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Evaluation of Sesame Seed Oil as a Potential Feedstock for Biodiesel Production

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ABSTRACT

The continued use of conventional petroleum-based fuels has diverse environmental and energy security consequences which has motivated the need to as search for sustainable and environmentally friendly alternatives. This study thus investigated the potential of producing environmentally benign biodiesel from Sesamum indicum (sesame seed) oil. The oil was obtained from the seed via a batch-mode solvent extraction using n-hexane. The results obtained showed that an oil yield of 50% was obtained after extraction. The oil had a low kinematic viscosity (5.92 mm^2/s), acid value (3.93 mgKOH/g), iodine value (106.40 mgI_2/g) and peroxide values (2.8 $meqO_2/g$), making it a suitable feedstock for biodiesel production.

1. INTRODUCTION

Sesame seed (*Sesamum indicum* L.) is one of the world's most important and oldest oil seed crops known to man (Abou-Gharbia et al., 2000). The genus sesamum is a member of the family Pedaliaceae, which contains 16 genera and 60 species (Hassan, 2012). Sesame seed, a rich source of protein, is one of the first crops processed for oil production (Anilakumar et al., 2010), also known as bennissed, benne, sesamum, gingelly, sim–sim and tila. It has been cultivated for centuries, particularly in Asia and Africa specially Sudan, Ethiopia and Nigeria (Casadei and Albert, 2003). Nearly 70% of the world production is from Asia. Africa grows 26% of the world's sesame, with Sierra Leone, Sudan, Nigeria and Uganda being key producers. Latin America grows 4% of the total world production (Abou-Gharbia et al., 2000). Sesame plays an important role in human nutrition, medicinal, pharmaceutical, industrial and agricultural uses. Sesame seed has many culinary applications in many bakery products and for the oil production (raw or roasted). Sesame seed oil is very rich in polyunsaturated fatty acids used in margarine production and cooking oils. Sesame contains significant amounts of the lignans sesamin and sesamolin. These compounds have beneficial effects on serum lipid levels and liver function and give sesame seed oil a marked antioxidant activity. The lignans are also responsible for the great stability of sesame seed oil to oxidation (Crews et al., 2006). All these substances have been shown to possess cholesterol-lowering effect in humans and to prevent high blood pressure and increase vitamin E supplies in animals (Kamal-Eldin et al., 1995). Sesame seeds are an excellent source of copper and calcium. It is also rich in phosphorous, iron, magnesium, manganese, zinc and vitamin B1. Many medicinal properties and health benefits of sesame may be attributed to its mildly laxative, emollient and demulcent (Anilakumar et al., 2010). Sesame seed oil has been found to inhibit the growth of malignant melanoma in vitro and the proliferation of human colon cancer cells. In the tissues beneath the skin, this oil neutralizes oxygen radicals. It penetrates into the skin quickly and enters the blood stream through the capillaries. Sesame seed oil is a useful natural UV protector. It has been successfully used in the children's hair to kill lice infestations (Anilakumar et al., 2010).

The chemical composition of sesame shows that the seed is an important source of oil (50–60%), protein (18–25%), carbohydrates and ash (El Khier et al., 2008). The oil fraction shows a remarkable stability to oxidation due to the presence of antioxidants (sesamol, sesamolin and sesamin) together with tocopherols. The quantity and quality of the oil contained in the seed have been shown to depend on ecological, genetics and physiological factors such as climate, soil type, cultivars and maturity of plant respectively (Rahman et al., 2007).

Solvent extraction has emerged as the most efficient way of extracting oil from oil-bearing seed. Solvent extraction offers a number of advantages which include high yield, less turbidity and relatively low operating cost (Ajala and Betiku, 2014). Thus, this study adopted this method to extract oil from sesame seed and evaluated its potential as a feedstock for biodiesel production.

2. MATERIALS AND METHODS

2.1. Materials

All chemical reagents used in this study were of analytical grade, manufactured by BDH Chemicals Ltd., Poole, England. The sesame seeds used as source of oil were obtained from a local market in Niger State, Nigeria. The seeds were separated from the chaff and dried for 5 days in the sun at ambient temperature for easy dehulling of seeds. The seeds were further dried in an electric oven at 60 ^oC for 5 hours so as to reduce the moisture content to an appreciable value in order to ease the extraction process. The prepared seeds were grounded using an electric mill so as to improve the surface area for extraction (Betiku and Adepoju, 2013).

2.2. Oil Extraction

The Soxhlet extraction procedure was adopted for the extraction of the sesame seed oil using n Hexane as solvent. The prepared sesame seed was weighed and then charged into the equipment in a muslin cloth placed in the thimble of the extractor. The extractor was connected to a round bottom flask containing n-hexane. The set up was completed with a condenser which was tightly fixed at the bottom. The whole setup was heated up in a heating mantle at a fixed temperature of 70 ^oC. Multiple runs were carried out in order to have enough amount of oil for the production of biodiesel. At the end of each run, the residue was discarded, and the extractor was charged again with fresh seed. Furthermore, the excess solvent in the oil was recovered using a rotary evaporator. The oil yield was gravimetrically determined using Equation (1).

$$Oil\ yield\ (wt\%) = \frac{mass\ of\ extracted\ oil}{mass\ of\ seed\ used} \times 100 \quad (1)$$

2.3. Characterization of Sesame Seed Oil

The physical and chemical properties of the extracted sesame seed oil were determined to assess its suitability as a feedstock for biodiesel production. The properties investigated include density, specific gravity, peroxide value, acid value, saponification value, iodine value, viscosity, chemical composition etc according to the methods of A.O.A.C (1990).

3. RESULTS AND DISCUSSION

3.1. Physicochemical Characteristics

Table 1 shows the properties of the sesame seed oil used as feedstock for biodiesel production. The characterization tests were carried out to assess the suitability of the oil as a feedstock for biodiesel production. The oil yield obtained during extraction was obtained as 50%. This value is within the range of 44 to 54 reported by Saydut et al. (2008). The oil yield obtained is higher than those of other commonly used seed oils such as castor (39.4%), rubber seed (38-45%) and jatropha (38-46%) (Ebewele et al., 2010; Yusuf et al., 2015; Jonas et al., 2020). The high oil yield obtained is indicates that sesame seed can serve as a sustainable oil feedstock for biodiesel production. The colour of the extracted oil was light yellow while its physical state was a liquid at room temperature. This is similar to other reports in the literature (Saydut et al., 2008). The moisture content of the oil was obtained as 0.46%. This is close to the value reported by Younis et al. (2014). The moisture content is important in that a high moisture content encourages microbial growth during storage and might also interfere with the production of biodiesel during transesterification (Banerjee and Chakraborty, 2009). The density and specific gravity were both obtained as 895.8 kg/m^3 and 0.896 respectively. This is an indication of the unsaturation of the oil as increasing levels of unsaturation is linked to high values of density and specific gravity (Enemor et al., 2021). Similar values were reported by previous researchers (El Khier et al., 2008). The viscosity of the oil was obtained as 5.92 mm^2/s. This value is significantly lower than those reported by Younis et al. (2014) (33.6 mm^2/s) and Sabarinath et al. (2020) (35.9 mm^2/s). High viscosity has the consequence of low volatility and poor cold flow characteristics and this is the major reason why oils are not suitable as direct fuels in diesel engines (Saydut et al., 2008). A peroxide value of 2.8 meq O_2/g was obtained. This is close to the value of 2.7 meq O_2/g obtained by Gharby et al. (2017). This low peroxide value is indicative of good oxidative stability of the oil meaning that it can be stored for long periods without becoming rancid (Dim et al., 2013).

Table 1: Properties of sesame seed oil

Properties	Value
Yield	50%
Colour	Light yellow
Physical state at room temperature	Liquid
Density	895.8 kg/m^3
Specific gravity	0.896
Kinematic viscosity @ 40 ^{o}C	5.92 mm^2/s
Peroxide value	2.8 meq O_2/g
Acid value	3.93 mg KOH/g
Free fatty acid value	1.97%
Saponification value	175 mg KOH/g
Iodine value	106.40 g I_2/100 g oil

The iodine value of the sesame seed oil was determined to be 106.4 g/100g. The iodine value is also used as an indicator of oxidative stability of oils. Oils with high iodine values have a higher degree of unsaturation and thus reduced oxidative stability. The value obtained in this work is lower than that reported by Dim et al. (2013) (113 g/100g). The free fatty acid content of the oil was obtained as 1.97%. The free fatty acid content is also an indication of the stability of the oil. High free fatty acid content is not desirable for biodiesel production as it can lead to the conversion of the oil to soap. The value of 1.97% obtain in this work is close to the 1.5%, 1.8% and 2.5% respectively reported by Enemor et al. (2021) and Dim et al. (2013). The saponification value gives a measure of the chain length of the molecules making up the oil and thus, its average molecular weight. A value of 175 mg/g was obtained for the oil sample used in this study which is comparable with the values reported in literature (Nzikou et al., 2010).

3.2. Fatty Acid Composition Profile

The results of the fatty acid composition profile of the sesame seed oil as obtained from gas chromatography and mass spectrometry is presented in Figure 1 and Table 2. As shown in Figure 1, there were a total of six identifiable peaks with each peak corresponding to a fatty acid constituent of the oil. The details of the peaks are summarized in Table 2. The predominant fatty acid present in the oil were vaccenic acid, stearic acid and oleic acid with proportions of 45.18%, 37.08% and 10.11% respectively. There were also some fractions of palmitic acid (1.32%), isopalmitic acid (4.92%) and arachidic acid (1.38%). Similar observations have also been reported previously. For instance, Nzikou et al. (2010) reported that linoleic acid (46.26%) and oleic acid (38.84%) were the major fatty acid present in sesame seed oil with some smaller proportions of palmitic acid (8.58%), stearic acid (5.44%) and arachidic acid (0.9%). Were et al. (2006) and Arslan et al. (2007) also reported that stearic, linoleic, palmitic, oleic, and linolenic acids were the major fatty acid present in sesame seed.

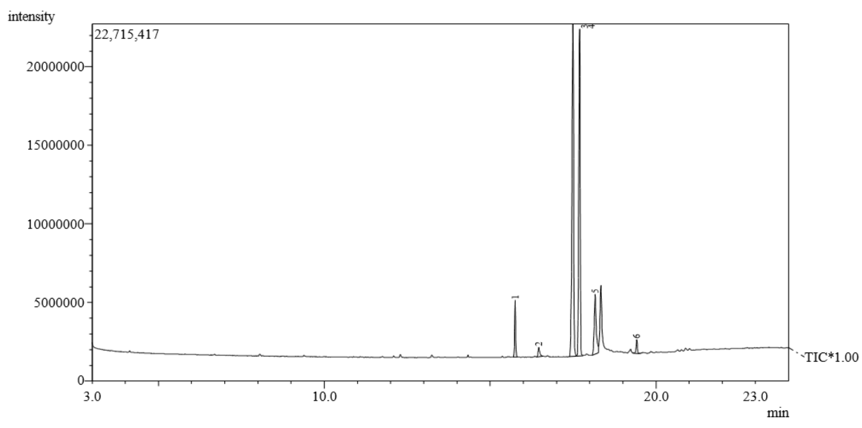

Figure 1: GC-MS of sesame seed oil

Table 2: Composition of sesame seed oil

Fatty acid	Chemical formula	Retention time (min)	Area (%)
Isopalmitic acid	$C_{16}H_{32}O_2$	15.752	4.92
Palmitic acid	$C_{16}H_{32}O_2$	16.467	1.32
Vaccenic acid	$C_{18}H_{32}O_2$	17.498	45.18
Stearic acid	$C_{18}H_{36}O_2$	17.698	37.08
Oleic acid	$C_{18}H_{34}O_2$	18.167	10.11
Arachidic acid	$C_{20}H_{40}O_2$	19.419	1.38

4. CONCLUSION

The focus of this study was to evaluate the potential of sesame seed oil as a feedstock for biodiesel production. The following conclusion have been drawn on the basis of the findings of the work.

1. Oil with a high enough yield has been extracted from sesame seed for the purpose of biodiesel production.
2. Sesame seed oil is a suitable oil feedstock for biodiesel production as seen from its desirable physical properties and fatty acid compositional properties which indicated that it contained mainly saturated fatty acids.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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