with a range within 0.50max (Gerpen et al, 2004).

CONCLUSION

Based on the experimental results gotten from the characterization of the produced biodiesel in comparison with the America Standard Test Method (ASTM), it suggests that primary sewage sludge can be a viable source of raw material for biodiesel production and the bio-refinery. The study is also open for further physicochemical assessment to verify the quality of the extracted oil and biodiesel. This will help to know the range and limit of applications of biodiesel that are produced from sewage sludge.

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