AVOCADO SEED OIL AS AN ADDITIVE IN THE FORMATION OF GREASE LUBRICANT FROM SPENT ENGINE OIL

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ABSTRACT

The improper disposal of spent engine oil poses a significant environmental challenge with far-reaching consequences. Traditional methods of discarding used engine oil often result in soil and water contamination, air pollution when combusted, and adverse effects on ecosystems. The magnitude of this problem is exacerbated by the sheer volume of used engine oil generated globally, contributing to the degradation of the environment on a substantial scale. The consequences of inadequate waste management practices are not confined to specific regions; they transcend borders and impact diverse ecosystems, necessitating a concerted effort to address the issue at its core. This research aims at addressing the problem of improper spent engine oil disposal by advocating for its reuse, by investigating the feasibility of utilizing avocado seed oil as an additive in the formation of grease made from spent engine oil, with a focus on assessing its impact on the properties of the resulting lubricant thus exploring the viability of avocado seed oil as an additive in the formation of grease. Grease was formulated by the homogenization of sodium soap thickener and avocado seed oil additive in spent engine oil for 2 hours at 100°C. Different compositions of oil-to-thickener and additive ratio were designed which are 90/10, 80/20, 70/30 and 60/40. Sample A, 90% base oil, 8% thickener and 2% avocado seed oil, Sample B, 80% base oil, 16% thickener and 4% avocado seed oil, Sample C, 70% base oil, 24% thickener and 6% avocado seed oil, Sample D, 60% base oil, 32% thickener and 8% avocado seed oil. Consistency analysis results shows an NLGI (National Lubricating Grease Institute) number of Sample A,0, Sample B, 1 to 2, Sample C, 2 to 3, and Sample D, 3 to 4. Oil separation analysis results gives Sample A, 1.4%, Sample B, 0.6%, Sample C, 0.2%, Sample D, 0.0%. Dropping point analysis results gives Sample A, 40℃, Sample B, 69℃, Sample C, 98℃, Sample D, 162℃. Compared to commercially sold grease which has a consistency analysis NLGI number of 3 to 4, oil separation analysis result of 0.0% and dropping point analysis of 169℃. Sample D with a dropping point of 162℃, oil separation analysis of 0.0% and consistency analysis of 3 to 4 emerged as a standout formulation. Overall, the property of lubricant with increased percentage of avocado seed oil is promising, and this research as enabled us better understand its potential as a lubricant additive.

Keyword: Spent engine oil, Avocado seed oil, Grease lubricant, Consistency analysis, Oil separation, Dropping point

1 INTRODUCTION

Engine oils, including motor oils derived from crude oil, have unique chemical and physical characteristics that have an impact on how the oil spreads and decomposes, resulting in environmental and health concerns. [1] noted that various nations have adopted policies and strategies to manage the disposal of degraded oil in order to safeguard their environment. The contamination of used and unused engine oil, which results from spills and inadequate collection processes, has become a serious problem that poses a risk to marine and human life [2, 3]. Unfortunately, several African nations, such as Nigeria, face the common challenge of appropriately managing degraded oil, which poses

environmental and health hazards due to inadequate collection, storage, recycling, and disposal systems [4, 5]. As a result, the Secretariat of the Basel Convention has sponsored the current initiative to put in place policies and plans for the management of used oil in the country. The Basel Convention and its Regional Centers aim to establish a strong partnership with major oil companies operating in the region to implement environmentally sound management practices for used oil, thus protecting the environment and human health in Africa [4]. Recycling has become a popular waste management trend in recent times, offering several benefits, including reduced waste, decreased pollution, and more prudent use of valuable natural resources [6]. Turkey has one of the best recycling regulations for waste engine oils, given its high level of industrialization and annual production of millions of tonnes of waste engine oil. As a result, regulations require all waste engine oil, whether abandoned or utilized, to be analyzed for heavy and hazardous metals such as arsenic, cadmium, chromium, lead, and halogens before recycling for the benefit of humans and the environment [7]. In his research on spent crankcase oil and its treatment [8] highlighted the harmful effects of improper disposal of condemned oil, as waste engine oils often contain hazardous heavy metals such as Arsenic, Zinc, Copper, and Iron that exceed the limits set by the World Health Organization. The cost of cleaning up such waste is high, making recycling a more viable option. Recycling used oils not only reduces harmful waste in the environment but also provides a cheap alternative raw material for metal-based manufacturing industries. In metal forming operations, reducing friction is crucial, and lubrication of interfacial surfaces during deformation has been identified as the most effective method. The awareness of the limited nature of oil reserves and the absence of an environmentally sustainable approach to disposing of the significant amount of degraded engine oil produced each year, currently exceeding 200 million liters [4], prompted this research to explore the possibility of enhancing degraded engine oil by mixing it with Avocado Seed oil. A study by [9] found that avocado seed oil has a high viscosity index, high oxidative stability, and good anti-wear properties, making it a promising candidate for lubrication applications. In another study [10] compared the lubrication performance of avocado seed oil with mineral oil and synthetic ester oil. The results showed that the avocado seed oil had a lower coefficient of friction and wear rate than mineral oil and synthetic ester oil, indicating better lubrication performance. Furthermore [11] investigated the effect of adding different amounts of avocado seed oil to a mineral oil base. The results showed that as the concentration of avocado seed oil increased, the coefficient of friction and wear rate decreased, indicating better lubrication performance. Avocado seed oil has also been found to have good thermal stability, which is important for lubrication applications in high-temperature environments. A study by [12] tested the thermal stability of avocado seed oil and found that it had a high flash point and good oxidation stability, indicating that it could be suitable for use in high-temperature applications. Table 1 reveals those properties of avocado seed oil which buttress its potential as an additive in grease formation from spent engine oil. The compatibility of these properties with the demands of grease applications positions avocado seed oil as a promising candidate for sustainable and effective lubrication, contributing to the development of environmentally responsible grease formulations [14].

Table 1. Properties of Avocado Seed Oil Relevant to Grease Formation [13]

Property	Significance
Fatty Acid Composition	High content of monounsaturated fats, primarily oleic acid, contributing to lubricating properties and compatibility with traditional base oils used in grease formulations.
Viscosity Index	High viscosity index, indicating less susceptibility to viscosity changes with temperature variations, contributing to the stability of grease in diverse environmental conditions.
Natural Lubricity	Inherent lubricating properties, enhancing the overall lubricity of grease formulations and contributing to reduced friction and wear between moving parts in machinery.
Thermal Stability	Good thermal stability, enabling avocado seed oil to withstand high temperatures without significant degradation, ensuring reliable lubrication in applications exposed to elevated temperatures.
Flash Point	High flash point, indicating resistance to combustion and contributing to the safety and stability of the grease, particularly in applications with a risk of exposure to high temperatures or open flames.
Biodegradability	Biodegradable nature aligns with environmentally friendly lubricant practices, contributing to sustainable waste management and reducing the environmental impact of lubricants.
Antioxidant Content	Presence of natural antioxidants, including tocopherols and phenolic compounds, contributing to the oxidative stability of the grease, preventing the formation of sludge and deposits over time.
Low Volatility	Low volatility, ensuring that the lubricant remains in its intended application, providing consistent and effective lubrication over extended periods in grease formulations.

2 MATERIALS AND METHODS

The materials that were used in this research work include base oil (spent engine oil), Sodium soap and avocado seed oil. Avocado fruit was purchased from Jambutu Bye Pass (Yola – Adamawa State) after which the seeds were removed and oil was extracted from it. Spent engine oil was collected from the Department of Chemical Engineering Generator of Modibbo Adama University, Yola. The equipment to be used include mortar and pestle, magnetic heat stirrer, conical flasks, test tubes (50ml), electronic weighing balance, consistency analysis apparatus, oil separation apparatus, and dropping point apparatus. Chemicals such as sodium hydroxide, stearic acid, and hexane was utilized. The analyses were carried out in accordance with ASTM (D4683, D1289, D5558, D7946, D5554, D4052, and DS974) standards. The avocado seeds were washed to remove any dirt or debris. Then, the seeds were cut into pieces and dried in the sun for about one week to get rid of the moisture content. The dried seeds were crushed or ground into a fine powder using a mortar and pestle. The powder was then inserted into a hexane solvent, and mixed thoroughly to allow for the extraction of the oil by the solvent. Afterward, the mixture was filtered to separate the oil from the solid particles. The solvent was then evaporated using a distillation apparatus to leave behind pure avocado seed oil. Finally, the oil was stored in a dark, cool place to prevent oxidation and maintain its quality.

2.1 Preparation of Grease

Waste engine oil is used as base oil. The thickener used in this experiment was sodium soap thickener. Sodium hydroxide underwent saponification process with stearic acid to produce sodium soap thickener, ASTM D5558. Stearic acid is one of the materials needed for saponification process that has a long-chain fatty acid consisting of 18 carbon atoms without double bonds. In nature stearic acid occurs primarily as a mixed triglyceride, or fat, with other long-chain acids and as an ester of a fatty alcohol. Sodium hydroxide referred to as a sponge that hold the lubricant together used as a thickener, while stearic acid referred to as emulsifier used as a hardener. The grease in this study is prepared by mixing the base oil, stearic acid, sodium hydroxide, and avocado seed oil in various ratios as outlined below. 100 mL of each of the four samples was formed by mixing the volumes of the specific component. In this formulation shown table 2, base oil was utilized around 60 to 90% and 10 to 40% of sodium soap thickener and avocado seed oil was dispersed in the base oil. The base oil was heated to 90˚C and stearic acid was melted at 60˚C. 70% of the heated oil was transferred into the melted stearic acid and homogenized for about 15 minutes. NaOH solution was then added into the mixture drop by drop to control excessive foaming at low speed. After the addition of NaOH, the temperature was increased to 100°C and homogenized for 30minutes. The oil balances and the avocado seed oil was then added to the mixture and homogenized for 2 hours at high speed of 8000rpm and constant temperature. Finally, heat was then removed from the sample and homogenization was continued for another 30 minutes. Grease sample was stored in an enclosed container and allowed to cool to room temperature.

Table 2. Design of Experiment - Grease formulation

Sample	Base oil (%)	Stearic Acid (%)	Sodium Hydroxide (%)	Avocado Seed Oil (%)
A	90	4	4	2
B	80	8	8	4
C	70	12	12	6
D	60	16	16	8

2.1.1 Procedure of Consistency Analysis

The consistency analysis of the prepared grease formulations was conducted to evaluate their hardness or softness, utilizing an NLGI-consistent consistency analysis apparatus. The procedure commenced with the grease samples. The NLGI-consistent consistency analysis apparatus was then employed to measure the penetration depth of a standard cone into the grease samples. The prepared grease

samples were placed in a standardized container within the apparatus, and the cone was allowed to penetrate under a specified load for a predetermined period. This process was carried out in triplicate to ensure reliability and accuracy in the results. Subsequently, the depth of penetration was measured, and the consistency of the grease was determined based on the established NLGI classification standards. The entire procedure was conducted under controlled temperature conditions to eliminate external factors that could influence the consistency analysis. The results obtained from the consistency analysis provide insights into the structural attributes of the grease formulations, offering valuable information on their suitability for various lubrication applications. This standardized and meticulously executed procedure contributes to the comprehensive evaluation of the grease formulations, aligning with the study's objectives to assess the impact of Avocado Seed Oil as an additive in the formation of grease from spent engine oil.

2.1.2 Oil Separation Procedure

The oil separation analysis of the prepared grease formulations was carried out to assess their stability and tendency to expel oil over time. The procedure was conducted in a controlled laboratory environment using specialized equipment. Firstly, the grease samples were uniformly applied to a designated sample holder. Care was taken to ensure that the grease layer was consistent in thickness and devoid of air pockets. The sample holders were then placed in an oil separation apparatus, designed for accurate measurement of oil expulsion. The apparatus was set to operate under controlled temperature conditions to replicate real-world scenarios. Over a predetermined period, the grease samples were subjected to conditions simulating operational stresses, allowing any expelled oil to collect in a separate chamber. The collected oil was then carefully measured to determine the extent of oil separation from each grease formulation. The entire procedure was performed in triplicate to ensure the reliability and repeatability of the results. The recorded data provided quantitative insights into the oil separation characteristics of the grease formulations, contributing valuable information for the study's objectives. This methodically executed procedure ASTM D1742, aligning with the study's goals to evaluate the impact of Avocado Seed Oil as an additive in the formation of grease from spent engine oil, with a specific focus on oil separation behavior.

2.1.3 Procedure for Determination of Dropping Point

The dropping point determination of the grease formulations was conducted using a dropping point apparatus following standardized ASTM D2265 procedures. The dropping point serves as a critical indicator of the thermal stability of the grease. Initially, the grease samples were uniformly prepared by combining the base oil, stearic acid, sodium hydroxide, and avocado seed oil in precise proportions. The mixture was thoroughly stirred to achieve homogeneity and ensure the formation of a stable grease matrix. Subsequently, the prepared grease samples were carefully loaded into standardized containers within the dropping point apparatus. The containers were positioned to allow for free and unobstructed flow of the grease during the test. The dropping point apparatus was then set to gradually heat the grease samples at a controlled rate. As the temperature increased, observations were made for the point at which the grease underwent a distinct transition from a semisolid to a liquid state. This transition was marked by the dropping of the grease from the standardized cone within the apparatus. The dropping point temperature, corresponding to this transition, was recorded as the point at which the grease demonstrated a loss of consistency under the specified conditions. This procedure was carried out in triplicate to ensure the accuracy and reliability of the results. The recorded dropping point temperatures provided valuable insights into the thermal stability of the grease formulations, offering critical data for the study's objectives. The meticulous adherence to standardized procedures in the dropping point determination contributes to the comprehensive assessment of the impact of Avocado Seed Oil as an additive in the formation of grease from spent engine oil.

3 RESULTS AND DISCUSSION

3.1 Consistency Analysis

The presented consistency analysis results shown in table 3 and measured using standardized tests ASTM D217 and ISO 2137, provides a quantitative measure of consistency. Expressed in NLGI (National Lubricating Grease Institute) numbers, offer a comprehensive overview of the consistency variations among the four formulated samples (A, B, C, and D) and a commercially sold grease. The NLGI numbers categorize grease consistency, with lower numbers indicating softer greases and higher numbers representing harder greases. Sample A demonstrates the softest consistency with an NLGI number of 0, indicating a very soft and fluid grease. Moving along the spectrum, Sample B falls within the NLGI range of 1 to 2, suggesting a slightly firmer consistency compared to Sample A. Sample C exhibits a consistency falling between 2 to 3 on the NLGI scale, signifying a further increase in firmness. Sample D, with an NLGI range of 3 to 4, represents the firmest consistency among the formulated samples. Comparing these results to the NLGI range of 3 to 4 for commercially sold grease, it becomes evident that the formulated samples cover a broad spectrum of consistencies, from very soft to firm. Commercial grease, being the standard in this comparison, aligns with the NLGI range of Sample D, suggesting that Sample D and the commercially sold grease share a similar level of firmness. The NLGI results provide valuable insights into the impact of varying compositions on the consistency of the formulated grease samples. The various consistencies shown in table 3, ranging from soft grease to hard grease could be used for specific applications [15]. In relation to the commercial grease which is hard grease, Sample D emerges as a promising candidate, showcasing a consistency comparable to the industry-standard product. This aligns with the study's objectives of forming grease from spent engine oil and assessing the viability of avocado seed oil as an additive in the formation of grease from spent engine oil. The results for the consistency analysis of the four samples of grease produced is shown below

Table 3. Consistency Analysis

Sample	NLGI Number
A	0
B	1 to 2
C	2 to 3
D	3 to 4
Commercial Grease	3 to 4

3.2 Oil Separation

Table 4, presents oil separation results for the four formulated samples (A, B, C, and D) and a commercially sold grease using standards ASTM D1742, providing insights into the stability and oil-retention characteristics of the grease formulations. The values, expressed in percentage of oil separation, depict the extent to which each sample expelled oil over the testing period. Sample A, exhibits a relatively higher oil separation of 1.4%, indicating a moderate degree of oil expulsion. Sample B, demonstrates a decrease in oil separation, recording 0.6%, suggesting an improvement in oil-retention properties compared to Sample A. Furthermore, Sample C, shows a substantial reduction in oil separation, with only 0.2% observed. Notably, Sample D, demonstrates exceptional stability, with zero oil separation, signifying a superior ability to retain oil within the grease matrix. Comparing these results to the commercially sold grease, which also shows zero oil separation, it becomes evident that Sample D closely mirrors the performance of the industry-standard product. The absence of oil separation in both Sample D and the commercial grease underscores their high stability and resistance to oil expulsion under the testing conditions [16]. The oil separation results align with the NLGI consistency analysis, where Sample D demonstrated a consistency comparable to the commercially sold grease. The correlation between low oil separation and a higher NLGI number suggests that the formulated grease maintains its structure and oil-

retention capabilities, making it a promising candidate for lubrication applications. In summary, the oil separation results reinforce the potential of the formulated grease, especially Sample D, as an effective lubricant. Its performance closely aligns with that of the commercially sold grease, positioning it as a viable candidate for further exploration and validation in the study evaluating the impact of avocado seed oil as an additive in the formation of grease from spent engine oil [16, 17].

Table 4. Oil Separation

Sample	Oil Separation (%)
A	1.4
B	0.6
C	0.2
D	0.0
Commercial Grease	0.0

3.3 Dropping Point

The dropping point of grease is the temperature at which it transitions from a semisolid to a liquid state. ASTM D2265 was the method used to determine the dropping point, providing insights into a grease's thermal stability. Greases with high dropping points are suitable for applications where elevated temperatures are encountered, ensuring that the lubricant remains effective even under challenging operating conditions [16]. The dropping point results in table 5 are for the four formulated samples (A, B, C, and D) and a commercially sold grease which provides valuable insights into the thermal stability of the grease formulations. The dropping point, measured in degrees celsius, indicates the temperature at which the grease transitions from a semisolid to a liquid state. Sample A exhibits a dropping point of 40°C, reflecting a relatively low thermal stability. As we progress through the samples, there is a notable increase in dropping points, with Sample B at 69°C, Sample C at 98°C, and a significant improvement in Sample D, which shows a dropping point of 162°C. In comparison, the commercially sold grease boasts a dropping point of 169°C, aligning closely with the performance of Sample D. The dropping point results indicate that as the composition of stearic acid, sodium hydroxide, and avocado seed oil varies across the samples, there is a corresponding impact on the thermal stability of the grease. The observed trend of increasing dropping points suggests that the formulations with higher percentages of these components demonstrate enhanced resistance to thermal degradation. Comparing the dropping point of the commercially sold grease to that of Sample D, the formulated grease closely approximates the thermal stability of the industry-standard product. The dropping point of 162°C for Sample D is only slightly lower than the commercial grease, suggesting that this particular formulation exhibits a high level of thermal stability and can withstand elevated temperatures. In conclusion, the dropping point results shown in table 5, in conjunction with the NLGI consistency and oil separation analyses, contribute to a comprehensive understanding of the performance of the formulated grease samples. Sample D, with its high dropping point and consistency comparable to the commercially sold grease, emerges as a promising candidate in the formation of grease from spent engine oil using avocado seed oil.

Table 5. Presents the result for dropping point of the four grease samples.

Sample	Dropping Point (^oC)
A	40
B	69
C	98
D	162
Commercial Grease	169

4 CONCLUSIONS

In conclusion, the results from the consistency analysis in table 3, oil separation analysis in table 4, and the dropping point analysis in table 5, have provided valuable insights into the feasibility for the formation of grease from spent engine oil. The systematic variation in the composition of stearic acid, sodium hydroxide, and avocado seed oil across Samples A, B, C, and D allowed for a nuanced exploration of their impact on critical properties. Sample D, characterized by a dropping point of 162°C, a consistency comparable to commercially sold grease, and zero oil separation, emerged as a standout formulation. The dropping point results suggest that the inclusion of Avocado Seed Oil enhances the thermal stability of the grease, with Sample D demonstrating resistance to thermal degradation comparable to the commercially sold grease. The consistency analysis and oil separation result further support the promising performance of Sample D, showcasing its suitability as a lubricant with excellent stability and oil-retention properties. While these findings indicate a positive trend, it is important to acknowledge the complexity of lubricant formulations and the need for further exploration. Future studies should delve into additional tribological and performance tests, considering factors such as friction, wear resistance, and oxidative stability. Additionally, real-world applications and long-term performance should be assessed to ascertain the practical viability of Avocado Seed Oil as a sustainable additive in grease formulations.

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