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ASSESSMENT OF THE POTENTIAL EMISSIONSFROM BIODIESEL PRODUCED FROM GROUNDNUT AND SOYBEAN OILS

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Abstract

Biodiesel an alternative fuel to fossil fuel) does not only require production at commercial level, but the production process also needs to be a clean and environmental friendly. This research aim at assessing the potential emissions form the biodiesel produced from the trans-esterification of groundnut oil and soybean oil, using KOH homogenous catalyst. The impact assessment of the potential emissions wasanalysed, quantified and characterized using Simapro 8.2.3.0. Comparatively, soybean biodiesel produced higher yield of biodiesel compare to yield obtained from groundnut oil biodiesel, under same experimental conditions. Also, high yields of biodiesel observed (97.1 % using both soybean oil and 92.1 % using groundnut oil) were at experimental conditions of 52.5^{o}C and catalyst concentration 0.9 wt/wt%, at constant methanol/oil mole ratio of 6 and reaction time of 1 hour. The impact assessment of the emissions from the biodiesels obtained from the two oils revealed that groundnut oil biodiesel has the potential to release more fresh water toxic substances, terrestrial toxic substances and human toxic substances.

***Keywords:** - Biodiesel, Groundnut oil, Impact Analysis, Soybean oil, Trans-esterification.*

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1. INTRODUCTION

Energy is considered a basic need (like food, shelter and clothing) of human life, industry and transportation. It is now a very difficult task to have good food, shelter and clothing without Energy. Globalization, economic growth, living standard improvement and electrification have pushed energy demand up in all sectors. Hence its production, consumption and management have become of a global interest[1]-[3].

Statistics show that fossil fuel is the primary source of energy across the globe. The increasing challenges associated with the dependency on fossil fuel (such as fluctuating market price at the global market, fuel sustainability and environmental degradation) prompted the world leaders, organisations, industries and educational institutions to look for alternative energy sources that are sustainable, with less negative environmental impact. Energy production from biomass such as crop oils, woody and waste materials has a great advantage over fossil fuel [3]-[7]. The energy producing substances derived from biomass are referred to as biofuels (such as biodiesel, bioethanol).

Biodiesel is commonly produced through transesterification process. This is a process which involves reversible reaction between lipids (triglycerides of vegetable oils or animal fats) and short chain alcohol (methanol or ethanol) in the presence of a suitable catalyst [8]-[10].Some of the factors that affect the yield of biodiesel include reaction time, reaction temperature, catalyst concentration, methanol/oil mole ratio, speed of agitation etc. [11]-[12].
Non-edible and edible vegetable oils (such as soybean oil, palm oil and groundnut oil) can be used for biodiesel production, and the fuel produced (biodiesel) can be introduced directly into diesel engine without engine modification. It also prolongs the life of diesel engine and this reduces the need for frequent maintenance [13]-[15].

While the production technology of biodiesel remains an easily adaptable one for even rural dwellers who have no access to advanced technology, the production of high quality biodiesel is an uncompromised scientific process that requires thorough analyses of the feedstocks, chemical reagents and production process. The analyses are important in order to understand the environmental implications and benefits associated with the biodiesel as biofuel. And these analyses include potential emission assessment of biodiesel [17]-[19].

The potential emission assessment of biodiesel involves the use of analytical tool with a scientific approach in predicting, quantifying and comparing the environmental

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impacts of emissions from biodiesel, feedstocks and technologies (existing and emerging). Results from the assessment can aid Governments, consultants, academicians, and industries in the decision making process by incorporating green design objectives into engineering-related ones and by revealing the most suitable vegetable oil for biodiesel production [18]-[19].

In this research work, comparative analysis of the environmental impacts of the use of groundnut oil and soybean oil, as feedstock, in the production of biodiesel will be considered. That is, analysis of the potential emission from the biodiesel produced from groundnut oil and soybean oil will be comparatively investigated.

2. RESEARCH METHODS

2.1 Materials, Reagents and Equipment

The groundnut and soybean oils used were obtained in a local market in Ota, Ogun state, Nigeria. The chemical reagents used include n-hexane (97%, Sigma-Aldrich, UK), Ethanol (98%, Sigma-Aldrich, UK), methanol (98%, Romil Ltd UK), Sodium Hydroxide (97%, Qualikems, India), Potassium Hydroxide pellets (96%, J.T Baker, USA), Hydrochloric acid (97%, Sigma-Aldrich, UK), Tetraoxosulphate(VI) acid (97%, J.T Baker, USA), and benzene 97.7%, Riedel-Dietaen, Germany).

The equipment used during the research work include Atomic Absorption Spectroscopy (AAnalyst 200 Perkin Elmer precisely, USA), C 99 Multiparameter Bench Photometer HANNA, Pensky-Martens Automatic Closed Tester, (Normalab NPM 440) with Refrigerating cooling system, Viscometer Bath VB-1423 (P SELECTA) with U tube Ostwald Viscometer and pipette filler (Spain). Julabo F12 (France), Cimarec Digital Magnetic Stirring Hot Plate (7.25" x 7.25", USA), Anton Paar DMA 38 Density Meter (USA).

2.2 Properties of the Oils Used

The properties of groundnut oil and soybean oil considered include: acid value, water content, density and kinematic viscosity.

2.3 Design of Experiment and Biodiesel production

Minitab 16 software was used for the design of experiments, using factorial method. Reaction time of 1 hour and methanol/oil mole ratio of 6 were kept constant throughout the experiment. The two variable parameters considered during the experimental work were reaction temperature (50–60) and catalyst concentration (0.6–1.2 w/w oil). Biodiesel production was carried out using soybean oil and groundnut oil (separately), as reported by [17].

2.4 Elemental Analysis of the Potential Emissions from Biodiesel

Elemental analysis of the potential emissions from the biodiesel produced was done in the Instrumentation Laboratory Covenant University.

2.4.1 AAS Analysis of Biodiesel

Each of the digested biodiesel samples was aspirated into the nebulizer compact of AAS where the sample mixed with air and acetone to form a mixture. Flame burned and atomized the sample from ground state to the excited state. At excited state, absorption occurred and the monochromator selected the wavelength in agreement with the atom. The detector detected the atom and then transferred the concentration reading to the reader.

2.5 Impact Analysis of the Potential Emissions from Biodiesel

Impact assessment of the potential emissions from the biodiesel produced was performed using Simapro 8.2.3.0 software, the method adopted is ReCiPe Midpoint (I) V1.12 / World Recipe I. Characterizationof the potential emissions from biodiesel was carried out. The four midpoint categories considered, under characterization, are Freshwater Eutrophication, Human Ecotoxicity, Terrestrial Ecotoxicity and Freshwater Ecotoxicity.

3. RESULTS AND ANALYSIS

3.1 Physical Properties of Oils

Table 1 shows the values of the physical properties of the two oils used for biodiesel production. The values are within the standard values of these properties and this implied that the two forms of oil were suitable for trans-esterification process.

Table 1: Properties of Groundnut oil and soybean oil used

S/N	Oil Type	Density (g/cm^3)	Viscosity (mm^2/S)	Flash point (^0C)	Water content (%)	Acid value (mg KOH/g)
1	Groundnut oil	0.923	57.92	321	0.85	3.6
2	Soybean oil	0.917	40.87	318	0.23	2.1

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3.2 Biodiesel Yields

Biodiesel yield obtained during the transesterification of soybean oil and groundnut oil (separately) are shown in Table 2 and Figure 1.

Table 2: Biodiesel yield obtained from the transesterification process.

Experimental Run	Time (hour)	Methanol/ Oil mole ratio	Conc. of Catalyst (KOH) (w/w %)	Reaction temperature (^oC)	Biodiesel Yield using Soybean Oil (%)	Biodiesel Yield Using Groundnut Oil (%)
Run 1	1	6	0.60	50.0	96.2	91.6
Run 2	1	6	0.60	60.0	96.1	91.5
Run 3	1	6	1.20	50.0	96.0	90.9
Run 4	1	6	1.20	60.0	96.0	90.8
Run 5	1	6	0.90	55.0	95.4	90.2
Run 6	1	6	0.90	52.5	97.1	92.7
Run 7	1	6	0.90	57.5	95.6	90.7
Run 8	1	6	0.75	55.0	96.0	91.5
Run 9	1	6	1.05	55.0	95.7	90.8

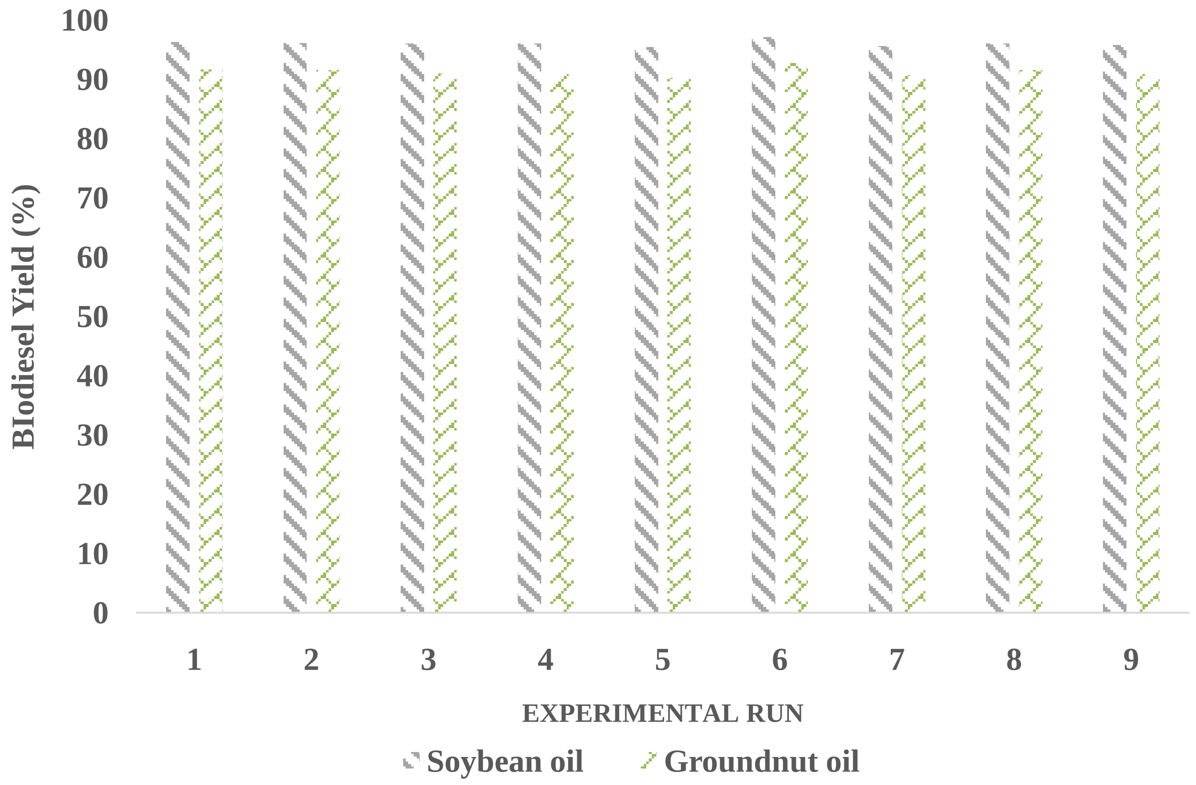

Fig 1: Biodiesel yield obtained from soybean and groundnut oils

The results showed that soybean oil produced higher yield of biodiesel compare to the yield obtained from using groundnut oil, under same experimental condition. And that the highest biodiesel was obtained (for both soybean oil and groundnut oil), at the experimental condition of the reaction time of 1 hour, methanol/oil mole ratio of 6, KOH catalyst concentration of 0.90 w/w oil and reaction temperature of 52^0C (experimental run 6). This result was also reported by [17], [20]-[21].

Table 3 shows the properties of biodiesel obtained during the trans-esterification process, the conformity of all these physical properties with the standard established the fact that biodiesel was obtained.

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Table 3: Properties of the biodiesel obtained from the two vegetable oils

Property	Unit	Standard Value	Soybean Biodiesel	Groundnut Biodiesel
Density	g/cm^3	0.860–0.900 (ASTM D36)	0.876	0.885
Viscosity	mm^2/s @ 40 ^0C	1.9 – 6.0 (ASTM D445)	2.92	4.99
Flash point	(^0C)	130 min (ASTM D93)	140	139
Water content	% vol	0.06 max (ASTM D2709)	0.03	0.12

min = minimum, max = maximum

3.3 Characterization of the Potential Emission from Biodiesel

The non-environmentally friendly substances analysed from the production of biodiesel were characterized into four (4) midpoint categories, these are Fresh water eutrophication, Human toxicity, Aquatic Ecotoxicity and Terrestrial Ecotoxicity. Based on the total quantity of biodiesel produced, the potential emissions from biodiesel are as shown in Table 4.

Table 4: Inventory Table of the Potential Emissions from the two kinds of Biodiesel

No	Substance	Compartment	Unit	Groundnut Biodiesel	Soybean Biodiesel
1	Cadmium	Water	mg	10	10
2	Cadmium	Soil	mg	10	10
3	Chloride	Water	mg	200	200
4	Chloride	Soil	mg	200	200
5	Copper	Water	mg	40	40
6	Copper	Soil	mg	40	40
7	Nitrate	Water	g	46.99	18.41
8	Nitrate	Soil	g	46.99	18.41
9	Nitrate	Water	g	1.65	4.70
10	Phosphate	Water	g	5.04	3.68
11	Phosphate	Soil	g	5.04	3.68
12	Sulfate	Water	g	200	200
13	Sulfate	Soil	g	200	20
14	Zinc	Water	mg	110	30
15	Zinc	Soil	mg	120	30

Figure 2 shows the four midpoint categories expressed in percentage (%). Simapro 8.2.3.0 software was used in the classification of the potential emissions into the midpoint categories. In each category, biodiesel with the higher value of non–environmentally friendly substance was assigned 100%. Considering Freshwater Eutrophication, for instance, groundnut oil biodiesel was assigned 100% due to its higher value of substances that accounted for Freshwater Eutrophication.

Comparatively, groundnut oil biodiesel production released the more harmful substances into the environment in all the four midpoint categories, and used to obtain the percentage of substances released for soybean biodiesel production through all four midpoint categories.

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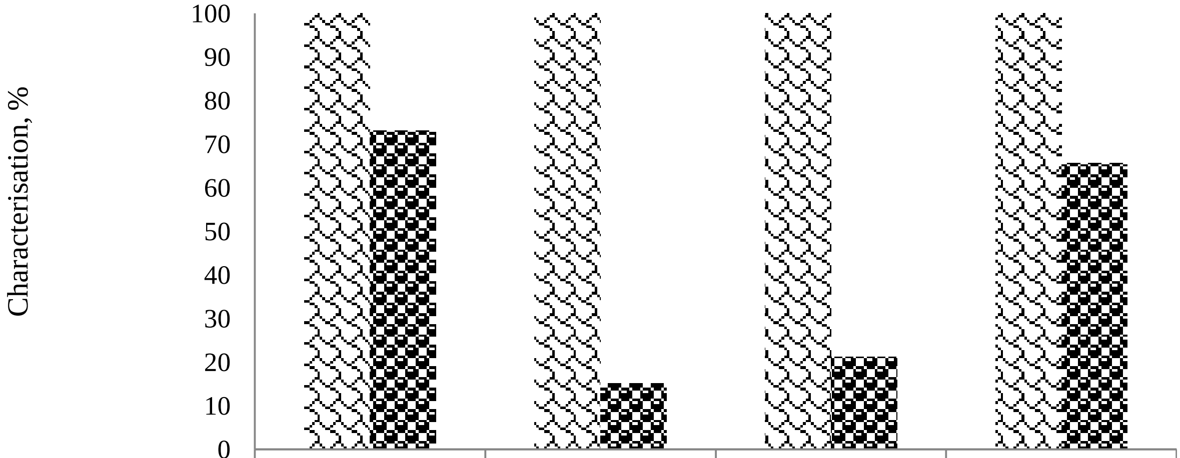

	Freshwater Eutrophication	Human Ecotoxicity	Terrestial Ecotoxicity	Freshwater Ecotoxicity
Groundnut Biodiesel	100	100	100	100
Soybean Biodiesel	73.03	15.13	21.14	65.63

Fig 2: Characterization of substances released from the production of biodiesel using groundnut and soybean oils

3.3.1 Freshwater Eutrophication

Eutrophication is the enrichment of water body with nutrients, usually excessive amount of nutrients. Eutrophication is mostly caused by the discharge of phosphate containing compounds into the aquatic ecosystem. In most cases, this causes massive production of microorganisms (algae boom) and the death of some aquatic animals [18]-[19].

In this category, the analysis showed phosphate to be the sole substance likely to be released into the water from the production of biodiesel. The quantity of phosphate likely to be released into water by the usage of the biodiesel from groundnut oil biodiesel production was higher than that released from soybean biodiesel. From Figure 2, groundnut oil biodiesel had 100% freshwater eutrophication while soybean oil had 73.02% freshwater eutrophication.

3.3.2 Human Ecotoxicity

The emission of some substances (e.g. heavy metals) can have negative impacts on human health. The analysis and assessment of the toxicity are based on tolerable conditions in air, water or soil using their human toxicity potential. The human toxic substances identified in this analysis are zinc, copper and cadmium.The assessment of this category revealed that soybean biodiesel production released lesser toxic substance into the environment causing 15.13% release of substances while groundnut oil biodiesel generates 100% of these substances. It is important to mention that the amount release is insignificant compared to the amount of biodiesel produced, so the likely effect on human may be mild.

3.3.3 Terrestrial Ecotoxicity

Terrestrial Ecotoxicitycan simply be defined as the study of the effect of chemical substances to terrestrial organism and terrestrial plants. Result showed that groundnut oil biodiesel releasedhigher harmful substances in this category with 100% of terrestrial substances release and soybean oil biodiesel released 21.14% of substancesthat threaten the healthy survival of the terrestrial plants.

3.3.4 Freshwater Ecotoxicity

Freshwater is a crucial component in the global ecosystem and it is important to human existence. The pollution of fresh water not only poses a risk to the environment but also on human health. The toxic substances identified in Freshwater Ecotoxicity include cadmium and chloride. The percentage of the potential freshwater toxic substances releasedfrom groundnut oil biodiesel was assigned 100% while soybean oil biodiesel released 65.63%.

4. CONCLUSION

The following conclusion can be made from this research work:

1. KOH catalyst is suitable for the trans-esterification of soybean oil and groundnut oil, with soybean oil producing higher yield of biodiesel under same experimental conditions.
2. High yield of biodiesel observed was at experimental conditions of 52.5^{o}C and catalyst concentration 0.9wt/wt%, at constant methanol/oil mole ratio of 6 and reaction time of 1 hour.

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3. The Impact assessment of the emissions from the biodiesels obtained from the two oils revealed that groundnut oil biodiesel has the potential to release more fresh water toxic substances, terrestrial toxic substances and human toxic substances.

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