DEPARTMENT OF SCIENCE LABORATORY TECHNOLOGY

PRODUCTION AND ANALYSIS OF BIOLUBRICANT FROM A LOCALLY PRODUCED COCONUT OIL (*ADIN AGBON*)

By

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HND/23/SLT/FT/0550

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2024/2025 SESSION

CERTIFICATION

This is to certify that this project work presented by IBRAHIM HADI BOLAJI with Matriculation Number HND/23/SLT/FT/0550 has been read, approved and submitted to the Department of Science Laboratory Technology (Chemistry Unit), Institute of Applied Sciences, Kwara State Polytechnic, Ilorin.

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DEDICATION

This research work is dedicated to almighty Allah and my supportive family who make this academy more easy for me and my group leader who dedicate his time on our project. Thank you for your love and support.

ACKNOWLEDGEMENT

I give thanks to almighty Allah and my parents mr&mrs Ibrahim and Taibat and also my lovely siblings who make this journey easy for me ‘ may almighty Allah bless them in abundant. Am also grateful to my group leader abdul razaq who make the project easier for everyone may almighty Allah reward you in good way and also my colleague that we are in this together may almighty Allah grant our effort, I will also appreciate our supervisor Mr Adeyemo for all he has done for us may almighty Allah reward him.

Ibrahim Hadi Bolaji

HND/23/SLT/FT/0550

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Abstract

In this study, a sample of coconut oil produced locally was purified and subsequently transformed into a biolubricant using the fatty acid methyl ester (FAME) from the oil sample and trimethylolpropane (TMP). The biolubricant produced was analyzed for its quality parameters and the chemical components elucidated by GC-MS, and FTIR analysis. The result showed that the biolubricant prepared from the coconut oilhad a quality comparable to ISOVG32 standard lubricant quality. The predominant carboxylic acids in the oil sample were identified to be octanoic, nonanoic and decanoic acids. This work has established that the locally produced coconut oil is a potential feedstock for biolubricant- an environmental friendly product.

Keywords: biolubricant, coconut oil, fatty acid, lubricant quality

CHAPTER ONE

1.0 INTRODUCTION

In industries (transportation and production) or any sliding operations lubricants are used to reduce wear and friction on interacting surfaces[1]. Apart from minimizing wear and friction, lubricants also help prevent corrosion[2] distribute power, remove heat [3], and Provide a liquid seal at moving contracts. From large gear like industrial metal-rolling mills to small equipment like computer hard drives. Lubricants are employed in a variety of equipment to maintain dependable machine performance [4]. Although not all lubricants are liquids, that way 19th century's industrial growth generated a demand for liquid lubricants that quickly outpaced the supply of every other type, thus meeting the expectations [5].

1. Suryawanshi S.R. and Pathwar J.T. "Effect of TiO_2 Nanoparticles Blended with Lubricating oil on the Tribiological Performance of the Journal Bearing; Tribology in Industry 40, (2018): 370-391.
2. Shah R, Woydt. M and Zhang S. "The economic and Environmental Significance of Sustainable Lubricants". Lubricants, No. 9 (2021): 21.
3. Wong V.M and Tung S.C. "Overview of automotive engine friction and reduction Trends-effects of Surface, Material and Lubricant-additive Technologies," Friction. No. 4 (2016): 1-28.
4. Mannekote J.K, Kailas S.V, Ventatesh. K and Kathyayini. N. "Environmentally Friendly Functional fluids from renewable and sustainable sources. A Review". Renewable and Sustainable Energy Reviews 81, (2018): 1787-1801.

5. Boroojeni K.G, et al.. “A Theoretical Bilevel Control Scheme for Power Network with large-scale penetration of Distributed Renewable Resources”, 2016 IEEE International Conference on electro Information Technology, (2016): 510-515.

In solving the lubrication challenges, mineral oil, a raw material made possible using petroleum source, was also produced. However, since ordinary base lubricant cannot withstand the working conditions, enhancement through inclusion of sui additives were introduced. In this synergistic approach, while the additives offers extra features to final product, base stocks contribute unique basic characteristics.

1.1 PROBLEM STATEMENT

The environmental impact of traditional lubricants is significant, with approximately 40% of all lubricants being discharged into the environment, particularly in developing countries where disposal regulations are often lacking. This creates a toxic working environment and leads to harmful pollutants being released into the air through practices such as burning lubricants for fuel. Additionally, the production of petroleum-based lubricants results in airbone poisons and harmful substances. Given these challenges, there is a pressing need for bio lubricants, which are derived from renewable source, to mitigate these environmental issues. However bio lubricants face their own challenges, including performance limitations, oxidation stability, compatibility with existing machinery, and higher production costs. Addressing these problems is essential for promoting the adoption of bio-lubricants as a sustainable alternatives[6].

1.2 AIM AND OBJECTIVES OF THE STUDY

The aim of this study typically focus on addressing environmental and performance challenges associated with conventional lubricants. The specific objectives of the study is as follows:

- ❖ To collect samples of coconut
- ❖ To extract the coconut oil from coconut milk press-cake
- ❖ Studying the solvent extraction of residual oil from wet coconut meal using isopropanol
- ❖ Extraction of coconut oil from coconut paste by a new enzymatic process

6. Mobarak H.M, Niza M.E., Masjuki H.N, Kalam M.A, Ai Mahmud K and Habibullah. M, (2014). “The prospects of biolubricants as alternatives in automotive application renewable and sustainable energy reviews”, 2014, 33: 34-43, http://dx.doi.org/10.1016/j.rser.01.062.

- ❖ Filtration extraction of granulated coconut on a bench scale
- ❖ To carried out laboratory scale studied the preparation of a highly nutritious coconut flour from granulated coconut
- ❖ The desiccated coconut produced can be used for mechanical extraction of colourless, odourless coconut oil suitable for direct consumption.

1.3 JUSTIFICATION OF THE STUDY

On completion of this study, it is grounded in their environmental benefits, sustainability, health and safety improvements, economic viability, technological advancements, and regulatory compliance.

1.4 SCOPE OF THE STUDY

The scope of this project research includes their sources, (such as animal fats, coconut) chemical properties, performance, environmental impact, applications, and regulatory aspects. This multidisciplinary approach aims to enhance the development and utilization of sustainable lubricants.

1.5 RELEVANCE OF THE STUDY

The relevance of this project research is significant in promoting environmental sustainability, creating economic opportunities, ensuring regulatory compliance, enhancing performance and fostering innovation.

CHAPTER TWO

2.0 LITERATURE REVIEW ON COCONUT OIL

Philippines, Indonesia, India, Sri Lanka, Mexico, west Malaysia, and Papua and New Guinea are the 7 countries which produce major quantities of coconut in the world. Coconut is available in two forms viz, wet and dry materials commonly known as wet coconut and dry coconut or copra. The oil can be extracted from both these raw materials. However, in India and Sri Lanka, it is a general practice to use only copra for oil extraction and the oil is used for food and cosmetic purposes. In Philippines, the oil is extracted from wet coconut also and is known as virgin coconut oil. In some countries solvent extraction of the dry coconut followed by refining bleaching and deodorization is carried out to get the refined bleached and deodorized coconut oil. The technology for the production of coconut oil through expeller is well developed and many medium scale industries in India produce oil by this method. However, some small scale industries produce the oil by processing fresh coconut also using local expeller press. Problems of sediments and rancidity persist in these oils[7].

2.1 SOURCES AND PREPARATION OF LUBRICANTS OIL

Conventional lubricants contain high molecular weight hydrocarbons derived from the vacuum residues in the refinery as base stocks. Unsaturated fatty acids are used as base stocks in bio-lubricants, which until now have been based on vegetable oil [8]. Due to their weak heat stability and poor oxidation stability from the presence of oxidizable functional groups brought on by an unsaturated bond pure vegetable lubricants are found inappropriate for use in applications like lubricating fluids [9]. Vegetable oils can have their unsaturated fatty acid

7. Cornelius J.A. “Coconuts: a review”. Trop. Sci 5, 1(1973): 15-37.
8. Woma T.Y, Lawal S.A, Abdulrahman A.S, Olutoye M.A and Ojapah M.M “Vegetable oil Based Lubricants” Challenges and Prospects”. Tribology online 14, (2019): 60-70.

9. Srivyas P.D and Charoo M.S. "A review on Tribological Characterization of Lubricants with Nano additives for Automotive applicatios", Tribology in Industry 40, (2018): 594-623.

content decreased to make them appropriate for use in engines and make them equivalent to conventional lubricants via chemical modification methods like hydrogenation, transesterification and epoxidation [10,11,12]. To enhance the final lubricant formulation's physical, chemical and thermal qualities, as well as stability through additives, added new feature to base stocks. Based on their function in lubrication systems, lubricant additives are derived into different categories: friction modifiers, anti-oxidation agents anti-wear. Additionally, they are categorized according to their working environment and role, like tribo-improvers, rheo-improvers, and maintainers [13]. Lubricants tribological performance is improved by tribo-improvers, rheo-improvers are designed for base oils fluidity, while maintainers prevent the lubricants and machines parts from degrading, as well as the breakdown of the substance involved in the lubrication system.

10. Kerni L, Raina A and Haq M.I.U. "Friction and wear performance of olive oil containing Nano Particles in Boundary and Mixed Lubrication Regimes" wear 426-427, (2019): 819-827.
11. Gad M.S. and Gadow S.I. "Enhancement of Combustion Characteristics and Missions Reductions of a diesel engines using Biodiesel and Carbon Nanotube", Furterene, Nanotubes and Carbon Nanostructure 29, (2020): 267-279.

12. Liu Z, Li J, Knothe. G, Sharma B.K and Jiang J. Improvement of Diesel Lubricity by Chemically Modified Tung-Oil-Based Fatty acid esters as additives", Energy and Fuel 33, (2019): 5110-5115.
13. Minami I. "Molecular Science of Lubricant additives". Applied Sciences, 7 (2017): 445.

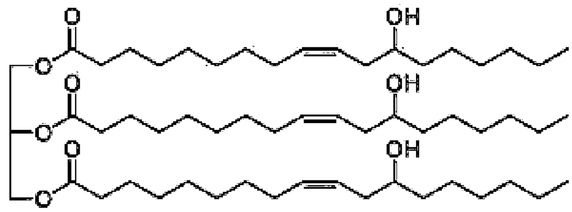


Figure 2.1: Chemical structure of most oil-base bio-lubricant showing triglyceride

2.2 PROPERTIES OF BIOLUBRICANTS

The major functions of biolubricants, i.e, reducing friction and wear, the dispersion of deposits, the inhibition of rust/corrosion, the dissipation of heat, and the sealing of critical contact joints, are reflected in the properties of the base oil. The base oil is expected to posses optimum viscosity and viscocity index, low volatility, low deposit formation, low temperature solidification, good hydrolytic and thermos-oxidative stability and biodegradability[14]. A good bio-lubricant should have its boiling point distribution towards high temperatures, high viscocity index, corrosion prevention capability,

14. Joseph P.V, Saxena D, and Sharma D.K. "Study of some Non-edible Vegetable oils of Indian origin for lubricant application J. Synth Lubr 24, (2007): 181-197.

high thermal stability, low freezing point, and high anti-oxidation potential[15]. While these are the preference characteristics of any biolubricant, specific applications to demand unique properties. For example (a) engine oil application demands low emissions of volatile organic compounds and polyaromatic hydrocarbons, (b) metal working fluids require good amplifiability, (c) hydraulic oils requires low compressibility and a quick release rate of air (d) transmission oils and gear oils requires high weld load, and (e) greases should possess good anti-wear and anti-scoring properties. The salient properties are explained in the following sections.

2.2.1 Viscosity

Viscosity is a key parameter that determines the time to replace the lubricant in a device. The viscosity depends on the factors such as the concentration of paraffins and the additives that affect the internal friction among the molecules, and it increase with the increase in the

15. Mobarak H.M, Niza Mohamed. E, Masjuki H.H, Kalam M.A, AI Mahmud K.A.H Habibullah. M and Ashraful A.M. The prospects of biolubricants as alternative in automotive applications", Renew Sustain. Energy Rev 33, (2014): 34-43.

chain length of the hydrocarbon portion of the fatty acid or alcohol in ester-based biolubricants. Owing to increased hydrogen bonding interactions, the presence of hydroxyl groups in the lubricant formulation or the addition of polyols modifies the viscosity index [16,17,18]. The viscosity index (IV), a metric used by lubricant users and refiners, describes the effect of temperature changes on the viscosity of the oil [19].

2.2.2 Thermo-Oxidative Stability

Auto-oxidation of the lubricant is promoted due to localized high temperature caused by frictional heat generated by the rubbing of solid surfaces against each other.

16. Cecilia J.A, Ballesteros Plata D, Alves Saboya R.M, Travares de Luna F.M, Cavalcante C.L and Rodriguez – Castellon E. "An overview of the biolubricant production process: Challenges and Future Prospective", Processes, 8 (2020): 257.
17. Saboya R.M.A Cecilia J.A, Carcia-Sancho C, Luna F.M.T, Sales A.V, Rodriguez-Castellon E and Cavalcante C.L. "Assesment of Commercial Resins in the Biolubricants Production from free fatty acids of caster oil", Catal. Today 279, (2017): 274-285.
18. Saboya R.M.A, Cecilia J.A, Garcia-Sancho. C, Luna F.M.T, Rodrigue – Castellon E, Cavalcante C.L. "Wo3-Based catalysts supported on porous clay Heterostructures (PCH) with Si-Zr Pillars for synthetic esters production." Appl. Clay Sci. 124-125, (2016): 69-78.

19. Verdier S, Coutinho J.A.P, Silva A.M.S, Alkilde O.F and Hansen J.A. "A Critical approach to viscosity index", Fuel 88, (2009): 2199-2206.

This tends to alter the viscosity of the lubricant due to reactions that promote the cleavage of long chain hydrocarbon molecules. Therefore, due to exothermic oxidation and endothermic. Pyrolysis reactions, the thermo-oxidative stability of the lubricant decrease with usage [20]. Thermo-oxidative stability can be tested using the RPVOT test (ASTM D2272). This involves the evaluation of the oxidation stability of the biolubricants in the presence of a copper catalyst and water at 423k and 620kpa of oxygen.

2.2.3 Pour Point

Pour point is the temperature below which the lubricant loses its flowability. In biolubricants, it is related directly to the viscosity index. The presence of ternary alcohols, such as trimethyl propane (TMP), reduces the pour point of the biolubricant, even though it tends to reduce the thermo-oxidative stability of the lubricant[21]. It can be measured using ASTM D5949, which involves the determination of

20. Minami I. "Ionic Liquid in Tribology", Molecules 14, (2009): 2286-2305.

21. Cecilia J.A, Baltesteros Plata. D, Alves Saboya R.M, Tavares de Luna F.M, Cavalcante C.L and Rodriguez-Castellon E. "An overview of the Biolubricant Production Process Challenges and Future Prospectives", processes, 8 (2020): 257.

pour point by applying a burst of nitrogen gas into the lubricant sample, while simultaneously cooling it. It is usually performed in an automated instrument, which also detects movement of the surface of the test sample using an optical device.

2.2.4 Ecotoxicity

Ecotoxicity is a metric used to characterize the environmental toxicity of a lubricant formulation. It is a major property that determines whether a lubricant formulation can irreversibly affect living things. As aqeous ecosystems are prone to damage by the organic and hydrocarbon components of lubricants, it is vital to determine lubricant to water toxicity. This is defined as the potential of a lubricant to poison target organisms such as bacteria, algae, small fish, or laboratory rats, ASTM D6081-20 is the standard protocol to test the aquatic toxicity of the lubricant.

2.2.5 Hydrolytic Stability

The resistance of biolubricants to chemical attack, especially when water molecules are involved either as a reactant or a product, is characterized by hydrolytic stability. The ASTM D2619-21 standard test method is used to determine the hydrolytic stability of petroleum or synthetic-based hydraulic fluids. Biolubricants for use as insulation fluids require high water solubility and a high dielectric constant. Therefore, the assessment of hydrolytic stability becomes imperative.

2.2.6 Biodegradability

If a lubricant can be structurally decomposed by enzymes or microorganism through aerobic process, it can be considered biodegradable [22]. A lubricant can be considered biodegradable if the precent degradation in a standard test exceeds a certain value. Vegetable oils are more biodegradable than mineral-based oils [23]. The environmental concern around the depletion of mineral reserves has sparked interest in biolubricants derived from natural triglycerides, as well as the fatty acid derived from them [24]. Biodegrability of the base fluid (or any other component) of an environmentally acceptable

22. Haase, K.D, Heynen A.J and Laane N.L.M. "Composition and application of isosteric acid", Fat Sci. Technol. 91, (1989): 350-353.
23. Mobarak H.M, Niza Mohamad. E, Masjuki H.H, Kalum M.A, AI Mahmud K.A.H, Habibullah M, and Ashraful A.M. "The prospects of Biolubricants as Alternatives in Automotive Applications", Renew. Sustain Energy Rev. 33, (2014): 34-43.
24. Kamalakar. K, Rajak A.K, Prasad R.B.N and Karuna M.S.L. "Rubber Seed oil-based biolubricant base stocks: A Potential Sources for hydraulic oils", Ind. Crop. Prod 51 (2013): 249-257.

lubricant (EAL) depends on both its molecular properties and the test method utilized [25]. Importantly, the chemical composition of base oils can change during the application of lubricants, i.e, when they are subjected to varying temperature, air humidity, metals and pressure.

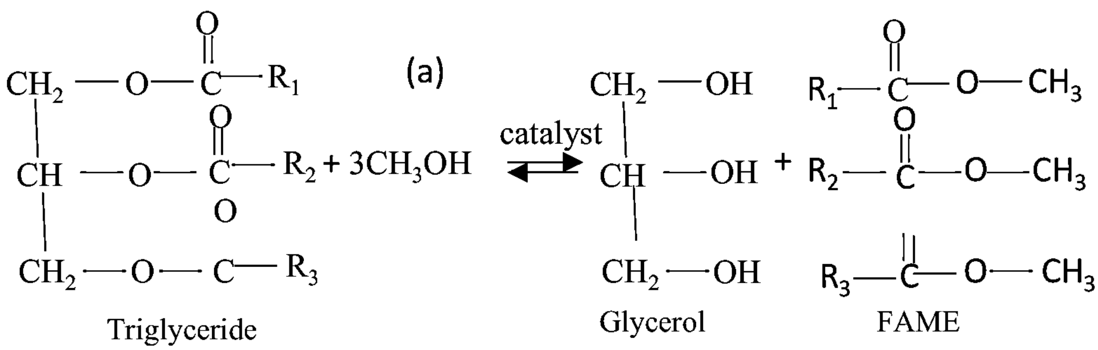
2.3 MODIFICATION OF BASE BIOLUBRICANT

The objective of bio-lubricant research has been to comprehend the connection between chemical assembly and molecular structure and to address the shortcomings of both natural and manufactured lubricants for instance, bio-lubricant made of branched fatty acids like isosteric acid, display outstanding low-temperature performance, including a low pour point, low viscosity, good chemical stability, and flush point [26,27]. Polyunsaturated C_{18} fatty acids are thermally isomerized and then hydrogenated to produce isosteric acid. Only the inside of the molecule has branching sites. Similar to that, 12-

25. Battersby N.S "Biodegradable lubricants: What does 'Biodegradable' Really Mean?" Synth. Lubr 22, (2005): 3-18.
26. Syahir A.Z, Zalkifi N.W.M, Masjuki H.H, Kalam M.A, Alabdulkarem. A, Gulzar .M, Khuong L.S. and Harith M.H. "A review on Bio-Based Lubricants and their application", Journal of Cleaner Production, 168(2017): 997-1016.
27. Eck N.J. and Waltman L. "Software Survey: VOS viewer, a Computer Program for Bibliometric Mapping", IOP Conference Series: Materials Science and Engineering 68, (2013): 152-157.

hydroxystearic acid, which is produced by hydrogenating ricin oleic acid, can also employed. As was previously mentioned, the performance of the biolubricant is improved by eliminating the double bonds and glycerol molecules form the triacylglycerols.

In the modification several approaches are used including esterification/transesterification, hydrogenation[28], oligomerization/ estoloides and epoxidation but in course of this research, only transesterification synthesis of formulation of fatty acids methyl esters and ethylene glycol di-esters were considered.



28. Zhu J. Su. Y, Chai. J, Muravev. V, Kosinov. N and Hensen E.J.M. "Mechanism and Nature of active sites for methanol Synthesis from CO/CO_2 on Cu/CeO_2" ACS Catalysis 10, (2020): 11532-11544.

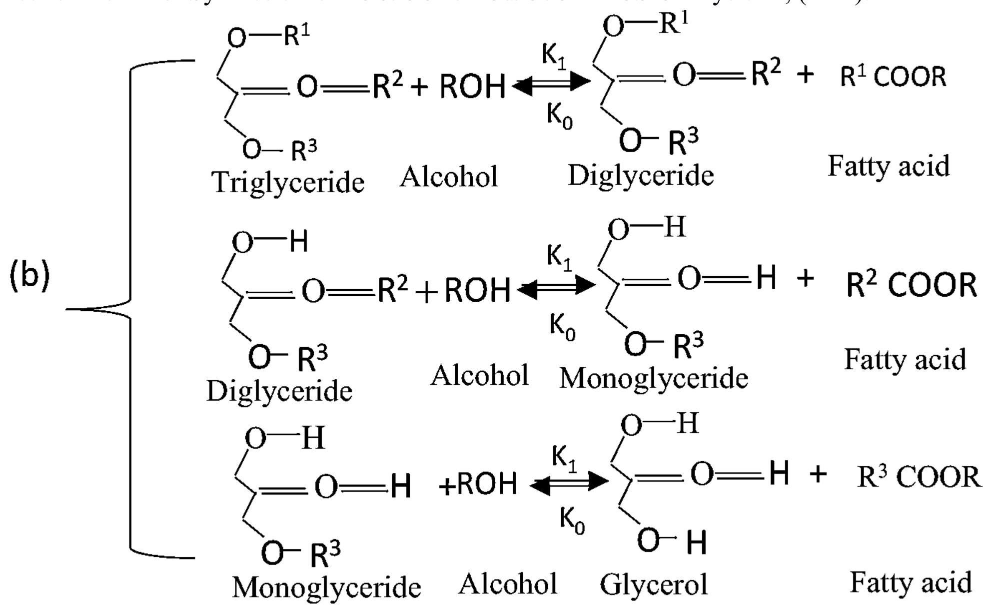


Figure 2.2: Triglycerides reaction to produce FAMEs via Transesterification technique

2.4 TRIBOLOGICAL PERFORMANCE OF BIO-LUBRICANTS

Some investigation had been conducted on different bio-lubricants under application of different NPs as additives, with recommended results as presented in table below.

Table 2.1: Summary of tribological qualities of some bio-lubricants and their applications.

Bio-lubricant	Application	Quality/performance
Pongamia oil	Anti-corrosive coating and Power transformer applications,	At medium loads, minimal frictional losses, low emissions, low specific fuel consumption, and good break thermal efficiency.
Jatropha oil	Biodiesel	High VI, little weight loss from wear or progressive weight reduction, and little friction
Rapeseed oil	hydraulic fluids, Power transformer applications, greases	improved cold flow characteristics, improved oxidation stability, and low coefficient of friction
Palm oil	metal working fluids (MWFs)	High viscosity, low coefficient of friction, and less corrosive
Sunflower oil	biodiesel fuel, Hydraulic oils, engine oils, paints, detergents	High VI, higher flash point than some standard oils, greater lubricity, reduced evaporating loss, lower frictional coefficient, and non-toxic
Coconut oil	Engine oils	Better lubricity, low coefficient of friction, and high anti-wear
Canola oi	Transmission fluids, transmission fluid, hydraulic fluids, penetrating oils	High VI, higher flash point than some standard oils, greater lubricity, reduced evaporative loss, lower frictional coefficient, and non-toxic
Linseed oil	Stains, vanishes, paint	High VI, higher flash point than some standard oils, greater lubricity, reduced evaporative loss, lower frictional coefficient, and non-toxic
Castor oil	Greases, gear lubricants	Low volatility, high levels of antioxidants, and low deposit formation

Thottackad[29], conducted tribological investigation using CuO NPs combined with coconut oil. According to the finding, the CuO nanoparticle concentration that produced the lowest wear rete and friction coefficient was 0.34 mass%.

The viscosity and fire point increased when the nano-additive was

29. Thottackad. M.V. Perikinali R.K and Kumarapillai P.N. "Experimental Evaluation on the Tribological Properties of Coconut oil by the addition of CuO Nanoparticles," International Journal of Precision engineering and manufacturing 13, (2012): 111-116.

applied, while the surface roughness reduced [30]. On analysis conducted by [31]. Employing zinc oxide (ZnO) and copper oxide (CuO) as lubricant additive. The outcome found that both Zinc oxide and copper oxide NPs were rendered inactive as an anti-wear addition for soybean and sunflower oil due to the rise in frication coefficient and the presence of abrasive wear on the worn surface, in another study by Arumugan and Srilam argued on the performance of microparticle addition [32]. TiO_2 NPs were added to chemically changed rapeseed. Comparing the TiO_2 microparticles, TiO_2 NPs visibly observed to enhanced the lubricant lubrication performance [32,33]. Under nanoscale TiO_2 of 6.9% and micro TiO_2, the COF of rapeseed oil blended additives yielded reduction by 15.2% and 6.9% respectively [34]. Performed through experiment on biolubricant behavior under additives of TiO_2, CeO_2 and ZrO_2 NPs using rice bran oil as base lubricant.

30. Alves S.M., Barros. B.S, Trajano M.F, Ribeiro K.S.B and Moura. E. "Tribological Behavior of Vegetable oil-Based Lubricants with Nanoparticles of oxides in Boundary Lubrication Conditions", Tribology International 65, (2013): 28-36.
32. Arumagam S and Sriram G. "Preliminary Study of Nano-and Micro Scale TiO_2 additives on Tribological Behavior of Chemically Modified Rapeseed oil", Tribology Transactions 56, (2013): 797-805.

33. Kumar M, Afzal. A and Ramis M.K. "Investigation of Physiochemical and Tribological Properties of TIO_2 Nano-Lubricant oil of different Concentration", Tribological 35, (2017): 6-15.
34. Rani S. "The Tribological Behavior of TiO_2, CeO_2 and ZrO_2 Nano Particle as a Lubricant additive in Rice Bran Oil", International Journal of Scientific and Engineering Research, 7 (2016): 708-712.

The result revealed that 0.5 mass % CeO_2 and 0.3 mass% TiO_2 respectively yielded the greatest COF and wear reduction. This was afformed by [35] through analysis on Al_2O_3 NPs mixed with jojoba oil with concentration of oil mass% thus minimal friction and wear was achieved compared the base lubricant. Again, [36] carried out tribological investigation utilizing CuO blended with pongumia oil. The result observed that 0.075 mass% of CuO was the optimal concentration to the based lubricant used with excellent wear and friction reduction. Again, copper and h-BN NPs were added to apoxidized olive oil during tribological investigatory work by [37].

35. Suthar K, Singh. Y, Surana A.R, Rajubhai V.H and Sharma. A. "Experimental evaluation of the friction and wear of Jojoba oil with aluminum oxide (Al_2O_3) Nano Particles as an additive," Material Today: Proceedings 25, (2020): 699-703.

36. Rajubhai V.H, Singh Y, Suthar. K, and Surana A.R. 'Friction and Wear Behavior of AI-7% Si Alloy pin under pongamia oil with copper Nanoparticles as additive", Materials Today: Proceedings 25, (2019): 695-698.
37. Kerni L, Raina. A and Haq M.I.U. "Friction and wear Performance of olive oil containing Nanoparticles in Boundary and Mixed lubrication Regimes", Wear 426-427 (2019): 819-827.

2.5 MECHANISM OF BIO-LUBRICANTS DURING OPERATION

Enhancement of physiochemical and tribological performance of bio-lubricant is through modification and inclusion of suitable additives. For good compatibility and performance of NPs in bio-lubricants, most of them were discovered to be of hydrophobic potential with ability repel oxidative agent. The investigatory study on lubricating strength of Eichhornia crassipes NPs (EC-NPs) further revealed that reduction in the size of EC into nanoscale changes from hydrophobic to amphiphilic (hydrophobic tail and hydrophilic heal) form [38,39] as a result of increase in surface area, thus illustrated in figure 2.1(a).

38. Opia A.C. Mohd KAMELI A.H, Syahrullail. S., Abd Rahim A.B and Johnson C.A.N. "Eichhornia Crassipes Transformation from Problems to wide unique Source of Sustainable materials in engineering application", Iop Conference Series:" Material Science and Engineering 1051, (2021): 012-100.

39. Zhu Q, Pan. Y, Jia X, Li J, Zhang. M and Yin. L. "Review on the Stability mechanism and application of water-in-oil emulsions encapsulating various additives", Comprehensive review in food Science and Food Safety 18, (2019): 1660-1675.

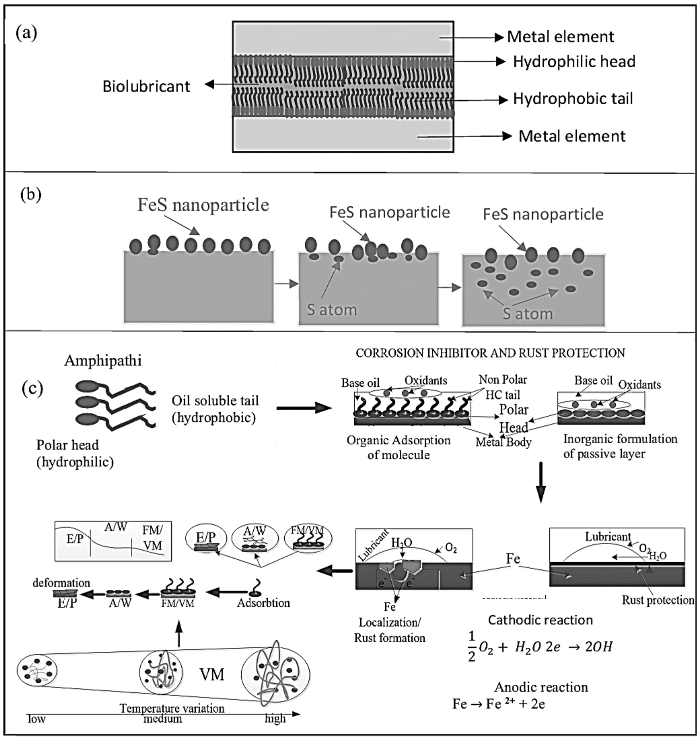


Figure 2.1: Arrangement of amphipathic additives inside bio-lubricant (a); diffusion of sulphur (S) atom of FeS NPs (b) and defensive operation of organic/inorganic additive in biolubricant against oxidation and rust (c) Note: Extreme pressure additive (EP); anti-wear additive (AW); Viscosity modifier (VM), friction modifier (FM).

Also, the diffusion behavior of the FeS NPs on the sliding material surface was conducted by [40], illustrating the sulfur (S) atom diffusion resulting in friction reduction, thus illustrated in Figure 2.1 (b) while figure 2.1 (c) illustrated the defending mechanism of additives in biolubricants during operations. The behavior of various additives during operation are demonstrated in Figure 2.1 (c), owing to the degradation effect.

Rust and corrosion are both electrochemical processes that result in the oxidative deterioration of metallic materials. The corrosion process that most characterizes lubrication systems is galvanic corrosion [41]. In a nutshell, the mechanism, is as follows. An oxide layer typically covers metal surfaces. The oxide is removed by the tribological process, exposing metal surfaces. Between metal and metal oxide, there is a difference in electrical potential. Galvanic cells are created when a conductive liquid occurs

40. Zhou L.H, Wei X.C, Ma Z.J and Mei B. "Anti-Friction Performance of FeS Nanoparticle Synthesized by Biological method", Applied Surface Science 407, (2017): 21-28.
41. Minami. I. "Molecular Science of Lubricant additives", Applied Science, 7 (2017): 445.

between the surface [42]. The metal atom increases its oxidation number, releasing electrons to form metal ions (this process is the oxidation of metal). An oxygen molecule in the system is reduced by the metal's released electron.

2.6 BENEFIT OF BIO-LUBRICANT AND MARKET AVAILABILITY

Lubricants from vegetable source can be naturally used. They have several advantages and disadvantage as will be seen in the challenges which make the product lack some values in the market. Vegetable oils after outstanding lubricity, which is significantly better than that of mineral oils. Furthermore, vegetable oils have a high VI. For instance, vegetable oils frequently have a VI of 223, but most mineral oils typically have a VI of 90-100. Vegetable oils have high flash points of 326°C, while common mineral oils have a flash temperature of 200°C. Other benefits from the use of vegetable lubricants are summarized below.

42. Minami. I "Molecular Science of Lubricant additives", Applied Science 7 (2013): 16598-16605.

Table 2.2: Key benefits of bio-lubricant type in lubrication

Property	Performance contribution
Good lubricity	Controlled friction losses with good fuel economy
Low volatility	Enhanced reduction of exhaust emissions
Good viscosity index	Applied for a wide range of temperature
Excellent boiling temperatures	Reduced emissions during operation
Higher detergency	Eliminating the requirement of detergent additives
Rapid biodegradation	Minimized toxic contaminants and environmental danger
Good compatibility	Better cleanliness with less harm at work environment

The global market for bio-lubricants in expected to be influenced by the expanding opportunities for sustainable solutions, such as green buildings and sustainable lubrication. The international market for bio-lubricant is anticipated to reach US$ 2.6 billion under a CAGR of 5.2% over the forecast timeline of 2020-2027, based on recent report by global industry Analyst [43]. The demand for bio-lubricants is still high, especially in Europe where it is encouraged by national and global branding regulations, subsidization and tax benefits, [44].

43. Global Industry analysis Production and Trade of Lubricants in the United Kingdom, (2010-2021). 2021, 2021.
44. Global Industry analysts Production and Trade of Lubricants in the united kingdom, (2010-2021). 2021, 2021.

2.7 ADVANTAGES AND DISADVANTAGES OF BIO-LUBRICANTS

Table 2.3: Advantages and Disadvantages of Bio-lubricant[45,46]

Sl. No.	Advantages	Disadvantages
1	High lubricity	High cost.
2	High viscosity index	Several vegetable oils are edible. This can lead to food vs. fuel debate.
3	High volatility	Vegetable oils have higher melting points.
4	High boiling point (lower emissions)	Vegetable oils have low oxidative stability.
5	Longer tool life	Biolubricants are less developed compared to fossil-based technologies.
6	Better skin compatibility	Poor oxidation stability of pyrolysis bio-oils.
7	Better safety on the shop floor	High acidity of pyrolysis bio-oils.
8	Biodegradability is high (as they are free of aromatics)	Higher extent of upgradation required for thermochemically derived base stocks.
9	High volatility	High viscosity of HTL biocrudes.
10	Customizable chemical structures	
11	Lesser amount of contaminants	
12	The base stocks for biolubricants can be derived from a variety of sources	

2.8 APPLICATIONS OF BIO-LUBRICANT

Engine oils tend to minimize the transport of contaminants and other particulate, and keep them away from the moving parts [47]. As

45. Cecilia J.A, Ballesteros Plata. D, Alues Saboya R.M, Traveres de Luna F.M, Cavalcante C.L and Rodriguez-Castellon. E. “An overview of the Biolubricant Production Process: Challenges and Future Perspective”, Processes, 8 (2020): 257.

46. Ho C.K, McAuley K.B. and Peppley B.A. “Biolubricants through renewable Hydrocarbons: A perspective for new opportunities”, Renew Sustain, Energy Rev. 113, (2019): 109261.

47. Liston T.V. “Engine Lubricant additives what they are and how they function”, Lubr, Eng. 48, (1992): 389-397.

engine oils undergo oxidative degradation and wear during service, it is vital to characterize the ageing of engine oils at simulated conditions to understand and evaluate the performance of existing oils and also design new formulations [48]. Researchers have employed pongamia oils as a compression ignition (CI) engine lubricant [49], showing that it improves efficiency and unlike a mineral oil lubricant, can potentially eliminate the emission of trace metals, as it is devoid of any metal constituents.

Catton fluids control the temperature rise by giving adequate lubrication and cooling between the work piece and the tool [50]. Even through minerals oils are comparatively cheaper for this application, they exhibit poor performance due to low-temperature solidification, oxidative instability and loss of viscosity at elevated temperatures. They are also susceptible to explosion in the presence of an oxidizing agent. Importantly, the additives used to enhance the performance of

48. Jedrzejczyk M.A, Vanden Bosch. S, Van Aelst. J, Van Aelst. Kouris P.D, Moalin. M, Haenen G.R, Boot M.D, Hensen E.J and Lagrain. B "Lignin – Based additives for improved thermo-oxidative stability of Biolubricants", ACS Sustain, Chem. Eng. 9(2021): 12548-12559.
49. Bekal S and Bhat N.R. "Bio-lubricant as an alternative to mineral oil for a CI Engine – An experimental investigation with pongamia oil as a lubricant", Energy source part A recovery util. Enviorn. Eff. 34, (2012): 1016-1026.
50. Katna. R, Suhaib. M and Agrawal. N. "Nonedible vegetable oil-based cutting fluids for machining processes", A review mater, manuf. Process 35, (2020): 1-32.

the lubricant may be dangerous to humans and the environment. Non-edible vegetable oils are biodegradable and are ultimately decomposed and mineralized into carbon dioxide and hydrogen by microbes. Biodegradability ensures the safe integration of biomaterial back into carbon cycle of nature. Non-edible vegetable oils degrade faster than mineral oils in the natural environment [51,52].

The minimum quantity lubrication (MQL) is an environmental protection technology that employs a nozzle to spray a small amount of lubricating fluid and compressed gas into the cutting zone for the purpose of cooling and lubrication [53,54]. Discussed the temperature of the minimum quantity lubrication (MQL) milling of the 45 steep using cottonseed, palm, caster, soybean, and peanut oils base stocks. It was shown that the cottonseed and the palm oils exhibited a good cooling effect. This is due to the presence of short carbon chain length palmitic

51. Emmanuel. O.A. Kessington, O.O, Mudiakeoghene. O. “Biodegradation of vegetable oils”, A review Sci. Res. Essay, 4 (2009): 543-548.
52. Ghuge N.C, Dhatrak V.K and Mahalle. “A minimum Quality Lubrication Iosrjen, 2 (2012): 55-60.
53. Ghuge N.C, Dhatrak V.K and Mahalle. “A minimum Quality Lubrication Iosrjen, 2 (2012): 55-60.
54. Dong L, Li. C, Zhou. F, Bai. X, Gao. W, Duan Z, Li. X, Lv. X and Zhang. F. “Temperature of the 45 steel in the minimum Quality lubricant milling with different Biolubricants”, Int. J. Adv. Manuf. Technol, 113 (2021): 2779-2790.

acid in cotton seed and palm oils, which is conducive to the minimum quantity lubrication (MQL) milling.

Gear oils are necessary for industrial and automatic lubrication, wherein they are generally used in differentials, transmissions, power take-offs and non-drive applications. Besides the usual functions of lubricants, these oils are required to reduce noise, inhibit corrosion, transfer heat, and improve overall efficiency [55,56]. In order to obtain good protection in both the hydrodynamic and elastohydrodynamic regimes, strict viscosity regulation of the base oil is needed. While vegetable oils do not possess the required viscosity for the application, this limitation can be overcome by thermal polymerization of the oil by heating the oil in inhert ambrence to generate high molecular weight products [54].

55. Mang. T, Freiler. C and Horner .D. "Metalworking Fluids", In Lubricants and Lubrication, 2nd ed, Mang. T, Diesel. W, Eds. "Wiley VCH: Weinheim", Germany, (2007).
56. Arca. M, Sharma B.K, Perez J.M and Doll K.M. "Gear oil Formulation designed to meet Bio-Preffered Criteria as well as give High Performance", Int. J. Sustain Eng, 6 (2013): 326-331.

Table 2.4: Oils, their properties and their major applications

Sl. No.	Oil	Major Properties *	Major Applications
1	Palm oil	Less corrosive, low coefficient of friction, high viscosity	Greases, metal working fluids (MWFs)
2	Coconut oil	High antiwear, better lubricity, low coefficient of friction	Engine oils
3	Crambe oil	n.a.	Greases, surfactants, cosmetics, chemicals
4	Sunflower oil	High VI, high flash point than some conventional oils, high lubricity, low evaporative loss, low co-efficient of friction, better lubricity, non-toxic	Diesel fuels, greases
5	Soybean oil		Hydraulic oils, biodiesel fuel, engine oils, transmission fluids, printing inks, paints, detergents, coatings, pesticides, shampoos
6	Safflower oil		Resins, diesel fuels, enamels
7	Linseed oil		Stains, coatings, vanishes, paints
8	Olive oil		Engine oils
9	Canola oil		MWFs, transmission fluids, food-grade lubes, hydraulic fluids, penetrating oils, transmission fluids
10	Castor oil	High VI, low volatility, high antioxidants, low deposit formation	Greases, gear lubricants
11	Pongamia oil	Low frictional losses, low emissions, minimum break-specific fuel consumption and high break thermal efficiency at medium loads	Power transformer applications, anticorrosive coating
12	Tallow oil	n.a.	Soaps, cosmetics, plastics, hydraulic oils
13	Cuphea oil	n.a.	Motor oils, cosmetics
14	Jojoba oil	n.a.	Greases, cosmetics, lubricants
15	Jatropha oil	High VI, low wear loss, low cumulative weight loss, low coefficient of friction	Biodiesel

2.9 COCONUT OIL

Coconut oil is an edible oil that has been consumed in tropical countries for thousands of years. As it has a long shelf life and meting point of 76°F, it is used in baking industries. A negative campaign against saturated fats in general, and the tropical oils in particular, led to most food manufactures abandoning coconut oil in recent years in favor of hydrogenated polyunsaturated oils, particularly soy, which contain trans fatty acids. Studies done on population consuming diets high in coconut oil show on adverse effects on the health of the population[56].

Coconut, also known as Cocos Nucifera[57], a tree known for its many nutritional and medicinal properties has gained new found interest in western medicine. It is believed that certain parts of the coconut, for example, tender coconut water and kernel have medicinal qualities including but not limited to antibacterial antiviral, antifungal, antioxidant, low glycemic index, hepatoprotective, and immune system enhancement[58]. Coconut oil is very commonly used as a tropical edible

56. Thampan P.K, Glimpses of Coconut industry in India, Coconut Development Board, Cochin 1988.

57. Debmandal. M and Mandal. S. Asian Pac. J. Trop. Med. 4, 3(2011): 241-247.

oil in many assign cultures and is composed of almost 90-95% saturated fatty acids[58]. The health and nutritional benefits derived from coconut oil are both compelling and contradictory, mainly due to its high saturated fat content as relates to chronic diseases, especially those involving the cardiac system[59].

2.9.1 Methods of Production of Coconut oil

Different types of coconut oil for edible purpose are available viz, virgin coconut oil from wet coconut (unrefined grade); coconut oil from dry coconut (unrefined grade); and coconut oil by solvent extraction method (refined from coconut expeller cake). Virgin coconut oil is claimed to have more health benefits compared to coconut oil extracted from copra.

2.9.1.1 Solvent extraction

Cancel et al[60] has standardized condition for coconut oil extraction from coconut milk press-cake[61] studied the solvent extraction

58. Burnett C.L. Int. J. Toxicol. 30, 3 (2011): 55-165.
59. Nevin K.G. and Rajamohan T. Clin. Biochem 39, 9(2004): 830-835.
60. Cancel L.E, Rosario Hernandez J.A, and Hernandez E.R. de. "Coconut oil extraction from coconut milk Press-Cake", J. Agric Unipuereto rice 60, 3(1976): 281-293.
61. A. L. Gonzalez, et al. "Studies on Solvent extraction of residual oil from wet coconut meal using isopropanol", Phillip. J. Sci. 102, ½ (1973): 31-43.

of residual oil from wet coconut meal using isopropanol. Bernardini[62] has described a new single solvent direct extraction process (by CMB, Pomezia) which Obtiates and Buccat[63] studied the filtration-extraction of granulated coconut on a bench scale. Claudio et al[64] carried out laboratory scale studies on the preparation of a highly nutritious coconut flour from granulated coconut. Preliminary feeding expt. Indicate a PER comparable with casein prepared foods (cakes, doughnuts, cookies, pastries) with 20-30% wheat flour replaced by coconut flour obtained high taste rating.

2.9.1.2 Enzymatic Process

Coconut oil is extracted from coconut paste by a new enzymatic process[65] and the method used less energy than the conventional processes. A Srilankan inventor[66] has developed a simple method for making high quality coconut oil and desiccated coconut using more

62. Bernardini E. "Direct extraction of oil from oil seeds without Pressing", Riv. Itali de. Sost. Gras 49, 8 (1970): 385-391.
63. Aliwalas A.R. and Buccat C.P. "Filtration- extraction of granulated Coconut on a bench scale", Phillip .J. Sci. 96, 3 (1970): 215-285.
64. Claudio – TR, Capulso S.A, Gonzales A.L, Fuente F.S. de la, and Manalac G.C. "Laboratory Scale Studies on the Preparation of Coconut flour from granulated coconut", Phillip J. Sci. 97, 1(1968): 45-56.
65. Thampan P.K, Glimpses of Coconut industry in India. Coconut Development Board, Cochin (1988).
66. Leonard. E, "Sri Lankan Inventor who makes life easier for his countrymen. (1983). Community, APCC/QS/45/83, 33-35.

manpower and little or no electricity, it involves breaking the coconut, scraping it and drying in a specially designed solar drier. The desiccated coconut produced can be used for mechanical extraction of colourless, odourless coconut oil suitable for direct consumption[67,68] developed a simple process for producing coconut oil and food grade copra cake which has been potential. Nambiar[69] developed a method for the production of refined oil form the milk of fresh ripe coconuts and has been granted an Indian patent.

2.9.1.3 Wet Processing of Coconut

Nambiar (1977)[70] has developed a method of processing fresh ripe coconut to obtain refined oil and to simultaneously recover coconut products including solid coconut products for human consumption which has also been patented in India. Castellanos and Asturias[71]. Investigated the wet milling processes for the extraction of oil from

67. "Small-Scale oil extraction from groundnuts and copra. International Labour office", United Nations Industrial development organization Technical Memorandum, United Nations Industrial development Organization, 4 (1983) xi+111pp. ISBN 922103503.4.
68. Mojica I.N. Jr. "Process for Producing Coconut oil and food grade copra cake". (1978) Philippines-Patent 11661/C.
69. Nambiar T.V.P Method for the production of refined oil from the milk of fresh ripe coconuts. (1977), Indian-Patent.
70. Nambiar T.V.P. A method of Processing fresh ripe coconut to obtain refined oil and to simultaneously recover coconut products including solid coconut products for human consumption, (1977): India-Patent.
71. Castellanos P.S, and Asturias C.R. "Extraction of oil from fresh coconut", Oleagineux 24, 1 (1969): 419-21: 24 (819) 505-09.

decorticated fresh coconut under a variety of experimental conditions to get oil of better quality and it required less refining[72] identified the critical unit operations in the wet processing of fresh coconuts for the recovery of oil and food grade protein.

2.9.1.4 Copra Milling by Traditional Methods

The extraction of oil from copra is one of the oldest seed crashing operations. In India and Sri Lanka Copra is still crushed for oil extraction in the primitive chekkus as well as in rotary ghains, expellers and hydraulic presses.

The Chekku is a fixed wooden or stone mortar inside which revolves on a hard wooden pestle. The pestle is attached to a long pole which is moved round via bullocks, donkey or by human labor. About 20-40kg of copra can be handled by a chekku.

72. Hagenmaier R.D, Cater C.M and Mattil K.F. "Identification of the critical unit operation in the wet processing of fresh coconut for the recovery of oil and food grade protein", Abstr. Papers. American Chemical Society, J. Amer. Chem. Soc. 162, (1971): AGFD8.

2.9.1.5 Copra Processing by Continuous Pressing

This is done with the help of expellers. The oil expeller is essentially a mechanical screw press in which the oil is expelled from the copra by the pressure exerted by a continuous rotating warm shaft in the barrel is built with openings to allow the escape of oil and these can be adjusted according to the types of seed being crushed. Traditionally, virgin coconut oil is produced by fermentation method, where coconut milk expelled from freshly harvested coconuts is fermented for 24-36hrs, and during this period, the oil phase. Further, the resulting wet oil is slightly heated for a short time to remove the moisture and filled-filtered. The main disadvantages of this process are low oil recovery and fermented odor, which masks the characteristic coconut flavor of the oil.

2.9.1.6 Hydraulic Process

These are used in the large installations. They are of two main types-open or Anglo-American presses and the closed or cage types presses. In this the space between the plates above ram and the head is divided by plates between which copra is put wrapped in press clothes.

The common method is to extract oil from copra or dry coconuts conventionally coconut oil is produced by expelling dry copra followed by refiring during which oil is exposed to high temperature. The copra based refined coconut oil or the solvent extracted and refined coconut oil will have a brand taste due to the refining processes.

2.9.2 Importance of Coconut as Oil Seed

The coconut palm is the most important parental source of oil, which is grown in India. The cultivation of coconut is spread over the entire coasted belt and also some interior tracts. Compared to all other oil seed crops coconut has the highest productivity as well as consistency in production compared to other oil seed crops coconut is less susceptible to abnormal climatic condition.

2.9.3 Biological Effects of Coconut oil

Historical information claims that coconut oil was the cure for illness in ancient India and China, treating anything from infections and disease, to nausea and toothaches. The creamy, soft texture of coconut oil has also been used as a skin moisturizer and as hair therapy, aiding in preventing and treatment of dry skin and damaged hair in the hot, tropic sun. claimed to guaranteed blemish and infection free skin as well as strong bones, Samoon mothers massage their children's entire bodies frequently since infancy with the miracle oil. Coconut oil can also be rubbed on the gums of babies to ease the pain during teething. Jamaicans believes coconut oil to be valuable to hear health, and drank it as a tonic whenever sick[73].

2.9.3.1 Anti-Microbial Effects of Coconut oil

Coconut oil has been found to aid as an antibacterial, antifungal antiviral and antidermatophytic agents. It has been used in Ayurvedic medicine as well as in many other culture worldwide studies have been conducted to test the effects of coconut oil as an antimicrobial agent and findings for many support this thousand-year old universal remedy. By products of coconut oil breakdown result in the production of medium-chain fatty acids (MCFA) and monoglycerides (MG). it is these MCFA and MG that confer antimicrobial properties, by destroying pathogenic bacteria, virus, fungi and protozoa[74].

73. South Pacific Coconut oil: http://rudanetrading.com/au/ information/coconut-oil. Html (July 5th 2013).
74. Fife B. Agro food ind Hi Tec 24, 3 (2013): 7-10.

Coconut oil has been proven very successful and effective against viruses that lipid-coated, such as Epstein-Bar virus, influence virus, leukemia virus, hepatitis C virus, and cytomegalovirus (CMV), to name a few. It accomplishes this by interfering and discrupting the virus membrane, assembly, and maturation[75].

2.9.3.2 Hypolipidemic effects of Coconut oil

While cardiovascular disease is on the rise, mainly, due to its correlations with obesity, a growing epidemic across the globe, risk factors of cardiovascular disease include several components, such as diet, level of physical activity, psychological well-being, and other lifestyle components like smoking of these scientific evidence have indicated that dietary factors predominantly influence serum lipid concentrations[76]. It is largely believed that certain dietary fats lower low density lipoprotein (LDL) Levels while assisting in elevating higher density lipoprotein (HDL) level in the blood. Clinical evidences have

75. Deb Mandal. M and Mandal. S. Asian Pac. J. Trop. Med 4, 3 (2011): 241-247.
76. Nevin K.G and Rajamohan. T. Clin Biochem 37, 9 (2004): 830-835.

also indicated that risk for cardiovascular disease increase dramatically when serum LDL is easily oxidized[76]. There is new found interest in the cardio-protective effect of coconut oil as reported by the coconut research center in one study, coconut oil was reported to cause an increase in total cholesterol levels. However, it is noteworthy that some of the elevation in cholesterol levels is attributed to an increase in HDL or good cholesterol[77]. Therefore, it is essential to understand the chemical composition of coconut oil in order to extrapolate the health benefit and clinical significance of consuming coconut oil as a heath promoting dietary fat.

2.9.3.3 Effects of Coconut oil on Cardiovascular Health

A recent study investigated the risk for cardiovascular diseases upon consumption of coconut oil in the Philippines, a country wherein coconut oil is abundantly used for cooking purposes. Coconut oil being extremely rich in saturated fats, the premise of this study was to

77. Fife. B. Agro food Ind Hi Tec 24, 3 (2013): 7-10.

investigate the effects of saturated fats in coconut oil and its atherogenic properties in a cohort of 1,839 Filipino women[78]. The results of this study indicated that consumption of coconut oil did not elevate serum total cholesterol or serum triglycerides. However, measurement of coconut oil intake was calculated using self-reporting via two 24-hours dietary recalls. Thus, due to the nature of the designed practiced by the study and lack of ability to control various external and confounding variables, it would be safe to assume that additional clinical trials are required before health professionals are confidently able to prescribe coconuts oil consumption as it relates to being a cardio-protective agent.

2.9.3.4 Hepatoprotective Effects of Coconut oil

Liver is one of the largest and most importance organs in human body. The human liver is responsible for controlling carbohydrates storage and metabolism, protein synthesis, breakdown of red blood

78. Feranil A.B. Asia Pac. J. Clin. Nutr. 20, 2 (1971): 366-369.

cells, and detoxification[79]. Despite the many advances in the medical field, western medicine has been unable to prevent and cure many chronic conditions, one being offering protection from much chemical and physiological damage to hepatic cells resulting from routine exposure to different nutrients, drugs, and environmental factors. In the most recent times, VCO has gained a lot of popularity in the clinical field, especially in relation to its anti-oxidant and cardoprotective properties. However, the understanding of the functional properties of coconut oil clinically within the human body requires sophisticated research methodologies. Data in animals suggest that VCO may induce a hepato-protective effect in addition to the antiviral, anti-inflammatory, and cardio-protective mechanism. Zakaria[79] investigated the hepato-protective effects of VCO on paracetamol induced liver damage in rats. The result indicated that treatment of the damaged rat liver with VCO significantly reduced liver damage concluding that coconut oil may indeed offer some hepato-protective effects. The

79. Zakaria Z.A. Evid. Based Complement Alternat. Med, 2011 (2011): 142739.

authors concluded that further in-depth studies are required to observe similar results in human[79].

2.9.3.5 Effects of Coconut oil on Metabolic Syndrome

There is a surge in chronic diseases, mainly stemming from presence of obesity, very little preventive cure is available through western medicine. Type 2 diabetes, hypertension, cardiovascular disease, and certain cancers are all chronic conditions, risk for which can be increased by what is deemed as metabolic syndrome a cluster of factors comprising of low levels of HDL, hyperglycemia, abdominal obesity, hypertion and high triglycerides[80]. Although the pathogenesis of metabolic syndrome is complex, very little is known about the underlying mechanisms and successful prevention and treatment through western medicine. It has been observed that in animal (mice models), consumption of MCT such as those found in coconut oil may offer enhanced lipid oxidation and greater energy expenditure. A recent study suggested that consumption of MCT's (Coconut and Milk)

80. Nagao K and Yanagita T. Phamacol Res 61, 3 (2010): 208-212.

resulted in greater elevation of post prandial oxygen consumption in healthy men as compared to LCT[81]. Hyperlipidemia, a classic condition associated with metabolic syndrome is one of the many leading causes of cardiovascular diseases and while there are numerous synthetic drugs available to treat the condition none come without the added risk of side effects sometimes debilitating and interfering with body processes and metabolism[82].

2.9.3.6 Anti-Cancer Effects of Coconut oil

In 1987, Lim-Sylianco [83] published a 50-year literature review showing the anti-cancer effects of coconut oil. In chemically induced cancers of the colon and breast. Cohen et al[84] showed that coconut oil was by far more protective than unsaturated oils. For example, 32% of corn oil eaters got colon cancer whereas only 3% of coconut oil eaters got the cancer. Animals fed unsaturated oils had more tumors. This shows the thyroid-suppressive and hence, immune-suppressive effects of unsaturated oils.

81. Seaton T.B. Am J.Clin Nutr 44, (5) (1986): 630-634.
82. Zakaria Z.A. Evid. Based Complement Alternat. Med 2011, (2011): 384-387.
83. Lim-Sylianco C.Y. "Anticarcinogenic effects of coconut oil", Phillip J. Coconut studies 12, 2 (1987): 89-102.
84. L. A. Cohen, et al. "Dietary fat and mammary cancer, I. Promoting effects of different dietary fats on N-nitrosomethylurea-Induced rat mammary tumorigenesis", J. Natl. Cancer Inst. 77, 1 (1986): 33-42.

2.9.4 Healing Properties of Coconut oil

Coconut oil is antiviral, antifungal (kills yeast too) and antibacterial. It affects and kills viruses that have a lipid (fatty) coating, such as herpes, HIV, Hepatitis C, the flu, and mononucleosis. It kills the bacteria that cause pneumonia, sore throats, dental cavities, urinary tract infections, meningitis, gonorrhea, food poisoning and many more bacterial infections[85]. It kills the fungus/yeast infections that cause candida, ringworm, athletes food thrush, jock itch and diaper rash.

2.9.5 Applications of Coconut oil

Coconut oil has a long shelf life and is used in baking industries, processed foods, infant formulas, pharmaceuticals, cosmetics and as hair oil. The oil contains 92% of saturates consisting of medium chain fatty acids in the form of triglycerides, and about 8% of unsaturated consisting of oleic and limoleic acids as triglycerides. The oil has a small amount of unsaponifiable matter (<0.5%), is colorless and has a

85. S. Nandi, S. Gangopadhyay and S. Ghosh. "Production of Medium chain glycerides from coconut and palm kernel fatty acids distillates by lipase-catalyzed reactions", Enz. And Microbial Technol 36, (2005): 725-728.

odor typical of the coconuts. The oil has a small amounts of tocopherols. The oil is known to have antiviral and antibacterial effects and excellent healing properties. It gets easily absorbed in the body and is a nature mimic of human breast milk fat and hence used in infant formulae.

2.9.5.1 Edible Applications of Coconut oil[86]

Coconut oil has a high degree of saturated with a high content of saturated fatty acids. Because of high content of saturated fatty acids coconut oil is highly resistant to oxidative rancidity, coconut oil is used as a component of infant milk powders because of its easy digestibility and stable flavor coconut oil is extensively used in the food industries as a confectionary fat particularly in the preparation of ice cream. In initiation chocolates coconut oil is used in place of cocoa butter along with cocoa powder.

86. A. G. Gopala Krishna et al. "Coconut Oil: Chemistry, Production and Its Applications -A Review". Indian Coconut Journal. 2010, 15-27

2.9.5.2 Non-Edible Applications of Coconut oil [86]

One of the major non-edible applications of coconut oil is in the soap industries, one important chemical derivative of coconut oil is methyl esters of coconut fatty acids, which are produced by treating coconut oil with methyl alcohol. These methyl esters constitute an important raw material for the chemical industries as they are more stable and are easier to separate by fractional distillation. Coconut oil has many other industrial uses in the pharmaceuticals, cosmetics, plastics rubber substitutes, synthetic resins etc. coconut oil has also been found useful for mixing with diesel. These mixtures in the proportion as 30:70 has given excellent road performance of diesel vehicles. Methyl esters of coconut oil fatty acids is also being used as lubricants and biodiesel in aviation industry.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 REAGENTS AND APPARATUS

3.1.1 Reagents

All reagents used are of analytical grade and included: N-hexane, methanol (CH_3OH), sodium hydroxide (NaOH) pellets, sodium methoxide (NaOMe), sodium hydroxide, silica gel, activated charcoal, distilled water, Trimethylolpropane (TMP), phenolphthalein, alcohol ether, ethanol, potassium hydroxide (KOH),

3.1.2 Equipment and Apparatus

Heating mantle, beakers, funnel, round-bottom flask, measuring cylinders, chromatography column, separating funnel, distillation apparatus, thermometer, two-necked round bottom flask (500ml), anti-bumping stone, electric-mechanical stirrer, weighing balance, burette (50mL), pipette (25mL), and magnetic stirrer.

3.2 COLLECTION AND PREPARATION OF SAMPLE

The commercially available locally produced coconut oil (*adin agbon*) produced by traditional method was purchased at OJA-OBA (translated as King's market) in Ilorin, Kwara State, Nigeria. The sample was procured in plastic containers tightly stoppered. It was transported to the laboratory in same container and kept at ambient temperature until the time of use.

3.3 PURIFICATION OF OIL SAMPLE BY COLUMN CHROMATOGRAPHY

The oil sample was mixed with a few grams (2-3 g) of activated charcoal and stirred well for a period of time (about 5 minutes) with a glass rod. Silica gel was mixed with another small amount of activated charcoal in the ratio 10:1 respectively, and was packed (as the stationary phase) into fritted chromatography column that was initially clogged with cotton wool. The n-hexane which was the mobile phase was carefully poured into the column and kept a few centimeters above the top of the stationary phase. The mixture of the oil sample, activated charcoal and some volume of n-hexane were mixed and poured into the chromatography column and allowed to run through the stationary phase with n-hexane as a solvent The purified oil containing the solvent was collected into a beaker and redistilled to remove the solvent. The purified sample from each oil was collected and kept for analysis.

3.4 PREPARATION OF REAGENTS

3.4.1 Preparation of 1% $^{w}/_{v}$ Phenolphthalein Solution: 1.00g of phenolphthalein powder was dissolved in 100ml of ethanol in a 100ml standard flask. This was used as the indicator solution.

3.4.2 Preparation of 1% w/v Sodium methoxide: 1.00g of sodium methoxide was dissolved in 100ml of methanol. This Represent 1% w/v of the catalyst in the reactant.

3.4.3 Preparation of Potassium hydroxide: 5.611g of potassium hydroxide was dissolved in small amount of distilled water. The solution was carefully and quantitatively transferred into a clean 1 L volumetric flask and made up to the mark with distilled water. This gave an approximately 0.1 M solution which was subsequently standardized.

3.5 TRANS-ESTERIFICATION OF OIL SAMPLE

The methyl esters of fatty acid in each oil sample using sodium methoxide NaOME catalyzed-transesterification with some modification such that the methoxide was prepared by dissolving sodium hydroxide granules in methanol. 1g of NaOH was dissolved in 20ml of methanol with electric hot plate. 100ml of each oil sample was heated to about $60^{o}C$. The 20ml methanolic sodium hydroxide (NaOME) solution was poured into the hot oil and maintained at that temperature with vigorous stirring using magnetic stirrer for 10 minutes. Thus the conversion of each oil sample to its methyl ester was practically completed. It was later transferred to a separating funnel for separation of the bio-diesel from the glycerin by-product and other products. The set up (i.e. separating funnel and its contents) was left undisturbed to allow the fatty acid methyl ester to separate from other components. The lower phase containing the glycerol, unreacted methanol and catalyst was removed. The upper phase containing the methyl ester was then washed with distilled water severally. The emulsion produced was resolved adding few grams of sodium chloride (NaCl) crystals. The fatty acid methyl ester of each oil sample was collected and stored in labeled plastic container. The thevetia peruviana sample could not be transesterified to its FAME but rather it formed soap. This was due possibly to its high acid value. So no further work could be done on the thevetia peruviana seed oil as regard conversion to biolubricant in this work.

3.6 PREPARATION OF BIOLUBRICANT SAMPLES

100g of the FAME (Fatty acid methyl ester) of each oil sample was weighed into a clean dry 500ml two-necked round bottom flask. The oil was heated initially to 60°C and about 11.5g of TMP was added, followed by 44.35g of KOH (potassium Hydroxide).The entire mixture in the flask was heated to 130°C and maintained at this temperature for an hour. The resulting biolubricant was allowed to cool and transferred into a 250ml beaker to further cool. The

Biolubricant obtained was then kept in plastic reagent bottle for analysis and labelled COBL.

3.7 CHARACTERIZATION OF BIOLUBRICANTS

The biolubricant samples were analyzed for quality parameters and characterized by instrumental methods which include GC-MS and FTIR.

3.8 ANALYSIS OF THE BIOLUBRICANTS

The biolubricants were analysed for their physical properties (color and odor) and other quality parameters for lubricants.

3.9 DETERMINATION OF SOME PHYSICAL PROPERTIES

Color: The oil and biolubricant samples were observed organoleptically for its colors. Bio-lubricant golden yellow)

Odour: The odors of the oíls and biolubricant samples were also perceived by simply wafting toward the nostrils.

3.10 ANALYSIS OF THE BIOLUBRICANT QUALITY PARAMETERS

The following analyses were carried out on the biolubricants prepared; viscosities at 40°C and 100°C, other quality parameters of lubricants were analyzed and comparison of the parameters with various standard values of different grades was also carried out.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

The tables below present the results of the physical properties, quality parameter and instrumental analysis of the biolubricant prepared from locally produced coconut oil.

Table 4.1: Result of appearance of sample before and after purification

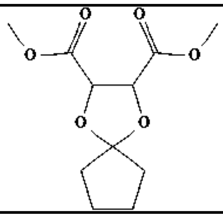
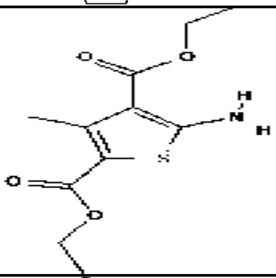
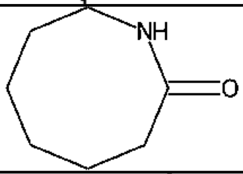
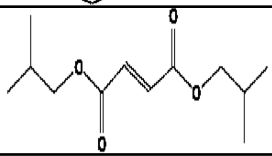
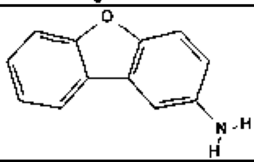
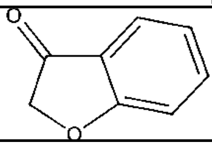
Physical properties	Color before purification	Color after purification	Odor before purification	Odor after purification
Coconut oil sample	Off white	Colorless	Strong odor of rancid coconut oil	Odorless

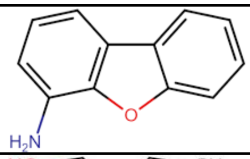
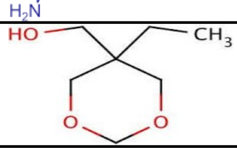
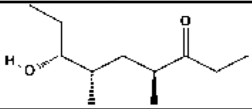
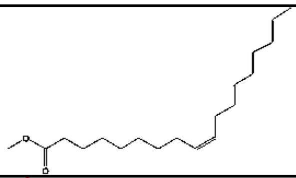
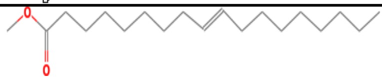
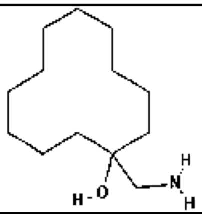
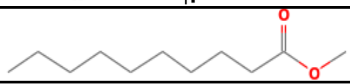
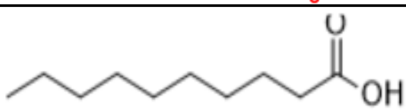
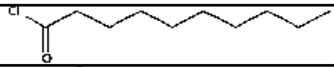
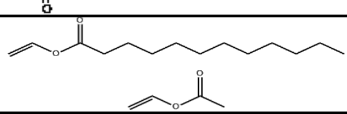
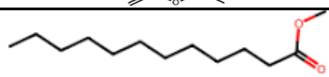
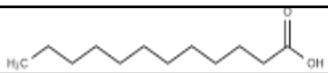
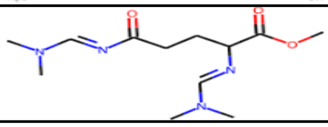
Table 4.2: Result of Quality parameter of the biolubricants

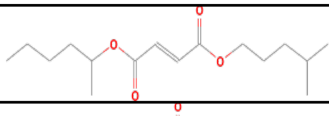
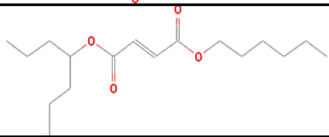
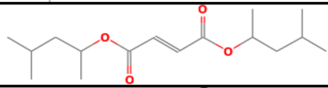
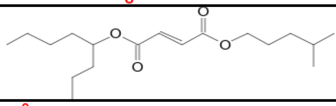
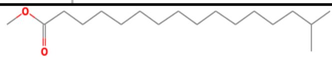
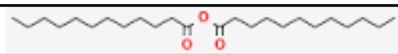
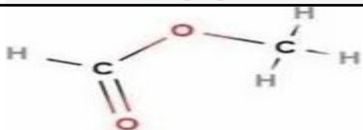
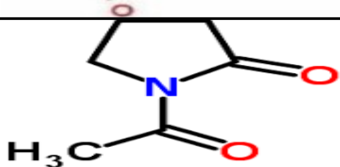
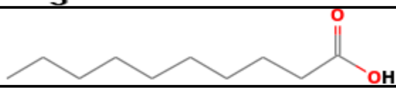
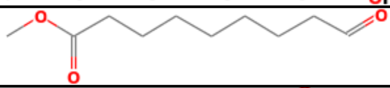
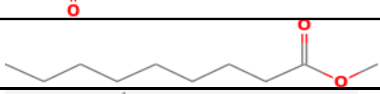
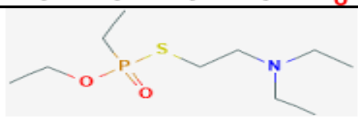
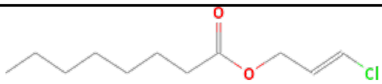
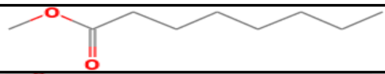
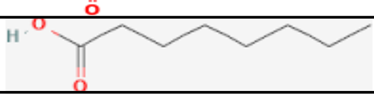
Sample	Visc @ 40oC (cSt)	Visc @ 100oC (cSt)	Viscosity index (VI)	Flash point (ºC)	TBN (mgKOH/g)	Pour point (ºC)	Crackle
Test methods	**ASTM D445**	**ASTM D445**	**ASTM D2270**	**ASTM D92**	**ASTM D2896-11**	**ASTM D97**	
COBL	**24.39**	**4.62**	**104**	**144**	**9.8**	**-**	**Passed**
Standard	**Visc @ 40oC (cSt)**	**Visc @ 100oC (cSt)**	**Viscosity index (VI)**	**Flash point (ºC)**	**TBN (mgKOH/g)**	**Pour point (ºC)**	**Crackle**
ISOVG 32		>4.10	104	-	-	<-10	-
ISOVG 46	> 41.40	>4.10	>90.0	220	-	<-10	-
ISOVG 68	> 61.40	>4.10	>198	-	-	<-10	-
ISOVG 100	>90.00	>4.10	>216	-	-	<-10	-
Mineral oil SN500	95.76	10.86	98	-	-	<-31	-

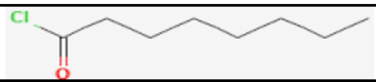
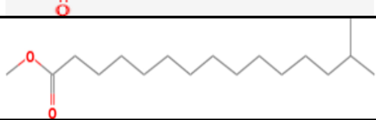
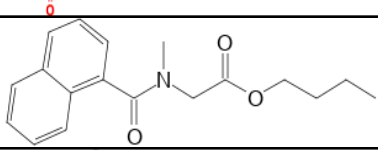
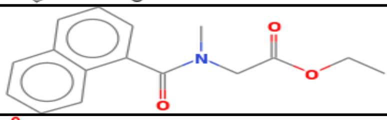
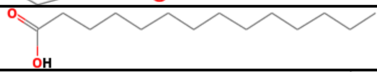
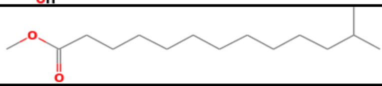
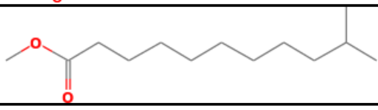
Table 4.3: Result of instrumental analysis of biolubricant

Table 4.2: Other chemical compounds in the coconut oil (*adin agbon*) biolubricant

S/N	STRUCTURES	NAMES
1		1,4-Dioxaspiro[4.4] nonane, 7-butyl- (R,R)-2,3-dimethyl-
2		2,4-thiophenedicarboxylic acid, 5-amino-3-methyl-, diethyl ester
3		2-Azacyclooctanone
4		2-Butenedioic acid (E)-, bis(2-methylpropyl) ester
5		2-Dibenzofuranamine
6		3-benzofuranamine

7		4-Dibenzofuranamine
8		5-Ethyl-1,3-dioxane-5-methanol
9		7-hydroxy-4,6-dimethyl nonan-3-one
10		8-octadecenoic acid, methyl ester
11		9-octadecenoic acid (z)-, methyl ester
12		9-octadecenoic acid, methyl ester, (E)-
13		cyclododecanol, 1-aminomethyl-
14		Decanoic acid, methyl ester
15		Decanoic acid
16		Decanoyl chloride
17		Dodecanoic acid, ethenyl ester
18		Dodecanoic acid, Methyl ester
19		Dodecanoic acid
20		D-Ornithine, N,N,'-bis (dimethylaminomethylene)-, methyl ester

21		Fumaric acid, 2-hexyl isohexyl ester
22		furamic acid, 4-heptyl hexyl ester
23		Furamic acid, di(4-methylpent-2-yl) ester
24		furamic acid, isohexyl 4-octyl ester
25		hexadecanoic acid 15-methyl- methyl ester
26		hexadecanoic acid methyl ester
27		Lauric anhydride
28		Methyl ester
29		N-Acetylpyrrolidone
30		n-Decanoic acid
31		Nonanoic acid, 9-oxo-, methyl ester
32		Nonanoic acid, Methyl ester
33		o-(3-methylcyclohexyl) s-(2-diethylaminoethyl) ethylphosphonothiolat
34		Octanoic acid, 3-chloroprop-2-enyl ester
35		Octanoic acid, methyl ester
36		Octanoic acid

37		Octanoyl chloride
38		pentadecanoic acid 14-methyl- methyl ester
39		sarcosine, N-(1-naphthoyl)-, butyl ester
40		sarcosine, N-(1-naphthoyl)-, ethyl ester
41		tetradecanoic acid
42		tridecanoic acid 12-methyl- methyl ester
43		Undecanoic acid, 10-Methyl-, Methyl ester

4.2 DISCUSSION

Table 4.1 shows the change in the physical all properties of the *adin agbon* achieved via purification from off white to pure white color due to the removal of impurities and removal of odor.

From Table 4.2, the results of the COBL viscosity at 40°C agrees only with the ISOVG 32 grade. While at 100°C the value agrees with all the grades. It however has lower values to that of the mineral oil used as based oil for synthetic lubricants.

4.3 CONCLUSION

This work shows that the locally produced coconut oil can be successfully transformed to biolubricant with comparable quality parameters to ISOVG 32 and 46 in certain respect. It thus can find industrial application in this area as a renewable feedstock.

And with further refining, the quality of the resulting biolubricant can be enhanced.