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EXTRACTION AND CHARACTERIZATION OF BIODIESEL FROM SOYBEANS SEED OIL (SSO) CULTIVATED IN JALINGO, TARABA STATE

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ABSTRACT

The use of petrol diesel has associated environmental challenges, hence, the need for an alternative source of diesel which is environmentally friendly. Biofuel, a triglyceride of vegetable oils and animal fats has remained a viable substitute for petrol-based diesel. This research is on extraction and characterization of biodiesel from soybeans seed oil (SSO). The seeds were obtained, sundried, crushed and weighed. Solvent extraction approach was adopted to extract oil from the crushed seeds using cold maceration method with n-hexane as a solvent. The biodiesel produced was characterized according to its physicochemical properties. The results obtained showed that the physicochemical properties of the biodiesel produced from soybeans seed oil were comparable with that of standard biodiesel in the range of ASTM specifications with a density of 0.860g/cm^3, viscosity of 2.81mm^2/s, flash point of 142^{o}C, Moisture content of 0.028%V and pour point of 7^{o}C. This implies that soybeans seeds can be used as biodiesel.

1. Introduction

There has been an increase in the world production of oilseeds over the last thirty years, Murphy (1994). This would appear to be related to the increasing demand for oilseed products and by-products as oilseeds are primarily grown for their oil and meal. Vegetable oil is always at a higher price per ton than the cake, this is because the demand for oil is often higher than the cake.

Oils from most edible oilseeds are used in the food industry, though there is growing emphasis on industrial utilization as feedstock for several industries with about 80% of the world production of vegetable oils are for human consumption. The remaining 20% utilization is between animal and chemical industries, Murphy (1994).

According to Rajagopal *et al*. (2005), biofuels from oilseeds are used as Straight Vegetable Oil (SVO) or as biodiesel (trans-esterified oil) depending on type of engine and level of blend of the oil; soybean oil is not an exception. This phenomenon has created a school of thought that it is better to use oilseeds as bio-fuel, which will lessen the competition for fossil fuels, which are not renewable. Fossil fuels are not only costly in terms of price but are also costly to the environment as they degrade land, pollute water and cause a general destabilization of the ecosystem with global warming as an end result. Furthermore, crude oil wields socio-political power that often dictates the pace of economic growth in specific locations, especially non-oil producing nations.

In order to meet the required amounts needed by all industries, these fats and oils must be available in large quantities locally with an effective extraction process at an affordable cost. The ability of a particular oilseed to fit into the growing industries depends on its utilization potential, rate of production, availability and ease of the processing technology. Thus, while some oilseeds are being largely utilized in the oil processing industries, quite a number of oilseeds are under-exploited.

Generally, oils and fats from seeds and nuts constitute an essential part of man's diet. Fats and oils, together with proteins, carbohydrates, vitamins and minerals, are the main nutrients required by the human body. Fats and oils are rich sources of energy, containing two and a half times the calories of carbohydrates (per unit weight). In addition to being a source of vitamins A, D, E and K, fats and oils also contain essential fatty acids. These essential fatty acids are not manufactured by the body and must be obtained from diets, with linoleic, oleic and linolenic acids as examples

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of unsaturated fatty acids, NRI (1995).

Modern processing of vegetable oils yields valuable products such as oleo chemicals. Oleo chemicals are now largely being used in the manufacture of many industrial products, namely building auxiliaries, candles, and detergents and cleaning agents, cosmetics, fire-extinguishing agents, flotation agents, food emulsifiers, insecticides, lubricants, paints, paper, medicine and chemicals. The meal or cake is used in the formulation and preparation of livestock feeds and food additives.

The production of oil plants takes third place in the world production in terms of value, after starchy plants and fruits, and ahead of beverages and stimulants.

Edible seeds and nuts noted for their oil contents include palm nut, coconut, soybean, olive, groundnut, sunflower seed, and cottonseed, while non-edible seeds and nuts include jatropha seed, neem seed, and castor bean. Moreover, soybean oil has strengthened its dominant role among fats and oils produced based on its quality and nutritional grade. Soybean oil contains linoleic, oleic and linolenic acids that are found in many plant oils. Shortage of these fatty acids leads to deficiency symptoms especially in growing children and animals.

Soybeans oil has the highest content of lecithin (1.1-3.2%) which is a surface-active compound used as an emulsifier in the food and pharmaceutical industries, and other industries, Sigmund, and Gustav (1991). According to Khan and Hanna (1983), the heat of combustion of soybean oil is 39 MJ/kg as compared to diesel fuel with 42 MJ/kg. This makes soybean oil an effective competitor in the petroleum industry.

Among the industries that use oils and fats from oilseeds, apart from the food industry, are the beauty, pharmaceuticals, aromatherapies, building and construction, and the petroleum industry.

The use of petrol diesel has environmental challenges and there is need for an alternative source of diesel which is environmentally friendly and biofuel, a triglyceride of vegetable oils and animal fats has remained a viable substitute for petrol-based diesel, Tarkuba *et al*. (2017). Generally, biofuels are considered as long term renewable energy source with huge potential to address the current environmental and security concerns associated with dependence on fossil fuels (Alamu, *et al*., 2008; Batidzirai, *et al*., 2006, and Gupta *et al*., 2007). Aremu *et al*. (2024) used a ternary azeotropic mixture of water / ethanol / ethyl acetate as extraction solvent, with ranges 5–10% water, 5–10% ethanol, 80–85% ethyl acetate, optimized via D-optimal design under mixture methodology. They characterized the extracted oil: refractive index = 1.454; acid value = 8.39 mg KOH/g; saponification value = 56.12; iodine value = 15.17; peroxide value = 27.00.

Usenu *et al*. (2021) optimized solvent extraction conditions using a mixture (ethanol + ethyl acetate + water) and studied kinetics. The maximum extraction rate they recorded was 32.35 mg oil/min under their optimum solvent proportions and conditions.

In their review, Farouk *et al*. (2024) surveys heterogeneous catalysts (e.g. ashes, metal oxides, base catalysts) for transesterification of soybean and other oils. The review describes general transesterification reaction mechanism (three-step, reversible) and discusses challenges (free fatty acids, water, and catalyst deactivation). On the other hand, Martins *et al*. (2013) synthesized Mg/Al hydrotalcite as a heterogeneous solid catalyst (co-precipitation then calcination) and used it to catalyze soybean oil + methanol reaction. They measured viscosity and GC to confirm ester conversion.

Their best conditions: methanol:oil = 20:1, catalyst 5 % (w/w), reaction time 10 h at 64 °C; achieved 94.8 % conversion of FAME. Panchal *et al*. (2019) used an ionic liquid catalyst ([DDPA][Tos]) in soybean oil + methanol reaction. Optimized conditions: oil : methanol = 1:2 v/v, ionic liquid catalyst = 8.0 % w/v, reaction time = 4 h, 65 °C, agitation 300 rpm. Achieved ~75% biodiesel yield.

This work is considered one alternative of producing a biodiesel from vegetable oil with specific emphasis on soybean oil obtained from soybean seeds.

2. Materials and Equipment

The following materials were used in addition to the required reagents and apparatus found in standard laboratories. All the reagents used in this work were of analytical grade as produced by the respective companies.

2.1 Equipment:

Beaker, Retort stand, Burette, Pipette, Conical flasks, Mortar and pestle, Oven, Glass funnel, Cotton wool, Toilet tissue, Pour point tester, Open metal container, Viscometer, magnetic stirrer, Weighing balance.

2.2 Reagents:

Distilled water, NaOH, n-hexane, and Methanol, HCl.

2.3 Sample collection and preparation

The soybeans undergo various processing in the course of their preparation for oil extraction. Soybean seeds were purchased from a local market at Jalingo Local Government Area, Taraba State, Nigeria. The seeds were selected according to their condition where damaged seeds and some foreign materials were discarded after seeds in good condition were cleaned thoroughly with clean water, sun dried in the open, cracked and de-hulled. The de-hulling was done by cracking the soybeans using mortar and pestle and a separation of the hulls and cracked soybeans was achieved using a tray to blow away the hulls in order to achieve very high yield. The de-hulled soybeans were heated to 105°C for 35 minutes to coagulate the soy proteins to make the oil extraction easier. The de-hulled and heated soybeans were grounded into powder using a grinder prior to extraction in order to weaken or rupture the cell walls to release soy fat.

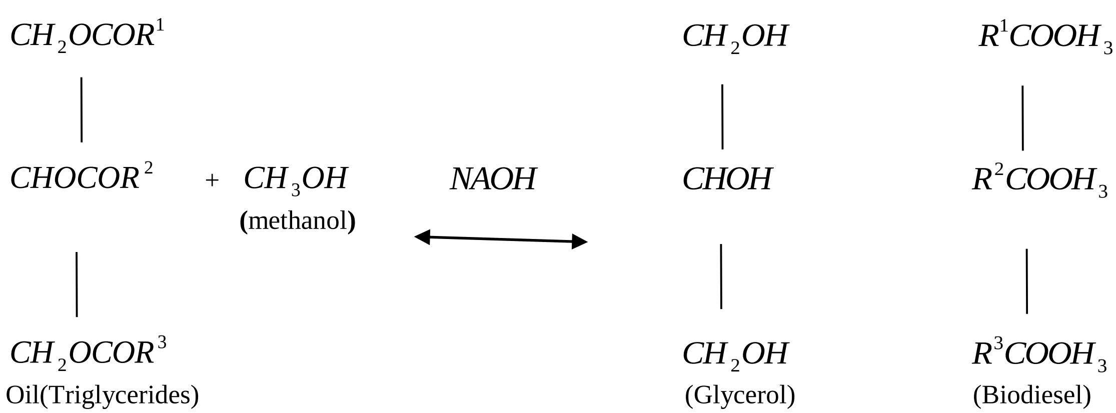
2.4 Extraction of Oil

The oil was extracted according using cold maceration method. 300g of the powder sample was dissolved in 1 litre of n-hexane, stirred and was kept at room temperature for 72 hours with constant stirring every 12 hours. The solution was filtered in a mushily clothes and the filtrate was heated at 30^0C to obtain the oil.

2.4.1 Conversion of the oil to biodiesel (trans-esterification)

Oil sample extracted was used for biodiesel production using a base-catalyzed trans-esterification reaction. Oils containing low free fatty acids level therefore would require 0.30-1.5% of the oil weight as base catalyst. It would require one-fifth of its weight or volume of alcohol for treating triglycerides to produce (biodiesel) fatty acid methyl esters, Gerpen, (2005).

A methanolic solution of NaOH was prepared by dissolving 4g NaOH in 200 mL of methanol. 100 mL of the previously extracted oil was placed in a flask and warm at 55ºC. 20 mL of the methanolic solution was added to the oil and stirred for 15 minutes. The resulting mixture was transferred to a separating funnel. This stood for 1 hour to allow for separation of glycerol (a dark brown colored liquid) and biodiesel (a light yellowish less dense liquid). Excess methanolic NaOH solution was added to the fatty acid methyl ester and stirred again, the mixture was allowed to stand overnight for gradual separation. The oil was trans-esterified into biodiesel using methanol catalyzed by sodium hydroxide. The reaction is shown below:



Scheme 1: Base catalysed transesterification reaction

3. Results and Discussion

The value shown in the Table l below is the result of the physicochemical properties of methyl ester (soybeans oil biodiesel) and ASTM standard for biodiesel. It summaries the result of the physicochemical properties of the biodiesel obtained from soybeans

Table 1: Physicochemical properties of biodiesel

Properties	Units	Standards values	Soybeans biodiesel
Density	g/cm^3	0.860-0.900 (ASTM D36)	0.860
Viscosity	mm^2/s at 40ºC	1.9-6.0 (ASTM D445)	2.81
Flash point	ºC	130 (ASTM D93)	142
Moisture content	%vol	0.06 maximum (ASTM D2709)	0.028
Pour point	ºC	Not given	7

3.1 Density

The density of the biodiesel was 0.860g/cm^3. Therefore, the density of the biodiesel is within the range of ASTM standard.

3.2 Viscosity

Viscosity which is the tendency for a liquid to be resistance to flow. However, the viscosity of the biodiesel is 2.81mm^2/s which is low compared to the range of ASTM standard. Viscosity is one of the important criteria in evaluating diesel quality. High viscosity leads to operational problems including engine deposits.

3.3 Flash Points

Flash point, which is the temperature at which the fuel can ignite when exposed to a heat source, is important from the point of view of safe handling, storage and transportation. The flash point of the biodiesel is 142°C which is high compared to the ASTM standard. This shows that the biodiesel produced have a good flash point and its use will eliminate the fear of fire outbreaks on storage

3.4 Moisture content

Moisture content, which is the amount of water obtained in a product, it influences the physical properties of a substance including weight, viscosity, density and others. The moisture content of the biodiesel was 0.028%V which is low compared to the ASTM standard.

3.5 Pour Point

Pour point, which is the temperature below which a liquid loses its flow characteristics. The pour point was determined to be 7ºC. Although no ASTM standard has been specified for this parameter.

4. Conclusion

This study has shown that most of the properties evaluated from the biodiesel produced conform to the ASTM standard values. It can be concluded from this study that the biodiesel produced from soybeans seed oil can be among the potential replacements of fossil fuel while the production and effective usage of biodiesel will help to reduce the cost of protecting the atmosphere from the hazards in using fossil fuels, waste from the environment and hence will boost the economy of the country.

Recommendation

Based on the findings of this study, it is recommended that soybean seed oil be considered a viable and sustainable feedstock for biodiesel production. Given its favourable physicochemical properties that align with ASTM standards, further investment in the cultivation of soybeans and development of large-scale biodiesel production infrastructure should be encouraged. Additionally, promoting soybean-based biodiesel could contribute to reducing environmental pollution associated with petroleum diesel and enhance energy security through the adoption of renewable energy sources.

On the other hand, it is further recommended that nonedible vegetable oils be used as alternative to edible oils as source of raw materials for biodiesel production. This will help checkmate food insecurity which has become a global phenomenon today.

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