OMANARP INTERNATIONAL JOURNALOF ENGINEERING.

Vol. 1, Pp. 1-9; NOVEMBER; 2024

OMANARP INTERNATIONAL JOURNAL OF ENGINEERING

ENVIRONMENTAL IMPACT ANALYSIS OF A BIOLUBRICANT USING LAGENARIA BRIVIFLORA SEED OIL

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ARTICLE INFO

Received Date: 8th Sept; 2024
Date Revised Received: 20th Oct; 2024
Accepted Date: 1st November, 2024
Published Date: 21th November; 2024

Citation: Yerima Y; Ekpendu, C.R; Anselm. I.I; Azuokwo A.A; Turu E;M; WirsiyF.N; & Azike, R.U; (2024). Environmental Impact Analysis of a Biolugbricant Using Lagenaria Briviflora Seed Oil.OMANARP INTER. J. Engr. Vol.1, Pp. 1-9,Nov. 2024.

ABSTRACT

Biolubricants play a significant role in promoting sustainability in Africa due to their eco-friendly characteristics, potential to reduce dependence on fossil fuels, and opportunities for local production. By promoting biolubricants, Africa can move towards a more sustainable future, reducing environmental impact, fostering economic growth, and improving social well-being, This work investigated the impact of biolubricant on the environment specifically on water and soil. Extraction of oil from the seeds of *Lagenaria breviflora* was done using Soxhlet apparatus and n-hexane as the solvent. Physical and chemical characteristics of the oil were examined, and the results indicate that the extracted oil was a liquid at room temperature, brownish in colour, and odorous. The results were as follows: density (0.8953 g/cm^3), FFA (13.8), peroxide value (3.94 MeqO$_2$/kg), acid value (26.162 mgKOH/g), saponification value (253.571 mgKOH/g), and value for oxidation (3.94 MeqO$_2$/kg). FTIR and GC-MS analysis were also used to characterize the oil. The study' findings show that the extracted oil is of good grade. Esterification and transesterification of the oil was carried out to produce the biolubricant used for the study. The biolubricant was compared with that of the petroleum lubricant in terms of environmental safety and compared with World Health Organization (WHO) standards. The water quality parameters analysed includes temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD). The environmental impact of both lubricants on soil was carried out by monitoring the growth rate of plant when exposed to the soil contaminated by these lubricants. Three samples were prepared, A (Control), B (biolubricant contaminated water) and sample C (petroleum lubricant contaminated water). The growth rate of beans seed planted on the contaminated soil was monitored. The result showed sample B to be better that sample C, highlighting that the biolubricant was more suitable than the petroleum lubricant in terms of environmental safety consideration.

KEYWORDS: Extraction, Esterification and Trans esterification, Environmental impact, Characterization.

1. INTRODUCTION

In global economic growth energy plays a vital role and fulfils active social needs of the society (Yen *et al,* 2021, Taauseef *et al,* 2022).The demand for energy is growing by the day (Azad *et al*, 2020). Most of the energy currently produced worldwide is from fossil fuels which are neither sustainable nor environmentally friendly (Khan *et al*, 2022). The world's economic sustenance, as based on the oil industry, has originated serious environmental issues (George *et al.*, 2011; Iturbe *et al.*, 2007; Ortiz *et al*., 2005; Hall *et al*., 2003). Today, the environmental threats posed by fossil fuels are currently a big global concern in the world today (Ogundigie *et al*, 2023, Khalifa *et al*, 2022, Owuna *et al.* 2019). At every stage of their usage, including extraction, transportation, and consumption, fossil fuels seriously harm the environment and have an adverse impact on nearby communities **(Khan *et al* 2022**). Most notably, the combustion of fossil fuels results in approximately 89% of all carbon dioxide emissions, or 35 billion tonnes (35 Gigatonnes) of carbon dioxide annually (Ambrose & Jillian, 2020). The primary greenhouse gas responsible for both ocean acidification and global warming is carbon dioxide. Most air pollution is unintentionally caused by the combustion products of fossil fuels; it is estimated that this pollution costs more than 3% of global GDP (Lauri, 2020), and that the phase-out of fossil fuels would save 3.6 million lives annually (Zhang, 2020). Nowadays the technological and industrial development has to be environmentally responsible in accordance with the global needs. That is why the creation of new technologies and resources exploitation must be based on a responsible energetic development. Regarding this matter, being environmental friendly is a main goal for the society (Rodríguez et al., 2009). Alternative energy sources to petroleum-based fuels and oils are needed due to the depletion of the world's petroleum reserves, global warming, and environmental devastation brought on by oil exploration (Nawaz *et al*, 2022, Hameed *et al*, 2022).

Most lubricants are produced from petroleum based products that are not safe for the environment (Igbafe *et al*, 2020, Kamtu *et al*, 2023). Additionally, mineral oil is less biodegradable than other lubricants, with a range of 15 to 35 percent biodegradation, falling short of the 80 percent recommended biodegradation rate for ecologically friendly lubricants (Nadia & Jumat, 2021). There is a great interest in developing alternative lubricants such as biolubricants to address issues related to mineral lubricants that can reduce the use of mineral oil due to their environmental friendly behaviour, biodegradable, and have a high viscosity index (McNutt & He, 2016, Ozgulsun *et al*., 2000). Biolubricants can be formed from various sources, including edible oil, non-edible oil, agricultural residues, animal waste, etc (Kazmi *et al*, 2022, Hagstrom, 2005, Celicia *et al,* 2020, Gawrilow, 2004). Such lubricant offer intrinsic benefits regarding technical characteristics, such as, high lubricity, high anti-wear properties, high viscosity index high flash point, though regrettably has poor cold-flow properties and oxidation stability resulting in polymerization and degradation.

Transesterification is one of the most practical ways to convert vegetable oil to esters and overcome its drawbacks. Glycerol is a by-product of transesterification that produces mono-alkyl esters, or biodiesel (Knothe *et al*, 2005). Transesterification increases volatility while decreasing molecular weight and viscosity, while keeping the cetane number and heating value the same (Bello *et al*, 2013). Environmentalists have recently begun debating the drawbacks of producing biofuels from edible oils because to the widespread production of biodiesel from edible oils, which has the potential to bring world food supply and market demand into balance (Khan *et al*, 2021). This paper investigated the manufacture of biolubricant from a non-edible biomass (*Lagenaria breviflora*) seed oil in order to maximize its potential as a feedstock. The pesticide plant *Lagenaria breviflora* B. Robert (Cucurbitaceae), a native of Nigeria, was used to make the biolubricant. Its fruits are frequently employed as depilatory and antiseptic agents, as well as traditional remedies for a variety of viral illnesses. Triterpenoids, saponins, phenols, alkaloids, anthraquinine, flavonoids, tannins, and terpenoids are the primary chemical components of *L. breviflora* fruit. This biolubricant will benefit the bio-based business and provide an answer to the problem of producing a non-toxic, biodegradable, and eco-friendly lubricant for sustainable African economy.

2. METHOD

2.1 Synthesis of the lagenaria bieviflora Bio-lubricant

Materials: The materials used in the study included seeds of *Lagenaria breviflora*, n-hexane 98%, methanol 99.8% and potassium hydroxide pellet 95% of analytical grade BDH chemicals, trimethylolpropane, sodium methoxide, Soxhlet apparatus, 0 -100^{0}C thermometer, model N-1110S rotary evaporator (Rikakikai, Tokyo), separating funnels, pycnometer.

***Lagenaria bieviflora* bio-lubricant synthesis:** In this study, bio-lubricant of *lagenaria breviflora* oil also referred as *lagenaria breviflora* oil biolube was synthesised from *lagenaria breviflora* oil biodiesel, technically known as *lagenaria breviflora* oil fatty acid methyl esters which was obtained from the transesterification of the fatty acids of the oil extracted from *lagenaria breviflora* seeds in line with the procedures described elsewhere (Ebtisam, 2017).

2.2 WATER ANALYSIS AFTER CONTAMINATION

2.2.1 pH:

Using an automatic digital pH meter, pH was measured. Standard bu ffer solutions were used to calibrate the pH meter initially. In order to clean the glass electrode, distilled water was used. After that, until the reading steadied at a particular point, the glass electrode was dipped into the beaker containing the water sample. The pH reading was then recorded.

2.2.2 Electrical conductivity

The electrical conductivity (EC) was determined using conductivity/TDS/DO meter model 4520 (Jactson, 1976; ASTM, 1979). The meter was switched on and allowed to stabilize for 10 mins. The meter was calibrated by immersing the probes in KCl solution. The probe was rinsed and immersed in the sample solution. The conductivity value was then read.

2.2.3 Dissolved Oxygen (D.O):

Using the dissolved oxygen meter JENWAY-3405, the value of dissolved oxygen (DO) was read on the spot (Manufacturer: Barloworld Scientific Ltd-England). Readings were taken directly after the meter probe was inserted into the sample.

2.2.4 Biological Oxygen Demand (B.O.D):

The amount of biological oxygen demand (BOD) in the water samples was determined using modified Winkler's APHA 1995. The dissolved oxygen (DO) in the sample was first determined as DO_1. The sample was also aerated thoroughly and seeded with a little diluted domestic wastewater (1-2 mL per litre). A screw-topped incubation bottle was filled to the brim with the remainder of the diluted water, and was sealed and incubated in the dark for 5 days at 20 ^oC. Dissolved oxygen (DO_2) determination was carried out on a suitable portion for the incubated sample by allowing for dilution of the sample.

$$BOD = DO_1 - DO_2. \quad (1)$$

2.2.5 Chemical Oxygen Demand (C.O.D.)

The amount of chemical oxygen demand (COD) in the water samples was determined using ASTM D 1252, APHA 508 dichromate method. 50 mL of the sample was pipetted into a conical flask, 10 mL of 0.00833 M $K_2Cr_2O_7$ solution and 1 g of $HgSO_4$ and 80 mL of $Ag_2SO_4.H_2SO_4$ solution with few beads were added to the pipetted sample. A reflux greaseless condenser was fit into the conical flask, heated gently to boiling for exactly 10 min, left to cool and the condenser rinsed with 50 mL of water, while the flask was cooled under running tap. Two drops of ferroin indicator was added to the solution and titrated with 0.025 M Fe $(NH_4)(SO_4).6H_2O$ until the colour changed from blue-green to red-brown. Blank determination was also done on 50 mL of water. The difference in value between the two titres gave the titre of the sample.

2.2.6 Temperature

The temperature of the water was measured with the aid of a thermometer and readings were taken on spot.

2.3 SOIL ANALYSIS AFTER CONTAMINATION

The beans seed was planted in 4 different soil samples; soil contaminated with biolubricant, petroleum lubricant, a mixture of petroleum lube and biolubricant, and the uncontaminated soil. The soil type used was loamy soil. Growth rate was measured at every interval of 4 days for each soil sample using a metre rule.

3.0 RESULTS AND DISCUSSION

3.1 Physical and Chemical Properties of Lagenaria Breviflora Oil

Table 1: Physco-chemical properties of *Lagenaria breviflora* seed oil

PARAMETERS	L.*breviflora*[1]	L.*breviflora*[2]	L.*breviflora* (This work)
% Yield	22.50	29.50	22.20
Odour	Slightly Pungent	Pleasant	Pleasant
Colour	Greenish brown	Brown	Brown
State	Liquid	Liquid	Liquid
Peroxide Value (Meq.O_2/kg)	5.60	7.50	3.94
Acid value (mgKOH/g)	2.50	5.57	26.20
Iodine Value (mgI_2/g)	110.70	110.0	112.20
Saponification value (mgKOH/g)	211.78	213.18	253.571
FFA (%)	2.20	2.8	13.08
Density(g/cm^3)	NA	NA	0.8953

Table 1 lists and contrasts the oil's physio-chemical characteristics with those of other oils from the literature. The primary oxidation level and consequent likelihood of it going rancid are indicated by the peroxide value. A lower peroxide value, such as the one in the Table 1 (3.94 Meq.O_2/kg), denotes good oil quality and preservation. Due to the fact that free fatty acids are typically produced during the breakdown of triglycerides, acid value is a relative indicator of rancidity. The high prevalence of palmitic, oleic, lauric, and ricinoleic acids is what causes the high acid value/FFA that has been found. The saponification value calculates the amount of free acids and ester in a substance. The oil's high levels of saponification suggest that it contains a lot of triacylglycerol, which is consistent with a high ester value (>99%).

3.2 Physical and Chemical properties of Lb. Biolubricant

Table 2: Comparative Physico-chemical properties of Lb. biolubricant with other and standards

Parameter	Method	*L. breviflora* Biolubricant (This study)	*L. Siceraria* Biolubricant[1]	Natural Esters[2]	IEC 61099 specification[3]
Acid Value mg KOH/g	ASTM D664	0.765	2.72 ± 1.03	N/A	<0.03
Iodine Value, mg I_2 g^{-1}	ASTM D4607	1.25	1.28 ± 1.40	N/A	N/A
FFA, %	ASTM D5555-95	0.3825	N/A	N/A	N/A
Biolubricant Yield, %		88.74	N/A	N/A	N/A
K. Viscosity mm/s^2@ 40^{o}C	ASTM D445	29.214	9.59 ± 0.02	36	<35
D. Viscosity, mP.s @ 40^{o}C	ASTM D445	26.1	N/A	N/A	N/A
Viscosity index	ASTM D2270	180.5	181 ± 0.01	316	254
Density, g/cm^3 @ 30^{o}C	ASTM D1298	0.8934	N/A	N/A	N/A
Flash Point, ^{o}C	ASTM D92-12b	213.0	230 ± 1.20	254	≥250
Pour Point, ^{o}C	ASTM D92-12	-10.0	-30 ± 0.03	-21	≤ -45
Oxidation Stability	ASTM D2272	5hrs 17mins	N/A	N/A	N/A

[1]Owuna *et al*, 2018. [2]Raof *et al*, 2022. N/A – not available

[3]IEC, 61099 - Insulating liquids - Specifications for unused synthetic organic esters for electrical purposes.

3.2.1 Viscosity index

The most important lubricating function for an adequate protective film thickness is highly dependent on fluid viscosity, making it the most important characteristic for lubricant selection and application (Rashmi *et al.*, 2017; Zulkifli *et al*., 2013). The viscosity should be high enough to provide a thick film between moving components even at high temperature and pressure, yet low enough to keep the lubricant fluid around each component part (Sharma & Sachan, 2019).

The viscosities of products at 40 ˚C are generally much greater than the viscosities at 100˚C due to the fact that intermolecular forces resisting flow in liquids such as hydrogen bonds and Van der Waals forces are largely broken down at higher temperatures. The viscosity index of the produced Lb. biolubricant was found to be 180.5 while that of *L. Siceraria* was 181±0.01 (Table 2), and is lower compared to a value of 195.22 for Jatropha biolubricant (Bilal *et al*, 2013), a value of 225.36 for modified Jatropha oil (Jeevan & Jayaram, 2018), and a value of 219.00 for modified *Pongamia* oil (Jeevan & Jayaram, 2018). Though the viscosity index of the synthesized biolubricant was within the standard for engine oils (Owuna *et al*, 2018; Mukhtar *et al*, 2014; Danjuma & Dandago, 2009), Lb. biolubricant will experience greater changes in its viscosity with change in temperatures compared to Jatropha lube oil, modified Jatropha oil, and modified *Pongamia* oil.

3.2.2 Flash point

The propensity to fire hazards of products is determined by the flash and fire points. The flash and fire points of the biolubricant is slightly lower than that of *L. Siceraria* biolubricant showing the enhanced thermal resistance of the product of transesterification. The flash point of the produced Lb. biolubricant was found to be 213 °C but lower compared to that of *L. siceraria* 230 ±1.20 °C (Table 2). These products are therefore classified as non-hazardous products because of their high flash points. The flash point of a lubricant refers to the temperature at which some vapour is emitted from the substance to momentarily ignite a flame (Alang *et al*, 2018). The high flash point confirmed that *Lb*. biolubricant has oxygen atoms in its molecular structure, and hence has low risk associated with vapourization during transportation and storage (Dabai *et al*, 2018; Owuna *et al*, 2018). The approximate results are in the range of those reported by Alang *et al* (2018) flash point for palm kernel oil (PKO) biolubricant as 210˚C while Aji *et al.* (2015) which gave the flash point of Neem biolubricant as 262˚C and that of Jatropha biolubricant as 274˚C (Bilal *et al*, 2013).

3.2.3 Pour point

Pour point is the temperature below which biolubricant ceases to flow and is measured using ASTM D97-17b standard. This low temperature property is essential when machinery using hydrodynamic journal bearing has to perform at lower temperatures (Raof *et al,* 2022). The pour point of the produced Lb. biolubricant was found to be -10 °C compared to that of L. *Siceraria,* -30 ± 0.03 (Table 2) which could be attributed to some trace FFA (0.3825 %), and it is lower compared to a value of -7 °C for Jatropha biolubricant (Bilal *et al*, 2013), a value of -03.00 °C for modified Jatropha oil (Jeevan & Jayaram, 2018), and a value of -02.00 °C for modified *Pongamia* oil (Jeevan & Jayaram, 2018). The large differences in the pour points between the biolubricants, *Lb*. biolubricant and that of *L. siceraria* was as a result of additives formulated with the produced *L. siceraria* biolubricant which were absent in the others (Dabai *et al*, 2018).

3.2.4 Acid value

The acid value of the Lb. biolubricant was found to be 0.765 mg KOH g^{-1} which is at variant with that of *L. siceraria,* 2.72±1.03 mg KOH g^{-1} (Table 2) when compared, and it is higher than a value of 0.05 mg KOH g^{-1} for modified jatropha oil (Jeevan & Jayaram, 2018) and a value of 0.13 mg KOH g^{-1} for modified *Pongamia* oil (Jeevan & Jayaram, 2018). This shows that requisite additives are necessary to enhance the usefulness of the produced biolubricant for any particular application as in the case of *L. siceraria* (Dabai *et al*, 2018, Christensen *et al*, 2017; Danjuma & Dandago, 2009).

3.2.5 Iodine value

The iodine value of the produced Lb. biolubricant was found to be 1.25 mg I_2/g when compared to that of *L. siceraria*, 1.28 ± 1.40 mg I_2 g^{-1} (Table 2), and it is lower compared to a value of 22.00 mg KOH g^{-1} for modified jatropha oil (Jeevan & Jayaram, 2018) and a value of 21.41 mg KOH g^{-1} for modified *pongamia* oil (Jeevan & Jayaram, 2018). This shows that the produced *Lb*. biolubricant has fewer methylene interrupted double bonds in its molecules and has high resistance to oxidation reactions than modified Jatropha oil, and modified *Pongamia* oil (Dabai *et al*, 2018, Owuna *et al*, 2018; Christensen *et al,* 2017). This work has indicated the feasibility of an alternative process for biolubricant using unexploited material from the agriculture industry.

3.3 Water Analysis

The major water quality parameters that affect aquatic life includes dissolved oxygen (DO), Temperature, pH, Nutrients, Turbidity, Salinity, Conductivity, Chemical Oxygen Demand (COD) and Biological oxygen demand (BOD). Maintaining these parameters within optimal ranges is essential for the health of aquatic ecosystems.

3.3.1 pH

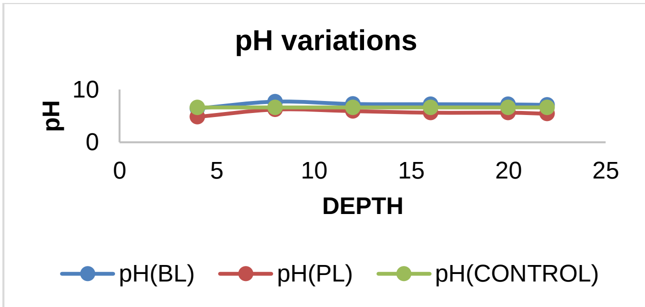

Figure 1: pH values of polluted water at various depths

If the pH is too high or low, the aquatic organisms will die, majority of aquatic organisms and microbes that survive in aquatic environment are neutrophils that prefer a pH range of 6.5-9.

3.3.2 Electrical Conductivity

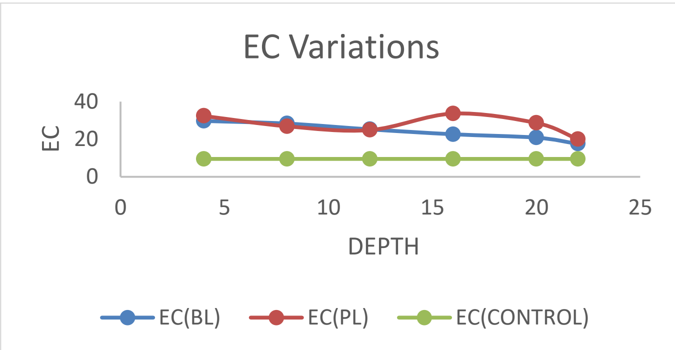

Figure 2: Electrical conductivity values at various depths

A high conductivity indicates that there is much concentration of ions in the water. Conductivity also depends upon the temperature of the water, as temperature increases, conductivity increases and vice-versa. Some aquatic life can't survive in a water with large concentration of conductivity because they won't be able to keep water in their bodies. Results also tallied with that of (Ndeh *et al* 2017).

3.3.3 Dissolved Oxygen

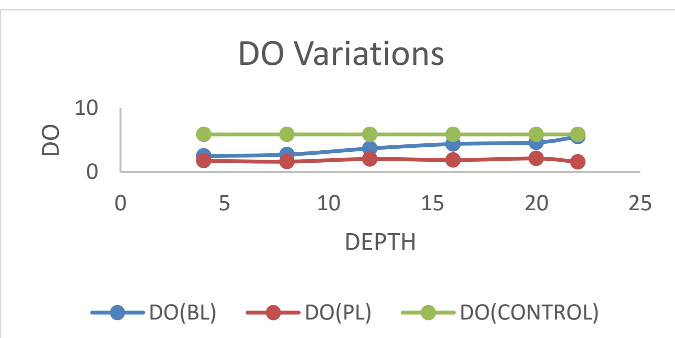

Figure 3: Dissolved oxygen of polluted at various depths

Dissolved oxygen is the level of free oxygen present in water, plants and animals use D.O to survive, and a D.O that is very low is deleterious to the aquatic life. From Fig 3, the D.O of the petroleum lubricant kept reducing as depth increased. This is a very bad because it shows that the petroleum lubricant when deposited into water bodies would kill aquatic lives. Results also tallied with that of (Ndeh *et al* 2017). Gnerally, a minimum of 5 mg/L is required to support most aquatic life though some species may need higher levels.

3.3.4 Biological Oxygen Demand (B.O.D) Variations

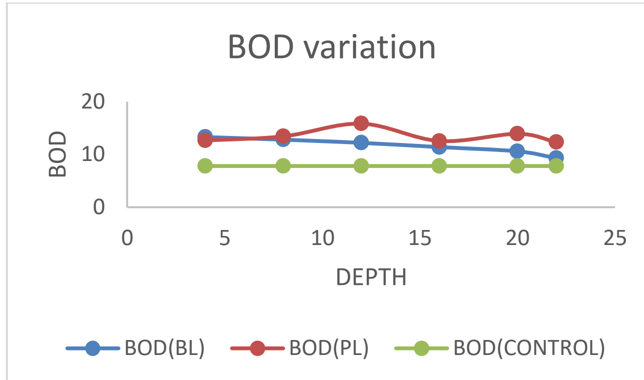

Figure 4: Biological oxygen demand of polluted water at various depths

A high BOD is harmful to ecosystem as fish and other organisms may suffocate in oxygen depleted waters. When BOD is high, microbes will deplete away the D.O and cause other species to suffocate. High BOD concentration in water body is an indicator of high organic loads with consequent effects on D.O. Fig 4 clearly shows the different contaminated water samples and their BOD variations. The biolubricant kept reducing as depth increased but the petroleum lubricant was fluctuating, which keeps the environment unsafe for the aquatic lives. Results also tallied with that of (Ndeh *et al* 2017).

3.3.5 Chemical Oxygen Demand Variations

A high COD values means a greater amount of oxidizable organic material in the sample, which will reduce D.O thereby leading to an anaerobic environment which is deleterious to aquatic life. From figure 4, the petroleum lubricant had a very high COD level at first depth which indicates that it is more harmful than the biolubricant when compared, to the aquatic lives. Results also tallied with that of (Ndeh *et al* 2017).

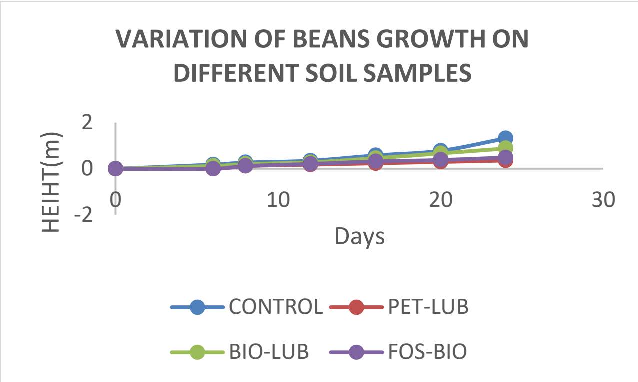

Figure 6: Plant growth of cow pea on lubricant polluted soils

There is a systemic and synergic interaction of the effects of the hydrocarbon polluted soils; in this sense, all of the ecosystems' components are altered, which affects the soils' properties, the present microorganisms, and even the plants' growth and reproduction, endangering the ecosystems' sustainability (Palma-López et al., 2007). From Fig 6 the control had no effect on growth rate, because it had no contaminants. But the contaminated soil had some effects except that of the biolubricant, the petroleum lubricant and the mixture (petroleum and bio lubricant) had difficulty and delay in growth, even at day 24 while the control and the biolubricnt kept growing, the pet-lube and the fos-bio struggled. From the works of (Igbafe *et al, 2021*), the biolubricant oil was better than the petroleum diesel oil when the growth rate was compared by monitoring the growth of maize. The oil affectations are due mainly to oil spills; the negative effects of oil depend on the spill type (Kolesnikov et al., 2010), the zone's ecological characteristics, the amount and type of spilled oil, as well as the time over the soil (Hernández-Acosta et al., 2004) and weathered degree (Rivera-Cruz et al., 2005). In this sense, the pollution levels vary in accordance with the hydrocarbons' source (Adams et al., 1999). Hydrocarbon polluted soils also experience physical, chemical and biological processes (Li et al., 1997; Martínez & López, 2001; Rivera-Cruz et al., 2002; Rivera-Cruz, 2004), altering the sustainability and productivity of the systems (FAO et al., 1980). Nevertheless, there are properties inherent to soils that favour the fixation and toxicity of the pollutants (Charman & Murphy, 2007).

The toxicity mechanisms caused by the oil on soils is not limited to the microorganisms, since it also includes plants that suffer from hydric stress (Chaîneau et al., 1997) due to the lack of water and nutrients. Concurrently, the lipid structures within the cells of the plants may be affected if the former are not quickly metabolized. In this sense, the oil has diverse effects over the plants since it inhibits the germination, growth and the biomass accumulation, reflecting these effects on a smaller plants production and, with time, in detriment of the natural resources sustainability. The variables that have a determining effect over the plants affected by the soil hydrocarbons pollution are the soil ecology, the rhizosphere, emergence and germination, aerial and radical growth, biomass accumulation and salts present on the soil.

4.0 CONCLUSION

In this study, non-edible vegetable oil was chemically extracted from *Lagenaria bieviflora* seeds using n-hexane solvent in a Soxhlet extractor, the oil was synthesised into a biolubricant through double esterification and transesterification. The physiochemical properties of the oil were examined, and the results indicate that the extracted oil was liquid at room temperature, brownish in color, and odorous. The results were as follows: density (0.8953 g/cm^3), FFA (13.8), peroxide value (3.94 MeqO$_2$/kg), acid value (26.162 mgKOH/g), saponification value (253.571 mgKOH/g), and value for oxidation (3.94 MeqO$_2$/kg). FTIR and GC-MS analysis were also used to characterize the oil. The biolubricant was taken through series of analysis to test for its toxicity and impact towards the environment. From the results obtained the biolubricant showed less negative impact to the environment as compared to that of the petroleum lubricant. The biolubricant had a very good value of dissolved oxygen which was greater than 3 from the standard. Its pH was within normal range as compared to the petroleum which was acidic. From the growth rate monitored, the soil sample that got contaminated with the biolubricant had no negative effect on the growth of the beans as compared to the petroleum lubricant that had delayed growth and slow growth rate. These factors prove the fact that the biolubricant is less toxic and more environmentally friendly than the petroleum lubricant.

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