

Research Article

Performance Enhancement of Degraded Engine Oil with Blends of Neem Oil and Avocado Oil for Lubrication

Ephraim T. B¹., Hammajam., A. A*²., and Pius, C.P¹

¹Department of Mechanical Engineering, University of Maiduguri, P. M. B. 1069, Maiduguri, Nigeria

²Department of Mechanical Engineering, Nigerian Army University Biu, P. M. B. 1500, Biu, Nigeria

*Corresponding Author: hammajam92@gmail.com, doi.org/10.55639/607zyxwv

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ABSTRACT

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A blending of different non-edible vegetable oils (Neem and Avocado) with synthetic oil (SAE 20W50) that is commercially available has attracted several studies towards making it sustainable, biodegradable and environmentally suitable for mineral oil for lubricant production. The physicochemical, thermo-oxidative stability and corrosion properties of Nigerian degraded engine oil (Society of Automotive Engineers SAE 20W50) were studied using mixing ratios of 40/60, 50/50, and 60/40 blends of neem/degraded engine oil and Avocado/degraded engine oil respectively. The study revealed specific gravity values of 0.893, 0.897, 0.901 for neem/degraded engine oil and 0.893, 0.897, 0.901 for avocado/degraded engine oil which fall within SAE standard of 0.901. pH values for neem/degraded engine oil were: 5.83, 5.85, 5.62 and 5.59, 5.49, and 5.71 for avocado/degraded engine oil indicating acidic compared to (SAE 20W50) of 7.12. The viscosity of neem/degraded engine oil and avocado/degraded engine oil was found to be lower compared to the SAE 20W50. The Neem and Avocado oil each has a promising effect on the physicochemical properties of the SAE 20W50 blend.

Corresponding author: Hammajam A. A. Email: hammajam92@gmail.com

Department of Mechanical Engineering, Nigerian Army University Biu, P. M. B. 1500, Biu, Nigeria

INTRODUCTION

Several countries in the world have put in place policies and plans to manage the disposal of degraded oil to protect their environment (Akbar *et al.*, 2009). Engine oil and other motor oils derived from crude oil have distinct physical and chemical properties that impact the way oil spreads and breakdown ultimately giving rise to environmental and health challenges. Used and unused engine oil pollution due to leakage into the environment, and improper collection procedures is now a serious problem that requires attention and poses a hazard to marine and human life (Aluyor, 2009; Sisman, 2016). Unfortunately, the appropriate management of degraded oil is a common problem for many African countries, including Nigeria, where much of the wastes have negative environmental and human health risks because of inadequate systems for collection, storage, recycling, disposal etc. (Bamiro and Osinbanjo 2004; Hassan *et al.*, 2011). The need to put in place policies and plans for the management of used oil in the country informed the present initiative and sponsorship by the Secretariat of the Basel Convention. The Basel Convention and its Regional Centers aim to develop a close partnership with major oil companies operating in the region, to put in place environmentally sound management practices for used oil to protect the environment and human health in Africa (Bamiro and Osinbanjo 2004). A common trend in waste management in recent times is the recycling of wastes. Some benefits of recycling are less waste, less pollution and more prudent utilization of precious natural resources (Harrison, 1994). Countries such as Turkey have one of the best recycling regulations for waste engine oils as the country is highly industrialized with an annual generation of million tonnes of waste engine oil. Such regulations require all waste engine

oil either abandoned or utilized must be analyzed for heavy and dangerous metals (arsenic, cadmium, chromium, Lead and halogens) before recycling for human and environmental benefits (Pelitli *et al.*, 2017). Ekot (2020) in his work on an analytic study on spent crankcase oil and its regenerative treatment using multiple beds extraction approach stated that improper disposal of condemned oil has detrimental effects as the cost of mopping up waste engine oil is daunting and most waste engine oils have hazardous heavy metals presence whose values are always above World Health Organization (WHO) limits which are Arsenic (0.01 mg/L), Zinc (0.04mg/L), Copper (0.01 mg/L) and Iron (0.05mg/L).

Recycling of used oils will not only reduce harmful wastes in the environment, but will also provide cheap alternative raw materials for industries, particularly the metal-based manufacturing industries. In metal forming operations generally, friction has been identified as one of the important influential factors whose reduction is one of the main tasks in planning and realization of metal forming processes (Plancak *et al.*, 2012). Of all the methods currently available for reducing friction, the most effective and most employed way is lubrication of interfacial surfaces during deformation (Plancak *et al.*, 2012). Neem oil which is eco-friendly and biodegradable known for its insecticidal effects and abundantly available in Nigeria dubbed “green gold” as stated by Hassan *et al.* (2011), where oil extracted from its seeds has been identified as suitable additive for lubrication as it has been extensively used in foundry and pharmaceutical industries.

In conventional lubrication practices, the choice is often a mineral oil-based lubricant (Pettersson, 2006). Mineral oils used as lubricants have well-known properties and have been used as lubricants on a large scale

since the end of the 19th century (Pettersson, 2006). Vegetable oils have also joined the list of lubricants in use in metalworking operations. Prior to recent developments, vegetable and animal oils have functioned mainly as additives to mineral lubricating oil formulations (to provide lower friction and add to the load-carrying capacity of the formulation), although in some cases they are applied exclusively, or as blends for friction reduction purposes. For example, castor, peanut and rapeseed oils have been used in blends with mineral oils to improve lubrication performance (Aluyor and Ori-Jesu, 2008; Biresaw *et al.*, 2003). In this work, potentials of these vegetable oils in serving as either additives or blends in mineral lubricating oils have been explored in enhancing friction-reducing properties of degraded oils.

assays.

Materials

The major materials used in this research work include neem oil, avocado oil, and degraded SAE 20W50 engine oil. Neem oil was purchased from Monday market in Maiduguri, Borno state, and avocado oil was purchased from Monday market in Maiduguri, Borno state. While the degraded one was collected from a generator plant at the University of Maiduguri, Borno state. The physicochemical analyses of these oils were carried out at the Department of Chemical Engineering Laboratory, University of Maiduguri.

Equipment

The following equipment was used: pH (model PHS – 3c precise pH meter) meter, magnetic

It is conceivable that within some of our lifetimes we will see the beginning of the end of the petroleum industry as we now know it. With that demise, we will see the end of lubricants derived from petroleum and the development of lubricants from other more abundant materials (Abro *et al.*, 2013; Szeri, 1980). Recognition of the limited nature of oil reserves and lack of environmental sound path of disposing the large quantity of degraded engine oil generated in the country – which is currently beyond 200 million liters per annual (Bamiro and Osibanjo, 2004) - prompted this research work to look at the possibility of enhancing degraded engine oil by blending with some vegetable oils (Avocado and neem oils) with the view of utilizing the blend in metalworking operations.

MATERIALS AND METHODS

heat stirrer model 78-1 (Plate 1), conical flasks (Plate 2), test tubes (50 ml), micro burette viscometer (High-shear viscosity (10/s) at high temperature of 150°C HSHT, electronic compact scale with 0.01 sensitivity (Plate 4). Chemicals such as sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$), Hydrochloric acid (HCL), Potassium hydroxide (KOH) and phenolphthalein ($\text{C}_{20}\text{H}_{14}\text{O}_4$) were utilized. The analyses were carried out in accordance with ASTM (D4683, D1289, D5558, D7946, D5554, D4052, and DS974) standards.



Plate 1: the Specimen on Magnetic Heat Stirrer



Plate 2: The conical flask with sample specimen



Plate 3: 50 ml of Avogadro oil Sample in test tube



Plate 4: Electronic Compact Scale

Data analysis of oil Samples

Blends of each of the two vegetable oils (neem and avocado oils) with the degraded motor oil were prepared in the ratios 40ml/60ml, 50ml/50ml and 60ml/40ml to produce a total set of six (6) blend samples (three sets for each vegetable oil). Specific gravity, density, pH, viscosity of these oils was analyzed and presented in charts and graphs. The laboratory analysis was performed in Chemical the ratio of the weight of the oil mixture to a known volume of water as illustrated in equation 1

$$\text{Density} = \frac{\text{Sample weight of Mixture}}{\text{Sample volume of Water}} \dots\dots\dots 1$$

Specific gravity

An empty beaker was weighed and recorded, and then 50 ml of neem/degraded engine oil and 50 ml of avocado/degraded engine oil mixtures were poured into the beaker and

$$\text{Specific gravity} = \frac{\text{Sample weight of Mixture}}{\text{Weight of water}} \dots\dots\dots 2$$

Engineering, University of Maiduguri Borno State.

Density

An empty beaker was weighed and recorded, and then 50ml of neem/degraded engine oil and 50ml of avocado/degraded engine oil was measured and poured into the beaker. From the sample weight obtained, the density was determined by taking

weighed as well. The water of the same volume was also weighed and recorded. The specific gravity was determined by taking the ratio of the weight of the oil to the known volume of water (50ml) in S.I units according to equation 2

Iodine value (IV)

A 0.44g mixture of neem/degraded engine oil and 0.44g of avocado/degraded engine oil were placed into a conical flask and 10 cm³ of carbon tetrachloride was added to individual mixture to dissolve it. A 20 cm³ of chlorine solution was added and the mixtures were placed in a dark cubicle at ambient temperature. The sample result (V₁) and that of the blank (V₂) were recorded. The iodine value of the samples was then calculated using the equation 3

$$IV = \frac{[(V_2 - V_1) \times M \times 12.7]}{W} \dots\dots\dots 3$$

Where IV=Iodine value

V₁=Volume of sodium thiosulfate used for neem/degraded oil engine and avocado/degraded engine oil

V₂=Volume of sodium thiosulfate used for blank

M=Molarity of sodium thiosulfate

W=Weight of neem/degrade engine oil and avocado/degraded engine oil

12.7= constant

for 30 minutes. A 15 cm³ solution of 10% Potassium was then added with water (100cm³) to rinse the flask. This is to reduce excess and free iodine (Altaani *et al.*, 2009). The solution was then titrated liberating the iodine with a solution of sodium thiosulfate (0.1M) using starch as an indicator: A blank sample was also prepared and back titrated accordingly.

Saponification value

4.0g mixture of neem/degraded engine oil and 4.0g mixture of avocado/degraded engine oil were measured, weighed and placed into an Erlenmeyer flask and 0.5M alcoholic KOH (50cm³) was added. The mixture was then heated to saponify the fat or oil. The unreacted

$$SV = \frac{(V_2 - V_1) \times M \times 56.1}{W} \dots\dots\dots 4$$

Where SV = Saponification value

V₁=Volume of sodium thiosulfate used for neem/degraded oil, and avocado/degraded oil mixtures

V₂=Volume of sodium thiosulfate used for blank

M=Molarity of sodium thiosulfate

W=Weight of neem and avocado with degraded oil

56.1= Constant

KOH was back titrated with 0.5M HCL using phenolphthalein as indicator (Ashton *et al.*, 2006). A blank sample was also prepared and back titrated accordingly. The samples mixtures and the blank titrate **V₁ and V₂** were recorded. The saponification value was calculated using equation 4

Free fatty acids

(10.0g) mixtures of neem/degraded engine oil and (10.0g) mixture of avocado/degraded engine oil **was** measured, and weighed into 250 boiling flasks, followed by the addition of

neutralized alcohol (ethanol 150). The mixture was boiled on a hot plate until all oil dissolved completely and 3 - 4 drops of phenolphthalein were added. The solution was titrated with 0.1M sodium hydroxide until a faint pink end

point was observed and the titre value (T) recorded the percentage of free fatty acid in the sample was calculated using equation 5

$$FFA = \frac{56.1 \times M \times T}{W} \dots\dots\dots 5$$

Where FFA= Free fatty acid value

M = Morality of sodium thiosulfate

W = Weight of neem/degraded engine oil and avocado/degraded engine oil

T = titration of neem/degraded engine oil and avocado/degraded engine oil

56.1 = constant

RESULTS AND DISCUSSION

Density value of the investigated oils

Figure 1 shows the density values of neem/degrade engine oil and avocado oil/degraded engine oil. The density value of each ratio has almost the same value compared with the standard of Society of America Engineering (SAE) 20W50 of 0.925. This indicates that the

blends of neem and avocado oil with degraded engine oil were found to be suitable for lubrication. Interestingly, density of oil has profound impact on lubrication capability of using either neem/degraded engine oil or Avogadro/degraded oils in machining operations such as or extrusion as stated by Obi (1996).

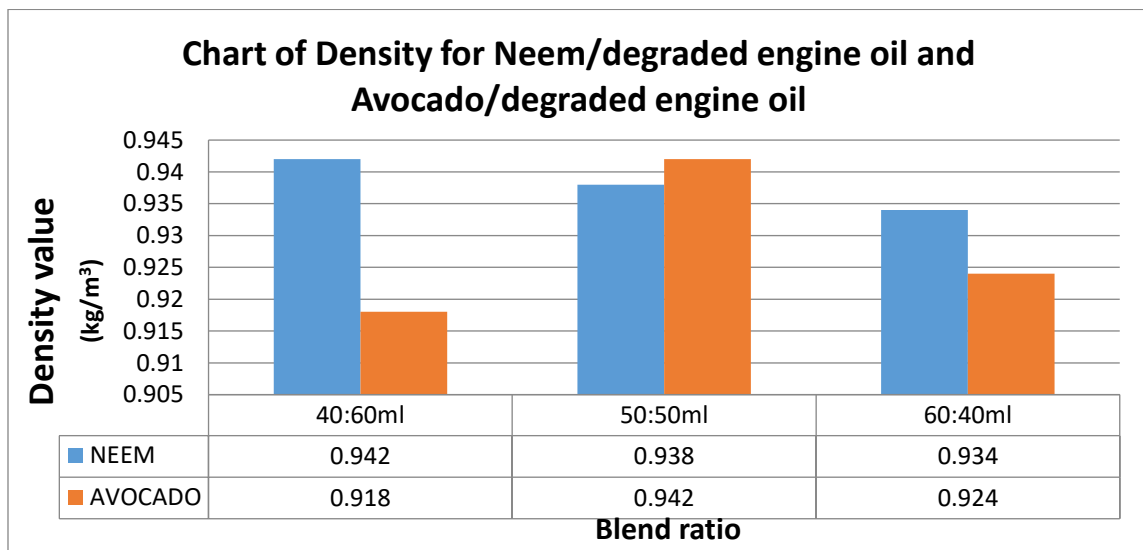


Figure 1: Density values for Neem/degraded engine oil and Avocado/degraded engine oil

Specific gravity value of the investigated oil

Specific gravity defined as the ratio of the density of a fluid to that of water of the same volume is often seen as major physical

indicator in utilization of lubricants (Ochi *et al.*, 2020). Specific gravity values illustrated in Figure 2 were observed to be within range of Society of American Engineering (SAE)

standard of 0.901 (kg/m³ ASTM D1298). The specific gravity values recorded in this study were comparable to specific gravity value of 0.903 (kg/m³) in the transesterification of neem seeds (*Azadirachta Indica*) according to a study conducted by Ochi *et al.* (2020), signifying the

non-existence of heavy metals in neem oil. Additionally, the 60/40 blend mixtures for neem/degrade oil has exact value of 0.901 to the SAE standard signifying the most suitable blend for machining operation.

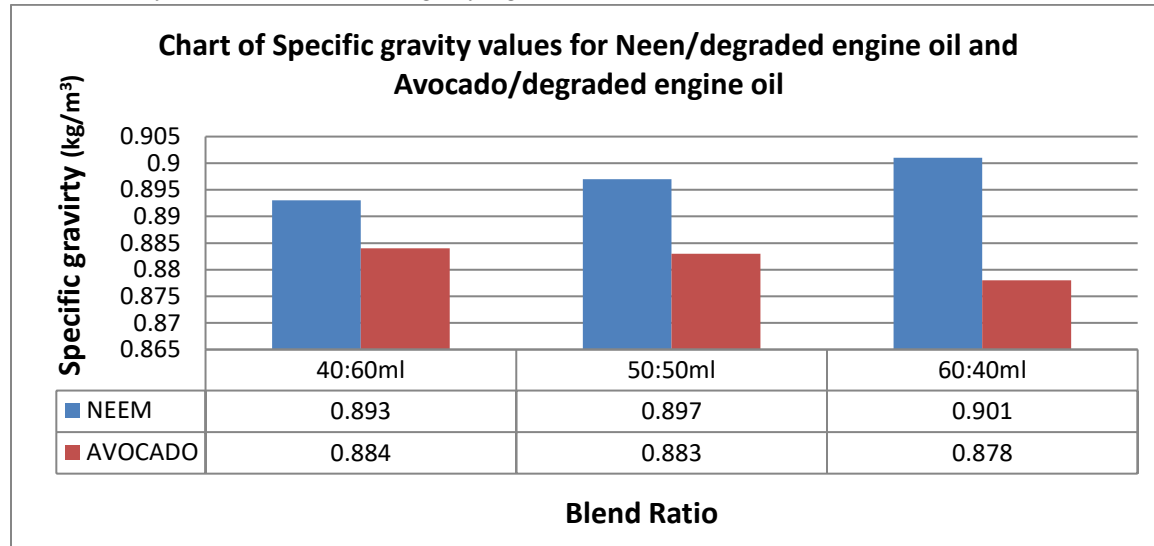


Figure 2: Specific Gravity values for Neem/degraded engine oil and Avocado/degraded engine oil

pH value of the investigated oil

pH values of neem/degraded engine oil and avocado/degraded engine oil as seen in Figure 3 showed that the values fall below the standard of 7.12 according to the Society of Automotive Engineers (SAE) for 20W50 lubricant. The pH readings from this study indicate that the blends of neem and avocado oil with degraded SAE 20W50 engine oils are slightly acidic rather than neutral as specified by ASTM D7946 standards. The acidity of the blends has a profound impact on the corrosion protection of machine components according to a study by Paranusorn *et al.* (2018) who revealed that the pH of blend additives such as neem oil, mango oil and Avogadro oils have a profound impact on the corrosion tendency of lubes largely to the different chemical composition of each blend.

Viscosity value of the investigated oil

Figure 4 shows the viscosity readings of neem/degraded engine oil and avocado/degraded engine oil. The values were found to be lower when compared with the Society American Engineering (SAE) (ASTM D4683) standard of 55.39 (cSt). However, the low values indicate suitability in lubricating effect on engines thus reducing wear and tear in engines as stated by Hameed (2021). Furthermore, a study conducted by Tarun K.S (2020) revealed that having a 50:50 ml blend of neem/synthetic oil gives good lubrication between mating surfaces largely due to the low fatty acids content of neem oil compared to other oils hence giving a better frictional coefficient during lubrication. Albeit, a study by Marotrao, (2012) to determine the viscosity of lubricating oils and their blends revealed that viscosity decrease with the rise in temperature which reduces the intermolecular forces of the

molecules so the layers of liquid easily slide over one another leading to reduction of viscosity.

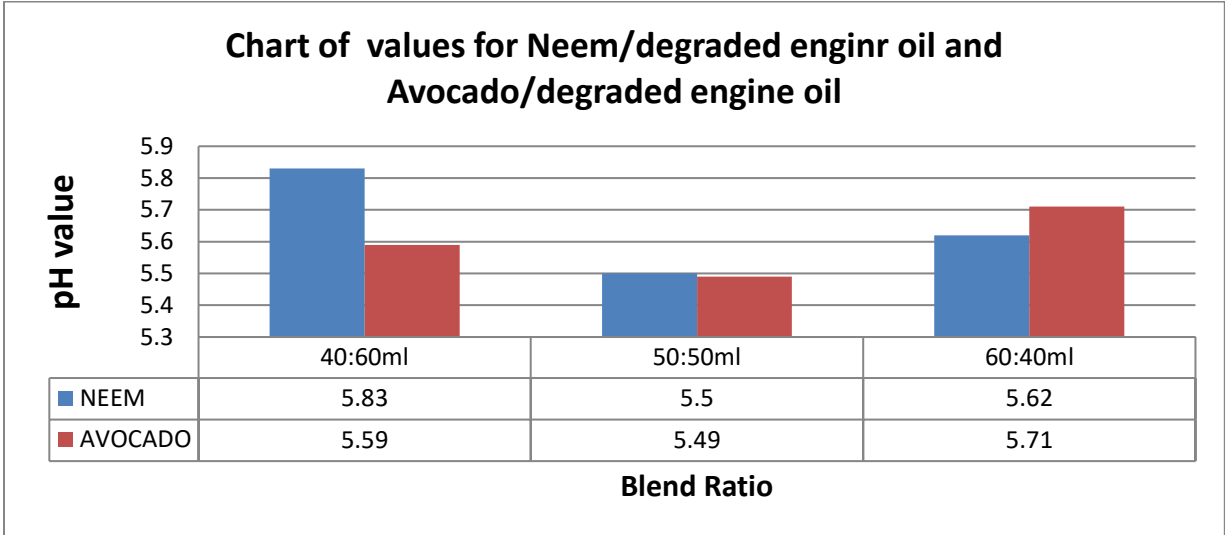


Figure 3: pH values for Neem/degraded engine oil and Avocado/degraded engine oil

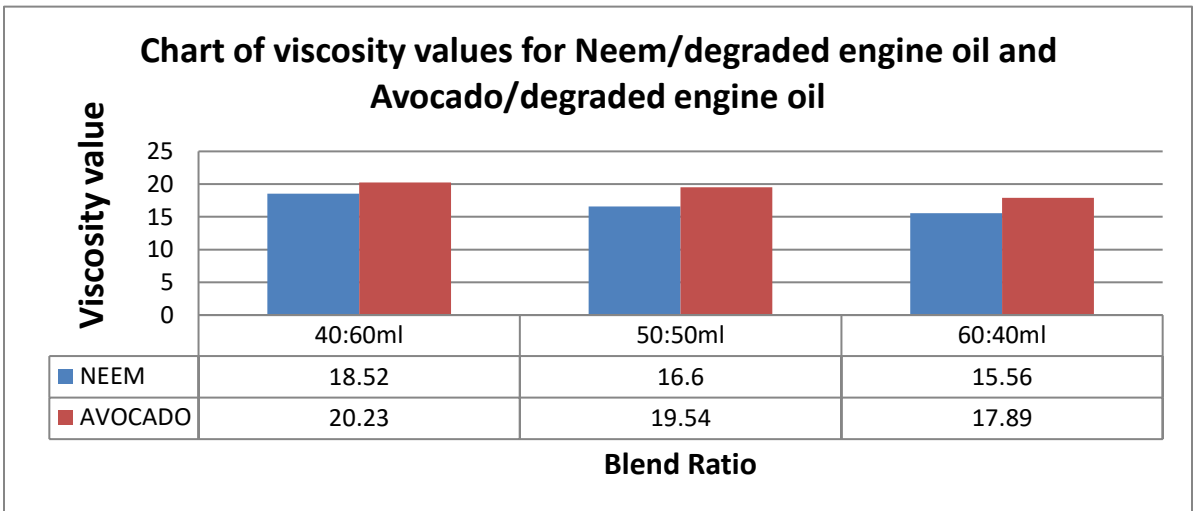


Figure 4: viscosity values for Neem/degraded engine oil and Avocado/degraded engine oil

Iodine Value of the investigated oil

Iodine value (IV) provides information on the number of unsaturated oils and is used to determine the drying property of the oil. As a rule of thumb, the greater the iodine values the higher the chances of oil undergoing fats

decomposition giving off an offensive smell due to a high level of unsaturated double bonds (Ochi *et al.*, 2020). The iodine values obtained from this study showed that the values observed were lower than that of the SAE-20W50 specification of 80 (gI₂/100g). The readings

suggest that there is a low degree of unsaturation in the mixtures of neem and avocado with degraded engine oil. Additionally, the low pH contents in neem and

avocado oils have proven to be good sources for biodiesel production according to studies by Odi-Owei *et al.* (2021) and Ochi *et al.*, (2020).

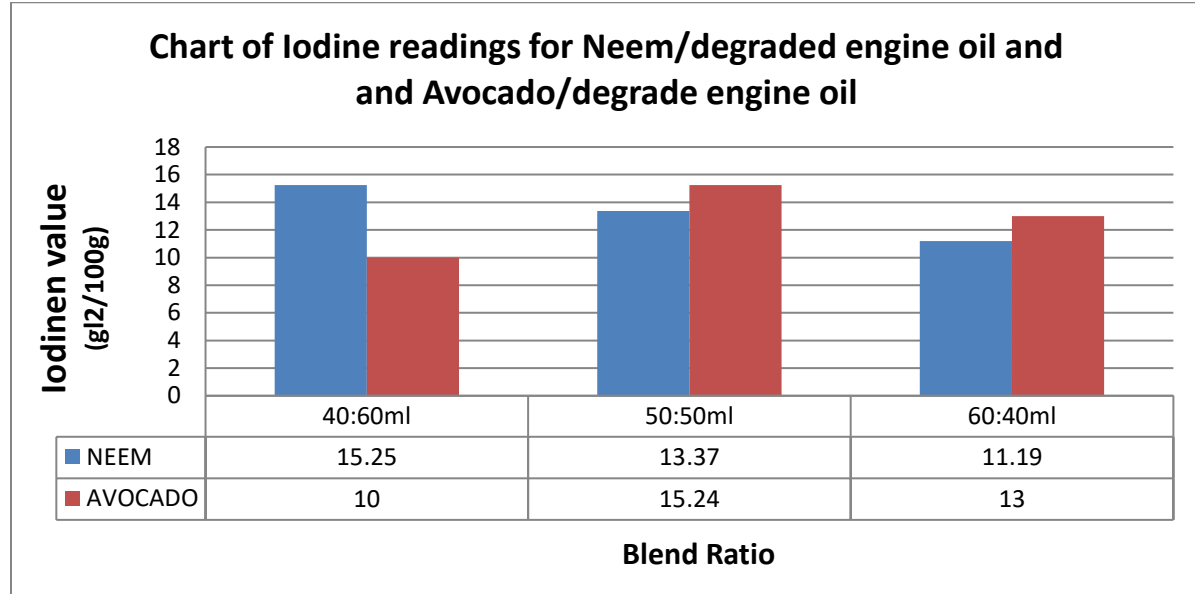


Figure 5: Iodine values for Neem/degraded engine oil and Avocado/degraded engine oil

Free fatty Acid Value of the investigated oil

Free fatty acid values of neem/degraded engine oil and avocado/degraded engine oil as seen in Figure 6 indicate that the blends have lower values compared with the Society of Automotive Engineers (SAE-20W50) specification of 5.6 mg KOH/g. ASTM D974 standards stated that the lower the free fatty acid number the better the oil

as a lubricant. Similar work was reported by Baladincz *et al.* (2008). The fatty acid contents in both blends of neem/engine oil and Avogadro/degraded engine oil revealed significant amount of oleic and linoleic acids as dominant fatty strands which according to studies by Arkar (2009) and Musa (2012) suggested that theses high fatty acids have excellent effect on biodiesel production and enhanced lubrication.

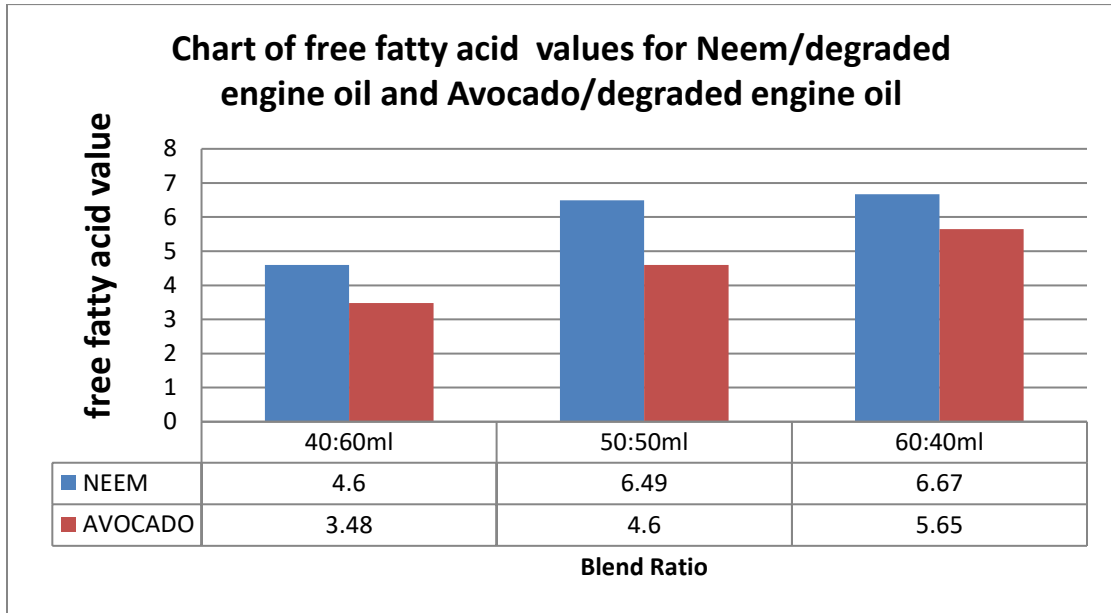


Figure 6: Fatty acid values for Neem/degraded engine oil and Avocado/degraded engine oil

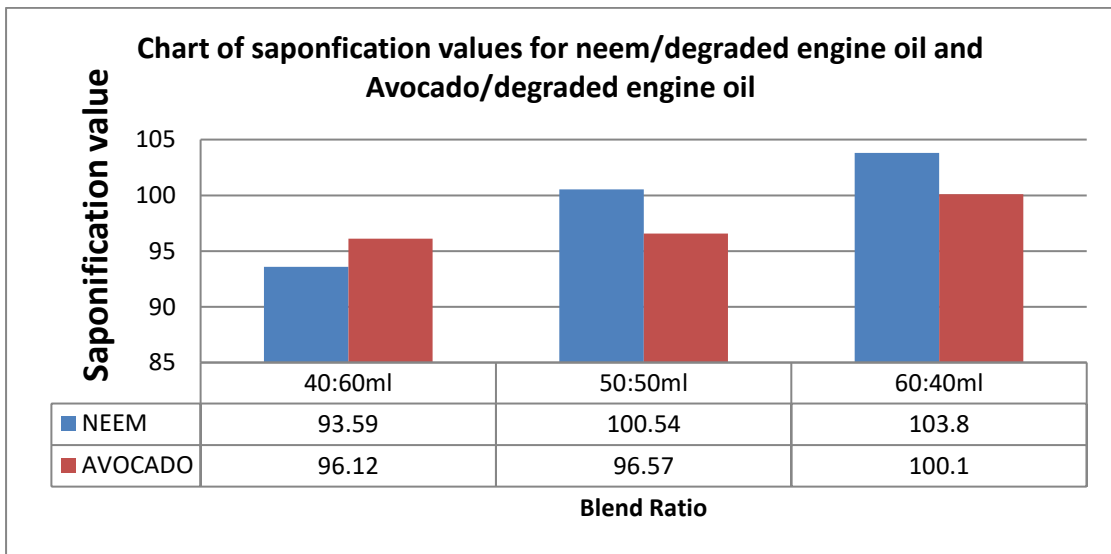


Figure 7: Saponification values for Neem and Avocado oil blends with degraded engine oil

Saponification value of the investigated oil

Saponification values obtained from the blends of neem/degraded engine oil and avocado/degraded engine oil are illustrated in Figure 7. This study shows these values to be below the specified standard of 190.1mg KOH/g specified by the Society of Automotive Engineers (SAE) for 20W50 lubes. Values from 50/50 of neem/degraded engine oil and

60/40 of avocado/degraded engine oil blends were observed to be highest, however, significantly lower than the specified SAE standard. Saponification value indicates the presence of triglycerides used for soap-making shampoos (Bhandare *et al.*, 2015). The values reported in this study revealed that both blends of neem/waste engine and avocado/waste engine oils are not suitable for soap and shampoo production (Akbar *et al.* 2009:

Bhandare *et al.*, 2015). Although, studies by Wani *et al.* (2018) and Singh *et al.* (2021) revealed that neem and avocado oils laced with copper nanoparticles could be beneficial in cold weather procedures like cutting and extrusion techniques.

Physicochemical properties of pure engine oil (ASTM Standards)

The physicochemical properties of pure engine oil total 20W–50 SAE are shown in table 8 below. Physicochemical readings of the studied samples were lower than the standards

specified by the American Society for Testing Materials (ASTM) for 20W50 lubricant. This indicates a good prospect in the usage of neem and avocado oils blends in less heat generation machining operations such as extrusion, smaller diameters wire cutting as suggested by Atlas *et al.* (2015). Lubricant additives like Neem or Avocado oils are viewed to have friction-reducing properties coupled with moderate production costs compared to other synthetic oils.

Table 1: Physicochemical Standards of 20W-50 SAE Lubricants (Akbar *et al.*, 2009; Bhandare *et al.*, 2015)

Number	Properties	Values	Units	Standards
1	Free Fatty acid value	5.6	mgKOH/g	ASTM D974
2	Density value	0.925	Kg/m ³	ASTM D4052
3	Iodine value	80.0	gl2/100g	ASTM D5554
4	PH value	7.12	-	ASTM D7946
5	Saponification value	190.1	Mg KOH/g	ASTM D5558
6	Specific gravity value	0.890	kg/m ³	ASTM D1298
7	Viscosity value	55.39	(cSt)	ASTM D4683

CONCLUSION

Results from the experiment revealed additives such as Neem and Avocado oils have favourable physical-chemical properties (viscosity value, Saponification value, acid value, and iodine value) that result in good chemical reactivity in improving the use of degraded or waste engine oils. The study found both additives to have profound enhancement effects on degraded engine oil, especially in cold weather machining operations where the temperature has a negligible effect on viscosity.

Nonetheless, the density values of neem/degraded engine and avocado/degraded engine oil have almost the same value compared with the SAE standard for 20W50 lubes. Viscosity values recorded were far below the specified standard however, a study has shown it to be suitable for reducing wear and tear in engine parts. This study demonstrated that blending avocado oil with waste or degraded engine oils has a higher potential in enhancing the lubricating performance of waste or degraded engine oils compared with neem oil.

REFERENCES

- Abro, R., Chen, X., Harijan, K., Dhakan, Z. A. and Ammar, M. (2013). A Comparative Study of Recycling of Used Engine Oil Using Extraction by Composite Solvent, Single Solvent, and Acid Treatment Methods. *ISRN Chemical Engineering*, Vol. 2013, article ID: 9525589.
- Akbar E Yaakob Z, Kamarudin S, Ismail M and Salimo,J. (2009) characteristic and composition of Jatropha Curcas oil seed from Malaysia and it potential Biodiesel feedstock. *European Journal of Scientific Research*. 29 (3),396-403
- Aluyor, E. O. and Ori-Jesu, M. (2008). The Use of Antioxidants in Vegetable Oils- A Review. *African Journal of Biotechnology*, 725 (25): 4836-4842.
- Aluyor, E. O. and Ori-Jesu, M. (2009). Biodegradation of Mineral Oils- A review. *African Journal of Biotechnology*, Vol.8 (6), pp. 915-920.
- Ashton, O.B.O.; M. Wong; T.K. Mcghie; R. Vather; Y. Wang; C. Requejo-Jackman; P. Ramankutty; A.B. Woolf. Pigments in avocado tissue and oil.J. Agric. Food Chem. **2006**, 54,10151–10158.
- Altaani, R. H., Samaneh, T.S. and Al-Zboon, K. K. (2009). Effect of Using Waste Oil as a Source of Energy in Cement Plant on Ambient Air Quality- Case Study for Al-Rashadeya Factory. *Engineering Science*, 36 (1): 51-69.
- Atlas R. M., Stoeckel D. M., Faith S. A., Smith A. M., Thorn J. R and Benotti M. J. (2015). Oil Biodegradation and Oil-Degrading Microbial Population in Marsh Sedimentation Impacted by oil from the Deepwater Horizon well Blowout. *Environmental Science & Technology*. Vol. 49 (14). pp. 8356-8366.
- Bhandare, P and Naik G.R. (2015). Functional Properties of neem as Potential Feedstock for Biodiesel Production. *International Letters of Natural Sciences*. Vol 7, pp. 1-14.
- Baladincz, J., Szabó, L., Nagy, G. and Hancsók, J. (2008). Possibilities for Processing for Used Lubricating Oils – Part 1.Development, 3: 81-86.
- Bamiro, O. A. and Osibanjo, O. (2004). Pilot Study of Used Oils in Nigeria. Sponsored by the Secretariat of the Basel Convention, Geneva, pp. 2, 21.
- Biresaw, G., Adhvaryu, A. and Erhan, S. Z. (2003). Friction Properties of Vegetable Oils. *JAOCS*.Vol. 80 (7) 697-704.
- Ekot, E. Anietie. (2020). Analytical Study of the Physicochemical Properties of Condemned Crankcase oil and its G=Regenerated Form Obtained by a Combination of Acid Treatment and Multiple Beds Extraction Approach. *Global Scientific Journals*. Vol. 8 (5).
- Hameed Kareem Dana. (2021). Deterioration in Physical Engine oil Properties after Different Trip Length. *Kurdistan Journal of Applied Research*. Vol 6(1). pp. 13-20.
- Harrison, C. (1994). The Engineering Aspects of a Used Oil Recycling Project, *Journal of Waste Management*, 14 (3-4): 231-235.
- Hassan S. B., Agboola J. B., Aigbodion V. S. and Williams E. J. (2011). Hardening Characteristics of Plain Carbon Steel and Ductile Cast Iron Using Neem Oil as Quenchant. *Journal of Minerals and Materials Characterization and Engineering*, vol. 10 (2) pp. 161-172
- Marotrao, Talkit kailas, (2012). Physiochemical Properties of Oil blend and Their Effects on Lubrication Properties. *International Journal of Advanced Engineering Research and Studies*. Vol 1(3). Pp: 35-38.
- Musa Umaru and Aberuagba Folorunsho. (2012). Characteristics of a Typical Nigerian Jatropha curcas oil seeds for Biodiesel Production. *Research Journal of Chemical Sciences*. Vol 2(10).pp. 7-12.
- Obi A. I and Oyinola A.k. (1996). Frictional Characteristics of Fatty based Oils in

- Wire Drawing Wear. Vol 194 (1-2). pp. 30-37
- Ochi, D. O., Umezuegbu, J. C., Mahmud, H. Ekebafé, I. O. Ani, M. O. (2020). Transesterification of Neem (*Azadirachta Indica*) Seed Oil. *Nigerian Research Journal of Chemical Sciences*. Vol. 8(1). ISSN: 2682-6054.
- Odi-Owei, S., Ameh, J., Alibi, S. and Chikezie A. (2021). Potential Vegetable Oil based Lubricants: A Review. *Journal of Newviews in Engineering and Technology* (JNET). Vol 3(4).
- Paranusorn P., Fernandez B. L., Supavasuthi C., Somwangthanaroj A. (2016). Effects of Additives in Ethylene Glycol- based Lubricant on Selectives materials Removal in Slider Lapping Process. *5th International Conference on Recent Advances in Materials, Minerals and Environment (RAMM) & 2nd International Postgraduate Conference on Materialls, Mainerals and Polymer. Procedia Chemistry*. Vol 19
- Plancak, M., Car, Z., and Krsulja, M., Vilotic, D., Kacmarcik, I. and Movrin, D. (2012). Possibilities of Measure Contact Friction in Bulk Metal Forming. *TechnickiVjesnik*, 19 (4): 727-704.
- Pettersson, A. (2006). Environmentally Adapted Lubricants- Properties and Performance. Ph.D Dissertation, Lucea University of Technology, Sweden.
- Sisman, T., Atamanalp M., Dane, H. and Adil S. (2016). The Toxicity of 10W-40 Motor Oil on Zebrafish early life Statges. *Turkish Journal of Fisheries and Aquatic Sciences*. Vol 16, pp. 567-604
- Singh A. P., Dwivedi K. R. and Suhane A. (2021). Influence of Nanoparticles on the the Perfomance of Lube oil- a Review. *Material Research Express*. Vol 8 (10).
- Szeri, A.Z. (1980). Tribology: Friction, Lubrication and Wear. Hemisphere Publishing Corporation, U.S.A. pp. 429.
- Pelitli, V., Dogan O and Koroglu H. J. (2017). Waste oil Management: Analyses of waste oils from Vehicle Crankcases and Gearboxes. *Global Journal of Environmental Scientific Management*. Vol 3 (1). 11 -20.
- Tarun, K.S. (2020). Analysis of Vegetable oils and Synthetic Oil Blend with Additives. *International Journal of Engineering Applied Sciences and Technology*. Vol 4 (10). 94 - 100
- Wani K. S., Raina A., and Haq M. I. (2018). Tribological Performance of avocado oil containing Copper Nanoparticles in Mixed and Boundary Lubrication Regime. *Industrial Lubrication and Technology*. Vol. 70