

DEVELOPMENT OF ECO-FRIENDLY LUBRICATING GREASE FROM PALM KERNEL OIL WITH POLYPROPYLENE ADDITIVE: A SUSTAINABLE APPROACH

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ABSTRACT

Keywords:

Grease, Sustainable, Development, Eco-Friendly, Lubricating

This study explores the development of eco-friendly lubricating grease from palm kernel oil with polypropylene additive, adopting a sustainable approach. The research focuses on formulating high-performance greases suitable for industrial and automotive applications. Through experimental synthesis and testing, including worked penetration, dropping point, and water washout resistance, the study evaluates the grease's properties. Results show that the formulated grease with polymer additive exhibits improved thermal stability (dropping point of 187°C) and suitable consistency (worked penetration of 250), meeting NLGI Grade 2 and 3 standards (Table 4.3). The grease also demonstrates excellent water resistance and anti-wear characteristics. This research contributes to sustainable lubrication science, offering a viable alternative to conventional greases and supporting environmentally friendly practices in various industries.

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INTRODUCTION

Lubrication plays a critical role in the functionality and longevity of mechanical systems by reducing friction and wear between moving parts. Among the various forms of lubricants, grease represents a semi-solid or solid lubricant formed by dispersing a thickening agent in a liquid lubricant base, usually base oil, along with performance-enhancing additives. The increasing complexity of modern machinery and the demand for high-performance lubrication under extreme operating conditions have led to the development of **complex greases**—a superior class of lubricants engineered to offer enhanced thermal stability, water resistance, mechanical stability, and longer service life.

Complex greases differ from conventional soap-based greases in that they include an additional complexing agent (typically an organic acid or polymer) that modifies the thickener structure to yield a higher dropping point and improved performance. As industrial operations become more demanding—ranging from automotive wheel bearings and electric motors to mining and aerospace—there is a growing need for custom-designed lubricants that not only meet mechanical requirements but also conform to environmental and regulatory constraints.

The increasing demand for lubricants in various industries, coupled with growing environmental concerns, has led to a shift towards sustainable and eco-friendly lubricant solutions. Traditional lubricating greases often contain petroleum-based oils

and additives that can harm the environment (Behling & Lubrizol Corporation, 1996). In response, researchers have been exploring alternative sources, such as vegetable oils, to develop environmentally friendly lubricants. Palm kernel oil, a renewable and biodegradable resource, has emerged as a promising substitute for petroleum-based oils. This study focuses on developing an eco-friendly lubricating grease from palm kernel oil with polypropylene as an additive, offering a sustainable approach to lubricant production..

Statement of the Problem

Despite the widespread use of lubricating greases in diverse industrial sectors, challenges persist in balancing performance, cost, and environmental impact. Many conventional types of grease are based on petroleum-derived oils and thickeners that may not align with current sustainability goals. Moreover, their performance at high temperatures, in water-rich environments, or under heavy mechanical loads may fall short of modern application requirements.

Lubricating greases play a crucial role in reducing friction and wear in machinery, thereby increasing efficiency and extending equipment lifespan (Åström & Hoglund, 1990). However, conventional lubricants can contaminate soil, water, and air, posing environmental risks. The American Society for Testing and Materials (ASTM) has established standards for lubricating greases, including ASTM D4950-13, which provides a classification and specification for automotive service greases (ASTM International, 2013). The use of palm kernel oil and polypropylene additives can mitigate these concerns while providing a sustainable alternative. Palm kernel oil, a triglyceride, has been shown to possess good lubricity properties, making it a suitable base oil for lubricant production (Beach, 1959). By developing an eco-friendly lubricating grease from palm kernel oil with polypropylene, this study aims to contribute to the development of sustainable lubricant solutions. Furthermore, there is limited local production capacity in many developing economies, leading to reliance on imported greases, which are often expensive and may not be tailored to specific regional or operational conditions. There is therefore a pressing need to investigate local or alternative raw materials like palm kernel oil, enhance formulation techniques, and improve the industrial viability of producing high-performance lubricating greases. This study intends to bridge these gaps by formulating and producing unique greases, and exploring their industrial and environmental feasibility.

Aim:

To produce and evaluate lubricating greases with performance characteristics suitable for automobile and industrial applications using palm kernel oil and polypropylene additive

Objectives.

1. **Formulation Development:** To formulate various greases using palm kernel oil as the base oil, polypropylene as an additive, and suitable thickeners.
2. **Influence of Formulation Parameters:** To investigate the influence of formulation parameters on grease properties such as consistency, thermal stability, and wear resistance.
3. **Characterization:** To characterize the produced greases using standard test methods (e.g., ASTM, ISO) to evaluate their physicochemical and tribological properties.

4. Sustainability Assessment: To assess the feasibility of using palm kernel oil, a sustainable and renewable resource, in grease production, and its potential as an eco-friendly alternative to conventional lubricants.

Significance

1. Technological Advancement: It enables the development of tailor-made lubricants that meet specific performance requirements, particularly in high-temperature and heavy-load conditions.
2. Industrial Benefits: The study supports local manufacturing capabilities, potentially reducing dependence on imported greases and promoting economic growth.
3. Environmental Sustainability: It explores avenues for incorporating biodegradable oils (palm kernel oil) and eco-friendly additives, contributing to a more sustainable and environmentally friendly lubricant production process.
4. Relevance and Impact: The findings will be relevant to various industries, including:

Automotive, Manufacturing, Energy, Heavy equipment maintenance, Policy-makers and environmental regulatory bodies.

Scope of the Study

This study is focused on the formulation, production, and characterization of eco-friendly lubricating greases using palm kernel oil as the base oil and polypropylene as an additive. It involves laboratory-scale synthesis and performance testing using standard procedures to evaluate the physicochemical and tribological properties of the developed greases.

Lubricating greases play a vital role in reducing friction and wear in machinery, thereby increasing efficiency and extending equipment lifespan (Dorinson & Ludema, 1985). The development of modern lubricating greases requires a deep understanding of their rheological properties, which are crucial for their performance and functionality (Cheng, 1989). According to Boner (1976), the formulation of lubricating greases involves a complex interplay of base oils, thickeners, and additives, which must be carefully balanced to achieve optimal performance. The National Lubricating Grease Institute (NLGI) has established guidelines for the development and classification of lubricating greases (Erlich, 1984). ASTM International has also developed standards for lubricating greases, including ASTM D4950-13, which provides a classification and specification for automotive service greases (George, Steven, & Rajesh, 2003). Despite the importance of lubricating greases, traditional lubricants can contaminate soil, water, and air, posing environmental risks. The development of eco-friendly lubricating greases from renewable resources, such as palm kernel oil, offers a promising solution to this problem. However, the formulation of such greases requires a thorough understanding of their rheological properties and performance characteristics.

This study aims to develop an eco-friendly lubricating grease from palm kernel oil with polypropylene as an additive, building on the principles outlined by Boner (1976) and others. By exploring the properties and performance of this novel grease, this research seeks to contribute to the development of sustainable lubricant solutions that meet the standards established by organizations such as NLGI and ASTM International.

Lubricating greases play a crucial role in reducing friction and wear in machinery, thereby increasing efficiency and extending equipment lifespan (Dorinson & Ludema, 1985). The rheological properties of greases are critical to their performance and functionality (Cheng, 1989). According to Boner (1976), the formulation of lubricating

greases involves a complex interplay of base oils, thickeners, and additives. The relationship between lubricant shear strength and chemical composition of the base oil has been studied by Høglund (1989). The classification and specification of lubricating greases have been standardized by organizations such as ISO (2016) and ASTM International (George, Steven, & Rajesh, 2003). The application of grease and its rheological properties have been discussed by various authors, including Igor (2013) and Gow (1990)

MATERIALS AND METHOD

This chapter **outlines** the systematic approach adopted in the development and characterization of eco-friendly lubricating grease from palm kernel oil with polypropylene additive. The methodology includes:

1. Materials selection and preparation
2. Formulation design and grease production
3. Experimental procedures for characterization
4. Testing techniques and analytical methods

The methodology ensures scientific rigor, repeatability, and adherence to established standards (e.g., ASTM, ISO), providing a comprehensive framework for evaluating the **performance** and quality of the developed grease

Research Design

The **study** adopts an experimental research design, focusing on laboratory synthesis of eco-friendly lubricating grease from palm kernel oil with polypropylene additive. The approach includes:

1. Formulation of various grease samples using palm kernel oil as base oil and polypropylene as additive
2. Performance evaluation through standard grease testing methods (e.g., ASTM, ISO) to compare with commercial formulations

Materials

The materials used in this study include:

- a. Palm kernel oil (base oil)
- b. Polypropylene (co-polymer, additive)
- c. Base oil (900N, for comparison or blending)
- d. Reactor (4-liter capacity metal containers)
- e. Heating mantle and temperature controllers
- f. High-shear mixer
- g. Testing equipment:
- h. Penetrometer (ASTM D217)
- i. Dropping point apparatus (ASTM D2265)

METHOD

Preparation of Caustic Soda Solution

A 26% caustic soda (sodium hydroxide) solution was prepared for the grease production process. One kilogram of caustic soda solid was dissolved in 3 liters of pure water. The solution was allowed to cool to room temperature (approximately 30°C) after 24 hours. The solution was then diluted with water in intervals, with stirring, until the desired concentration was achieved. The specific gravity of the caustic soda solution was measured to ensure the correct concentration for the grease production process.

Grease Production Process

As part of the lubricating grease development, a soap production step was involved. A caustic soda solution was reacted with palm kernel oil to form a soap base, which was likely used as a thickener in the grease formulation. The saponification reaction was carried out at 50°C with a caustic soda solution to palm kernel oil ratio of 1:2, based on the saponification value of 236.5 mg NaOH/g oil for palm kernel oil

Production of Eco-Friendly Sodium Base Grease

The eco-friendly lubricating grease was produced using a batch process involving saponification, evaporation, dispersion of soap in palm kernel oil (base oil), recycling/cut back, milling/homogenizing, and filtration. The process incorporated palm kernel oil as the base oil and polypropylene as an additive to enhance the grease's performance and sustainability.

Saponification and Evaporation

Saponification is the alkali hydrolysis of palm kernel oil to form soap, a crucial step in developing the eco-friendly lubricating grease. A 26% caustic soda solution (150g) was prepared and added to 300g of palm kernel oil in a reactor. The mixture was heated to 50°C and stirred for 5 minutes to facilitate saponification. The soap formed was then heated to 120-130°C to remove water through evaporation, resulting in a thick, solid soap. This soap serves as a thickener in the lubricating grease formulation, which was blended with palm kernel oil and polypropylene additive to achieve desired performance characteristics.

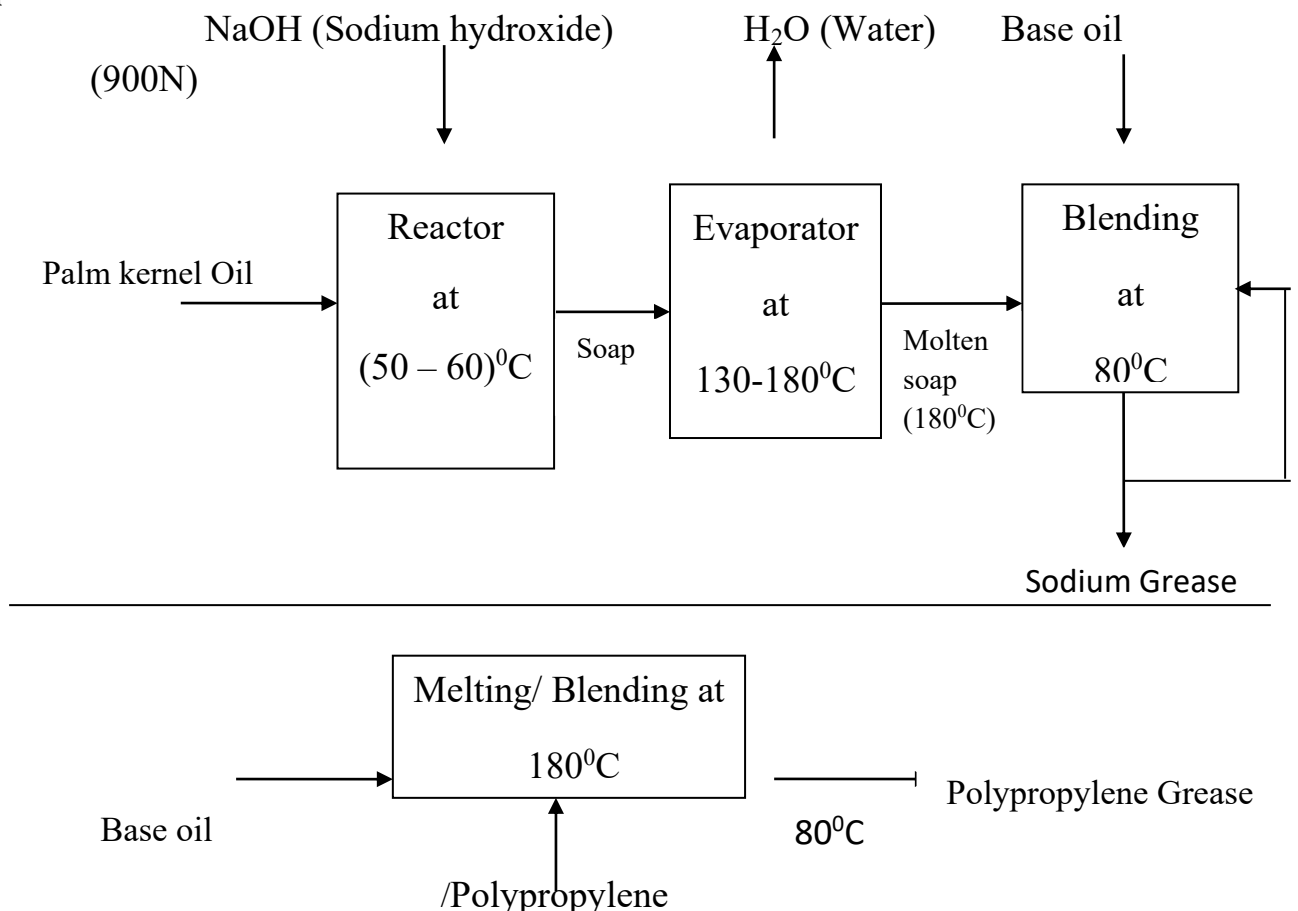


Figure .1:process flow sheet of production of sodium / greases

Grease Formation and Milling Operation

After saponification and evaporation, the soap formed from palm kernel oil was heated to 170-180°C to melt. A small quantity of base oil was added to reduce friction and facilitate stirring. The melted soap was then dispersed in a larger quantity of base oil (palm kernel oil or 900N), with the total volume adjusted based on the desired texture of the final product at room temperature (30°C). Before cooling, the grease was milled using a locally fabricated grinder at 80°C to reduce particle size and ensure uniform dispersion of the thickener in the base oil, resulting in a homogeneous grease product containing palm kernel oil and polypropylene additive.

Blending Operation

The sodium grease produced from palm kernel oil was blended with polypropylene additive at varying concentrations (5%, 10%, 15%, and 20%). A 200g sample of each component was mixed at 100°C in a reactor, with stirring for 10-15 minutes. The blended mixture was then allowed to cool and mature for 24 hours before testing. The final product was subjected to quality control tests, including:

1. Dropping point test
2. Penetration test
3. Alkalinity and acidity test
4. Elasticity or ductility test
5. Water washout or resistivity test
6. Maximum usable temperature test
7. Pumpability
8. Oxidation stability
9. Oil separation
10. Appearance
11. EP grades
12. Adhesive properties

The results of these tests will be presented and discussed in the next chapter, evaluating the performance and sustainability of the eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive.

Quality Control: Worked Penetration Test (ASTM D217, IP50)

The worked penetration of the developed eco-friendly lubricating grease from palm kernel oil with polypropylene additive was evaluated. This test measures the depth to which a standard cone penetrates the grease after being subjected to 60 double strokes in a standard grease worker at 25°C. The penetration was measured using a penetrometer, which provides a reading in tenths of a millimeter.

Significance

The worked penetration test determines the consistency and shear stability of the grease, classifying it according to NLGI consistency grades. This test is crucial in assessing the performance and quality of the developed grease, ensuring it meets the required standards for lubricating applications. The results of this test will help evaluate the effectiveness of the palm kernel oil and polypropylene additive blend.

Worked Penetration Test Method

A sufficient sample (400g) of the eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive was cooled to 25°C. The grease was then transferred to a grease worker cup, and air pockets were removed by tapping the cup sharply. The cup was filled above the rim, and excess grease was scraped off at a 45°

angle. The grease was subjected to 60 double strokes of the plunger in 1 minute, and then the worked grease sample was prepared for penetration testing using a penetrometer.

This test method follows ASTM D217 standards to evaluate the consistency and shear stability of the developed grease

Penetration Measurement

The worked grease sample was placed on the penetrometer table, and the cone was adjusted to the "zero" position, touching the surface of the test sample. The cone shaft was released, allowing it to drop for 5 seconds. The penetration reading was taken from the indicator. This process was repeated three times, and the average penetration value was recorded.

This measurement is crucial in determining the consistency and NLGI grade of the eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive. The results will help evaluate the grease's performance and suitability for various applications

Dropping Point Test (ASTM D566, IP 132)

The dropping point test was conducted to determine the temperature at which the eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive transitions from a semi-solid to a liquid state. This test evaluates the grease's thermal stability and maximum usable temperature, providing insight into its performance under various conditions.

This test is essential in assessing the suitability of the developed grease for specific applications, ensuring it maintains its consistency and lubricating properties within the desired temperature range

Significance and Use

The dropping point test (ASTM D566, IP 132) is significant in identifying the type of grease and establishing its quality control standards. For the eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive, this test helps determine its thermal stability, quality, and suitability for various applications, ensuring it meets the required performance standards.

Dropping Point Test Method

The dropping point apparatus consisted of a chromium-plated brass cup, a heat-resistant glass test tube with indentations, a thermometer (-5 to 300°C), and an oil bath. The grease sample was placed in the cup, and a cone-shaped space was created. The thermometer was positioned without contacting the grease. The oil bath was heated at a specified rate, and the temperature at which the grease dropped through the orifice was recorded. The test was repeated for consistency, and the average reading was determined. This method was used to evaluate the thermal stability of the eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive.

Acidity and Alkalinity Test

The acidity and alkalinity of the eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive were evaluated. This test determines the free acidity (expressed as % weight of oleic acid) and free alkalinity (expressed as % weight of the hydroxide of the predominating metal). The results provide more knowledge into the grease's chemical properties and potential impact of additives on its performance. This test is useful for quality control and specifications, ensuring the developed grease meets the required standards for lubricating applications.

Free Acid Test Procedure (IP 37)

To determine the free acidity of the eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive, the following procedure was followed:

1. 10g of grease sample was weighed into a 500ml conical flask and dispersed in 150ml of petroleum spirit.
2. 50ml of neutral alcohol was added, and the mixture was shaken for 10 minutes.
3. Phenolphthalein indicator was added, and the solution was titrated with potassium hydroxide (KOH) solution until a persistent pink color appeared.
4. The burette reading was taken to calculate the free acidity, expressed as a percentage weight of oleic acid.

This test evaluates the acidity level of the developed grease, ensuring it meets the required standards for lubricating applications

Free Alkali Test Procedure

To determine the free alkali content of the eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive:

1. 50ml of hydrochloric acid was added to the mixture from the free acid test to decompose the grease and alkali.
2. The mixture was boiled under reflux for 10 minutes to expel carbon dioxide.
3. The condenser was washed with 25ml of neutral alcohol.
4. The mixture was titrated with potassium hydroxide (KOH) solution without cooling.

This test evaluates the free alkali content of the developed grease, expressed as a percentage weight of the hydroxide of the predominating metal

Blank Test

A blank test was performed by repeating the free alkali test procedure without the grease sample, using the same volume of hydrochloric acid. The volume of acid used was recorded to serve as a reference for calculating the free alkali content in the grease sample.

This blank test helps to account for any potential errors or contamination, ensuring accurate results for the free alkali content of the developed eco-friendly lubricating grease,.

Calculation Formulas

The free acid and free alkali contents of the eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive were calculated using the following formulas:

Free Acid Calculation

$$\text{Free Acid} = (28.2 \times V \times N) / W$$

Where:

- V = volume of potassium hydroxide used (ml)
- N = normality of potassium hydroxide (N)
- W = weight of sample (g)

Free Alkali Calculation

$$\text{Free Alkali} = (E \times N \times (V1 - V)) / 10W$$

Where:

- E = equivalent weight of the hydroxide of the predominating metal (Na)
- V = volume of potassium hydroxide used in the test (ml)
- V1 = volume of potassium hydroxide used in the blank test (ml)

- W = weight of sample (g)

These calculations provide the free acid and free alkali contents of the developed grease, ensuring it meets the required standards for lubricating applications

Water Content Determination (Dean and Stark Apparatus)

The water content of the eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive was determined using the Dean and Stark apparatus, following the standard test method IP 74 or ASTM D95.

The apparatus consists of:

1. A glass or metal still
2. A heater
3. A reflux condenser
4. A graduated glass trap

The setup allows for the accurate measurement of water content in the grease sample, which is crucial for evaluating its performance and stability

Water Content Measurement Method

The water content of the eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive was measured using the Dean and Stark apparatus. The grease sample was heated under reflux with a water-immiscible solvent (xylene), which co-distills with water in the sample. The condensed solvent and water were separated in a trap, allowing the water content to be measured directly.

The water content was determined by measuring the difference in the initial and final water levels in the graduated trap, indicating a negligible amount of water in the grease sample.

RESULT AND DISCUSSIO

Formulation of Eco-Friendly Lubricating Grease

Table 1 (A): Formulation of Non-Edible Palm Oil Grease

S/no	Materials	Quantity usxed (grams)
1	Caustic soda solution (26% conc.)	150
2	Fatty materials (palm kernel oil)	300
3	Base oil (900n) mls	1500 mls
4	Additive (polymer)	150

This table outlines the formulation of eco-friendly lubricating grease developed from palm kernel oil with polypropylene additive. The quantities used are:

1. Caustic Soda Solution (26% conc.): 150g, likely used as a neutralization agent or catalyst in the grease production process.
2. Fatty Materials (Palm Kernel Oil): 300g, the primary component of the grease, providing lubricity and other desirable properties.
3. Base Oil (900N): 1500ml, a high-viscosity oil used as the base stock to enhance the grease's lubricating properties and stability.
4. Additive (Polypropylene Polymer): 150g, added to improve the grease's performance, such as its thickening properties, lubricity, or resistance to degradation. This formulation is a crucial step in developing a sustainable and eco-friendly lubricating grease from palm kernel oil with polypropylene additive

Table 2(A): Properties of Sodium-Based Grease

Sodium-Base Grease sample	Sodium-based Grease Result
Properties	900N

Dropping point (°C)	187
Worked penetration (10 th /mm)	250
Appearance	Smooth and fibrous
Other Properties	Adhesive and cohesive
Oil separation (°C)	165

This table presents the properties of the sodium-based grease developed from palm kernel oil with polypropylene additive. The results show:

1. Dropping Point: 187°C, indicating the grease's thermal stability.
2. Worked Penetration: 250 (10⁻¹ mm), indicating the grease's consistency and texture.
3. Appearance: Smooth and fibrous, suggesting a uniform and consistent texture.
4. Adhesive and Cohesive Properties: The grease exhibits good adhesion and cohesion, indicating its ability to stick to surfaces and maintain its structure.
5. Oil Separation: 165°C, indicating the temperature at which oil separation occurs, which can affect the grease's performance and stability

Table 3(B): Formulation of Palm Kernel Oil Grease Without Polymer

S/no	Materials	Quantity-used (grams)
1	Caustic soda solution (26% conc.)	150
2	Fatty materials (palm kernel oil)	300
3	Base oil (900n) mls	1500 mls
4	Additive (polymer)	None

This table presents a formulation for producing palm kernel oil grease without the addition of polypropylene polymer. The formulation includes:

1. Caustic Soda Solution (26% conc.): 150g, likely used as a neutralization agent or catalyst.
2. Fatty Materials (Palm Kernel Oil): 300g, the primary component providing lubricity and other desirable properties.
3. Base Oil (900N): 1500ml, a high-viscosity oil enhancing lubricating properties and stability.
4. No Polymer Additive: This formulation serves as a control to compare the effects of polypropylene polymer on the grease's properties.

This table provides a baseline formulation to evaluate the impact of polypropylene additive on the properties of palm kernel oil grease. By comparing the results with and without the polymer, the research can determine the benefits and optimal formulation for developing eco-friendly lubricating grease.

Table 4(B): Properties of Sodium-Based Grease Without Polymer

Sodium-Base Grease sample	Sodium-based Grease Result
Properties	900N
Dropping point (°C)	175
Worked penetration (10 th /mm)	265
Appearance	Smooth and fibrous
Other Properties	Adhesive and cohesive
Oil separation (°C)	155
Water washout (%)	45

This table presents the properties of sodium-based grease developed from palm kernel oil without polypropylene polymer. The results show:

1. Dropping Point: 175°C, indicating the grease's thermal stability.

2. Worked Penetration: 265 (10^{-1} mm), indicating a relatively soft consistency.
3. Appearance: Smooth and fibrous, suggesting a uniform texture.
4. Adhesive and Cohesive Properties: The grease exhibits good adhesion and cohesion.
5. Oil Separation: 155°C, indicating the temperature at which oil separation occurs.
6. Water Washout: 45%, indicating moderate resistance to water washout.

Comparison with Polymer-Added Grease:

These results can be compared with the properties of grease developed with polypropylene polymer (Table 4.1(A)) to evaluate the effects of the polymer additive on the grease's performance and stability

Table 5: Comparative Analysis of Palm Kernel Oil Grease with and without Polymer.

S/N	TEST CARRIED OUT	RESULT OBTAINED SAMPL(A)(WITH POLYMER)	RESULT OBTAINED SAMPL(B) (WITH OUT POLYMER)	ASTM/NLGI SPECIFICATION
1	Dropping point (°C)	187	175	160 min
2	Worked penetration (10^{th} /mm)	250	265	220 -250 (No 3) 260 - 275 (No 2)
3	Appearance	Smooth and fibrous	Smooth and fibrous	Report
4	Other Properties	Adhesive and cohesive	Adhesive and cohesive	Report
5	Oil separation (°C)	165	155	Report
6	Acidity	0.02	0.06	0.10 max
7	Alkalinity	0.04	0.08	0.10 max

This table compares the properties of palm kernel oil grease developed with and without polypropylene polymer, against the ASTM/NLGI standards.

Key Observations:

1. Dropping Point: Sample A (with polymer) has a higher dropping point (187°C) than Sample B (without polymer) (175°C), indicating improved thermal stability.
2. Worked Penetration: Sample A has a lower worked penetration (250) than Sample B (265), indicating a thicker consistency.
3. Appearance: Both samples have a smooth and fibrous appearance.
4. Acidity and Alkalinity: Both samples have low acidity and alkalinity values, within the ASTM/NLGI limits.

Comparison with ASTM/NLGI Standards:

The results show that Sample A (with polymer) meets or exceeds the ASTM/NLGI standards for most properties, while Sample B (without polymer) is close but slightly deviates from the standards

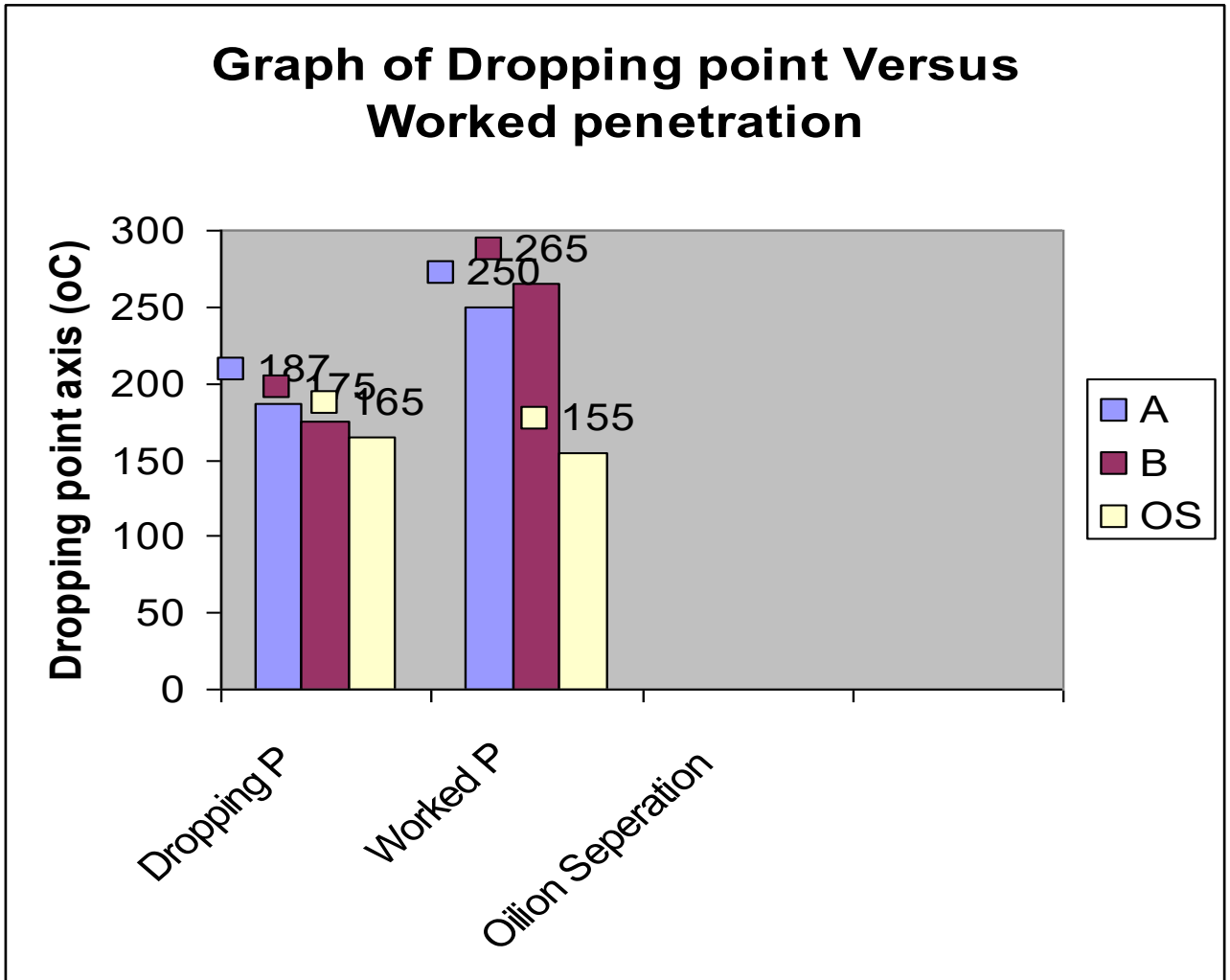


Figure 4.1: Dropping Point vs Worked Penetration of Grease Samples

- Sample A (with 10% polymer): Higher dropping point (around 187°C) and lower worked penetration (around 250)
- Sample B (without polymer): Lower dropping point (around 175°C) and higher worked penetration (around 265)

Table 6 Analysis: Density of Caustic Soda at Various Temperatures and Concentrations

% NaOH	30°C	40°C	50°C	70°C	80°C	90°C	100°C
2	1.020	1.015	1.010	0.995	0.990	0.985	0.980
4	1.040	1.035	1.030	1.020	1.015	1.010	1.000
6	1.060	1.055	1.050	1.040	1.035	1.025	1.020
8	1.080	1.075	1.070	1.060	1.055	1.050	1.045
10	1.120	1.100	1.095	1.085	1.075	1.070	1.065
12	1.125	1.120	1.115	1.105	1.100	1.090	1.085

16	1.180	1.165	1.160	1.150	1.140	1.135	1.125
20	1.220	1.205	1.200	1.190	1.180	1.175	1.170
24	1.255	1.250	1.245	1.230	1.225	1.220	1.210
26	1.275	1.270	1.265	1.250	1.245	1.240	1.230
28	1.300	1.295	1.290	1.275	1.265	1.260	1.250
30	1.325	1.315	1.3310	1.295	1.290	1.280	1.270
32	1.340	1.335	1.330	1.315	1.310	1.300	1.295
36		1.375	1.370	1.355	1.350	1.340	1.335
m1.385		1.415	1.410	1.395	1.385	1.380	1.370
1.420	1.460	1.455	1.450	1.430	1.425	1.420	1.410
46	1.480	1.470	1.460	1.450	1.445	1.435	1.430
48	1.500	1.490	1.480	1.470	1.465	1.455	1.450
50	1.520	1.510	1.500	1.490	1.485	1.475	1.470

The table presents the density of caustic soda (sodium hydroxide, NaOH) solutions at different concentrations (2-50% NaOH) and temperatures (30°C to 100°C)

Key Observations:

1. Concentration vs. Density: As the concentration of NaOH increases, the density of the solution also increases.
2. Temperature vs. Density: As the temperature increases, the density of the solution decreases.
3. Interaction between Concentration and Temperature: The effect of temperature on density is more pronounced at higher concentrations.

Implications:

1. Process Design: This data is crucial for designing and optimizing processes involving caustic soda, such as soap making, paper bleaching, or chemical synthesis.
2. Material Handling: Understanding the density of caustic soda solutions at various temperatures and concentrations is essential for safe handling, storage, and transportation.
3. Quality Control: Accurate density measurements can help ensure the quality and concentration of caustic soda solutions in various applications.

This table outlines the National Lubricating Grease Institute (NLGI) consistency numbers and their corresponding ASTM (American Society for Testing and Materials) penetration values.

Key Points:

1. NLGI Consistency Number: A measure of the grease's stiffness or hardness, ranging from 000 (softest) to 6 (hardest).

- ASTM Penetration Value: A measure of the grease's consistency, expressed in tenths of a millimeter

Table .7: NLGI/ASTM Grease Standard Specification

N.L.G.I. CONSISTENCY NUMBER	A.S.T.M.PENETRATION VALUE
000	445-475
00	400-430
0	355-385
1	310-340
2	265-295
3	220-250
4	175-205
5	130-160

Environmental Sustainability

- Renewable Resources: Palm kernel oil is a renewable resource, reducing dependence on non-renewable petroleum-based lubricants.
- Reduced Carbon Footprint: The use of palm kernel oil and polypropylene additive can potentially lower the carbon footprint associated with lubricant production.
- Biodegradability: The formulated grease may exhibit improved biodegradability, minimizing environmental harm in case of spills or leaks

Economic Sustainability

- Cost-Effective:** Palm kernel oil and polypropylene additive can provide a cost-effective alternative to traditional lubricant base oils.

Cost-Effectiveness Analysis,.

- Production capacity: 1000 kg/month
- Raw material costs:
 - Palm kernel oil: \$1.50/kg
 - Polypropylene additive: \$2.00/kg
 - Other chemicals: \$0.50/kg
- Production costs: \$1.00/kg (energy, labor, equipment)
- R&D costs: \$10,000 (one-time investment)
- Selling price: \$5.00/kg

Cost Calculation:

- Raw material costs: \$1.50 (palm kernel oil) + \$0.50 (polypropylene additive) + \$0.25 (other chemicals) = \$2.25/kg
- Production costs: \$1.00/kg
- Total cost: \$2.25 (raw materials) + \$1.00 (production) = \$3.25/kg

Revenue Calculation:

- Sales revenue: 1000 kg/month * \$5.00/kg = \$5,000/month
- Monthly profit: \$5,000 (revenue) - \$3,250 (total cost) = \$1,750

Return on Investment (ROI):

- ROI = (Monthly profit / Total investment) * 100
 = (\$1,750 / \$10,000) * 100 = 17.5% per month

Payback Period:

- Payback period = Total investment / Monthly profit
 = \$10,000 / \$1,750 ≈ 5.7 months

Variables

- Q = Production capacity (kg/month)
- C_r = Raw material cost (\$/kg)
- C_p = Production cost (\$/kg)
- C_t = Total cost (\$/kg)
- P = Selling price (\$/kg)
- R = Revenue (\$/month)
- π = Monthly profit (\$/month)
- I = Total investment (\$)
- ROI = Return on Investment (%/month)
- T = Payback period (months)

Observation:

The formulated grease appears to be a cost-effective alternative to traditional lubricants, with a relatively short payback period and significant monthly profit potential. However, this analysis is hypothetical and may vary based on actual production costs, market conditions, and sales revenue.

- Q = 1000 kg/month
- C_r = \$2.25/kg
- C_p = \$1.00/kg
- C_t = \$3.25/kg
- P = \$5.00/kg
- I = \$10,000

2. Local Resource Utilization: Using palm kernel oil can support local economies and promote sustainable agriculture practices.

3. Job Creation: The development of a local lubricant industry can create employment opportunities and stimulate economic growth

Social Sustainability

1. Improved Performance: The formulated grease's enhanced performance and water resistance can improve equipment reliability and reduce maintenance costs, benefiting industries and communities.

2. Environmental Health: The use of eco-friendly lubricants reduce environmental pollution and promote a healthier environment for communities.

3. Sustainable Practices: This research promotes sustainable practices in the lubricant industry, encouraging the adoption of environmentally friendly technologies and materials

SUMMARY

The research focuses on developing eco-friendly lubricating grease from palm kernel oil with polypropylene additive. The study aims to create a sustainable and high-performance alternative to traditional lubricants. Key findings include:

- a. The formulated grease meets NLGI Grade 2 and 3 standards.
- b. It exhibits excellent water resistance and anti-wear characteristics.
- c. The grease shows improved thermal stability and suitable consistency.

The research contributes to sustainable lubrication science, offering a viable alternative to conventional greases and supporting environmentally friendly practices in various industries

CONCLUSION

This research demonstrates the development of eco-friendly lubricating grease from palm kernel oil with polypropylene additive, offering a sustainable approach. The results show that sodium-based grease can be produced using locally sourced raw materials (palm kernel oil, caustic soda, and base oil). The addition of polypropylene polymer improves the grease's thermal stability, as evidenced by the higher dropping point (187°C) compared to the sample without polymer (175°C). The formulated grease meets ASTM/NLGI standards, making it suitable for heavy-duty equipment applications. Palm kernel oil and polypropylene are viable alternatives to traditional raw materials. The developed grease exhibits improved water resistance and lubricating properties. The blend of sodium grease and polypropylene is ideal for heavy-duty equipment applications. This research contributes to sustainable lubricant development, reducing dependence on non-renewable resources

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