AN INVESTIGATION OF USING *MORINGA OLEIFERA* SEEDS OIL AS LUBRICANT

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AN INVESTIGATION OF USING *MORINGA OLEIFERA* SEEDS OIL AS LUBRICANT

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Thesis submitted in partial fulfilment of the requirements
for the award of the degree of
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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Chemical Engineering (Gas Technology).

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Dedication

Special Dedication to my supervisor, my family members, my friends, my fellow colleagues and all faculty members for all your care, support and believe in me.

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Firstly, praise to Allah the Most Gracious and the Most Merciful. Also, I would like to thank the following people and organisations;

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ABSTRACT

Many liquids, including water have been used as lubricants since the Roman era to minimize the friction, heat, and wear between mechanical parts in contact with each other. Today, lubricating oil, or lube oil, is the most commonly used lubricant because of its wide range of possible applications. Recently, pollution and environmental health aspects have become increasingly important as public issues. The increased environmental awareness is a primary driving force for the new technological developments. Nowadays, the increasing application of biobased lubricants could significantly reduce environmental pollution and contribute to the replacement of petroleum base oils. Vegetable oils are recognized as rapidly biodegradable and are thus promising candidates for use as base fluids in formulation of environment friendly lubricants. Future lubricants also have to be more environmentally adapted, have a higher level of performance, and lower total life cycle cost (LCC) than presently used lubricants. Thus, this research aims to produce a standard lubricant from *Moringa oleifera* seeds oil which is more environmentally friendly and has higher level of performance based on ASTM standard. All the *Moringa oleifera* seeds have been dried at 70°C before the samples were grinded and sieved for 250µm in size by using grinder and sieve shaker. The *Moringa oleifera* seeds oil then was extracted by using 200mL n-hexane in soxhlet extractor with 10g of *Moringa oleifera* seeds. The sample was put into the rotary evaporator to remove the n-hexane and get the pure *Moringa oleifera* oil. The basic filtration was done to remove all the small particles in the oil. Then, some tests were conducted to measure the parameters and the correlation of the properties to the ASTM standards as light machine lubricant. From the experiments, the *Moringa oleifera* oil kinematic viscosity was 43.813 mm^2/s at 40°C and 8.974 mm^2/s at 100°C, density was 0.915 g/cm^3, cloud point was 12°C, pour point was 8°C, and has viscosity index of 192. Therefore, it should be considered as lubricant for gear according to ASTM Standard.

ABSTRAK

Kebanyakan cecair, termasuk air telah digunakan sebagai pelincir sejak era pemerintahan Roman untuk mengurangkan kesan geseran, haba, dan kelusuhan di antara bahagian-bahagian mekanikal yang bersentuhan antara satu sama lain. Pada hari ini, minyak pelincir merupakan pelincir yang paling banyak digunakan disebabkan oleh aplikasi yang munasabah secara meluas. Kebelakangan ini, aspek pencemaran dan kesihatan alam sekitar telah menjadi semakin penting sebagai isu umum. Peningkatan terhadap kesedaran alam sekitar telah menjadi pendorong kepada pembangunan teknologi baru. Kini, peningkatan aplikasi pelincir berasaskan bio secara ketaranya dapat mengurangkan pencemaran alam sekitar dan menyumbang kepada penggantian minyak pelincir yang berasaskan petroleum. Minyak sayuran yang diketahui mampu terbiodegrasi dengan pantas menjanjikan contoh yang sesuai untuk digunakan sebagai pelincir dalam pemfomularan pelincir yang mesra alam sekitar. Pelincir masa hadapan seharusnya perlu lebih bersifat mesra alam sekitar, mempunyai tahap pencapaian yang tinggi dan jumlah kos kitaran hidup yang lebih rendah berbanding pelincir yang sedia ada. Oleh yang demikian, kajian ini bermatlamatkan untuk menghasilkan pelincir yang yang berpiawaian daripada minyak bijian *Moringa oleifera* yang mana lebih mesra alam dan mempunyai pencapaian yang tinggi berdasarkan piawaian ASTM. Kesemua biji *Moringa oleifera* yang sebelumnya telah dikeringkan pada suhu 70°C dikisar dan diayak sehingga bersaiz 250µm dengan menggunakan pengisar dan penapis berayak. Minyak bijian *Moringa oleifera* seterusnya diekstrak dengan menggunakan 200mL n-hexana dan minyak tulen *Moringa oleifera* diperoleh dengan menggunakan 10g biji *Moringa oleifera*. Penapisan ringkas dilakukan bagi mengeluarkan kesemua zarah-zarah kecil di dalam minyak. Kemudian, beberapa ujian dilakukan bagi mengukur parameter dan hubung kait antara sifat-sifatnya dengan piawaian ASTM sebagai pelincir mesin ringan. Daripada hasil eksperimen, kelikatan minyak *Moringa oleifera* adalah 43.813 mm^2/s pada suhu 40°C dan 8.974 mm^2/s pada suhu 100°C, berketumpatan 0.915 g/cm^3, titik pembentukan gel pada 12°C, takat curah pada 8°C, dan mempunyai indeks kelikatan 192. Maka, ia seharusnya dipertimbangkan sebagai pelincir bagi gear berdasarkan piawaian ASTM.

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LIST OF ABBREVIATIONS

Greek

ν	kinematic viscosity
ρ	density

LIST OF ABBREVIATIONS

amu	atomic mass unit
ASTM	American Society of Testing and Materials
cSt	Centistokes
ISO	International Standard Organization
LCC	life cycle cost
MUFA	Monounsaturated Fatty-Acids
OSI	Oxidative Stability Index
PAG	Polyalkylene glycols
PAO	Polyalpha Olefin
PIB	Polyisobutylene
RBD	refined, bleached, and deodorized
SAE	Society of Automotive Engineers
SSU	Saybolt Universal Second
VI	viscosity index

1 INTRODUCTION

1.1 Motivation and statement of problem

Since the Roman era, many liquids, including water, have been used as lubricants to minimize the friction, heat, and wear between mechanical parts in contact with each other. Today, lubricating oil, or lube oil, is the most commonly used lubricant because of its wide range of possible applications. The two basic categories of lube oil are *mineral* and *synthetic*. Mineral oils are refined from naturally occurring petroleum, or crude oil. Synthetic oils are manufactured polyalphaolefins, which are hydrocarbon-based polyglycols or ester oils (Nadkarni, 1991).

Although there are many types of lube oils to choose from, mineral oils are the most commonly used because the supply of crude oil has rendered them inexpensive; moreover, a large body of data on their properties and use already exists. Another advantage of mineral-based lube oils is that they can be produced in a wide range of viscosities—viscosity refers to the substance's resistance to flow—for diverse applications. They range from low-viscosity oils, which consist of hydrogen-carbon chains with molecular weights of around 200 atomic mass units (amu), to highly viscous lubricants with molecular weights as high as 1000 amu. Mineral-based oils with different viscosities can even be blended together to improve their performance in a given application. (Nadkarni, 1991).

Synthetic base fluids were first used in an industrial scale in 1931 after Sullivan produced his research result on synthetic polymerized olefins. Many different synthetic base fluids have been invented, but the most commonly used in lubricant formulation are polyalpha olefin (PAO) and SEs of different types. Cost limits the use of synthetic base fluids, where the cost of a synthetic base fluid relative to a mineral one is high; i.e., the relative cost varies from 2–3 times up to over 500. Other synthetic fluids used in lubricant applications are polyalkylene glycols (PAG), phosphate esters, and polyisobutylene (PIB), but they are not included in this study (Pettersson, 2007).

The increasing application of biobased lubricants could significantly reduce environmental pollution and contribute to the replacement of petroleum base oils. Vegetable oils are recognized as rapidly biodegradable and are thus promising candidates for use as base fluids in formulation of environment friendly lubricants. Although many vegetable oils have excellent lubricity, they often have poor oxidation and low temperature stability. One of the examples of vegetable oils is *Moringa oleifera* seeds oil. It has 74% oleic acid content and possess improved oxidation stability over many other natural oils besides it exhibits the highest thermo-oxidative stability compared to other oils, this shows a good potential of lubricant for *Moringa* oil (Brajendra et al., 2009).

Future lubricants also have to be more environmentally adapted, have a higher level of performance, and lower total life cycle cost (LCC) than presently used lubricants. To be able to formulate those lubricants, the properties of the base fluids have to be well known. Base fluid properties that influence the formulated lubricant performance could be divided into three different groups. These groups are: physical, chemical, and film formation properties. In this study, properties from all of these groups are investigated to improve the understanding on their influence on base fluid overall performance (Pettersson, 2007).

Recently, pollution and environmental health aspects have become increasingly important as public issues. In the area of lubrication, the concern is to focus on the issues related to large proportion of lubricants waste in environment. The break down products is potential threats to the environment. Water and soil are contaminated directly by waste lubrication system while the air is affected by volatile lubricants or lubricants haze. The increased environmental awareness is a primary driving force for the new technological developments. Therefore, biodegradable synthetic lubricants used in environmentally sensitive areas have been extensively explored. One of the biggest challenges in the development of universal biodegradable base stock that could replace mineral oil base stocks is the new generation lubricants. From the better performance point of view, these should be environmentally friendly to the environment and be biodegradable (Nagendramma and Kaul, 2012).

The purpose of this research is to produce a standard lubricant from *Moringa oleifera* seeds oil which is more environmental friendly, have higher level of performance and lower total life cycle cost for light machines.

1.2 Objectives

The objectives of this research are:

- To extract the oil from *Moringa oleifera* seeds
- To measure the properties of *Moringa oleifera* seeds oil
- To produce a lubricant for light machine that compared with the ASTM standard

1.3 Scope of this research

The following are the scope of this research:

i) This study will be focused on finding an alternative to conventional lubricant from petroleum based oil.

ii) By using available crops *(Moringa oleifera),* to produce natural lubricant which is environmentally friendly, less cost, and biodegradable.

1.4 Main contribution of this work

The focus of this study is to produce a lubricant from extraction of *Moringa oleifera* seeds which it will be expected to be used for light machines such as sewing machine. The importance of producing a lubricant from vegetable oils nowadays is to reduce environment pollution and contribute to the replacement of petroleum based oils. By understanding the physical properties and chemical components in the *Moringa oleifera* seeds oil, it can be new alternatives source for production of lubricant with standard properties.

1.5 Organisation of this thesis

The structure of the reminder of the thesis is outlined as follow:

Chapter 2 provides a description on available lubricant used nowadays. It describes the applications of lubricant normally used besides how it can affect the environment and caused pollution. This chapter also covers on brief information about the *Moringa oleifera* and its uses. Other than that, it explains on what is actually biodegradable lubricant and the importance of biodegradable lubricant development for current life.

Chapter 3 gives a review on how the process of extraction the oil from *Moringa oleifera* seeds for lubrication uses. This chapter explains in details every single step of experiment procedures conducted to get the oil. Then, the description of the tests done to measure the selected properties of available standard lubricant and compared to *Moringa oleifera* oil properties based on ASTM Standard.

Chapter 4 will be discussing the results of the tests and how they were conducted. Each property measured was compared to available standard lubricant for light machine like sewing machine oil. The *Moringa oleifera* oil has been matched and categorized to certain class of lubricant according to the range and value of the properties tested.

Chapter 5 concluded the whole research basically for the properties measured. New findings and recommendations were proposed for the applications of *Moringa oleifera* oil after they were compared to some class of lubricant available. More and tests should be conducted for future work in order to find the suitability and performance of *Moringa oleifera* oil for a better use.

2 LITERATURE REVIEW

2.1 Overview

This chapter presents the information of lubricating oils and its uses. Besides, the correlation of producing lubricant from vegetable oil produced worldwide. This chapter also covers the background of *Moringa oleifera* with variety of its uses. Other than that, the information on biodegradable lubricant and the suitability of *Moringa oleifera* used as biodegradable lubricant. This chapter also briefs the future prospects and current challenges of the lubricant.

2.2 Introduction

Deliberate and accidental lubricant losses occurring due to evaporation, leakages and spills are causing pollution and environmental health concerns. Every year about 5–10 million tons of petroleum products enter into the environment from spills, industrial and municipal waste, urban runoff, refinery processes, and condensation from marine engine exhaust. In certain applications, strict specifications on various environmental matters, such as biodegradability, toxicity, occupational health and safety, and emissions, have become mandatory. According to Chhatre *et al.* (1996), of the 3.2 billion of oil produced per year, an estimated 3.2 million tonnes enter the marine environment (Brajendra et al., 2009).

Transportation is the main cause of oil spillage, where it contributes as much as 30 times of oil lost than during production (Crook, 1992). Furthermore, the utilization of crude petroleum all over the world as the sources for fuel and energy, lubrication, grinding, paper deinking, and other petrochemical products causes a lot of disposal problems. Lubricants (or lubricating oils) are commonly used as the friction reducer and coolant in automotive machinery. Lubricants are also widely used in the industries as hydraulic fluids, in metal working processes, refrigeration equipment, quenching oils, and turbine lubricating oils. These sources serve as the major contributor to the environmental problems especially in soil and water.

This has stimulated the search for environmentally friendly lubricants. Other factors adding to search for alternative energy sources are uncertainty in petroleum supply, high prices of petroleum crude oils ($140/barrel), and political considerations. Vegetable oils are a renewable resource and thus finding a way into lubricants for industrial and transportation needs. Vegetable oil-based products are environmentally friendly and non-toxic and thus offer easier disposal as compared to petroleum products. There are also biodegradable synthetic oils offering improved stability and performance characteristics over refined petroleum oils but prices for these niche products are higher than vegetable oils and significantly higher than petroleum-based lubricants.

At present, over 125 million metric tons of vegetable oils are produced worldwide. These vegetable oils offer excellent lubricity, biodegradability, favorable viscosity temperature characteristics, high flash points, and compatibility with mineral oil and additive molecules. The restrictions in using vegetable oils for formulating lubricants are; their insufficient thermal and oxidative stability, low temperature fluidity, and hydrolytic instability. Some of these restrictions can be overcome by using high oleic varieties of vegetable oils in combination with available additives (antioxidants, pour point depressants) and diluents or functional fluids (Brajendra et al., 2009).

2.3 Moringa oleifera

Moringa oleifera (referred to as Moringa in this study), a member of the Moringaceae family is a multipurpose plant native to sub-Himalayan regions of Northwest India, Africa, Arabia, Southeast Asia, the Pacific and Caribbean islands, and South America. It also has been distributed in many other regions such as the Philippines, Cambodia, and Central and North America. In Pakistan, it is mainly grown in plain areas of Punjab, Sindh and Baluchistan, and to some extent in Northwestern Frontier Province. It is esteemed nutritionally as an important food commodity, and also has many medicinal uses. The fully matured, dried seeds of this plant are round or triangular shaped, and the kernel is surrounded by a lightly wooded shell with three thin flexible wings. (Figure 2-1)

Figure 2-1 : *Moringa oleifera* seeds

Moringa seeds contain between 33% to 41% (w/w) of vegetable oil. Several authors investigated its composition including fatty acid profile and found its oil to be high in oleic acid which is more than 70%. Its oil is commercially known as ‘‘ben oil’’ or ‘‘behen oil’’, due to its content of behenic (docosanoic) acid. It possesses a significant resistance to oxidative degradation, and has been extensively used in the enfleurage process. A recent survey conducted on 75 indigenous (India) plant-derived nontraditional oils concluded that *Moringa oleifera* oil, among others, has good potential for biodiesel production. (Brajendra et al.,2009).

2.4 The uses of Moringa oleifera

The leaves of *Moringa* (Figure 2-2) are widely eaten like rape or spinach in many rural and urban communities in Zimbabwe. The leaves can be harvested during the dry season when no other vegetables are available. The leaves are known to have a high content of protein, minerals and vitamins. The leaves of *Moringa* are an excellent source of the sulphur containing amino acids methionine and cystine, which are often in short supply (Council of Scientific and Industrial Research 1962). The high concentration of essential amino acids, mineral ions and vitamins makes *Moringa* an ideal nutritional supplement. Its leaves can be dried and made into a powder by rubbing them over a sieve and stored for use as a nutritional additive to soups, sauces or meal dishes.

Figure 2-2 : The leaves of *Moringa oleifera*

The flowers (Figure 2-3), leaves and roots are widely used as remedies for several ailments. The bark of the *Moringa* root should be scraped off because of its toxicity and the flesh of the root should be eaten sparingly (Oliver-Bever 1986). *Moringa* seeds are effective against skin-infecting bacteria Staphylococcus aureus and Pseudomonas aeruginosa (Council of Scientific and Industrial Research 1962; Oliver-Bever 1986). They contain the potent antibiotic and fungicide terygospemin. *Moringa* seem to have most of the food nutrients required by the body to 180 replenish its defensive mechanisms. The Tonga people of Binga District use the root powder as an aphrodisiac and when it is mixed with milk, it is considered useful against asthma, gout, rheumatism and enlarged spleen or liver. It also helps in the removal of wind from the stomach and as a snuff can be used to alleviate ear and toothache (Maroyi, 2006)

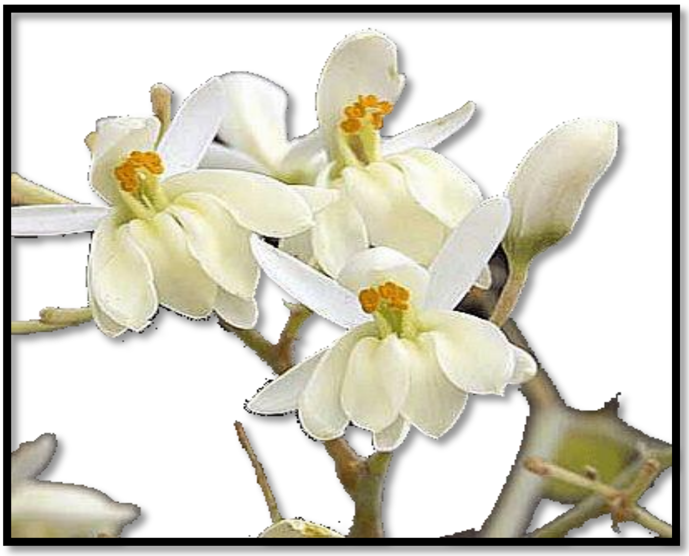

Figure 2-3 : The flowers of *Moringa oleifera*

The leaf juice has a stabilizing effect on blood pressure. The leaf juice controls glucose levels in diabetic patients. Fresh leaves and leaf powder are recommended for tuberculosis patients because of the availability of vitamin A that boosts the immune system. If leaf juice is used as diuretic, it increases urine flow and cures gonorrhoea. Fresh leaves are good for pregnant and lactating mothers, they improve milk production and are prescribed for anaemia. Paste made from bark treats boils. Paste from ground bark can be applied to relieve pain caused by snake, scorpion and insect bites. Oil is sometimes applied externally for skin diseases (Maroyi, 2006).

Some families use oil from *Moringa* seeds for cooking and lightening. Ben oil was erroneously reported to be resistant to rancidity and considered particularly suitable for enfluerage and as a lubricant for fine machinery. However, the oil turns rancid like any other vegetable oil. The oil is highly valued by watch makers as a lubricant. It is highly esteemed by perfumers, for its great power of absorbing and retaining even the most fugitive odors. The oil is useful in the manufacture of soap, producing a stable lather with high washing efficiency (Maroyi, 2006).

The wood from bark provides a pulp that is considered suitable for newsprint, wrapping, printing and writing papers (Council of Scientific and Industrial Research 1962). The bark and gum can be used in tanning hides. The wood yields a blue dye. Powdered seeds can be used to clarify honey without boiling. Seed powder can also be used to clarify sugarcane juice. Flowers are a good source of nectar for honey producing bees.

The presence of long taproot makes it resistant to periods of drought. *Moringa* can be a benefit in the fight against desertification. As it is fast growing, grows best in arid conditions, this makes it ideal for mass planting. It is also suited to areas where strong winds and long, dry spells occur simultaneously, causing serious soil erosion. The green leaves of *Moringa* make useful mulch. The press cake left after oil extraction from the seeds can be used as a soil conditioner or as a fertilizer (Maroyi, 2006).

2.5 Biodegradable lubricant

Biodegradability is not the only property or characteristic of a substance, but is also a system's concept, i.e. a system with its conditions determines whether a substance within it, is biodegraded. When material is released into the environment, its fate depends upon a whole range of physiochemical processes and its interaction with living organisms. The most stable compound of carbon is carbon dioxide. All the more reduced organic compounds are thermodynamically unstable and will be randomly attacked by microbial enzymes, provided that they have some structural similarity to naturally occurring substrates. The California Advertising Statute, was amended on April 30, 1991, states that a manufacturer cannot claim that a product is biodegradable unless it meets the following definition: 'Biodegradable means that a material has the proven capability to decompose in the most common environment where the material is disposed of within 3 years through natural biological processes into nontoxic carbonaceous soil, water, carbon dioxide or methane.'

2.6 Development of biodegradable lubricant

In Western Europe several biodegradable gasoline engine oils already have been introduced in the market. Most of these formulations consist of about 50:50 mixtures of esters with PAOs or hydro cracked oils and conventional additives. But further environmental optimization is possible if the ester contents are increased especially in terms of biodegradability and volatility. Test results and practical experience with an engine oil based on synthetic carboxylic acid esters (SAE 5W/30) demonstrated the advantages of such lubricants, e.g. low particulate emissions, reduced oil consumption, high engine cleanliness (low deposition) and biological degradability (Nagendramma and Kaul, 2012).

Concern for the environment has been shown by the continuous developments and researches on synthetic lubricants to multisite the way our daily activities impact on the environments. The lubricant industry's toughest challenges are performance, environmental compatibility and cost. It can only be done with the service, research and leading edge products most of which are based on natural renewable/synthetic raw materials. Vegetable oils as base fluids for "bio sphere safe" lubricants have proven to be a sound solution to the past of the problem that we face now and in future. They provide good performance, low impact on the environment and credibility in the public eye.(Nagendramma and Kaul, 2012).

Vegetable oils have many advantages over petroleum-based products (Ramadhas et al., 2004) and can be used in numerous products currently manufactured (Erhan et al., 1992). Successful development of vegetable-based materials can provide a wide range of potential benefits to consumers, farmers, and producers as well as reduce our dependence on foreign oil. Vegetable oils can be used as lubricants in their natural form as triglycerides. The plant oil comes from the seeds either through solvent extraction (Tysinger, 2009), screw pressins processes (Evangelista, 2009; Evangelista et al., 2012) or combinations of the two. The crude oil is either used as is or can be further refined (refined, bleached, and deodorized – RBD) to produce higher value oils and products (Steven et al., 2013)

Vegetable oils have both advantages and disadvantages over petroleum-based oils as lubricants. Vegetable oils such as corn and canola (Erhan et al., 2006) have excellent lubricity and far superior physical properties than those of mineral oils. Additionally, vegetable-based oils have a very high viscosity index (VI): greater than 200 for soybean oil vs. 100 for most petroleum-based oils (Kinawy, 2004). A lot of lubricants are used in applications where fire or explosions are a possibility and vegetable oils can perform well in these environments because they have high flash and fire points. The flash point of soybean oil is 610 ◦F (326 ◦C), compared to approximately 392 ◦F (200 ◦C) for most mineral oils. Finally, in terms of biodegradability, vegetable oils are generally less toxic compared to the petroleum alternative and are considered to be renewable. Most vegetable oils have shown to be >70% biodegradable compared to petroleum oils which biodegrade to 15–35% over the same time period (Aluyor et al., 2009). For an oil to be considered readily biodegradable, it must have greater than 60% degradation in 28 days (Steven et al., 2013)

There are a lot of different vegetable oils, but not all can be used as a performance lubricants. There are technical, logistic and cost barriers. It is very difficult to anticipate that up to what extent the mineral oils will be replaced by the vegetable oils (% world consumption) but approximately one can guess it up to 30% in several years. In Europe, rape seed oil has been found to be the best. It is locally produced agricultural crop which is currently in other production and possesses excellent tribological and environmental properties; compatibility with equipment seal elastomers is also excellent. In fact with the exception of thermo-oxidative stability, it is comparable in performance with best of synthetic base stocks. The role of vegetable oil other than rape seed in future as a replacement of mineral oil depends on where the material is grown. Palm oil, castor oil and other oils have also been investigated in different parts of the work emerging a future for these products (Nagendramma and Kaul, 2012).

In India, nearly a million tonnes of low priced fatty oils with superior lubrication and viscosity index (VI) characteristics are available from seeds of plants growing wild out in forest. These oils meet most of the characteristic of a high performance energy efficient lubricant except for pour points, high to very high VI, low viscosity, outstanding friction wear and lubricity characteristics and impart thermo oxidative stability. The objective should be to achieve those desirable characteristics without involving steep hike in the cost of producing such derivatives (Nagendramma and Kaul, 2012).

The aim of study eventually should be to transform low priced fatty oils into high performance, energy efficient, long life environment friendly lubricant components for automotive and gear oils at comparable cost. A number of alternative products can be obtained by simple chemical transformation of vegetable oils. The anti wear and friction reducing properties almost are twice as good as those of the mineral oils which signifies their energy efficient performance or in other words, one can say that demand for lower volatility, larger drain intervals and improved high and the temperature performance has led to a significant increase in the use of UHVI synthetic base oils, all of which require the use of less additive. Simply comparing the price of different synthetics with that of conventional lubricants can be misleading. The synthetics may require less frequent application, or it might have higher disposal costs. So the factors such as machine down time, unscheduled repairs and disposal costs should also have to be considered to get real group or the price/benefit relationship. For every type of synthetic lubricant, there is a balancing act between desirable and undesirable characteristics. So when considering a synthetic oil, it is suggested putting a value as each performance characteristic that is needed – including price – and then weighing all the advantages and disadvantages of the lubricant in the users' own specific application (Nagendramma and Kaul, 2012).

2.7 Biodegradable Moringa oleifera

In some studies they have evaluated the potential of *Moringa* oil as base oil for lubricant applications. The oxidative, thermal, low temperature and lubricity properties were compared with four other vegetable oils. The *Moringa* oil has kinematic viscosity in the range suitable for formulating lubricant of ISO viscosity grade 32. The viscosity index of *Moringa* oil is much higher compared to other vegetable oils studied, making it suitable for use as multi-grade lubricant. The *Moringa* oil showed excellent thermal and oxidative stability because of the presence of high amount of monounsaturated fatty-acids (MUFA) in it. The oxidative stability measured using PDSC and Rancimat showed good correlation between two methods. The low temperature properties were studied using pour, cloud point determinations as well as Cryo-DSC and a good correlation was found between two methods. The pour and cloud points for *Moringa* oil are higher and needs further treatment, such as use of pour point depressant, or other diluents to lower the pour point. The lubricity or *Moringa* oil is similar to other vegetable oils. Thus, *Moringa* oil has good potential for use as lubricant base oil and an acceptable alternative to food oils and high priced petroleum base oils (Brajendra et al.,2009).

2.8 Future prospects and current challenges

Current quality trends in lubricants indicate significant shift in viscosity grades and product specifications. In fact the unconventional base oils exceed performance of conventional lubricants in terms of volatility requirement, oxidation stability, low carbon forming tendency, viscosity, stability, and response to additives. The above changes along with environmental conditions have led to significant developments in lubricating oils based oil manufacturing technology. Introduction of smaller, faster, more efficient equipments operating at higher speeds, temperatures, stresses and pressures favours higher quality lubricants. Freedom from deposits, radiation resistance, greater efficiency, reduced maintenance and larger fluid life are the other possible benefits from using alternative lubricant base stocks. The need for automatic transmission fluids and engine oils, approaching the synthetic in performance, their systematic supply and cost has necessitated the improvement in refiner's ability to economically boost performance. Despite evidences that costs can be cut by switching to synthetic lubricants, the strong counter attack by petroleum lubricant manufacturers/sellers such as Chevron, Conoco, Exxon, Pennzoil and Shell resists the synlube market by providing high quality petroleum base oils (Nagendramma and Kaul, 2012).

The effectiveness of future higher performance lubricants will, inevitably, depend upon the end user's ability to select the appropriate performance lubricant for his engine and then use and dispose of the product in the correct manner so that the maximum benefit for the engine and the environment can be derived. Lubricating oil has a significant role to play in the reduction of energy losses caused by friction. The environmental aspects are to be discussed of using biodegradable lubricants in friction pairs of ceramic composite to reduce wear rate (Nagendramma and Kaul, 2012).

Vegetable oils also have some drawbacks as lubricants. Some concerns have been shown regarding the oxidative stability of vegetable-based functional fluids (Glancey et al., 1998). A functional fluid is any material that may be used in any working device: hydraulic, crankcase, or lubricating fluid, to name a few. A number of methods are used to improve the oxidative stability of an oil including synthesis of saturated derivatives or formulations with oxidative stability improvers. Akoh (1994) reported that refined soybean oil had an oxidative stability index (OSI) (Firestone, 1999 of 9.4 h at 110 ◦C, but once the oil was partially hydrogenated, the OSI increased to 15.3 h at 110 ◦C, an improvement of more than 60%. The challenge with hydrogenation is to determine the optimum degree of saturation; full hydrogenation of oil can lead to solid margarine-like products which are undesirable for lubricant applications. Additionally, the low temperature properties (pour and cloud points) of the vegetable oils tend to be inferior to petroleum oils. Again, this problem can be addressed by winterization, addition of pour point suppressants and/or blending with other fluids possessing better pour point properties (Steven C.,2013)

3 MATERIALS AND METHODS

3.1 Overview

This chapter is divided into three parts which presents the detailed on the materials that have been used for this research, the equipments used to conduct the experiments, and the methods on getting the result for each parameter tested.

3.2 Introduction

The study on producing lubricant from *Moringa oleifera* seeds oil begins with the searching of sufficient *Moringa oleifera* seeds. Then, the sample was prepared by conducting the extraction process of *Moringa oleifera* seeds oil. The part of getting the results for each physical property done based on some ASTM Standard experiments procedures that related to lubricant standard properties.

3.3 Materials

3.3.1 Raw materials

Materials that have been used in this experiment were obviously *Moringa oleifera* seeds.

3.3.2 Chemicals

N-hexane with standard lab grade was used for extraction process of *Moringa oleifera* seeds while acetone and ethanol were used for apparatus cleaning purpose which available at faculty laboratory.

3.4 Equipments

To extract the oil from *Moringa oleifera* seeds by using n-hexane, few types of equipments are required in this experiment:

a. Soxhlet extractor (App. A.2.4)
b. Three-necked round-bottom flask
c. Rotary evaporator : to recover excess n-hexane

3.5 Method of research

3.5.1 Collecting raw material

For this study, the *Moringa oleifera* seeds that have been used for entire experiment was collected from Tumpat, Kelantan, some were from Kuantan, Pahang and the rest from Penang.

3.5.2 Preparation of samples

a. All seeds sample that have been dried at 70°C were grinded using blender with stainless steel container. Then, the vibrator sieve shaker was used to sift the seeds powder (App. A.2.1), (App. A.2.2), and (A.2.3) respectively.
b. About 10g of seed powder were placed in a soxhlet extractor fitted with a 2-L round bottomed flask and a reflux condenser. After that, extraction was performed in a heating chamber for 30 minutes with 200 mL of n-hexane.
c. After doing the extraction of *Moringa oleifera* seeds with n-hexane, the next step was to remove the n-hexane from the mixture to get the *Moringa oleifera* oil by an evaporation process.
d. By using rotary evaporator, the temperature was set to n-hexane boiling point to evaporate it. The process took about one and half hour to settle until there was no more n-hexane evaporated and the produced oil is shown in (App. A.2.5) and (App. A.2.6) for *Moringa oleifera* oil with n-hexane and pure oil respectively.

3.5.3 Product analysis

Product analysis part was the last part of the experiment process. The tests were done with some repetitions for each physical property in order to get better readings or values before moving to results analyzing.

Some important physical properties of lubricant need to be tested to compare with the standard properties of lubricant that available in the market. Therefore, after getting the pure *Moringa oleifera* oil, the following tests were conducted to analyse the properties of standard lubricant which is then explained in details in Chapter 4.

Below were the important physical properties that have been tested during this research:

1) Kinematic viscosity (mm^2/s)
2) Density (g/cm^3)
3) Cloud point (°C)
4) Pour point (°C)

4 RESULTS AND DISCUSSIONS

4.1 Overview

This chapter presents all the results obtained from the tests of *Moringa oleifera* oil properties. The results then were compared to the standard lubricant that available in the market.

4.2 Introduction

As what have been planned for this study, each test of physical properties for *Moringa oleifera* oil will be compared to properties of selected sewing machine oil. The sewing machine oil was categorized in the group of light machine lubricant according to its range of kinematic viscosity and applications. Therefore, the main aim is to investigate whether the *Moringa oleifera* oil properties are matching with the properties of standard lubricant

4.3 Physical characteristics testing and analysis

From the experiments, Table 4-1 shows the physical properties of *Moringa oleifera* oil. The ASTM Standard was used as a guide for comparison with the standard lubricant basically for light machine.

Table 4-1: Physical properties comparison

Analysis		Experiment	ASTM Standard	*Test Method*
Kinematic viscosity	*@40°C*	43.813	15.0	ASTM D-445
(mm^2/s)	*@100°C*	8.974	3.55	ASTM D-445
Viscosity index (VI)		192	118	ASTM D-2270
ISO Grade		46/68	15	DIN 51 511
Density *(g/cm^{3})*		0.915	0.860	ASTM D-1298
Cloud point *(°C)*		12	-	ASTM D-97
Pour point *(°C)*		8	-12	ASTM D-97

For the comparison with available standard lubricant, the physical properties values were compared to sewing machine oil since it was categorized as lubricant for light machine. This is probably because *Moringa oleifera* oil is a vegetable oil and it has a little bit different compared to petroleum based lubricant.

4.3.1 Kinematic viscosity (mm^2/s)

Kinematic viscosity indicates the resistance of a liquid to flow under force. There are several units for measuring viscosity. Formerly, the unit commonly used in America was Saybolt Universal Second (SSU) and in Europe was Redwood I second (RWI). Both were measured at 100°F or 210°F. At present, most countries have switched over to the metric system that employs the unit Centistokes (cSt), measured at 40°C or 100°C. Traditionally kinematic viscosity is measured by noting the time it takes oil to travel through the orifice of a capillary under the force of gravity. (Troyer, 2002)

Oil with higher viscosity can stand greater pressure without being squeezed out of the lubricating surfaces. However, the high internal friction of the oil may offer greater resistance to the movement of the lubricating parts. An oil of lower viscosity offers less resistance to the moving parts but the oil can be easily squeezed out of the lubricating surfaces. It is therefore important to select a lubricating oil of appropriate viscosity to achieve optimum lubrication effect. Viscosity changes with temperature. Hence, the measuring temperature must be specified whenever the viscosity of a liquid is stated. When temperature rises, a liquid becomes less viscous. Similarly, a liquid becomes thicker when temperature drops.

In order to determine the kinematic viscosity of the *Moringa oleifera* oil, the kinematic viscosity tester was used (App. A.3.2) besides various glass capillary tubes needed to be prepared. In this research, viscometer number 350 was selected (App. A.3.1). A sample of 20 mL oil was poured into the capillary tube and it was pumped until it reached the top mark as shown in Figure 4-1. The time taken for the oil to flow through the capillary tube can be converted directly to a kinematic viscosity using a simple calibration constant provided for each tube as shown in Figure 4-2. The experiment was repeated four times to get accurate calibration as shown in Appendix A.1.1 and A.1.2.

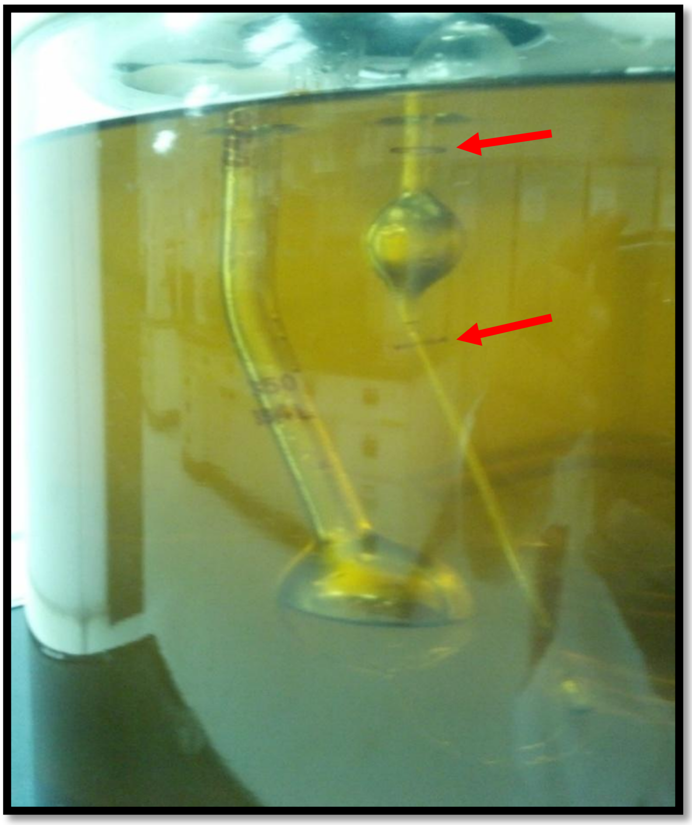

Figure 4-1: Viscosity test

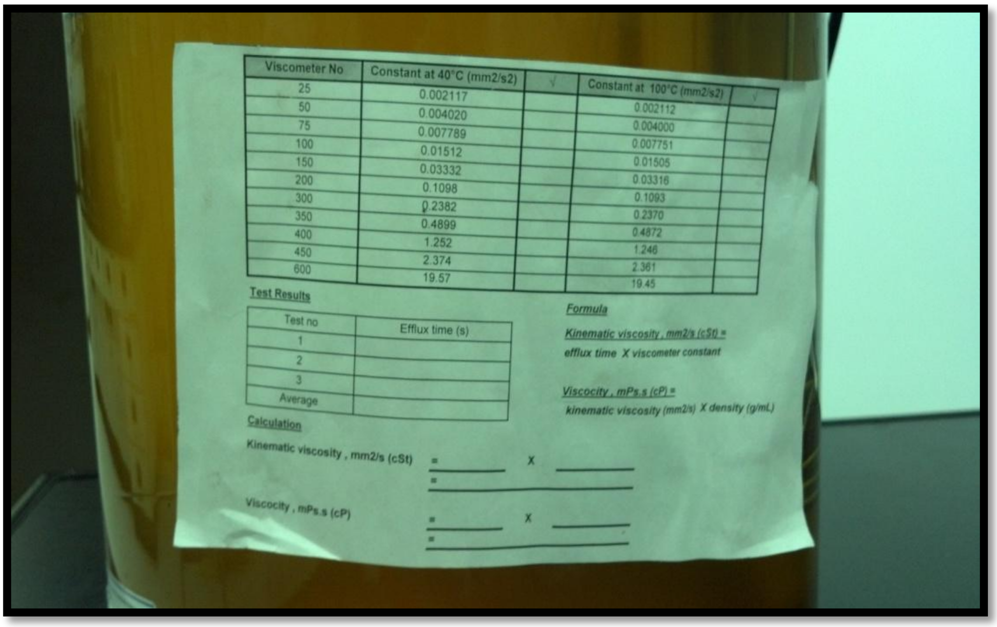

Figure 4-2: Viscosity constant

The viscosity of *Moringa oleifera* oil was recorded as 43.813 mm^2/s and 8.974 mm^2/s at 40°C and 100°C respectively (App. A.1.3). These values then were matched to the viscosity class to know what was the grade of lubricant for *Moringa oleifera* oil as shown in Appendix A.1.4.

4.3.2 Viscosity index

The viscosity index is a widely used and accepted measurement of the variation in kinematic viscosity due to changes in the temperature of a petroleum product between 40°C and 100°C. A high viscosity index means the liquid does not thin out so much when temperature rises. It is also indicates a smaller decrease in kinematic viscosity with increasing temperature of the lubricant. The viscosity index is used in practice as a single number indicating temperature dependence of kinematic viscosity. For *Moringa oleifera* oil, the viscosity index is 192. It was calculated as shown in A.1.5.

4.3.3 Density (g/cm^3)

Density is a physical property constant at a given temperature and density can help to identify a substance. It also plays a critical role in how a lubricant functions as well as how machines perform. The density of most oils will range between 0.7 and 0.95 grams per cubic centimetre (g/cm^3) while *Moringa oleifera* density was recorded as 0.915 g/cm^3. The higher the density, the tighter the particles are packed inside the substance. (Trayor, 2002)

In order to determine the density of the *Moringa oleifera* oil produced, the equipment used was Kyoto Electronics D-130N Density Tester as shown in Figure 4-3. The sample of oil that was used for the test was 10mL.

Steps to determine the density of the *Moringa oleifera* oil were as follow :

1. The inner tube of the density tester was cleaned by suction of acetone into the tube. This step had to be repeated few times to remove excess impurities and other mixing solutions.
2. Next, the *Moringa oleifera* oil was pumped into the density tester until it fully occupied the inner tube. This step needs to be repeated few times to ensure the device can make an accurate reading when record the value.
3. Now, the above step was repeated for 3 times to record the accurate values of the density (App. A.1.6).

Figure 4-3: Density tester

4.3.4 Cloud point (°C)

The cloud point is the temperature of the fuel at which, small solid crystals can be observed as the fuel cooled.

The sample of 20 mL of *Moringa oil* was poured into the test tube and located inside cloud and pour point apparatus (App. A.3.4) until it reached the level indicated on the test tube. Then, the sample was placed inside water bath. The sample had to be observed regularly for every 1 minute until solid-crystal appeared. The temperature at which first observation of solid-crystals appeared was the cloud point at 12°C as shown in Figure 4-4.

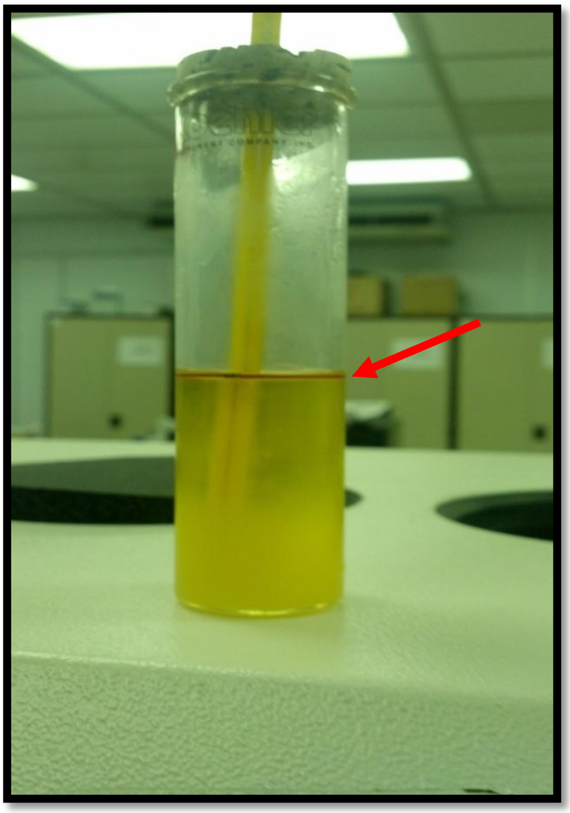

Figure 4-4: Cloud point of *Moringa oleifera* oil

4.3.5 Pour point (°C)

The pour point of an oil indicates the lowest temperature at which an oil cannot be poured as liquid.

With the same sample of *Moringa oleifera* oil from the cloud point test, the cooling process was continued until the oil was no longer moving when pouring horizontally. The temperature at which the pour point occurred was at 8°C as shown in Figure 4-5.

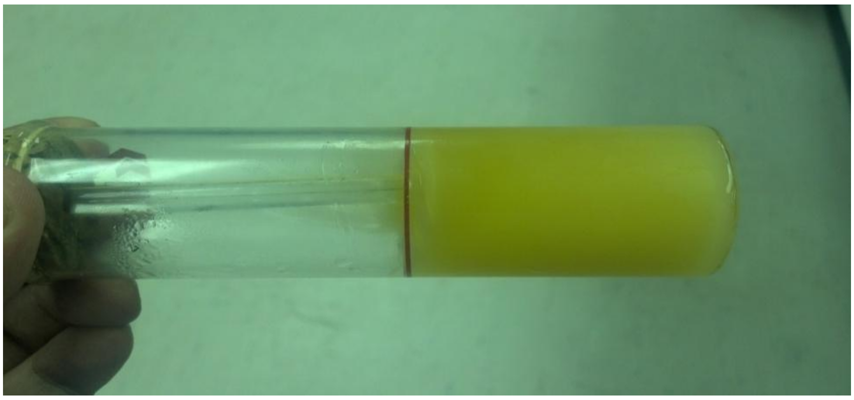

Figure 4-5: Pour point of *Moringa oleifera* oil

5 CONCLUSION

5.1 Overview

This chapter will conclude the whole research regarding the results from the tests conducted besides recommends any new findings of the research. There will be also some recommendations on improving the research based on experiments procedures or other valuable information added.

5.2 Conclusion

This research is about the production of *Moringa oleifera* oil as a lubricant and determining its characteristics. It was conducted by using *Moringa oleifera* oil as raw material and n-hexane was used for the extraction to get *Moringa oleifera* oil. The properties of *Moringa oleifera* oil was compared to the standard lubricant basically for light machine used based on ASTM standard.

Table 5-1: Physical properties of *Moringa oleifera* oil

Analysis		Experiment	ASTM Standard	ASTM Standard
Kinematic viscosity	*@40°C*	43.813	15.0	44.15
(mm^2/s)	*@100°C*	8.974	3.55	6.98
Viscosity index (VI)		192	118	116
ISO Grade		*46/68*	*15*	*46*
Density (g/cm^{3})		0.915	0.860	0.880
Cloud point (°C)		12	-	-
Pour point (°C)		8	-12	-33

From Table 5-1, it can be concluded that the properties of lubricant produced from *Moringa oleifera* is a little bit different when compared to the properties of sewing machine oil (ISO Grade 15) based on ASTM Standard as standard lubricant for light machine. This shows that the range of kinematic viscosity for *Moringa oleifera* is wider and suitable for other applications. Even though its density is slightly higher than available standard lubricant but it still in the range of density for other available vegetable lubricant.

5.3 Recommendations

From the research work, it was found that the kinematic viscosity of *Moringa oleifera* oil were 43.813 mm^2/s and 8.974 mm^2/s respectively. With these values, it was categorized as ISO Grade 46 and 68 which is commonly used as gear lubricant. Therefore, *Moringa oleifera* oil is recommended for the use of gearbox, vane and also for piston hydraulic without any additives and not to light machine.

It is also recommended for future works to include any test related to environmental pollution such as chemical compounds contained in the *Moringa oleifera* oil. For example, the percentage of carbon chain in the *Moringa oleifera* oil which contributes to combustion.

Besides, more tests on lubricant properties determination can be conducted like Four Ball Wear Test, Total Acid Number (TAN), Total Base Number (TBN) and so on. With more tests done, it will give more detail on characteristic and performance of *Moringa oleifera* oil as a lubricant.

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APPENDICES

APPENDIX A.1

PHYSICAL PROPERTIES ANALYSIS

Appendix A.1.1: Efflux time of *Moringa oleifera* oil at 40°C

Readings	Efflux time (s)
1	91.25
2	89.72
3	89.06
4	88.82
5	88.31
AVERAGE	**89.432**

Appendix A.1.2: Efflux time of *Moringa oleifera* oil at 100°C

Readings	Efflux time (s)
1	18.47
2	18.34
3	18.44
4	18.48
5	18.37
AVERAGE	**18.42**

Calculation for kinematic viscosity :

At 40°C :

Viscometer no. : 350

Viscosity constant : 0.4899

= Efflux time (s) x viscosity constant (mm^2/s^2)

= 89.432 x 0.4899

= 43.813 mm^2/s

At 100°C

Viscometer no. : 350

Viscosity constant : 0.4872

= Efflux time (s) x viscosity constant (mm^2/s^2)

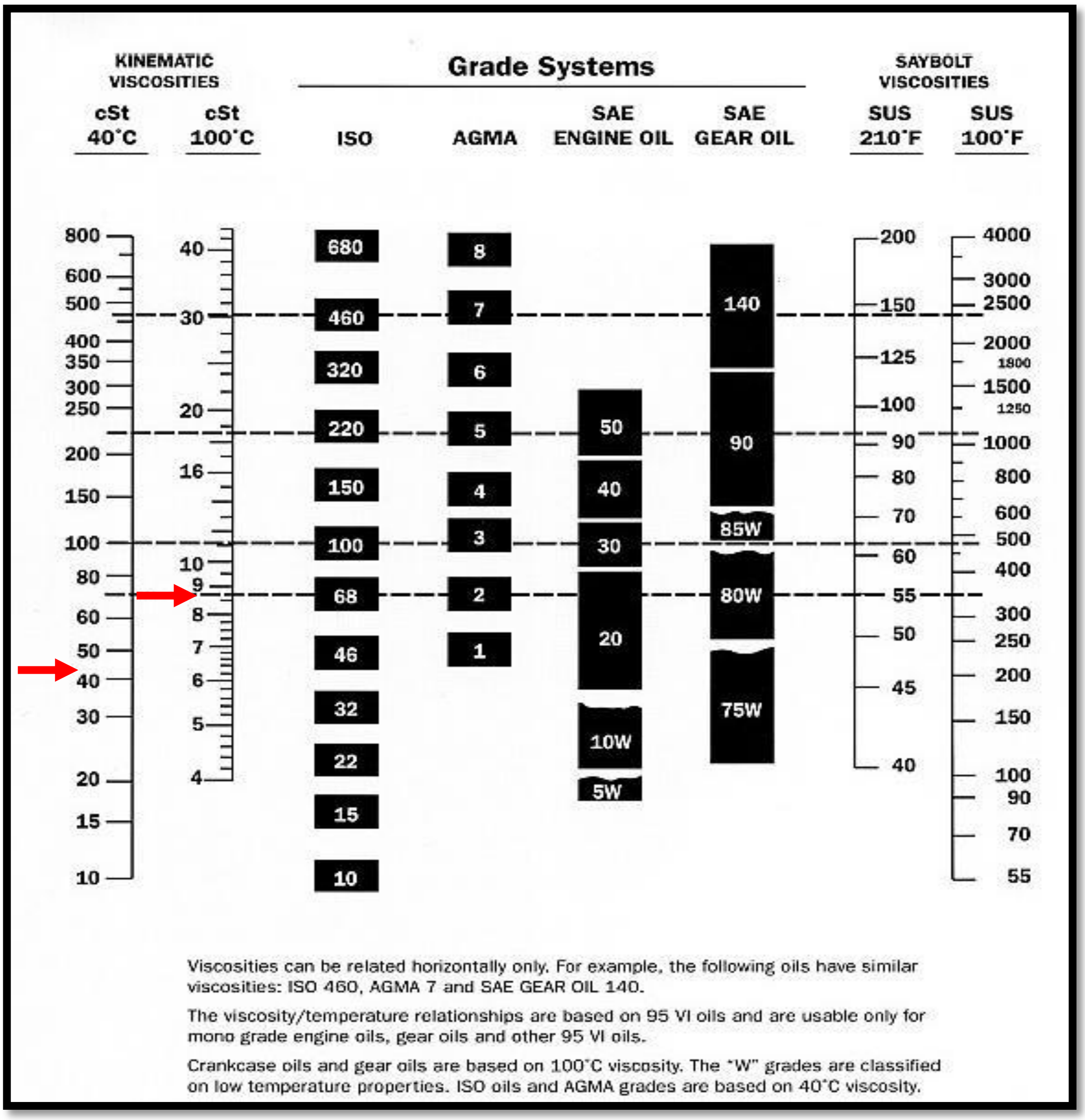
= 18.42 x 0.4872

= 8.974 mm^2/s

Appendix A.1.3: Kinematic viscosity of *Moringa oleifera* oil

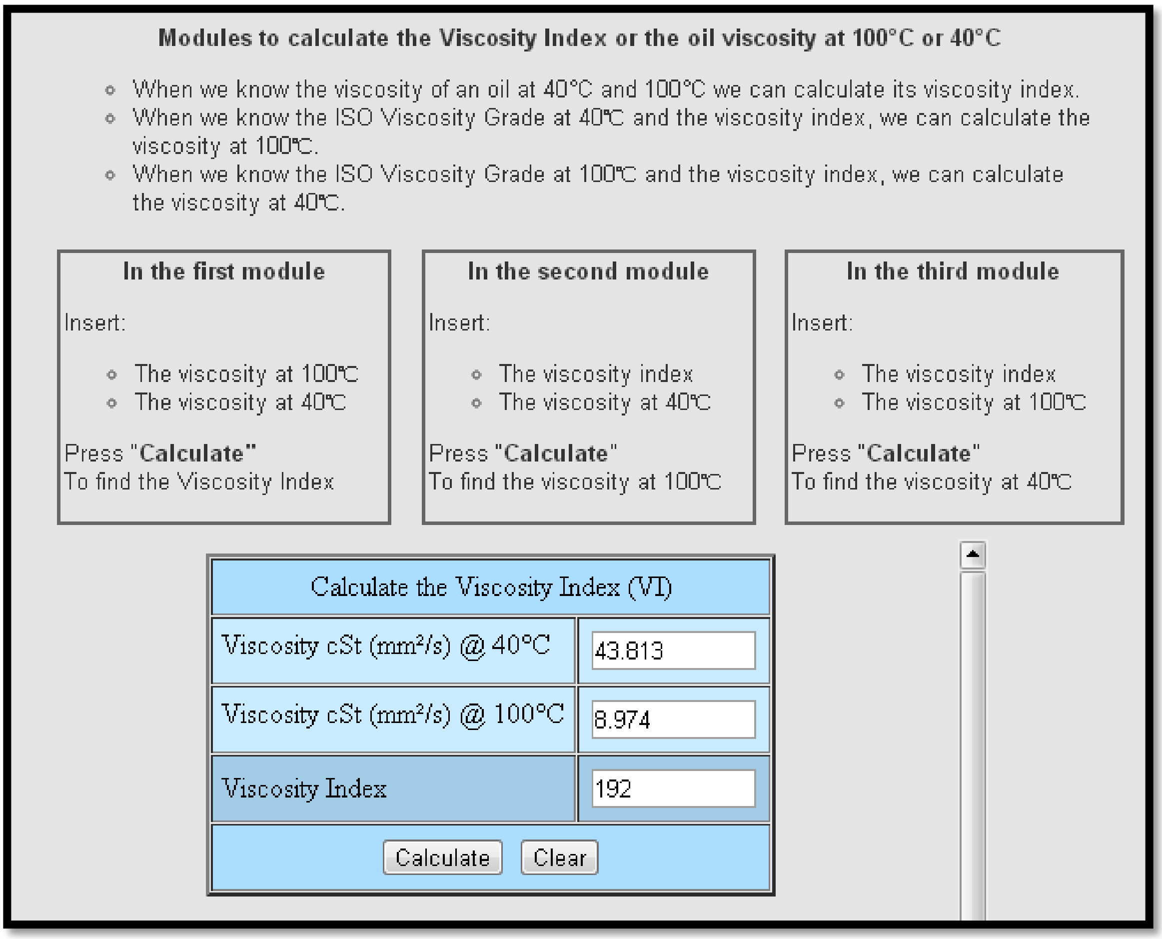
Readings	**(Unit) mm^2/s @ cSt**
@ 40°C	43.813
@ 100°C	8.974

Appendix A.1.4: Viscosity classification



(http://www.bobistheoilguy.com/viscosity-charts/)

Appendix A.1.5: Viscosity index calculation



(http://www.widman.biz/English/Calculators/VI.html)

Appendix A.1.6: Density of *Moringa oleifera* oil

Readings	**(Unit) g/cm^3**
1	0.916
2	0.915
3	0.915
AVERAGE	**0.915**

APPENDIX A.2

PRODUCTION PROCESS

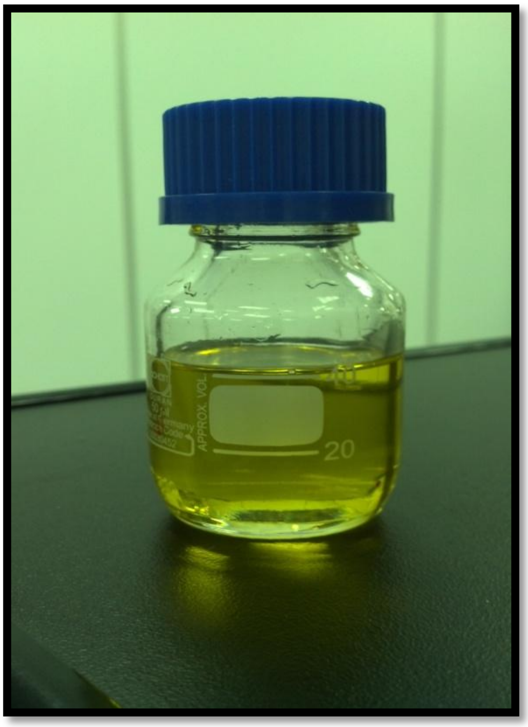
Appendix A.2.1: Dried *Moringa oleifera* at 70°C

Appendix A.2.2: Blended *Moringa oleifera seeds*

Appendix A.2.3: Blended and sieved *Moringa oleifera* seeds

Appendix A.2.4: Extraction of *Moringa oleifera using n-hexane*

Appendix A.2.5: Mixture of *Moringa oleifera* oil and n-hexane

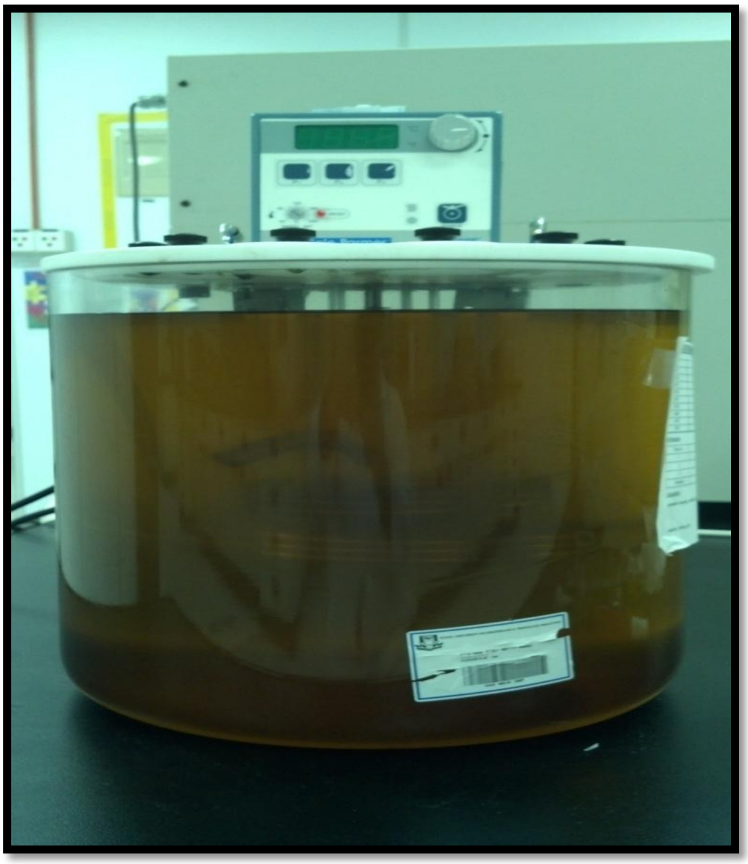


Appendix A.2.6: Pure *Moringa oleifera* oil

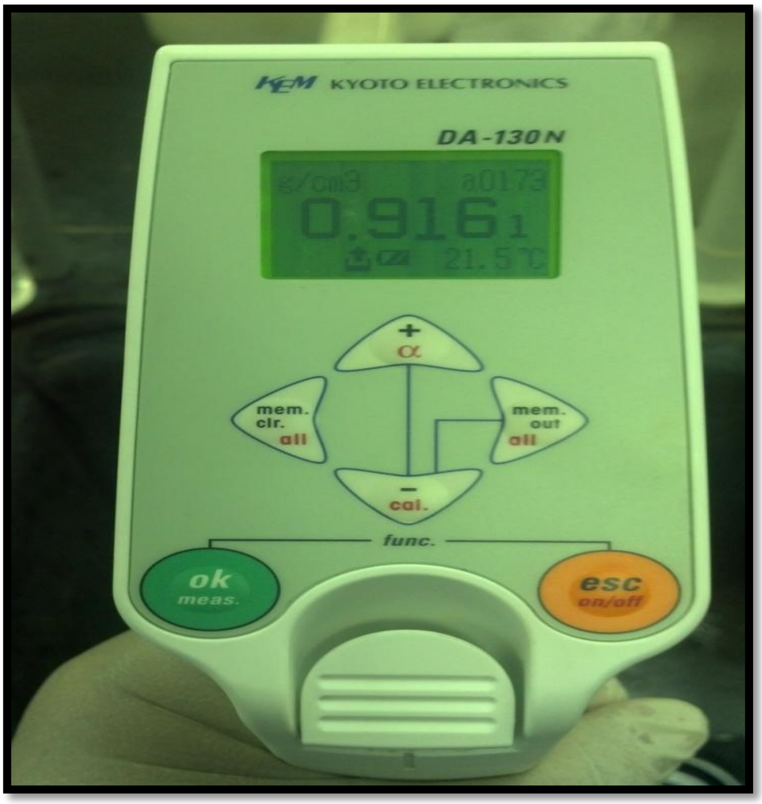
APPENDIX A.3

ANALYSIS EQUIPMENTS

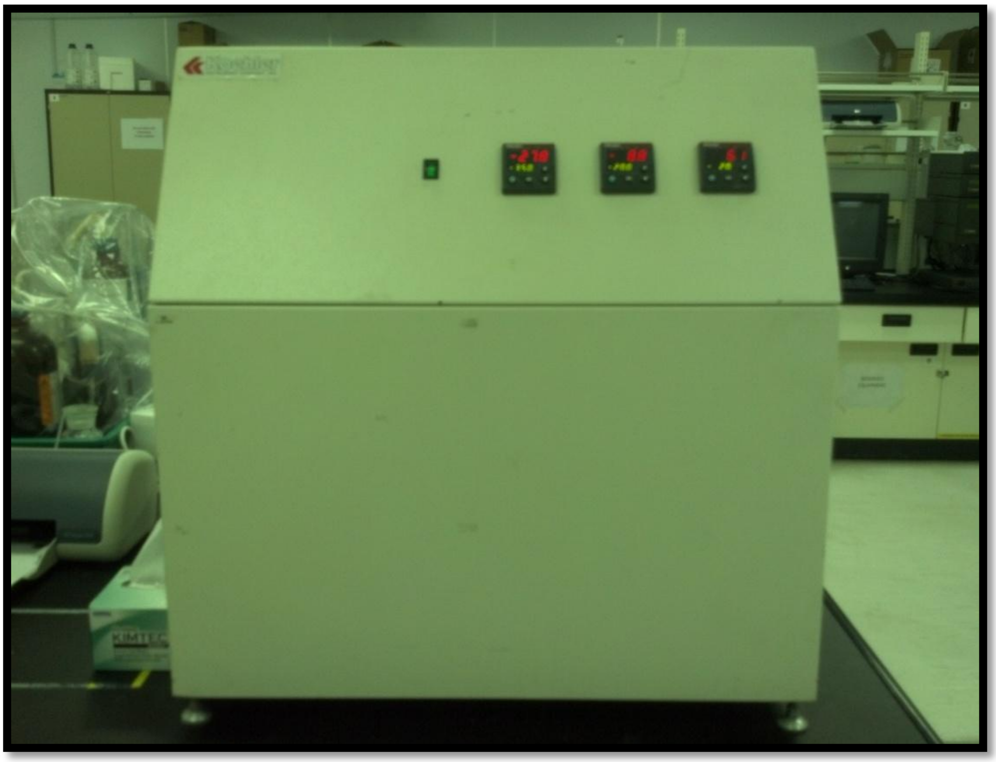
Appendix A.3.1: Kinematic viscosity capillary tube



Appendix A.3.2: Kinematic viscosity tester



Appendix A.3.3: Density tester



Appendix A.3.4: Cloud and pour point apparatus

APPENDIX A.4

TECHNICAL REPORT

AN INVESTIGATION OF USING *MORINGA OLEIFERA* SEEDS OIL AS LUBRICANT

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ABSTRACT

Many liquids, including water have been used as lubricants since Roman era to minimize the friction, heat, and wear between mechanical parts in contact with each other. Today, lubricating oil, or lube oil, is the most commonly used lubricant because of its wide range of possible applications. Recently, pollution and environmental health aspects have become increasingly important as public issues. The increased environmental awareness is a primary driving force for the new technology developments. Thus, this research aims to produce a standard lubricant from *Moringa oleifera* seeds oil which is more environmentally friendly and has higher level of performance based on ASTM standard. All the *Moringa oleifera* seeds which collected from Kelantan have been dried at 70°C before the samples were grinded and sieved. The *Moringa oleifera* seeds oil then was extracted by using n-hexane in soxhlet extractor. The rotary evaporator was used to remove the n-hexane and get the pure *Moringa oleifera* oil. Then, some tests were conducted to measure the parameters and the correlation of the properties to the ASTM standards as light machine lubricant. From the experiments, the kinematic viscosity was 43.813 mm^2/s at 40°C and 8.974 mm^2/s at 100°C, the density was 0.915 g/cm^3, cloud point was 12°C, pour point was 8°C, and the viscosity index of 192. Since the properties of the oil are matching with ISO Grade 46, it is recommended to use this oil as gear lubricant.

Key words: *Moringa oleifera;* environmentally friendly; biolubricant; biodegradable

INTRODUCTION

Lubricants (or lubricating oils) are commonly used as the friction reducer and coolant in automotive machinery which serve as the major contributor to the environmental problems especially in soil and water. In recent year’s pollution and environmental health aspects have become increasingly important as public issues. In the area of lubrication, the concern is to focus on the issues related to large proportion of lubricants waste in environment. The break down products is potential threats to the environment. The increased environmental awareness is a primary driving force for the new technology developments. Therefore, biodegradable lubricants used in environmentally sensitive areas have been extensively explored. One of the biggest challenges in the development of universal biodegradable base stock that could replace mineral oil base stocks is the new generation lubricants. From the better performance point of view, these should be friendly to the environment and be eventually biodegradable (Nagendramma and Kaul, 2012).

Vegetable oil-based products are environmentally friendly and non-toxic and thus offer easier disposal as compared to petroleum products. There are also biodegradable synthetic oils offering improved stability and performance characteristics over refined petroleum oils. The *Moringa* oil has kinematic viscosity in the range suitable for formulating lubricant of ISO viscosity grade 32. The viscosity index of *Moringa* oil is much higher compared to other vegetable oils studied, making it suitable for use as multi-grade lubricant. Thus, *Moringa* oil has good potential for use as lubricant base oil and an acceptable alternative to food oils and high priced petroleum base oils (Brajendra et al.,2009)**.** The main objective of this study was to measure the properties of oil that extracted from *Moringa oleifera* seeds which then compared to ASTM Standard to produce lubricant for light machine.

MATERIALS AND METHODS

Materials

The only material that has been used for this research was *Moringa oleifera* seeds which collected from village area in Kelantan. The chemicals used along this research were n-hexane with standard lab grade for extraction process of *Moringa oleifera* seeds while acetone and ethanol were used for apparatus cleaning purposes.

Sample preparation

All seeds sample that have been dried at 70°C were grinded using blender with stainless steel container. Then, the vibrator sieve shaker was used to sift the seeds powder. About 10g of seed powder were placed in a soxhlet extractor fitted with a 2-L round bottomed flask and a reflux condenser. After that, extraction in a heating chamber for 30 minutes with 200mL of n-hexane. After doing the extraction of *Moringa oleifera* seeds with n-hexane, the next step was to remove the n-hexane and water from the mixture to get the *Moringa oleifera* oil by an evaporation process. By using the rotary evaporator, the temperature was set to 70°C. The process took about one and half hour to settle until there was no more n-hexane evaporated. The pure *Moringa oleifera* oil was collected after filtration to remove the small particles in the oil.

Properties analysis

The pure *Moringa oleifera* oil then was used for some tests to analyze the properties of standard lubricant including its kinematic viscosity, density, cloud and pour point. In this research, the properties were compared to sewing machine oil based on ASTM Standards as it was categorized as lubricant for light machine.

RESULTS AND DISCUSSION

Based on the experiments conducted, the kinematic viscosity of *Moringa oleifera oil* was 43.813 mm^2/s at 40°C and 8.974 mm^2/s at 100°C, density of 0.915 g/cm^3, cloud and pour points were 12°C and 8°C, respectively.

This shows a little bit difference compared to the ASTM Standard as the properties were based on available sewing machine in the market. However, with the range of kinematic viscosity possess of *Moringa oleifera oil*, it can be categorized between ISO Grade of 46 and 68 which are basically for gear lubricant.

Table 4-1: Physical properties comparison

Analysis	Experiment	ASTM Standard *(sewing machine oil)*	ASTM Standard *(gear lubricant)*	*Test Method*
Kinematic viscosity @40°C	43.813	15.0	44.15	ASTM D-445
(mm^2/s) @100°C	8.974	3.55	6.98	ASTM D-445
Viscosity index (VI)	192	118	116	ASTM D-2270
ISO Grade	46/68	15	46	DIN 51 511
Density ($g/cm^{3)}$	0.915	0.860	0.880	ASTM D-1298
Cloud point (°C)	12	-	-	ASTM D-97
Pour point (°C)	8	-12	-33	ASTM D-97

CONCLUSION

From the research work, it was found that the kinematic viscosity of *Moringa oleifera* oil were 43.813 mm^2/s and 8.974 mm^2/s, respectively. With these values, it was categorized as ISO Grade 46 and 68 which is commonly used as gear lubricant. Therefore, *Moringa oleifera* oil is recommended for these types of machine without any additives which is more economical and not recommended for light machines lubricant. In the same time, it is recommended to be used in hot countries like Malaysia as it has high pour point, 8°C compared to ASTM Standard (-33°C) and some additives need to be used to lower the pour point.

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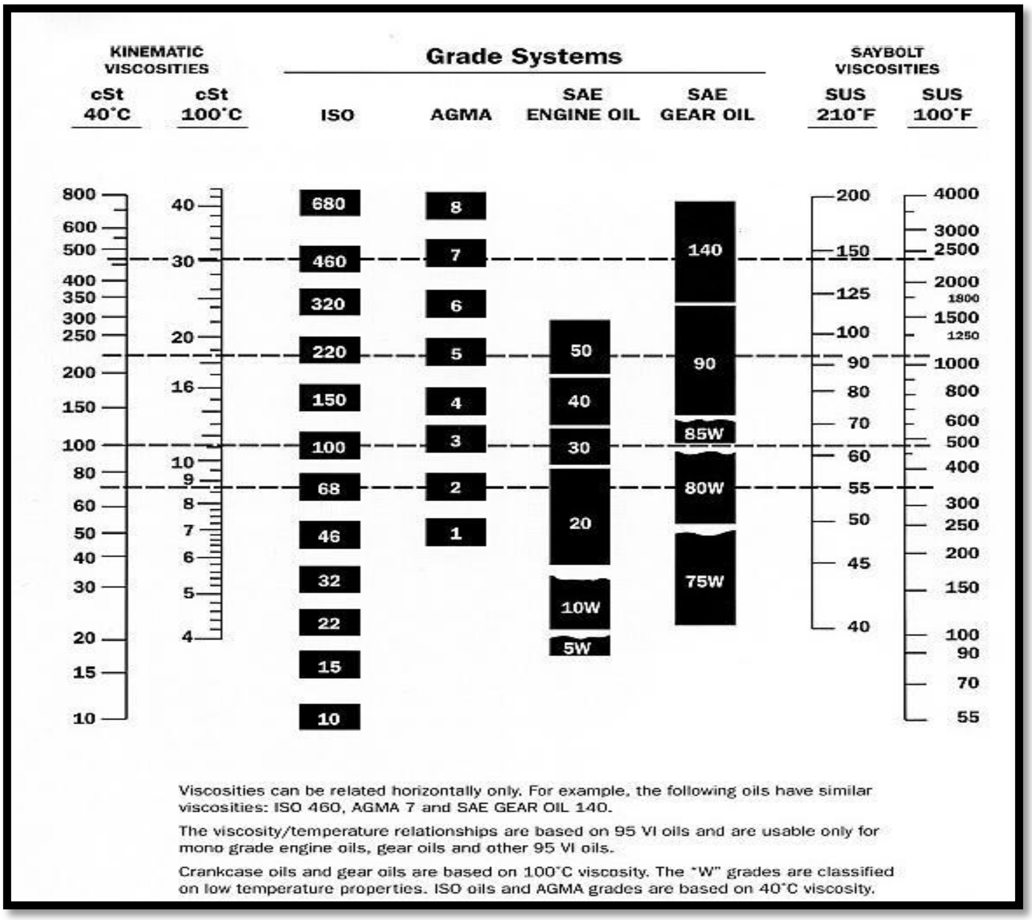
Appendix A.1.4 Viscosity classification



(http://www.bobistheoilguy.com/viscosity-charts/**)**