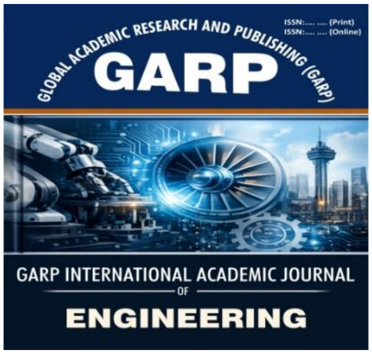
GARP INTERNATIONAL JOURNAL OF ENGINEERING



https://garp.org.ng/gijengr

Vol.1, Issue 1, Pp.1-16; MAR., 2026

DEVELOPMENT OF BIOLUBRICANT USING FATTY ACID METHYL ESTERS FROM SPOTTED MELON

[1]Yerima, Y. & [2]Ngubi F. W.

[1,2]Department of Chemical Engineering,
Igbinedion University Okada, Edo State Nigeria
Corresponding Author: yerima.yakubu@iuokada.edu.ng; orcid.org/0000-0003-4382-2461

ARTICLE INFO

Received Date: 4th Apr., 2026
Date Revised Received: 15th Apr., 2026
Accepted Date: 25th Apr., 2026
Published Date: 3rd May. 2026

Citation: Yerima, Y and Ngubi, F. W. Development of Biolubricant Using Fatty Acid Methyl Esters from Spotted Melon: GARP INTER J. of Engineering. Vol. 1 Issue 1 Pp.1-16; Apr. 2026

ABSTRACT

The desire for environmentally friendly energy sources, coupled with the depleted fossil oil reserves and rising cost per barrel, have generated interest in the search for world's alternative energy sources and derivatives such as lubricants. The production of biolubricant from renewable biomass materials as replacement for fossil lubricants align with the promotion of sustainable development goals contributing to the sustainable economic growth of developing countries such as Nigeria as well as preservation of the environment. The aim of this work was to synthesize an environmentally friendly biolubricant from spotted melon (*Lagenaria breviflora*), a plant that is known as a weed. The biolubricant was synthesized using double transesterification of the fatty acids methyl esters (FAME), characterized and physico-chemical properties were within the standards for engine oils and can compete with the synthesized environmentally acceptable lubricating oils. The biolubricant is usable in boundary lubricating machines

Keywords: *Biolubricant, Lagenaria Breviflora, Spotted Melon, Transesterification, Fatty Acids Methyl Esters*

Introduction

Lubricants are essential materials used to reduce friction, wear, heat generation and energy losses between moving surfaces in engines, machines and industrial equipment. For many decades, most commercial lubricants have been produced from petroleum-based mineral oils. Although these lubricants possess good performance properties, their dependence on nonrenewable crude oil, poor biodegradability, toxicity and environmental persistence have raised serious sustainability concerns. Improper disposal or leakage of mineral lubricants can contaminate soil and water, while their production and use contribute to greenhouse gas emissions and ecological degradation. Consequently, recent research has increasingly focused on bio-based lubricants as environmentally friendly alternatives to conventional petroleum lubricants (Teh et al, 2025; Patel et al, 2025; Almasi, 2021; Erhan & Asadauskas, 2000; Elisa *et al,* 2017). Growing consumption of different lubricant types, which are mostly mineral based or synthetic, leads to accidental but unavoidable inflow of considerable lubricants quantity into the environment. Therefore, biodegradable lubricants produced from agro-based oils and fats present a promising solution. They are generally biodegradable, less toxic, renewable and possess high lubricity due to the polar ester groups naturally preset in triglyceride molecules. Vegetable oils are particularly attractive because they have high viscosity index, good boundary lubrication properties, high flash point and low volatility. These properties make them suitable for applications in engines, hydraulic systems, metal working fluids, gear oils, chamsaw oils and industrial machinery (Nogales-Delgado et al, 2023). Biodegradable lubricants produced by classical procedure from inedible seeds oils and fats can be several times less expensive compared to conventional lubricants. These inedible seeds deserted as waste in the environment can be utilized as feedstocks oils and fats in the production of biodegradable lubricants which can be much more competitive in the market (Patelet al, 2025). The production and use of biolubricant as replacement for fossil lubricants aligns with the promotion of sustainable development goals (SDGs), contributing to the sustainable economic growth of developing countries like Nigeria as well as preservation of the environment.

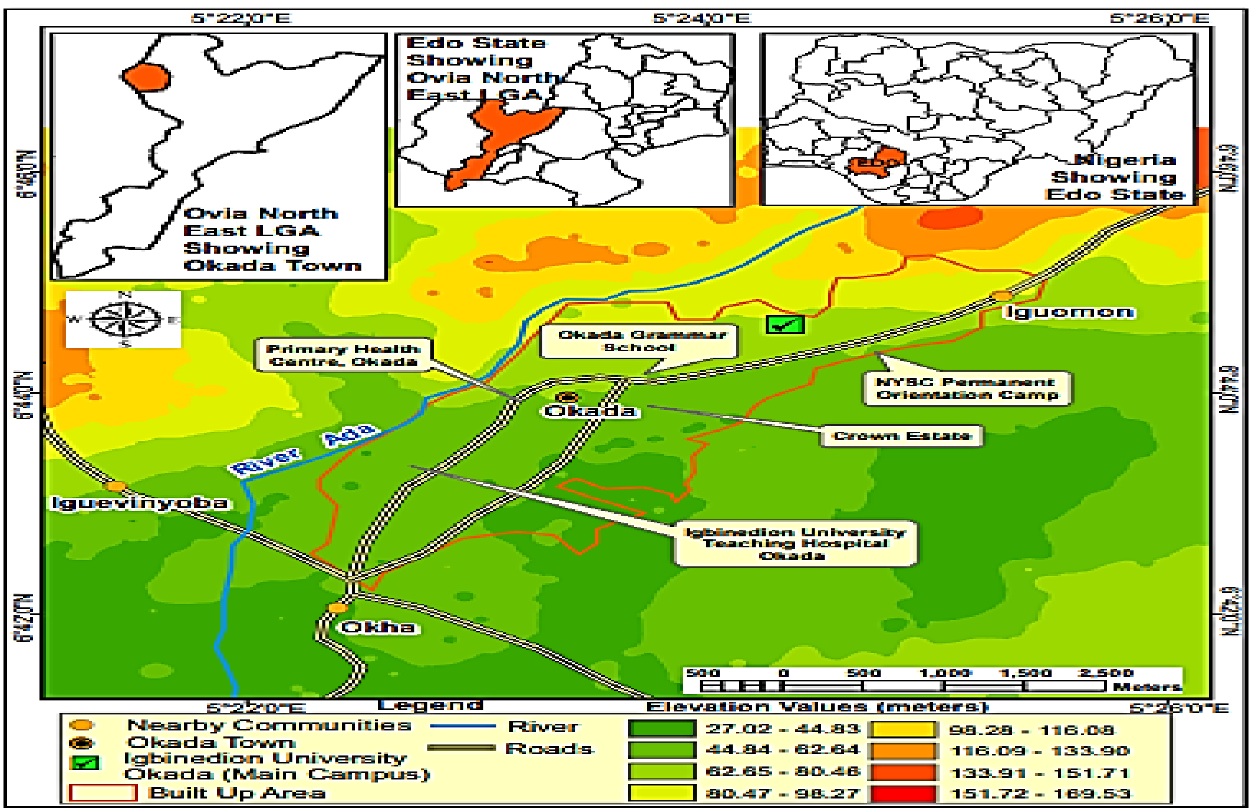


Fig. 1: Map showing studies location, Okada in Ovia North, Edo State, Nigeria (Yerima, *2023*)

Materials and Methods

The spotted melon (*Lagenaria Breviflora*) fruits were harvested wild in Crown Estate, Okada of Igbinedion University (Fig.1). The extraction of the vegetable oil and synthesis of the fatty acids methyl esters (FAME) has been reported in Yerima *et al* (2021) and Yerima *et al* (2022). Biolubricant was synthesized from fatty acid methyl ester as described by Ocholi *et al* (2018) with some modification. A batch experimental set up which comprises of a two neck 1000ml flat bottom flask, a reflux condenser and constant temperature magnetic stirrer were used. The synthesis was achieved by transesterification of methyl ester with ethylene glycol in 50 ml batches using 5 wt % of *Lagenaria breviflora* Shell (LbS) heterogeneous catalyst in 30wt% methanol to the mass of FAME and ethylene glycol.

The weight ratio of fatty acid methyl ester (FAME) -to-ethylene glycol (EG), were monitored, the amount of catalyst used was (0.8 % w/w) of total reactants (fatty acid methyl ester + ethylene glycol) and the reaction was conducted at a temperature of 150 ºC for 3 hours (Ghazi & Resul, 2010) which was also optimized. The reaction was carried out under vacuum conditions to promote a forward reaction by ensuring the entire methanol produced was removed from the reaction mixture.

Characterization of biolubricant

The biolubricant was produced by transesterification of the FAME followed by purification was characterized using standard methods such as ASTM D445 for Kinematic viscosity; ASTM D1298 for S.G and density; ASTM D93 for flash point; ASTM D97 for pour point; ASTM D92 for fire point; FTIR, GC - MS were conducted and its lubricant properties were compared with the conventional lubricants.

Results and Discussion

The physico-chemical properties of FAME from spotted melon seed oil (SMSO) are presented in Table 1 and previously discussed (Yerima *et al*, 2022)

Table 1: Properties of FAME from Spotted Melon (*Lagenaria breviflora)* Seed oil.

Analysis	Method	This study	Standard, ASTM D6751
Yield vol. %		89.32 %	
Colour	ASTMD – 1500 (98)	Greenish Yellow	
Density, g/cm^3	ASTM D-792	0.874	0.86 – 0.90
Specific Gravity	ASTMD- 1298	0.87	0.875 – 0.90
Kinematic Viscosity 40ºC mm^2/s	ASTMD-445 -97	4.426	3.5 – 5.0
Cloud point, ºC	ASTMD - 2500	3.5	-1
Pour point, ºC	ASTMD – 97	-2.0	-15 – 10
Flash point, ºC	ASTMD – 92	147	> 130
Fire point, ºC	ASTM D-92	165	> 145
Acid Value, mg KOH/g	ASTM D-974	0.539	<0.8

Physico-chemical properties of Spotted Melon Biolubricant

Table 2: Comparative physico-chemical properties of biolubricant with other and standards

Parameter	Method	*L. breviflora* Biolubricant (This study)	*L. Siceraria* Biolubricant[1]	Natural Esters[2]	IEC 61099 specification[3]
Acid Value mg KOH/g	ASTM D664	0.765	2.72 ± 1.03	N/A	<0.03
Iodine Value, mg I_2 g^{-1}	ASTM D4607	1.25	1.28 ± 1.40	N/A	N/A
FFA, %	ASTM D5555-95	0.3825	N/A	N/A	N/A
Biolubricant Yield, %		88.74	N/A	N/A	N/A
K. Viscosity mm/s^2@ 40ºC	ASTM D445	29.214	9.59 ± 0.02	36	<35
D. Viscosity, mP.s @ 40ºC	ASTM D445	26.1	N/A	N/A	N/A
Viscosity index	ASTM D2270	180.5	181 ± 0.01	316	254
Density, g/cm^3 @ 30ºC	ASTM D1298	0.8934	N/A	N/A	N/A
Flash Point, ºC	ASTM D92-12b	213.0	230 ± 1.20	254	≥250
Pour Point, ºC	ASTM D92-12	-10.0	-30 ± 0.03	-21	≤ -45
Oxidation Stability	ASTM D2272	5hrs 17mins	N/A	N/A	N/A

[1]Owuna *et al*, 2018. [2]Raof et al, 2022. N/A – not available
[3]IEC, 61099 - Insulating liquids - Specifications for unused synthetic organic esters for electrical purposes.

Viscosity index

The most important lubricating function for adequate protective film thickness is highly dependent on fluid viscosity, making it the most important characteristic for lubricant selection and application (Rashmi *et al.*, 2017; Zulkifli *et al.*, 2013). The viscosity should be high enough to provide a thick film between moving components even at high temperature and pressure, yet low enough to keep the lubricant fluid around each component part (Sharma & Sachan, 2019).

Viscosity is a measure of ease of flow of a fluid. It is determined by measuring the amount of time taken for a given measure of fluid to flow through an orifice of a specified size (Alamu *et al,* 2010). The viscosities of products at 40 ˚C are generally much greater than the viscosities at 100˚C because intermolecular forces resisting flow in liquids such as hydrogen bonds and Van der Waals forces are largely broken down at higher temperatures. The viscosity index of the produced biolubricant was found to be 180.5 while that of *L. Siceraria* was 181±0.01 (Table 2) and is lower compared to a value of 195.22 for jatropha biolubricant (Bilal *et al*, 2013), a value of 225.36 for modified jatropha oil (Jeevan & Jayaram, 2018), and a value of 219.00 for modified *pongamia* oil (Jeevan & Jayaram, 2018). Palm oil that is known as a biodegradable resource has a viscosity and viscosity index of 40.0 mm^2/s (at 40°C) and 191, respectively (Kotturu *et al.*, 2020). A transesterification of methyl ester that is derived from palm oil with Trimethylolpropane (TMP) to produce Trimethylolpropane ester (TMPE) showed better lubricity properties, with a viscosity of 42.5 mm^2/s (at 40 °C) and a viscosity index of 221 (Kotturu *et al.*, 2020; Qiao *et al.*, 2017). Though the viscosity index of the synthesized biolubricant was within the standard for engine oils (Owuna *et al*, 2018; Mukhtar *et al*, 2014; Danjuma & Dandago, 2009), Lb. biolubricant will experience greater changes in its viscosity with change in temperatures compared to jatropha lube oil, modified jatropha oil, and modified *pongamia* oil.

Flash point

The propensity to fire hazards of products is determined by the flash and fire points.

The flash and fire points of the biolubricant are slightly lower than that of *L. Siceraria* biolubricant showing the enhanced thermal resistance of the product of transesterification. The flash point of the produced biolubricant was found to be 213 ^oC but lower compared to that of *L. siceraria* 230 ±1.20 ^oC (Table 2). These products are therefore classified as non-hazardous products because of their high flash points. The flash point of a lubricant refers to the temperature at which some vapor is emitted from the substance to momentarily ignite a flame (Alang *et al*, 2018). The high flash point confirmed that biolubricant has oxygen atoms in its molecular structure, and hence has low risk associated with vaporization during transportation and storage (Dabai *et al*, 2018; Owuna *et al*, 2018). The approximate results are in the range of those reported by Alang *et al* (2018) flash point for palm kernel oil (PKO) biolubricant as 210˚C while Aji *et al.* (2015) which gave the flash point of Neem biolubricant as 262˚C and that of Jatropha biolubricant as 274˚C (Bilal *et al*, 2013).

Pour point

Pour point is the temperature below which biolubricant ceases to flow and is measured using ASTM D97-17b standard. This low temperature property is essential when machinery using hydrodynamic journal bearing must perform at lower temperatures (Raof *et al,* 2022). The pour point of the produced biolubricant was found to be -10 ^oC compared to that of L. *siceraria,* -30 ± 0.03 (Table 2) which could be attributed to some trace FFA (0.3825 %), and it is lower compared to a value of -7 °C for jatropha biolubricant (Bilal *et al*, 2013), a value of -03.00 °C for modified jatropha oil (Jeevan & Jayaram, 2018), and a value of -02.00 °C for modified *pongamia* oil (Jeevan & Jayaram, 2018). The large differences in the pour points between the reviewed biolubricant and that of *L*. *siceraria* was because of additives formulated with the produced *L*. *siceraria* biolubricant which were absent in the others (Dabai *et al*, 2018).

Acid value

The acid value of the biolubricant was found to be 0.765 mg KOH g^{-1} which is at variant with that of *L. siceraria,* 2.72±1.03 mg KOH g^{-1} (Table 1) when compared, and it is higher than a value of 0.05 mg KOH g^{-1} for modified jatropha oil (Jeevan & Jayaram, 2018) and a value of 0.13 m` KOH g^{-1} for modified *pongamia* oil (Jeevan & Jayaram, 2018). This shows that requisite additives are necessary to enhance the usefulness of the produced biolubricant for any application as in the case of *L. siceraria* (Dabai *et al*, 2018, Christensen *et al*, 2017; Danjuma & Dandago, 2009).

Iodine value

The iodine value of the produced biolubricant was found to be 1.25 mg I_2/g when compared to that of *L. siceraria*, 1.28 ± 1.40 mg I_2 g^{-1}, and it is lower compared to a value of 22.00 mg KOH g^{-1} for modified jatropha oil (Jeevan & Jayaram, 2018) and a value of 21.41 mg KOH g^{-1} for modified *pongamia* oil (Jeevan & Jayaram, 2018). This shows that the produced biolubricant has fewer methylene interrupted double bonds in its molecules and has high resistance to oxidation reactions than modified jatropha oil, and modified *pongamia* oil (Dabai *et al*, 2018, Owuna *et al*, 2018; Christensen *et al,* 2017). This work has indicated the feasibility of an alternative process for biolubricant using unexploited material from the agriculture industry.

Spectroscopy Analysis of *Lagenaria breviflora* Biolubricant

This section focuses on the Fourier transform infra-red and gas chromatomatography-mass spectroscopy results for the synthesized *Lagenaria breviflora* biolubricant.

Fourier transform infra-red of *Spotted Melon Oil* biolubricant

Vibrational frequencies of organic molecules are widely used in qualitative and quantitative analysis to identify different absorption chromorphores. The vibrational frequencies are sub-classified into group frequencies characteristic of groups of atoms or functional groups and fingerprint frequencies characteristic of specific molecules. The synthesized biolubricant was analyzed by FTIR to ascertain that the transesterification reaction between FAME and ethylene glycol did effectively take place. The IR spectra of the biolubricant are depicted by Table 3

Table 3: Observed FTIR functional groups in the synthesized biolubricant

Peak number	Wave no. (cm^{-1})	Intensity	Bond type3			Remark
1	476.68				Finger print	
2	497.73					
3	604.48		C-H			
4	723.30		C-H cis	Sharp		
5	846.8		C-H tri			
6	880.31		C-H tri			
7	913.94		C-H mono			
8	992.2		C-H mono	C=C bending alkene		
9	1016.43		Medium			
10	1101.2	C-O stretching ester	Alkoxy C-O			
11	1116.4					
12	1171.31		Sharp	Doublet		
13	1196.57		Sharp			Vampire fangs
14	1245.65	C-O stretching	Sharp			Alkyl aryl ether
15	1319.3					
16	1362.38		Sharp	O-H bending		Carboxylic acid
17	1397.63		O-H bending	medium		
18	1436.24			Doublet sharp		
19	1459.18					
20	1649.5		C=N stretching			Imine/oxime
21	1743.38		Very sharp	C=O		Cyclopentanone
22	2673.3		C-H stretching			
23	2854.97		Sharp	N-H stretching	Doublet	Amine salt
24	2926.54		Sharp			
25	3009.24		Sharp	alkane	C-H stretching	
26	3465.93		Medium beard	Bushy beard	O-H	-COO-H
27	3662.33		O-H stretching			
28	3682.43					
29	3789.99					

The absorption bands for C-H and $–CH_2$ for biolubricant were detected at 2673.3 cm^{-1}, this is an indication of alkane functional group in the lubricant. The alkene functional group (C = C) observed at 992.2 cm^{-1} is an indication of unsaturation of biolube oil (Dabai *et al*, 2018, Jeevan & Jayaram, 2018). The carbonyl functional group (C=O) was observed at 1743.38 cm^{-1} (Table 3) signifying cyclopentanone in the biolubricant (Mayo *et al*, 2003), whereas C=N stretching vibration occurred at 1649.5 cm^{-1}, indicating that the C= O is for ester since there is no matching O-H absorption (Dabai *et al,* 2018) but was observed in the 1397.63 cm^{-1} to 1459.18 cm^{-1} stretching. Ester group was also found at 1744 cm^{-1} for Rubber Seed Oil Trimethyloppropame (TMP) (Ainaatul & Jumat, 2013; Owuna *et al*, 2018)

Gas Chromatography- Mass Spectroscopy

The gas chromatography mass spectra of the biolubricant (Figure 2) showed the presence of ester groups (9,12-Octadecadienoic acid, methyl ester; 10-Octadecenoic acid, methyl ester; 9-Octadecenoic acid (Z)-, methyl ester; 1-Phenanthrenecarboxylic acid, tetradecahydro-7-(2-methoxy-2-oxoethylidene)-1,4a,8-trimethyl-9-oxo-, methyl ester; etc.) which are good for boundary lubrication (Owuna *et al*, 2018; Dabai *et al*, 2018, Aloko *et al,* 2017). The chemical and physical properties of vegetable oils depend on the degree of saturation and unsaturation of the molecules of the compounds present in the agro based plant oils (Gobinda *et al*, 2017), the degree of unsaturation affects the thermal stability of oil and consequently the biolubricant. This confirmed why agro based plant oils are not relatively good to produce biolubricant in their crude forms (Dabai *et al*, 2018, Adolf *et al*, 2018, Jeevan & Jayaram, 2018).

Some other compounds observed in the biolubricant includes: cis-Verbenol, 3-Keto-isosteviol, 2-Heptenoic acid, 4-cyclopropyl-5-methylene-, methyl ester, (E)- N-Adamantan-1-ylmethyl-2,5-diethoxy benzene sulfonamide, 2-Nonyl-1-ol, diethyl acetal, 3-Ethoxyamphetamine, Guanidine, N, N-dimethyl-3-Methoxyamphetamine which are commonly observed in biolubricant (Owuna *et al*, 2018; Alang *et al,* 2018). The `biolubricant synthetic method (double transesterification) causes the elimination of the β-hydrogen atom from the vegetable oil structure and provides an ester with high degree of oxidative and thermal stability which is seldom found in vegetable oils (Wagner *et al*, 2001).

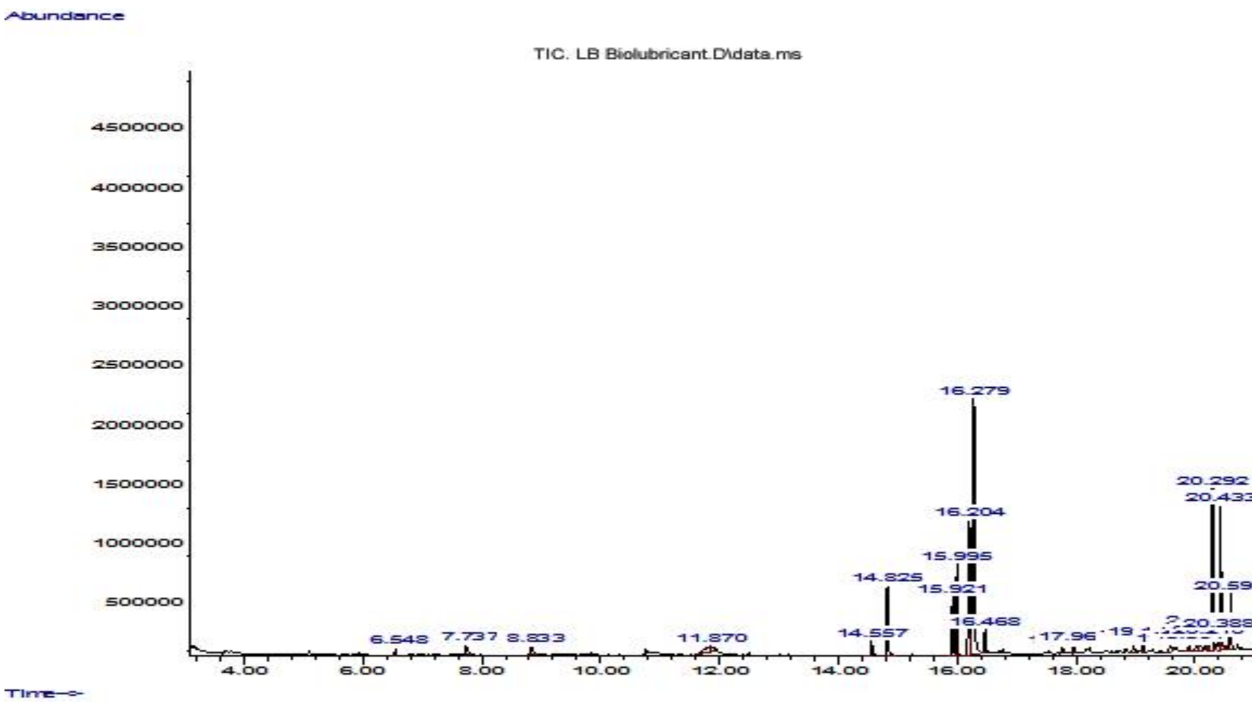
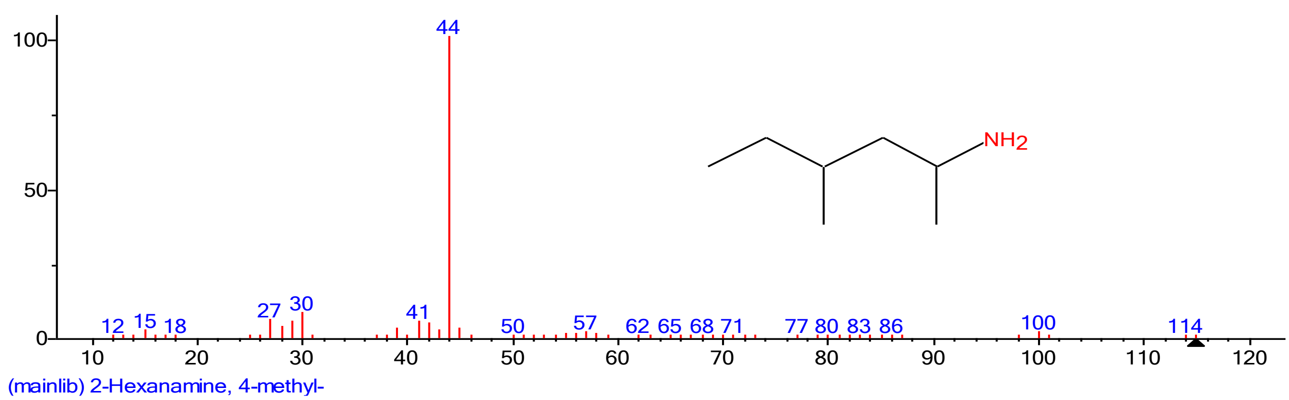
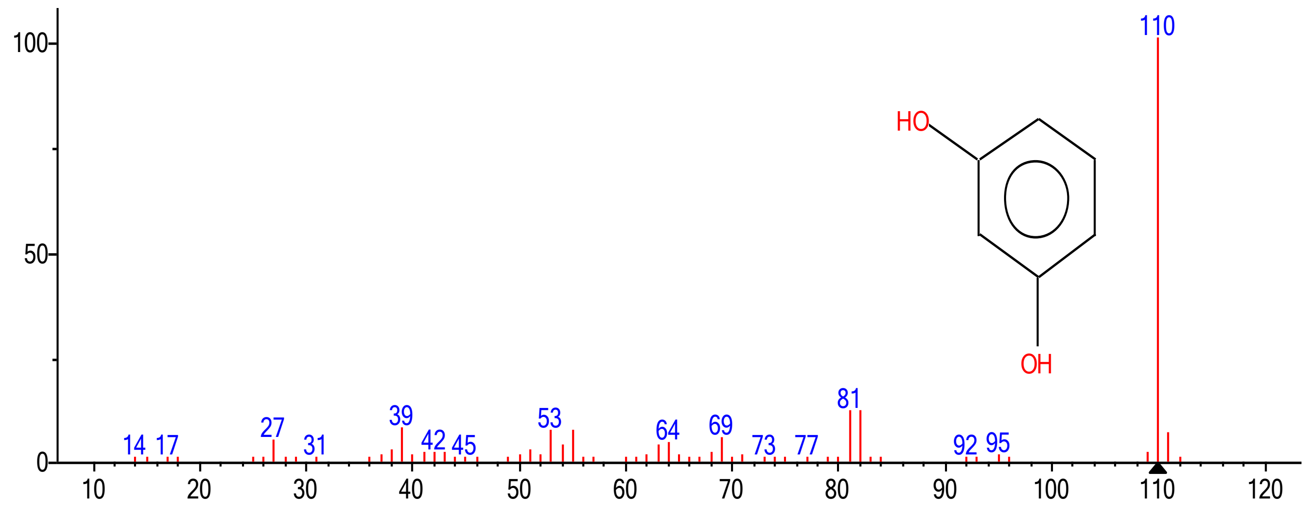
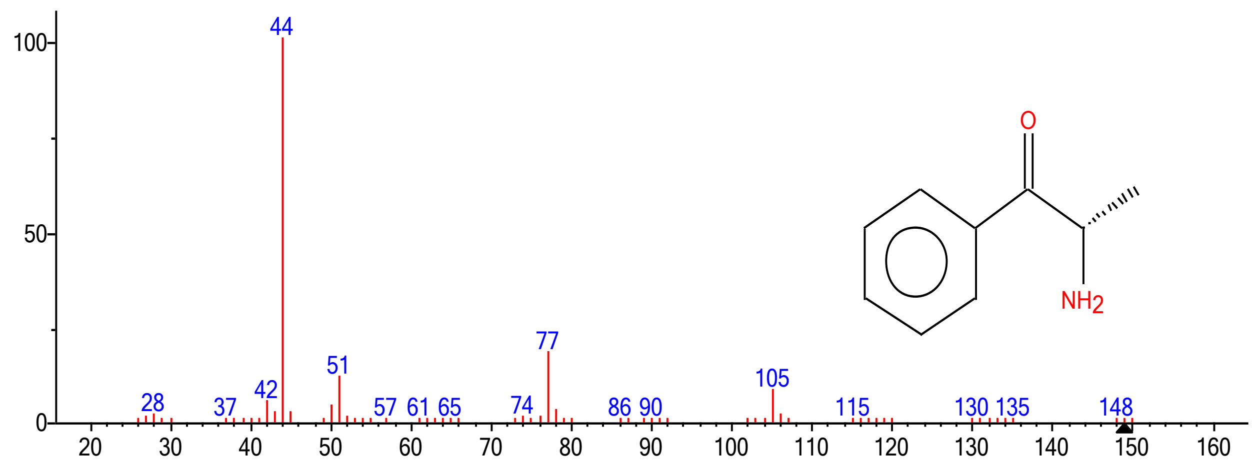


Fig.3: GC-MS Spectra of Spotted Melon Biolubricant

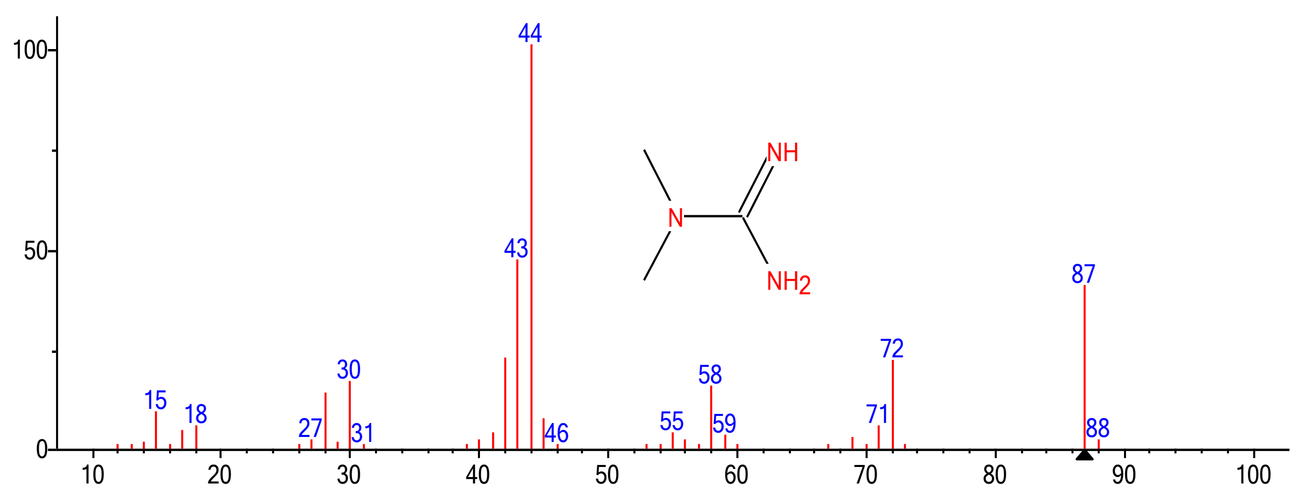




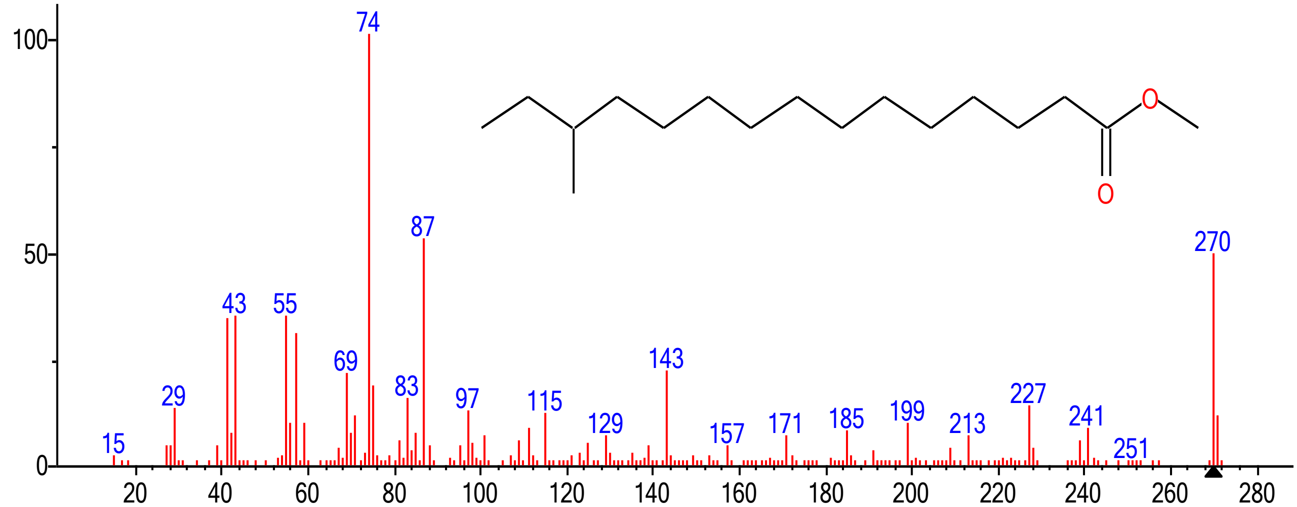
(mainlib) Resorcinol



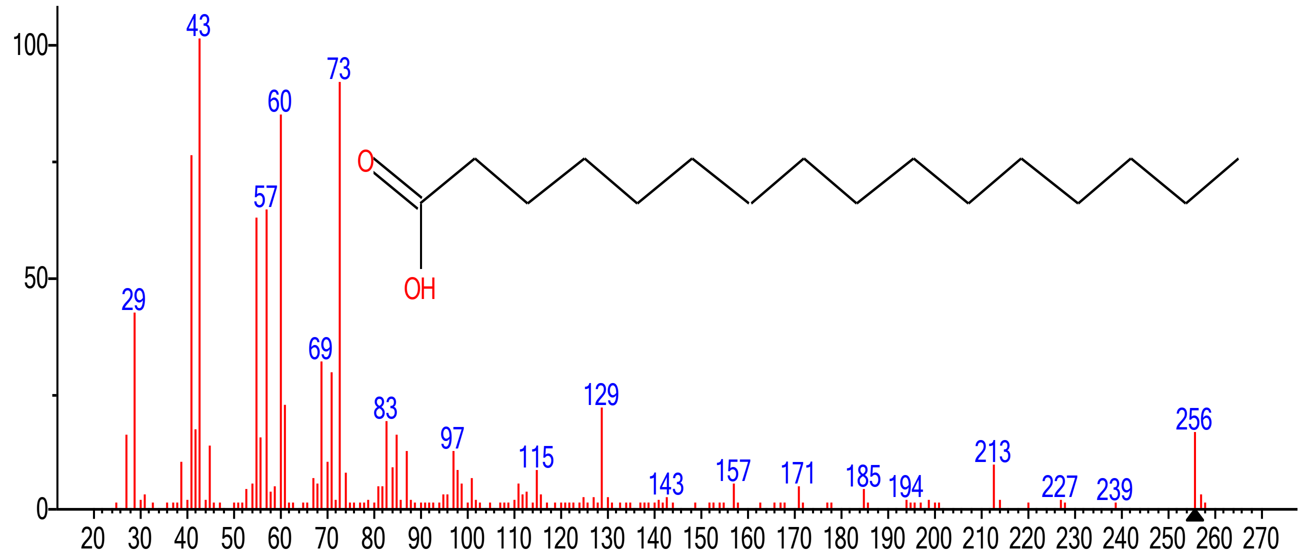
(mainlib) Cathinone



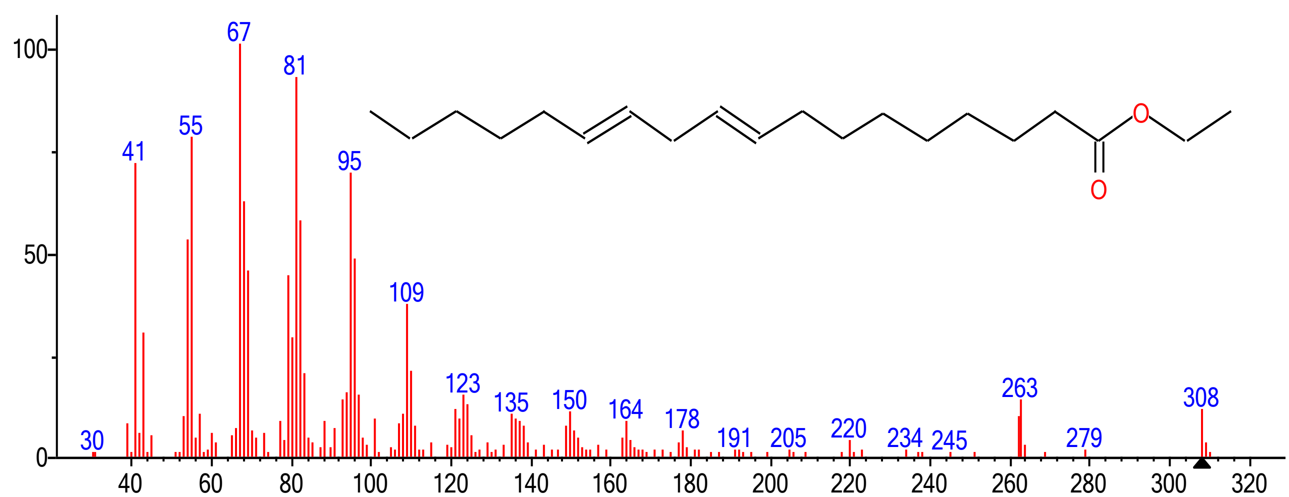
(mainlib) Guanidine, N,N-dimethyl-



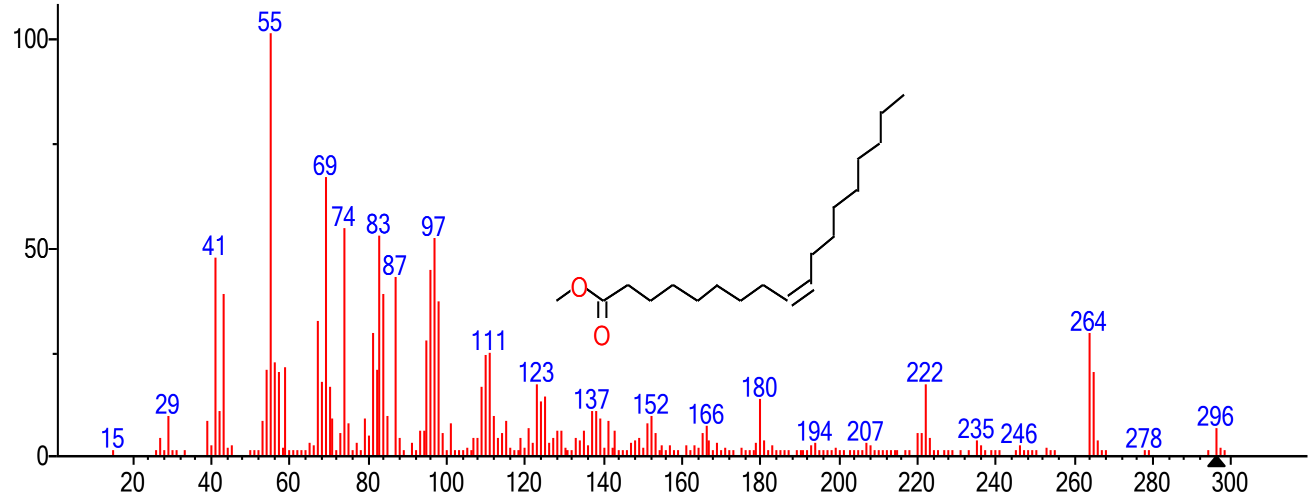
(mainlib) Pentadecanoic acid, 13-methyl-, methyl ester



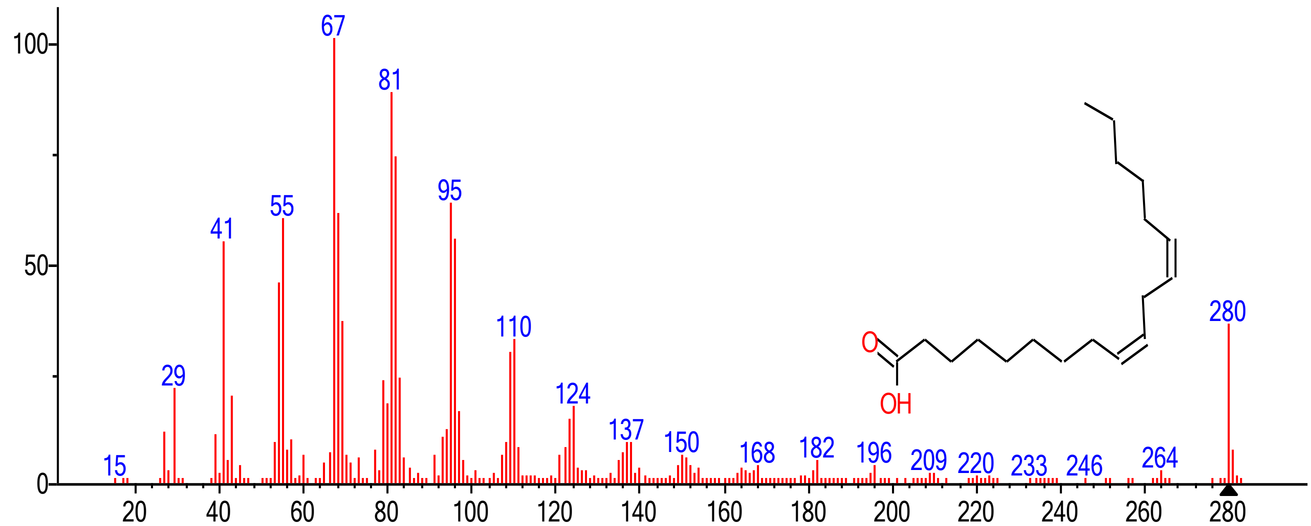
(mainlib) n-Hexadecanoic acid



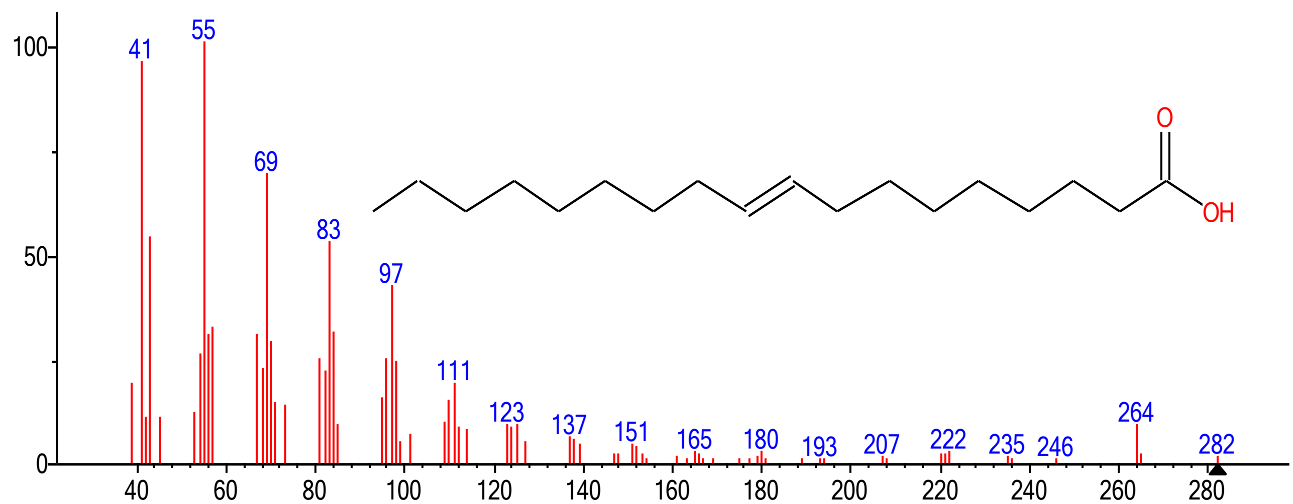
(mainlib) 9,12-Octadecadienoic acid, ethyl ester



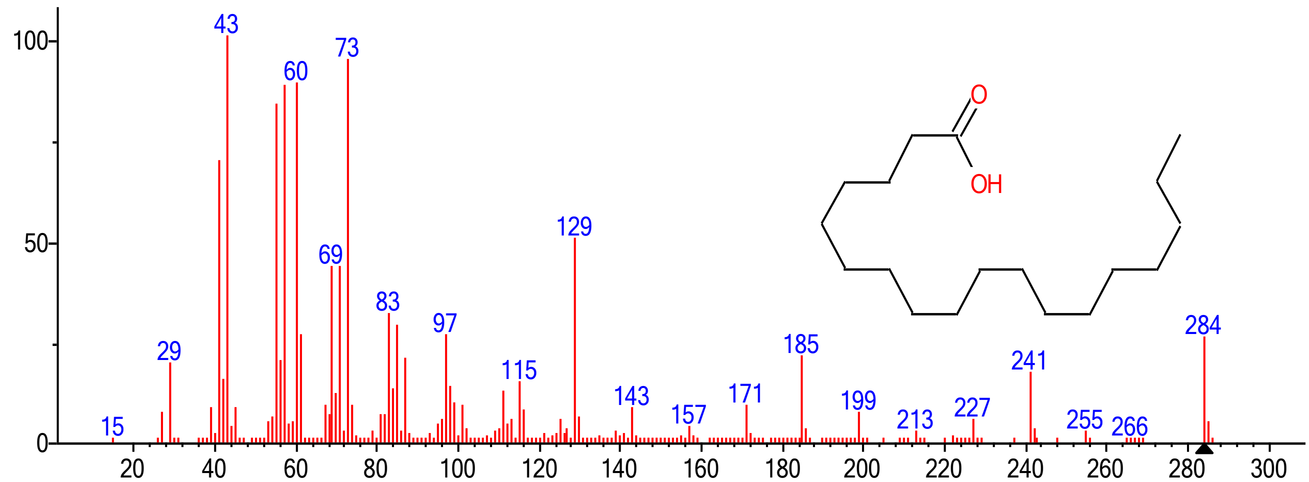
(mainlib) 9-Octadecenoic acid (Z)-, methyl ester



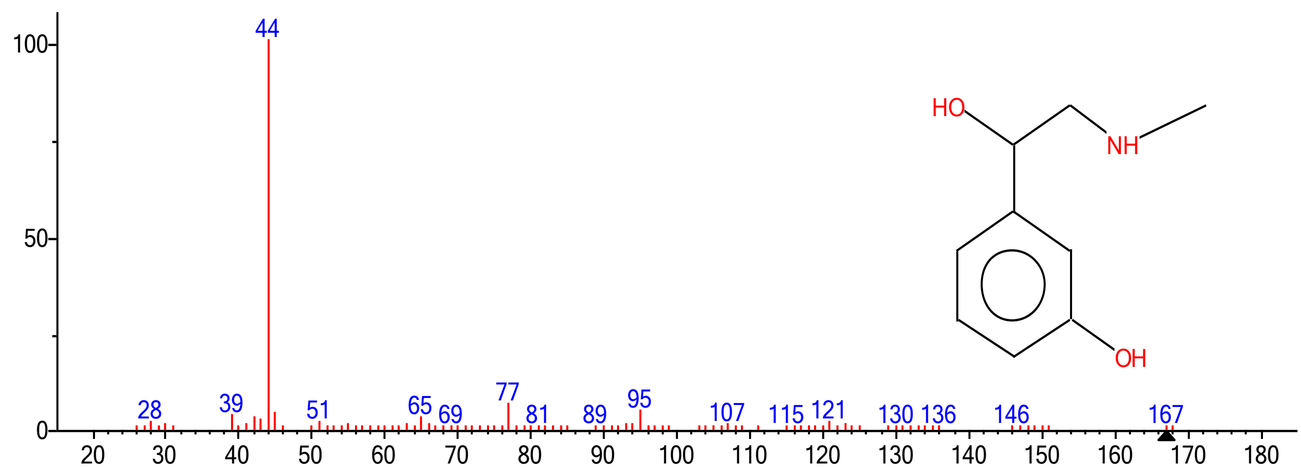
(mainlib) 9,12-Octadecadienoic acid (Z,Z)-



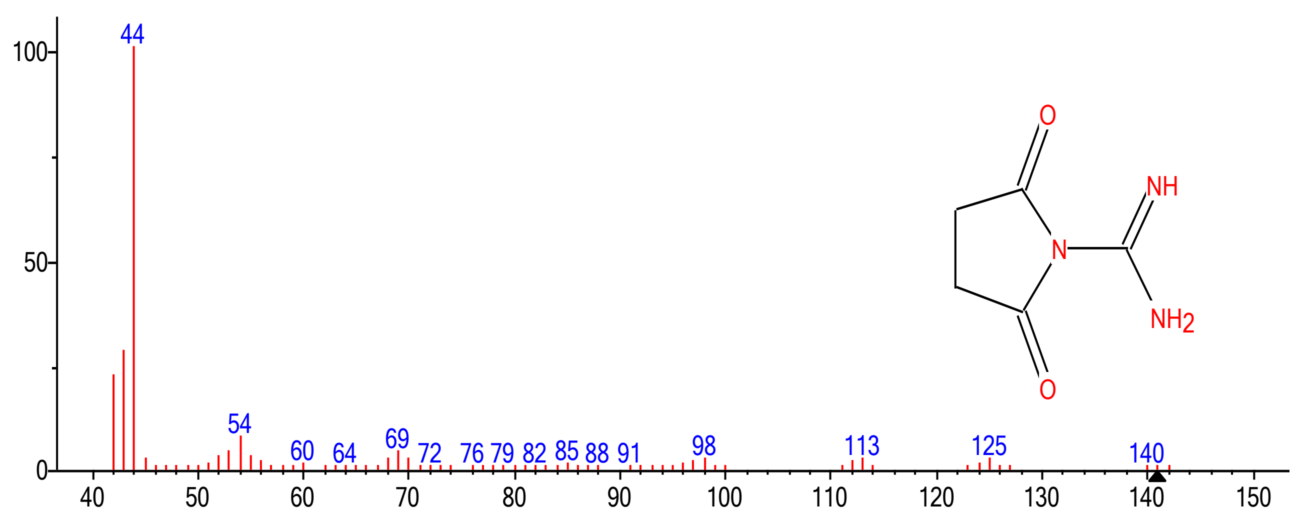
(mainlib) 9-Octadecenoic acid



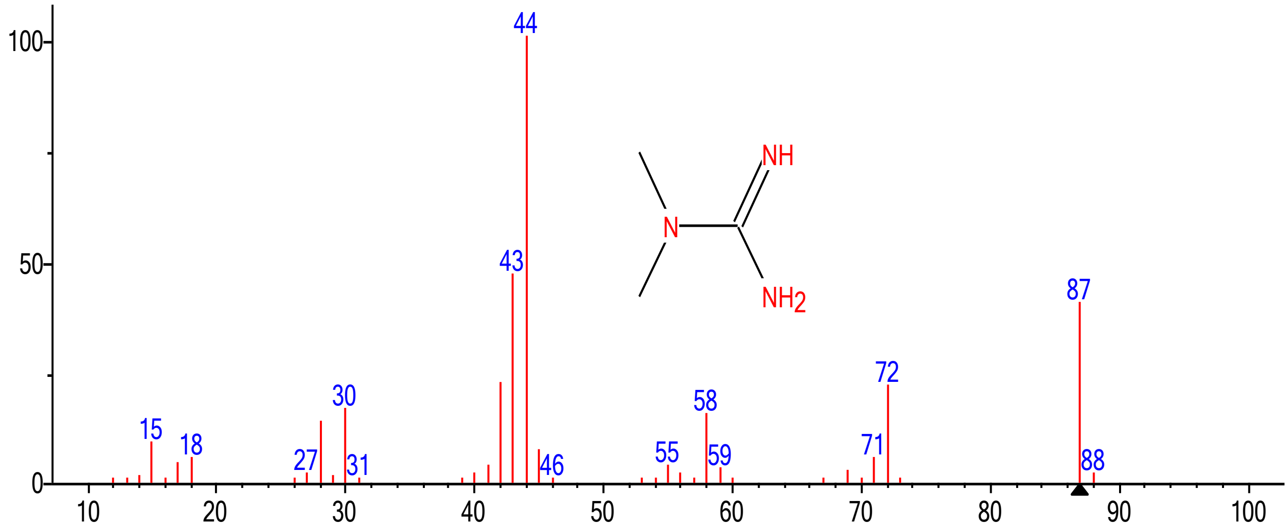
(mainlib) Octadecanoic acid



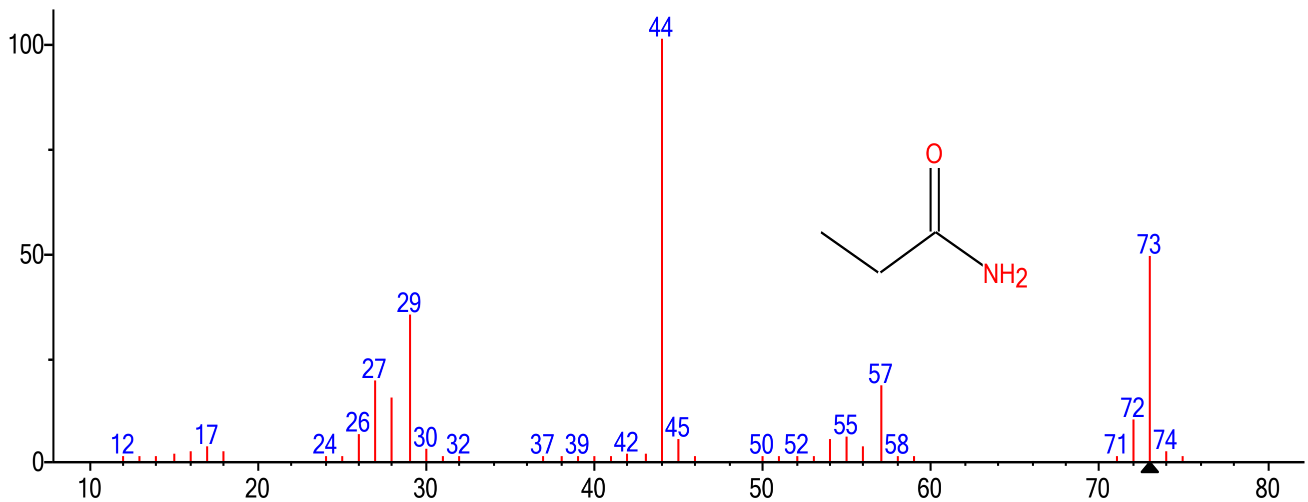
(mainlib) dl-Phenylephrine



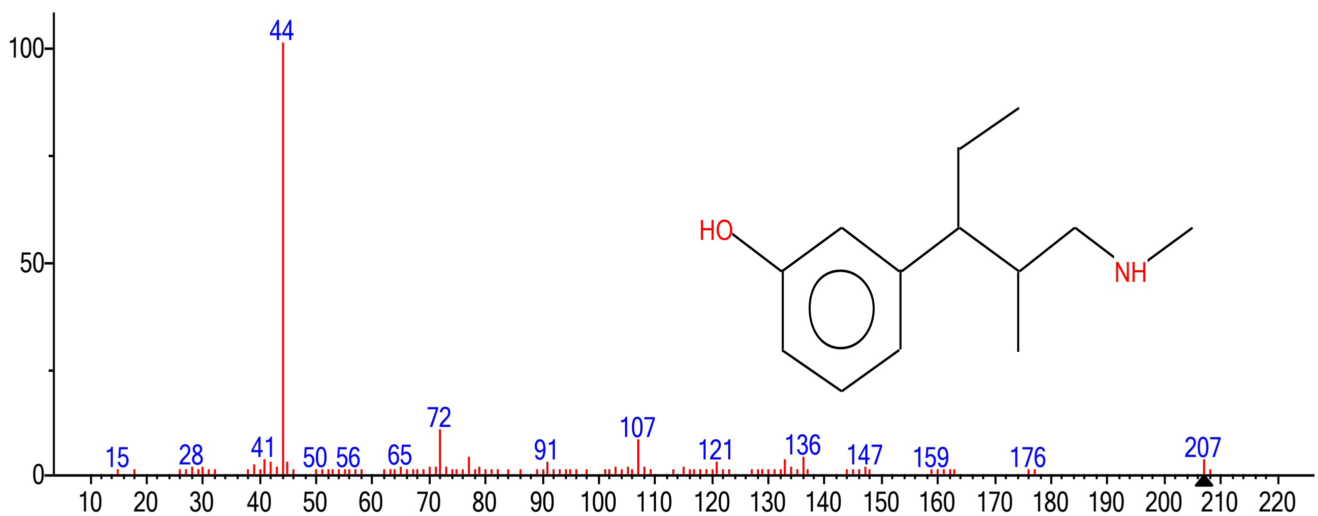
(mainlib) l-Guanidinosuccinimide



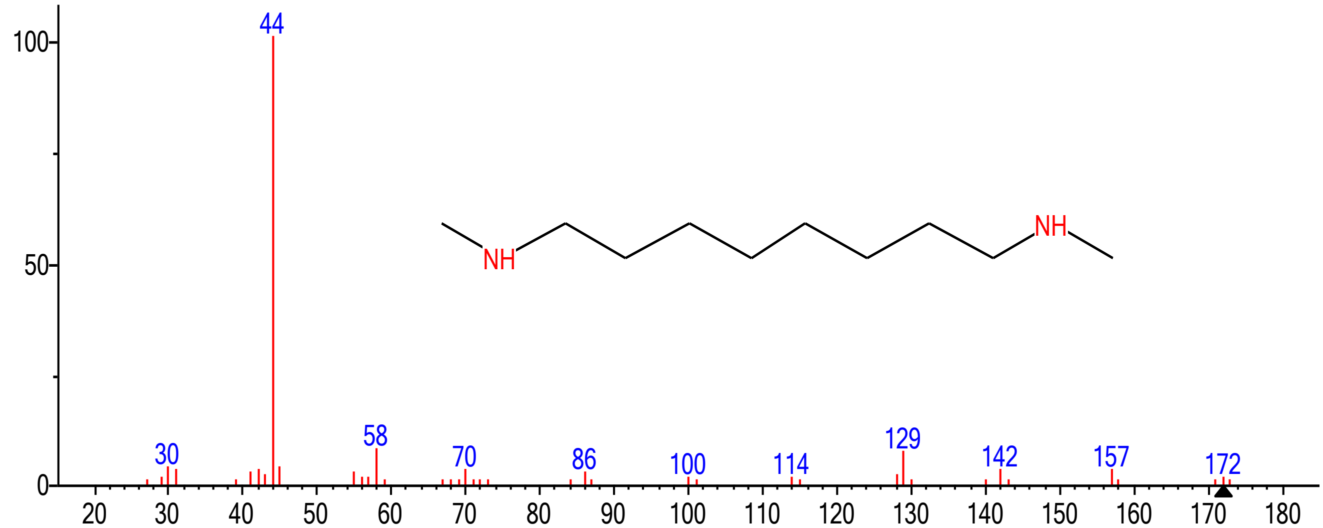
(mainlib) Guanidine, N,N-dimethyl-



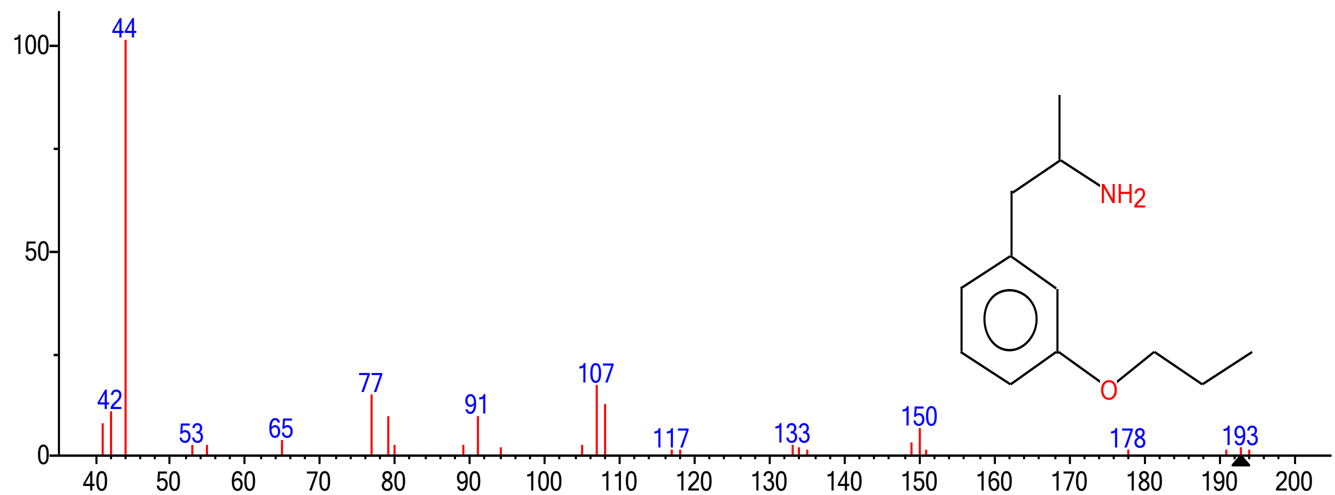
(mainlib) Propanamide



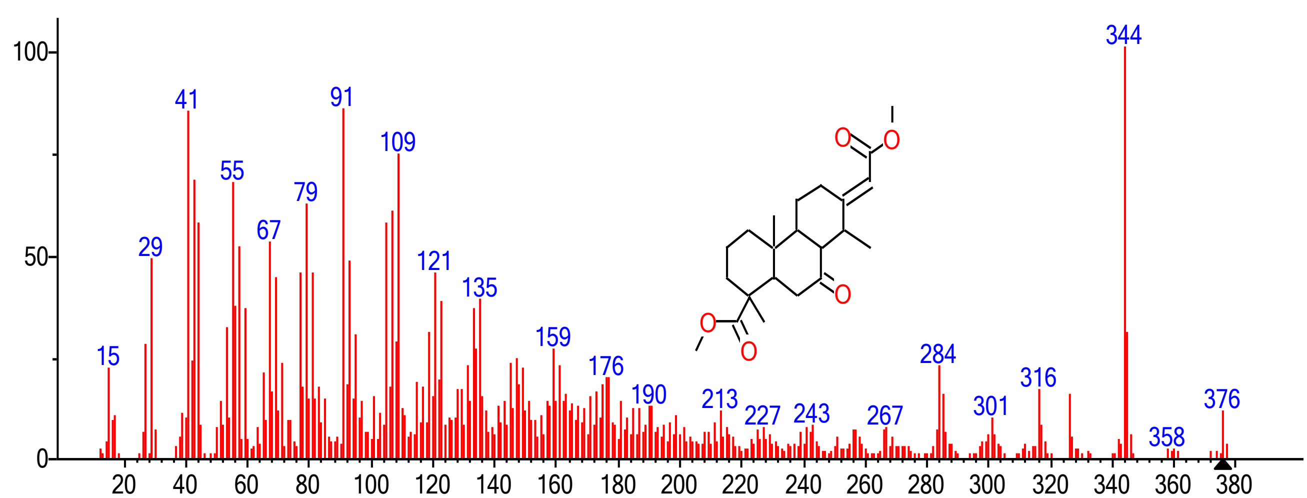
(mainlib) N-Desmethyltapentadol



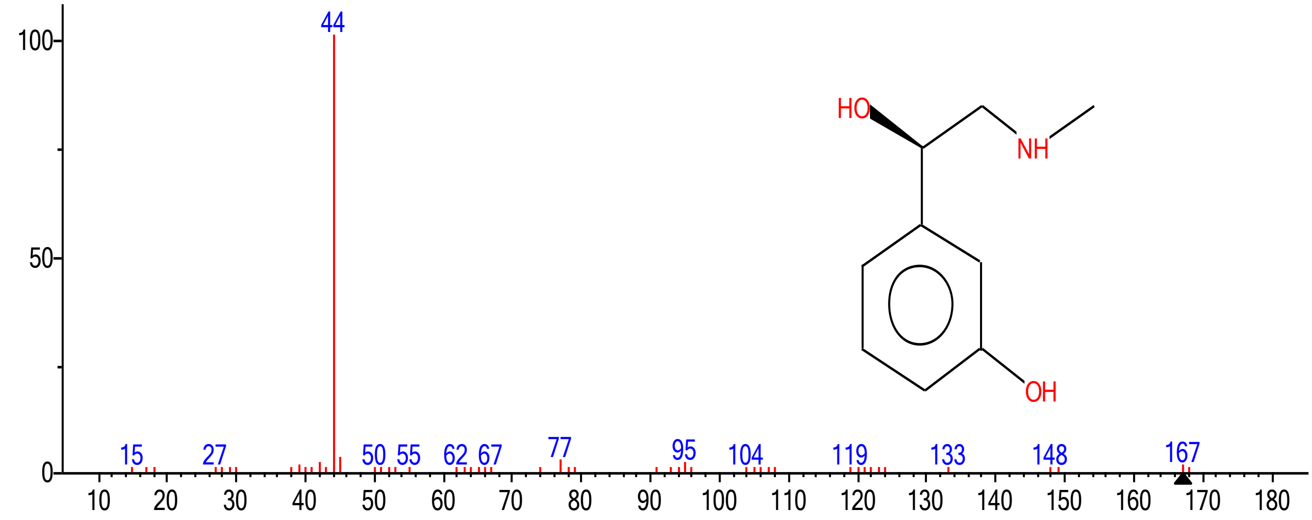
(mainlib) 1,8-Octanediamine, N,N'-dimethyl-



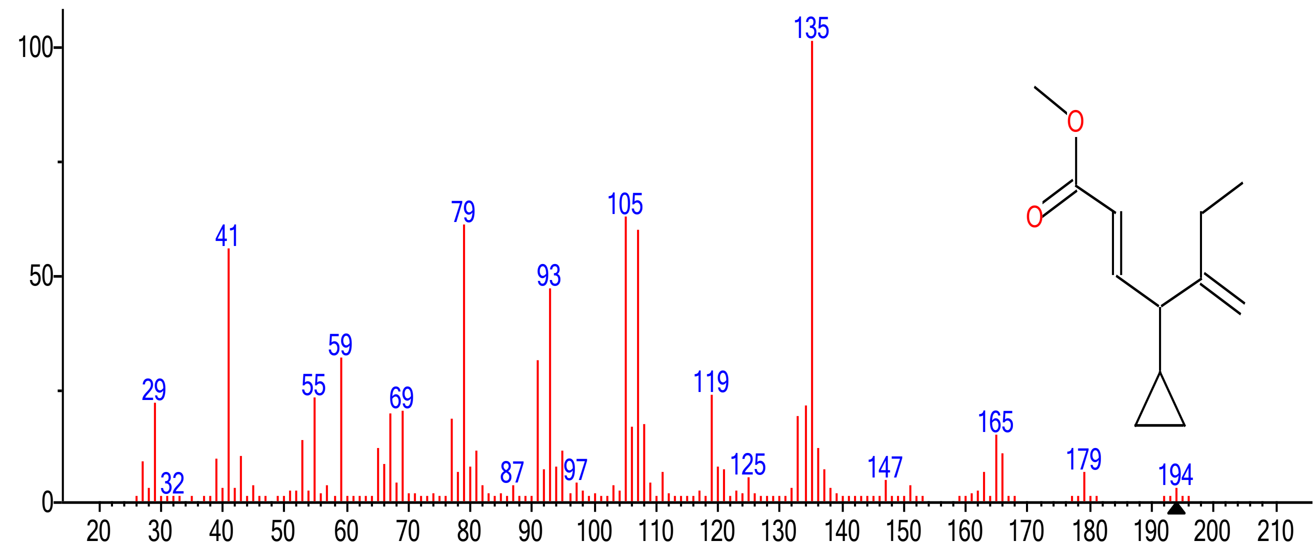
(mainlib) 3-Propoxyamphetamine



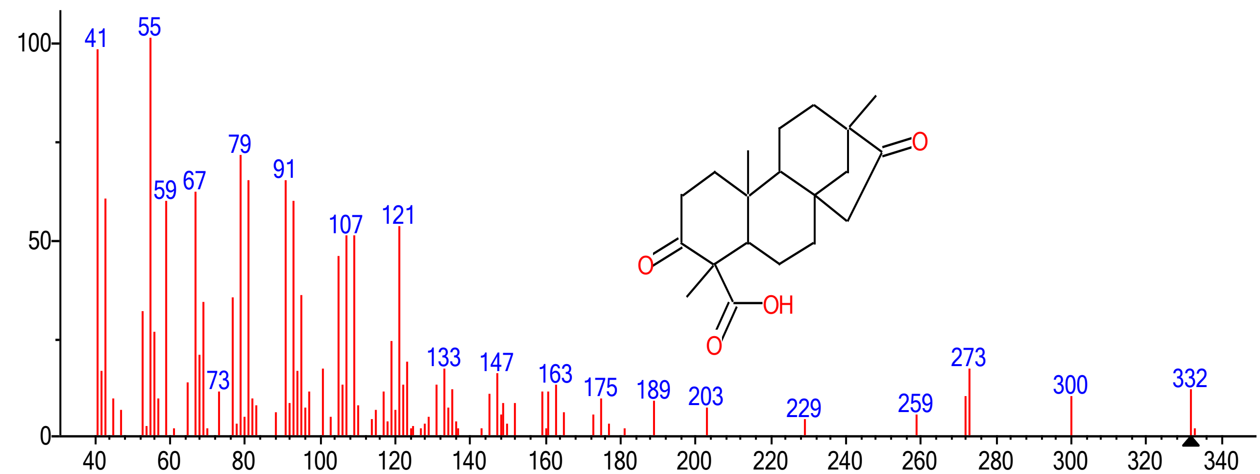
(mainlib) 1-Phenanthrenecarboxylic acid, tetradecahydro-7-(2-methoxy-2-oxoethylidene)-1,4a,8-trimethyl-9-oxo-, methyl ester, [1S-(1α,4ac



(mainlib) Phenylephrine



(mainlib) 2-Heptenoic acid, 4-cyclopropyl-5-methylene-, methyl ester, (E)-



(mainlib) 3-Keto-isosteviol

Conclusion

The Spotted melon biolubricant was synthesized from the FAME. The synthesis of the biolubricant followed a double transesterification process with a yield of 88.74% at the reaction conditions of EG to FAME molar ratio of 3.5 in 3hrs at a temperature of 130 °C. The biolubricant is synthesized from methyl esters based on spotted melon oil and showed good potential as base stock in biodegradable lubricant formulation. Despite the high pour point, other lubrication properties such as viscosity, Viscosity Index, and flash point are comparable to commercial industrial oil. Spectroscopic analysis of the `biolubricant using FTIR revealed the presence of alkane, alkene and esters groups. This was confirmed by the GC-MS analysis showing the presence of esters which are good for boundary lubrication.

References

Adolf, O., Akwasi, A., Gyang, N. O., Amoa, C. A. and Akorfa, A. A. (2018). Comparative Assessment of some Physico-chemical Properties of Seed Oils of Parkia biglobosa and Monodora myristica with some Commercial Oils. A*frican Journal of Food Science*, **12**:1- 5.

Ainaatul, A., and Jumat, S. (2013). Synthesis of Rubber Seed Oil and Trimethylolpropane Based Biolubricant Base Stocks. *Malaysian Journal of Analytical Sciences,* **17**:414-421.

Aji, M.M., Kyari, S.A. and Zoaka, G. (2015) Comparative Studies between Bio Lubricants from Jatropha Oil, Neem Oil and Mineral Lubricant (Engen Super 20w/50). *Applied Research Journal*, **1**, 252-257.

Alamu, O.J., Opeoluwa, D. and Adedoyin, M.S. (2010) Production and Testing of Coconut OilBiodiesel Fuel and Its Blend. *Leonardo Journal of Sciences*, **16**, 95-104.

Alang, M.B., Ndi-kontar, M.K., Sani, Y.M. and Ndifon, P.T. (2018) Synthesis and Characterisation of a Biolubricant from Cameroon Palm Kernel Seed Oil Using a Locally Produced Base Catalyst from Plantain Peelings. *Green and Sustainable Chemistry,* 8, 275- 287.

Almasi L. (2021). A review on bio-lubricant production from non-edible oil ASTM D445 Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

ASTM D92-12 Standard Test Method for Pour Point of Petroleum Products (nd)

ASTM D92-126 Standard Test Method for Flash and Fire Points by Cleveland open cup tester. (nd)

Bilal S., Mohammed D.I.A., Nuhu M., Kasim S.A., AlmustaphaI.H. and Yamusa Y.A., (2013). Production of Bio lubricant from jatropha curcas seed oil*, journal of chemical Engineering and materials science* vol. 4 (6) 72-79

Christensen, E., Gina M. F., Seonah, K., Lisa, F., Erica, G., Robert, S. P. and Robert, L. M. (2017). Experimental and Theoretical Study of Oxidative Stability of Alkylated Furans used as Gasoline Blend Components. *Fuel*, **212**:576-585.

Dabai, M. U., Owuna, F. J., Sokoto, M. A. and Abubakar, A. L. (2018). Assessment of Quality Parameters of Ecofriendly Biolubricant from Waste Cooking Palm Oil. *Asian Journal of Applied Chemistry Research*, **1**:1-11.

Erhan, S.Z.; Asadauskas, S. (2000). Lubricant base stocks from vegetable oils. *Ind. Crops*. *Prod.* **11**: 277-282.

Ghazi, T. I. M., Resul, M. F. G., & Idris, A. (2009). Bioenergy production of biodegradable lubricant from jatropha curcas and trimethylolpropane. *International Journal of Chemical Reactor Engineering.* https://doi.org/10.2202/1542-6580.1957.

Gobinda, K., Pranab, G. and Bragendra, K. S. (2017). Chemically Modified Vegetable Oils to Prepare Green Lubricants. *Lubricants*, 44:1-7.

Jeevan, T. P. and Jayaram, S. R. (2018). Performance Evaluation of Jatropha and Pongamia Oil Based Environmentally Friendly Cutting Fluids for Turning AA 6061. *Advances in Tribology,* 2018:1-9.

Kotturu, C. M. V., Srinivas, V., Vandana, V., Chebattina, K.R. R., and Seetha Rama Rao, Y. (2020). Investigation of Tribological Properties and Engine Performance of Polyol Ester- Based Bio-Lubricant: Commercial Motorbike Engine Oil Blends. Proc. Inst. Mech. Eng. *D: J. Automobile Eng*. 234 (5), 1304–1317. Doi: 10.1177/0954407019878359

Mayo, D.W., Miller, F.A. and Hannah, R.W. (2003) Spectra of Carbonyl Compounds of All Kinds (Factors Affecting Carbonyl Group Frequencies); Course Notes on the Interpretation of Infrared and Raman Spectra. Chapter 7, John Wiley & Sons, Inc., Hoboken, 179-204.

Mukhtar, M., Muhammad, C., Dabai, M. U. and Muhammad, M. (2014). Ethanolysis of Calabash (*Langeneria sinceraria*) Seed Oil for the Production of Biodiesel. *American Journal of Energy Engineering*, **2**:141-145.

Nogales-Delgado S, Encinar, J. M., and Gonzalez, J. F. (2023). A Review on Biolubricants Based on Vegetable Oil Through Transesterification and The Role of Catalysts: Current Status and Future Trends. Catalyst 13 (9), 1299.https://doi.org/10.3390/catal1309129

Ocholi, O, Menkiti, M., Auta, M and Ezemugu I. (2018). Optimization of the Operating Parameters for the Extractive Synthesis of Biolubricant from Sesame Seed Oil via Response Surface Methodology. Egyptian Journal of Petroleum. 27 (3) 265–275. https://doi.org/10.1016/j.ejpe.2017.04.001

Owuna Friday Junior, Dabai Musa Usman, Sokoto Muhammad Abdullahi, Muhammad Chika, Abubakar Aminu Lailaba. (2018). Use of Lagenaria Siceraria Seed Oil for the Production of Environmentally Friendly Biolubricant, *American Journal of Applied and Industrial Chemistry*. Volume 2, Issue 1, pp. 1-7. doi: 10.11648/j.ajaic.20180201.11

Pateh. JR, Chauhan, KV, Rawal S, Patel, NP Subheder D (2025). Advances and Challenges in Bio- Based Lubricants for Sustainable Tribological Applications: A Comprehensive Review of Trends, Additives, and Performance Evaluation. Lubricants 13 (10) 440. htps://doi.org/10.330/lubricants13100440.

Qiao, S., Shi, Y., Wang, X., Lin, Z., and Jiang, Y. (2017). Synthesis of Biolubricant Trimethylolpropane Trioleate and its Lubricant Base Oil Properties. *Energy Fuels* **31** (7), 7185–7190. doi: 10.1021/acs.energyfuels.7b00876

Raof, N. A, Hamid, H. A, Mohamad Aziz N.A. and Yunus, R. (2022) Prospects of Plant-Based Trimethylolpropane Esters in the Biolubricant Formulation for Various Applications: A Review. *Front. Mech. Eng* 8:833438. Doi: 10.3389/fmech.2022.833438

Rashmi, W., Khalid, M., Lim, X. Y., Gupta, T. C. S. M., and Arwin, G. Z. (2017). Tribological Studies on Graphene/TMP Based Nano-lubricant. *J. Eng. Sci. Tech*. 12 (2), 365–373.

Sharma, U. C., and Sachan, S. (2019). Friction and Wear Behavior of Karanja Oil Derived Biolubricant Base Oil. *SN Appl. Sci.* 1 (7). Doi: 10.1007/s42452-019-0706y

Teh, J. L, Walvekar, R, Ho, K. C; Khalil M (2025).Biolubricants from Waste Cooking Oil: A Review of Extraction Technologies, and Performance Enhancement Using Natural Antioxidant. Journal of Environmental Management. doi: 10.1016/j.jenvaman.2025.124267. PMID: 39879924

Wagner, H., Luther, R. and Mang, T. (2001) Lubricant Base Fluids Based on Renewable Raw Materials: Their Catalytic Manufacture and Modification. *Applied Catalysis A*, 221, 429. https://doi.org/10.1016/S0926-860X (01)00891-2

Yakubu Yerima, Anselm Igbafe, Rowland Ugochukwu Azike, Augustine Azubike Azuokwu, Fredriks Wirsiy Ngubi; (2021). Extraction and Characterization of Oil from Lagenaria Breviflora Seeds. European Modern Studies Journal. 5 (6) 107 -121. ISSN 2522-9400

Yerima, Y. (2023). Synthesis and Evaluation of a Biolubricant from Spotted Melon (*Lagenaria Breviflora)* For Environmental Sustainability. PhD Dissertation, Department of Chemical Engineering, Igbinedion University Okada

Yerima, Y., Igbafe, A. I., Azike, R.U., Azuokwu, A., and Ngubi, F. W. (2022). Studies on Lagenaria Breviflora Seed Oil for its Potentials as Feedstock for Fatty Acids Methyl Esters Production in Nigeria, European Modern Studies Journal Vol 6 No 4, ISSN 2522-9400, available at journal- ems.com,

Zulkifli, N.W.M, Kalam, M.A, Masjuki, H.H, Shahabuddin, M, Yunus, R. (2013). Wear prevention characteristics of a palm oil-based TMP (trimethylolpropane) ester as an engine lubricant. *Energy*. **54**:167–73. Doi: 10.1016/j.energy.2013.01.038