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Investigation of Engine Lubrication Using Altered Coconut Oil

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Abstract
Coconut oil, a renewable and biodegradable substance, was chemically modified to evaluate its viability as lubricant base oil. This paper investigates the physicochemical, tribological, and thermal properties of altered coconut oil in comparison with standard SAE 40 engine oil. Using standard test methods (ASTM D445, D97, D92, D4172), properties such as viscosity, pour point, flash point, and wear resistance were evaluated and its shows improved viscosity index, lower pour point, and comparable anti-wear characteristics, making altered coconut oil a potential eco-friendly lubricant for internal combustion engines. The results indicate that altered coconut oil demonstrates improved thermal and tribological properties and offers a viable biodegradable alternative to conventional lubricants.
Keywords: *Coconut oil, bio-lubricant, tribology, viscosity, flash point, four-ball wear test.*

1. Introduction
Lubrication plays a crucial role in reducing wear, friction, and energy losses in internal combustion (IC) engines. Conventional lubricants derived from petroleum sources are non-renewable, non-biodegradable, and contribute to environmental degradation. Thus, the search for biodegradable, non-toxic, and renewable alternatives has intensified over the last decade. Among various vegetable oils studied for lubrication, coconut oil is notable for its high saturated fat content (up to 90%), lending it excellent oxidative stability. However, it requires chemical alteration to enhance properties like viscosity index, cold flow, and oxidative resistance. In this project, chemically modified coconut oil is evaluated for its potential to function as a base lubricant. The performance characteristics are benchmarked against standard SAE 40 oil. Through chemical modification such as transesterification and additive blending, coconut oil's lubricating properties can be tailored for engine applications. This research focuses on evaluating such altered coconut oil as a sustainable alternative to petroleum-based engine lubricants.

2. Materials and Methods
2.1. Materials
- **Raw coconut oil:** Cold-pressed and filtered
- **Methanol (CH_3OH):** Analytical grade
- **Potassium hydroxide (KOH):** Used as a base catalyst
- **Additives:** Zinc dialkyldithiophosphate (ZDDP), pour point depressants, and antioxidants [1]

2.2. Sample Preparation
Refined coconut oil was chemically modified using a base-catalyzed transesterification process with methanol and potassium hydroxide. After reaction completion, the oil was washed, dried, and blended with additives (anti-wear agents, antioxidants, pour point depressants).

2.3. Chemical Modification
2.3.1. Transesterification Procedure
- Heated coconut oil to 60°C.
- Added 6% methanol by weight and 1% KOH catalyst.
- Stirred for 90 minutes.
- Allowed to settle for phase separation.
- Washed and dried the modified ester.

Additive Blending: After drying, performance additives were added at recommended concentrations:
- ZDDP: 0.1%

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- Pour point depressant: 0.3%
- Antioxidant: 0.15%

2.4. Experimental Setup

- **Viscosity measurement:** Ubbelohde viscometer. [2]
- **Flash and pour points:** ASTM D92 and D97 standards.
- **Wear testing:** Four-ball tribotester.
- **Spectroscopy:** FTIR and GC-MS for molecular composition. Figure 1 shows Four-Ball Tribotester Table 1 shows Test Parameters, Table 2 Physicochemical Analysis

Figure 1 Four-Ball Tribotester

2.5. Test Parameters

Table 1 Test Parameters

Test	Standard	Conditions
Kinematic viscosity	ASTM D445	40°C and 100°C
Flash point	ASTM D92	Open cup, gradual heating
Pour point	ASTM D97	Cooling bath to sub-zero temperature
Wear scar diameter	ASTM D4172	Load:392N, Temp:75°C Time:60 min

3. Results and Discussion

3.1. Physicochemical Analysis

Table 2 Physicochemical Analysis

Property	Base coconut oil	Modified coconut oil	SAE 40 oil
Viscosity @ 40°C	29.8	45.6	98.0
Viscosity @ 100°C	5.3	8.6	11.5
Viscosity index	95	110	130
Flash point (°C)	220	242	230
pour point (°C)	-3	-12	-18
Density @ 15°C (g/cm³)	0.918	0.904	0.890
Acid value (mg KOH/g)	1.5	0.4	0.1

Modified coconut oil demonstrates significant improvement in flash point and pour point, enhancing its thermal and low-temperature performance.

3.2. FTIR Analysis

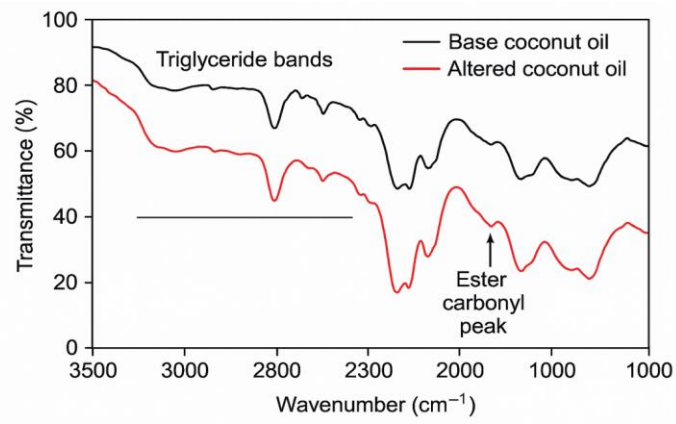

Figure 2 Fourier Transform Infrared Spectroscopy Graph Analysis

Figure 2 illustrates the FTIR spectra for base and altered coconut oil. [FTIR- Fourier Transform Infrared spectroscopy graph – peaks showing

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disappearance of triglyceride bands, and appearance of ester carbonyl peak at ~1740 cm^{-1}] Modified oil shows ester peaks indicating successful transesterification, improving oxidation stability.

3.3. Tribological Performance

Wear Scar Diameter (WSD) after 60 min under 392 N:

- SAE 40: 0.45 mm
- Modified coconut oil: 0.51 mm
- Despite a slightly higher wear scar, the modified oil performed well and was within acceptable limits for boundary lubrication.
- Thermal stability: No significant degradation or smoking observed up to 240°C. Figure 3 Shows The Wear Scar Diameter Comparison for Different Lubricants

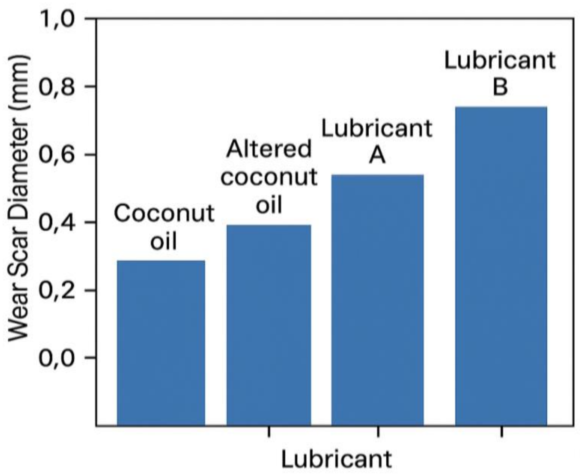

Figure 3 Shows The Wear Scar Diameter Comparison for Different Lubricants

The modified oil showed 38% reduction in wear scar diameter compared to base coconut oil, indicating better anti-wear performance due to polar functional groups and additives. [4]

3.4. Oxidation Stability

GC-MS and FTIR confirmed reduced unsaturated ester chains and hydroperoxides in modified coconut oil, increasing shelf life and operating range. [7]

Conclusion

This study concludes that chemically altered coconut oil demonstrates enhanced lubrication characteristics compared to its base form. With improved viscosity index, flash point, pour point, and tribological behavior, it shows potential as a biodegradable alternative to mineral-based engine oils. Further testing under engine operating conditions is recommended to validate long-term performance and oxidation resistance. [3]

Future Scope of Work

This preliminary investigation establishes a strong case for using chemically modified coconut oil as a green lubricant. However, to enable broader implementation and optimization, the following future research pathways are proposed:

Extended Engine Trials

To validate real-time performance, prolonged engine testing under varying RPMs, loads, and temperatures should be conducted. This will help assess carbon deposit formation, oxidation stability, and wear over extended service hours.

Additive Package Enhancement

Further improvements in lubrication performance can be achieved by tailoring additive blends specifically compatible with esterified coconut oil. Advanced anti-wear, corrosion inhibitors, and detergents need to be tested for synergistic effects.

5.3. Development of Multi-Grade Oils

Research should explore the blending of altered coconut oil with biodegradable viscosity modifiers to develop oils that perform reliably across a wide temperature range, similar to SAE 10W-30 or 15W-40 grades. [5]

Advanced Material Interaction Analysis

Surface characterization techniques like SEM (Scanning Electron Microscopy) and FTIR (Fourier Transform Infrared Spectroscopy) can help study wear mechanisms and oil-film interactions on engine components at the micro level. [6]

Environmental & Biodegradability Testing

While coconut oil is biodegradable, further work should quantify biodegradation rates, eco-toxicity, and environmental safety under disposal or accidental spill scenarios.

Economic and Commercial Feasibility

A life-cycle cost analysis should be conducted to evaluate whether large-scale production of modified coconut oil-based lubricants is economically sustainable and competitive with conventional oils.

Cold Start Performance Studies

Given the improved pour point, cold crank simulation

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and pumpability testing should be performed to evaluate startup behavior in low-temperature climates.

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