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Assessment of the Potentials of Non-Edible Oils (Waste Vegetable Oil and *Sesamum indicum* Oil) as Sustainable Feedstocks for Green Synthesis of Biodiesel

***Amenaghawon, N.A., Omede, O.M., Ogbebor, G.O. and Ayere, J.E.**

Bioresources Valorization Laboratory, Department of Chemical Engineering, University of Benin, Nigeria.
*andrew.amenaghawon@uniben.edu

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ABSTRACT

The ongoing use of traditional fossil-based fuels has a variety of negative environmental effects, motivating the need to seek out sustainable and environmentally favorable alternatives such as biodiesel. One of the major challenges associated with the biodiesel process is the cost associated with the feedstocks. Thus, there is motivation to seek out alternative and low-cost feedstocks for biodiesel production. Thus, the focus of this work was to assess the potentials of waste vegetable oil (WVO) and Sesamum indicum oil as inexpensive and sustainable feedstocks for biodiesel production. This was done by completely characterizing both oils to determine their key characteristic which indicate their suitability for producing biodiesel. The results showed that free fatty acid content, viscosity, peroxide value, density and saponification value of WVO and Sesamum indicum oil were 2.9 and 1.89 %, 21.4 and 6.40 mm^2*/s, 2.8 and 3.1 meq* O_2*/g, 971 and 896 kg/m*^{3}*, and 190 and 174.6 mg KOH/g respectively. These values were comparable with those reported in literature and indicated the suitability of both oil feedstocks for biodiesel production.*

1. INTRODUCTION

Energy is a vital resource whose availability is used to gauge a country's degree of development. Numerous industrial, household, and transportation operations rely on energy availability. Fossil fuels such as crude oil, coal, and natural gas meet the world's energy requirement. This is not sustainable due to the production of greenhouse gases, particularly carbon dioxide (Mutezo and Mulopo, 2021). There is a push to produce sustainable and ecologically friendly alternative energy sources. Renewable energy sources have been found as a realistic option capable of meeting global energy demand while avoiding the environmental damage associated with fossil fuels.

Biodiesel has received a lot of attention as a greener alternative to petrodiesel. Biodiesel has been demonstrated to have highly desirable properties. It is renewable, nontoxic, biodegradable, has intrinsic lubricity, has little or no sulfur, has good emission properties, and can be utilized in current engines without substantial changes (Singh et al., 2020). Because of its excellent miscibility with petrodiesel, it may be combined in various amounts with petrodiesel.

Transesterification of fats and oils is a typical method for producing biodiesel. The triglyceride in the oil or fat feedstock is reacted with methanol in the presence of an appropriate catalyst to form fatty acid methyl esters (biodiesel) and glycerol as a byproduct in this process (Amenaghawon et al., 2021a). The cost of the process is the most significant impediment to large-scale biodiesel production. The cost of feedstock can account for up to 80% of the total cost of biodiesel production (Etim et al., 2020). Because of land constraints and the food vs fuel argument, conventional edible feedstocks such as palm oil, corn oil, sunflower oil, and soybean oil are being discouraged. This has prompted a quest for less expensive and more easily available feedstocks, with the majority of effort presently focusing on low-cost non-edible oils such as castor seed oil (Roy et al., 2020), yellow oleander seed oil (Ighose et al., 2017), rubber seed oil (Sai et al., 2020), kapok oil (Pooja et al., 2021), jatropha seed oil (Ewunie et al., 2020), waste cooking oil, (Sahar et al., 2018), and among others.

In the context of the current effort, the emphasis is on waste vegetable oil (WVO) and *Sesamum indicum* oil. WVO is obtained from edible oils that were formerly used to cook meals. In Nigeria, prominent restaurants, hotels, catering services, and family kitchens create a considerable amount of WVO each year (Amenaghawon et al., 2021b). WVO causes environmental damage, particularly in underdeveloped nations such as Nigeria, where waste management is a concern. One solution to this challenge is to investigate the reuse potential of WVO, with one plausible possibility being its usage as a feedstock for biodiesel synthesis. On the other hand, *Sesamum indicum* L. (Sesame seed) is one of the world's most significant and oldest oil seed crops. *Sesamum* is a member of the Pedaliaceae family, which includes 16 genera and 60 species. The protein-rich sesame seed, also known as benniseed, benne, sesamum, gingelly, sim-sim, and tila, was one of the earliest crops processed for oil production. It has been grown for ages, notably in Asia and Africa, particularly in Sudan, Ethiopia, and Nigeria (Casadei and Albert, 2003). Sesame's chemical composition reveals that the seed is a good source of oil (50-60%), protein (18-25%), carbs, and ash. Because of the presence of antioxidants (sesamol, sesamolin, and sesamin) as well as tocopherols, the oil fraction is extremely resistant to oxidation. The amount and quality of oil contained in the seed have been proven to be affected by ecological, genetic, and physiological factors such as climate, soil type, cultivars, and plant age (Rahman et al., 2007).

However, to serve as a potential feedstock for biodiesel production, an oil feedstock needs to possess desirable characteristics in terms of physical properties and chemical composition. Thus, the objective of this study was to assess the physical and chemical properties of waste vegetable oil and waste palm oil to determine their suitability as feedstocks for biodiesel production.

2. MATERIALS AND METHODS

2.1. Raw Materials and Reagents

The waste vegetable oil utilized in this study was obtained from the University of Benin Campus cafeteria in Benin City, Edo State, Nigeria while waste palm oil was sourced from a bean cake seller in Ugbowo, Benin City, Nigeria. The collected waste oils some food particles and water, thus they were filtered using muslin cloth before being heated at 120 ºC to minimize the moisture content (Amenaghawon et al., 2021a). All chemical reagents used in this study were of analytical grade, manufactured by BDH Chemicals Ltd., Poole, England.

2.2. Preparation and Extraction of *Sesamum indicum* Seed Oil

The seeds were purchased at a local market in Niger State, Nigeria. The seeds were separated from the chaff and sun-dried for 5 days at room temperature to facilitate seed dehulling. The seeds were then dried in an electric oven at 60 ºC for 5 hours to decrease the moisture content to an acceptable level for extraction. To increase the surface area for extraction, the prepared seeds were ground using an electric mill (Betiku and Adepoju, 2013). The *Sesamum indicum* seed oil was extracted using the Soxhlet extraction method using n hexane as the solvent. The prepared seed was weighed and then charged into the apparatus through a muslin cloth put in the extractor's thimble. The extractor was linked to a circular bottom flask filled with n-hexane. The setup was completed with a condenser that was securely fastened to the bottom. The entire arrangement was heated in a heating mantle to a constant temperature of 70 ºC. Several runs were performed in order to have adequate oil for biodiesel production. The yield of oil obtained at the end of the process was calculated using Equation (1).

$$Oil\ yield\ (\%) = \frac{mass\ of\ oil}{mass\ of\ seed} \times 100 \tag{1}$$

2.2. Characterization of WVO and *Sesamum indicum* Seed Oil

The suitability of the collected WVO and WPO as feedstocks for biodiesel production was examined by determining their physical and chemical properties via appropriate characterisation methods. The properties examined included moisture content, acid value, saponification value, peroxide value, iodine value, and viscosity, density, specific gravity, etc. The density of the oils was determined following the ASTM D1298 method (Tat and Van Gerpen, 2000). The ASTM D2709 standard test method was used to determine the moisture content (%) of the waste cooking oil (Fernando et al., 2007). The specific gravity of the oils was determined using a simple density bottle. The ASTM D664 standard test method was used to determine the acid value of the oils (Wang et al., 2008). The ASTM D445 standard test method was used to determine the kinematic viscosity of the oils (Knothe and Steidley, 2005). The peroxide value of the oils was determined according to standard methods (AOAC 1990). The saponification value of the oils was determined following standard procedures reported in Sasongko et al. (2017). The chemical composition of the waste cooking oil was assessed by determining its fatty acid profile using Gas Chromatography (GC) according to the method reported by Alcantara et al. (2000).

3. RESULTS AND DISCUSSION

3.1. Physicochemical Characteristics

Table 1 displays the characteristics of waste vegetable oil and *Sesamum indicum* seed oil following their characterization. The characterisation tests were performed to determine the suitability of the oils as feedstocks for biodiesel production. The yield of *Sesamum indicum* seed oil obtained from the extraction process was 49.4%. This value falls between the 44 to 54% range reported by Saydut et al (2008). The oil yield is greater than that of other regularly used seed oils such as castor (39.4%), rubber seed (38-45%), and jatropha (38-46%) (Jonas et al., 2020). The significant oil yield observed suggests that *Sesamum indicum* seed oil may be used as a long-term oil feedstock for biodiesel synthesis. The extracted *Sesamum indicum* seed oil was light yellow in color while the WVO had a reddish-brown color. Both oils were liquids at room temperature. The moisture content of WVO and *Sesamum indicum* seed oil were determined to be 0.64 and 0.4% respectively. This is comparable to the value reported by Younis et al. (2014). The moisture content is crucial because a high moisture content promotes microbial development during storage and may interfere with biodiesel production during transesterification (Banerjee and Chakraborty, 2009). The free fatty acid content of both oils was determined to be 2.90 and 1.89% respectively. The free fatty acid level gives an indication of the stability of an oil. A high free fatty acid concentration is undesirable for biodiesel synthesis since it might cause the oil to be converted to soap. The viscosity of both oils was determined to be 21.4 and 6.4 mm^2/s respectively. These values are much lower than the values published by Sabarinath et al. (2020).

High viscosity results in low volatility and poor cold flow characteristics, which is why oils are not suited as direct fuels in diesel engines (Saydut et al., 2008). The saponification value determines the average molecular weight of the oil by measuring the chain length of the molecules that comprise it. WVO and *Sesamum indicum* seed oil yielded values 190 and 174.6 mg/g respectively, which is comparable to values published in the literature (Nzikou et al., 2010). The density of WVO and *Sesamum indicum* seed oil were obtained as 971 and 896 kg/m^3 respectively while the specific gravities were 0.971 and 0.896 respectively. These values show a sign of oil unsaturation, as rising degrees of unsaturation are associated with high density and specific gravity values (Enemor et al., 2021). The peroxide value of both oils was found to be 2.8 and 3.1 meq O_2/g respectively. The low peroxide values indicate that the oils have high oxidative stability, which means that they may be stored for long periods of time without turning rancid (Dim et al., 2013). The iodine value of WVO and *Sesamum indicum* seed oil was discovered to be 115 and 104.6 g/100g respectively. The iodine value is also used to determine the oxidative stability of oils. Oils with high iodine concentrations are more unsaturated and consequently have lower oxidative stability.

Table 1: Properties of WVO and *Sesamum indicum* seed oil

Properties	WVO	*Sesamum indicum* oil
Yield (%)	-	49.4
Colour	Light brown	Reddish brown
Physical state at room temperature	Liquid	Liquid
Moisture content (%)	0.64	0.45
Acid value (mg KOH/g)	5.8	3.78
Free fatty acid value (%)	2.9	1.89
Kinematic viscosity @ 40 ^{o}C (mm^2/s)	21.4	6.40
Saponification value (mg KOH/g)	190	174.6
Density (kg/m^3)	971	896
Specific gravity	0.971	0.896
Peroxide value (meq O_2/g)	2.8	3.1
Iodine value (g I_2/100 g oil)	115	104.6

3.2. Fatty Acid Composition Profile

Table 2 shows the findings of the fatty acid content profile of WVO and *Sesamum indicum* seed oil as determined by gas chromatography and mass spectrometry. The primary fatty acids were in WVO were linoleic acid (47.30%), oleic acid (23.20%) and palmitic acid (20.07%). Stearic acid (9.43%) was also present. Similar findings have already been published. For *Sesamum indicum* seed oil, the major fatty acids were vaccenic acid (45.08%), stearic acid (37.81%), and oleic acid (11.10). Other fatty acids present in smaller proportions were iso palmitic acid (4.84), palmitic acid (1.23%) and arachidic acid (1.83%).

Table 2: Composition of WVO and *Sesamum indicum* seed oil

Fatty acid	Chemical formula	Composition (%)	
		WVO	*Sesamum indicum* seed oil
Palmitic acid	$C_{16}H_{32}O_2$	20.07	1.23
Iso palmitic acid	$C_{16}H_{32}O_2$	-	4.84
Vaccenic acid	$C_{18}H_{32}O_2$	-	45.08
Linoleic acid	$C_{18}H_{32}O_2$	47.30	-
Stearic acid	$C_{18}H_{36}O_2$	9.43	37.81
Oleic acid	$C_{18}H_{34}O_2$	23.20	11.10
Arachidic acid	$C_{20}H_{40}O_2$	-	1.83

4. CONCLUSION

This study assessed the potentials of waste vegetable oil and *Sesamum indicum* seed oil as feedstocks for green biodiesel synthesis by assessing their physical and chemical characteristics. On the basis of the findings obtained, it can be concluded that both oils are suitable for the production of biodiesel and this will help to alleviate the economic challenges associated with sourcing inexpensive feedstocks for biodiesel production.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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