

Eco-friendly Multifunction Petroleum Additives: Preparation, Characterization and Evaluation

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ABSTRACT

ZDDP (zinc dialkyldithiophosphate) is one of the most commonly used petroleum additives as anti-wear, anti-rust and anti-oxidant but it has some environmental problems, so there is a must to find alternative eco-friendly compounds which can replace some of these conventional used petroleum additives. In this study, new compatible mixtures from different natural sources using phospholipids were prepared and their solubility in mineral base oils was evaluated to achieve complete solubility. Some of the prepared mixtures were characterized by FT-IR and then evaluated as anti-rust and anti-oxidant additives for lubricating oils according to standard test methods such as rust preventing characteristics and RPVOT (Rotary Pressure Vessel Oxidation test) for oxidation stability evaluation. The results of evaluation showed an excellent opportunity of widely usage of the vegetable oils derivatives specially Soy Lecithin (SL) in petroleum industry as multifunctional petroleum additives.

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1. INTRODUCTION

The Modern equipment must be lubricated in order to prolong its lifetime. A lubricant performs a number of critical functions. The main importance of lubricating oils is lubrication and cooling of metal parts in addition to cleaning and protecting metal surfaces against corrosive damage. Lubricant comprises a base fluid and an additives package. The primary function of the base fluid is to lubricate and act as a carrier of additives. The function of additives is either to enhance an already existing property of the base fluid or to add a new property. The already existing properties include viscosity, viscosity

index, pour point, and oxidation stability. The examples of new properties include cleaning and suspending ability, anti-wear performance, and corrosion control. Additives for lubricating oils were used first during the 1920s, and their use has since increased tremendously. Today, practically all types of lubricating oil contain at least one additive and some oils contain several different types of additives [1-3]. During the 1930s and 1940s with the discovery of zinc dialkyldithiophosphates (ZDDP), the most important advance in anti-wear chemistry was made [4]. ZDDP was initially used to prevent bearing corrosion but it was later found to have exceptional antioxidant and anti-wear properties.

The antioxidant mechanism of the ZDDP was the key to its ability to reduce bearing corrosion. Since the ZDDP suppresses peroxides formation, it prevents the corrosion of copper/ lead bearings by organic acids. Nowadays, efforts are made to replace the ZDDP with other materials with the same properties which wouldn't be harmful to the environment. Currently, around fifty percent of the lubricants sold worldwide end up in the environment via total loss, volatility, spills or major accidents [5,6]. In view of its high ecological toxicity and low biodegradability it poses a considerable threat to the environment. In the last decade a lot of interest was developed to use environment friendly readily biodegradable lubricant fluids [6]. Depletion of world petroleum reserves and uncertainty in petroleum supply also stimulated the search for environmental friendly alternative to mineral oils [7-10].

Plant oils and its derivatives have become more popular as lubricants over the last couple of decades. Today, around 2 % of the base stocks are of plant oil origin [10]. The triacylglycerol structure of plant oil derivatives makes it an excellent bio-lubricant [11-13]. They offer a number of advantages, including high biodegradability (>95 %), reduced environmental pollution [14-18] compatibility with additives, low production costs [19], large possibilities of production, low toxicity, high flash point, low volatility, high viscosity indices and, above all, better tribological performance. They have displayed superior performance than mineral oils in terms of anti-wear and fatigue resistance [20-22]. Also, they are superior in dissolving contaminants and additives than mineral oils [10]. Plant oils are derived from a renewable source, but it has some disadvantages such as poor thermo-oxidative stability [23] which oxidizes at a faster rate than mineral oils [24] and that is due to presence of fatty acids [25-30].

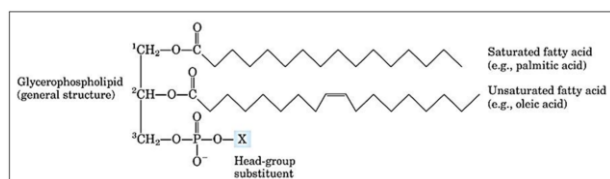


Fig. 1. A general structure of phospholipid molecule shows two hydrophobic fatty acid “tails” and a hydrophilic “head” consisting of a phosphate group. The two components are joined together by glycerol molecule.

One of these plant oils derivatives is soybean phospholipids. Soybean phospholipids are co-products of soybean oil processing. Phospholipids mainly include glycerol phosphatides, which consist of a glycerol molecule, two fatty acids, and a phosphate group as shown in Fig. 1.

Naturally occurring phosphatides are considered to be anti-wear and they are designed to be biodegradable for environmentally sensitive applications. They are readily biodegradable by aquatic organisms and overcome common environmental hazards associated with lubricants [31].

The aim of the present study is to evaluate the anti-rust and anti-oxidant characteristics of Soybean Lecithin (SL), when it is added to lubricating oils, in addition to its benefits such as chemical structure, bioavailability and biodegradability. Additionally we aim to improve oxidation stability of SL to be suitable to use it as an eco-friendly multifunctional additive in lubricating oils.

2. EXPERIMENTAL

2.1 Materials

Soy Lecithin liquid light color (non-GMO) (phosphatidylcholine) was obtained from DKSH, India. Quercetin and oleyl alcohol were obtained from Sigma-Aldrich. Base oils were obtained from Amreya Petroleum Refining Company, Egypt and from Alexandria Petroleum Refining Company, Egypt. All other chemicals and reagents were obtained from Fischer chemical and from Sigma-Aldrich.

2.2 Rust-Preventing Characteristics Test

This test evaluates the ability of inhibited mineral oils to aid in preventing the rusting of ferrous parts if water becomes mixed with the oil. A mixture of 300 mL of the oil under test is stirred with 30 mL of distilled water or synthetic sea water at a temperature of 60 ± 1 °C with a cylindrical steel test rod completely immersed therein. It is recommended to run the test for 4 h. The test rod is observed for signs of rusting and, if desired, degree of rusting. An indication of the degree of rusting occurring in this test

may be desired. For uniformity in such cases, use of the following classifications of rusting severity is recommended: Light Rusting: Rusting confined to not more than six spots, each of which is 1 mm or less in diameter. Moderate Rusting: Rusting in excess of the above but confined to less than 5 % of the surface of the test rod. Severe Rusting: Rusting covering more than 5 % of the surface of the test rod [32].

2.3 Oxidation Stability test

This test utilizes an oxygen-pressured vessel to evaluate the oxidation stability of new and in-service turbine oils having the same composition (base stock and additives) in the presence of water and a copper catalyst coil at 150 °C. The test oil, water, and copper catalyst coil, contained in a covered glass container, are placed in a vessel equipped with a pressure gage. The vessel is charged with oxygen to a gage pressure of 620 kPa (90 psi, 6.2 bar), placed in a constant-temperature oil bath set at 150 °C, and rotated axially at 100 rpm at an angle of 30° from the horizontal. The number of minutes required to reach a specific drop in gage pressure is the oxidation stability of the test sample. The vessel life of the sample is the time in minutes from the start of the test to a 175 kPa (25.4 psi, 1.75 bar) pressure drop from the maximum pressure [33].

2.4 Iodine value

The Iodine value is the amount of halogen in grams, expressed as iodine, which reacts with 100 g of material under specified conditions. This standard specifies a method for the determination of the iodine value of fats, fatty oils, and mixtures of such materials in mineral oils. The results obtained give an indication of the degree of unsaturation of the sample. A known quantity of sample is dissolved in carbon tetrachloride and allowed to react with an excess of iodine monochloride in glacial acetic acid. The excess reagent is then converted into free iodine by the addition of potassium iodide, and the liberated iodine determined by titration with thiosulphate solution. The iodine value was calculated by means of the following equation:

$$I = 12.7 M (B - A) / W \quad (1)$$

where: I = iodine value, B = volume of standard thiosulphate solution, in mL, used for the blank,

A = volume of thiosulphate solution, in ml, used for the sample, M = molarity of the thiosulphate solution, W = mass of sample [34].

2.5 Fourier Transform Infrared Spectrometer (FT-IR)

FT-IR spectra were recorded on FT-IR spectrometer (Bruker Optics GmbH, ALPHA model, Ettlingen, Germany). For data acquisition and processing, the software OPUS/Mentor was used. Spectra were recorded from 4000 to 400 cm^{-1} using a spectral resolution of 6 cm^{-1} . For each FT-IR spectrum a number of 64 scans were averaged. Liquid samples were sandwiched between two plates of potassium bromide. Solid samples were prepared by grinding a quantity of the sample with a potassium bromide finely. This powder mixture was then pressed in a mechanical press to form a translucent pellet through which the beam of the spectrometer can pass.

2.6 Addition of Soy Lecithin (SL) to mineral base oils

SL was blended with mineral base oils and evaluated as anti-rust and anti-oxidant additive for petroleum lubricating oils. In the blending of lubricating oils, a certain mass percent of each component was added where the total mass percent of all components of the blend equals 100 mass percent.

SL was added to mineral base oils with different mass percent: 5, 3, 1, and 0.5 mass % respectively, a blend was stirred at 60-70 °C for about 1 h and then a blank blend was prepared, without SL, to determine the effect of SL addition.

2.7 Improvement in the oxidation stability of Soy Lecithin (SL)

Some experiments such as modification of SL, addition of eco-friendly antioxidants and addition of prepared additives were carried out to enhance the oxidation stability of SL.

2.8 Modification of Soy Lecithin (SL)

The primary phospholipid components of lecithin are phosphatidylcholine (PC), phosphatidyl ethanolamine (PE), phosphatidylinositol (PI) and phosphatidic acid (PA). SL was modified to obtain

products with better oxidation stability. Modification of SL included fractionation, de-oiling and hydroxylation.

In fractionation, 95 % ethanol was added to SL and stirred at 60-70 °C for about 1h and then the mixture was centrifuged for 20 minutes. Oily Layer was removed and ethanol was distilled at 78 °C to separate PC residue.

In de-oiling, acetone was added to of SL and stirred for 1 h at room temperature. Oily fraction was removed and then the separated layer was rewashed several times using acetone to remove any oily content. Traces of acetone were removed by distillation at 56 °C.

In hydroxylation, 30 % hydrogen peroxide (H₂O₂) was added to SL and then 2 ml of acetic acid were added. The reaction was carried out at 70 °C with stirring for 2h. The mixture was neutralized with 10 ml of 20 % KOH aqueous solution. Methanol was added to the mixture to remove excess KOH. The mixture was centrifuged to separate the product of hydroxylation. Iodine values of SL and the product of hydroxylation were evaluated.

Each of the prepared modified Soy Lecithin was evaluated for oxidation stability after blended with mineral base oils.

2.9 Synthesis of lecithin borate using boric acid

A reaction vessel was charged with a mixture of SL and a small amount of toluene (as a zoetrope). Boric acid was added to the mixture with a molar ratio of (2:1) (SL: boric acid). The reaction mixture was heated to reflux in 115 °C for about 4 h till removing 2 ml water and then toluene was removed. The final product was viscous liquid and was blended with mineral base oils and then oxidation stability of blend was evaluated [35].

2.10 Addition of eco-friendly antioxidants

Mixtures of SL and eco- friendly antioxidants such as lactic acid, citric acid, vitamin E (α -tocopherol) and quercetin (natural poly phenol) were prepared to improve oxidation stability. Quercetin is considered to be a strong antioxidant due to its ability to scavenge free radicals and bind transition metal ions to inhibit lipid peroxidation [36,37].

The mixtures were blended with mineral base oils and then the compatibility and oxidation stability of blends were evaluated.

Each of lactic acid and citric acid was added individually to SL with a molar ratio (1:1) and stirred at 90 °C for about 1 h. Vitamin E was added to mineral base oils with different mass percent in presence and/or absence of SL and stirred at 90 °C for about 1 h. Quercetin was added with different mass percent to a mixture of SL and mineral base oils and the blend components were stirred at 90 °C for about 1 h. The solubility of quercetin was evaluated. Then oxidation stability of all blends was evaluated.

2.11 Using of different oils to dissolve Quercetin

Different oils were used in the blend to dissolve quercetin to be suitable to blend with lubricating oils. Different base oils and essential oils (natural liquid aroma compounds) were used. Base oils differ from each other's according to their chemical composition to aromatic, naphthenic and paraffinic, so base oils such as LBS 4 oil (high aromatic content), nynas T9 oil (high naphthenic content) and mineral white oil (high paraffinic content) were used.

Each of LBS 4 oil, nynas T9 oil and mineral white oil was added individually to quercetin. Blends were stirred at 90 °C for about 1 h and then solubility of quercetin and oxidation stability of blends was evaluated.

Locally available essential oils such as pine oil and rosemary oil were used and each of them was added individually to quercetin. Blends were stirred at 60 °C for about 1 h and then the solubility of quercetin and oxidation stability of blends was evaluated.

2.12 Preparation of lecithin enriched quercetin "Phenolipid"

Phenolipids result from the reaction of phospholipids with selected phenolic compounds as quercetin. Phenolipids are lipophilic and freely soluble in oils. Quercetin and phosphatidylcholine of Soy Lecithin are able to form chain-like structures linked by hydrogen bonds and form phenolipid Fig. 2 [38].

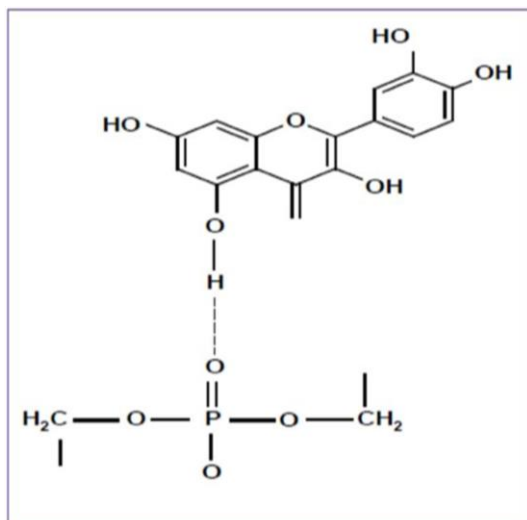


Fig. 2. Chain like structure of quercetin linked to phosphatidyl choline by hydrogen bonding.

SL was added to quercetin and the mixture was stirred at 90 °C for about 1 h and then the solubility of quercetin in SL was evaluated. Different ratios of (SL to quercetin) were used to allow preparation of phenolipid and to achieve complete solubility of quercetin and then the optimum ratio of SL to quercetin was determined. Prepared phenolipid was referred to it as phenolipid (1) and then it was added to mineral base oils with different mass percent: 1.6, 3.2, 4.8 and 8 mass % respectively and oxidation stability of blends was evaluated.

2.13 Preparation of lecithin - oleyl alcohol mixtures

Mixtures of SL and oleyl alcohol were prepared to replace a part of SL mass percent in phenolipid preparation to enhance oxidation stability.

Each of oleyl alcohol and SL was added individually to mineral base oils as blank samples, then mixtures of SL and oleyl alcohol were prepared with different ratios such as (3:1), (1:1) and (1:3) (wt.:%:wt.%) and each of these mixtures was added individually to mineral base oils. It was referred to a mixture with a ratio (3:1) as additives package (1), a mixture with a ratio (1:1) as additives package (2) and a mixture with a ratio (1:3) as additives package (3).

2.14 Using of lecithin - oleyl alcohol mixture in phenolipid preparation

The lecithin-oleyl alcohol mixture with the best oxidation stability, in comparison to other

prepared mixtures, was added to quercetin to prepare phenolipid.

The mixture of additives package (2) and quercetin was stirred at 90 °C for 1 h and then the solubility of quercetin was evaluated. Prepared phenolipid was referred to it as phenolipid (2) and was added to mineral base oils. Oxidation stability of blends was evaluated.

3. RESULTS AND DISCUSSION

3.1 Structural characterization

Quercetin, SL and prepared phenolipids (1) and (2) were characterized by FT-IR spectroscopy in order to determine the mechanism of encapsulation of quercetin by SL.

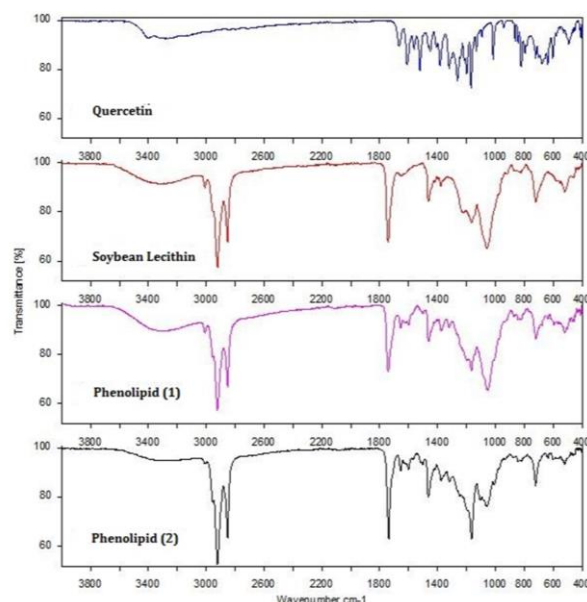


Fig. 3. FT-IR spectra of Quercetin, Soybean Lecithin, Phenolipid (1) and Phenolipid (2) show a lacking in the characteristic peaks of quercetin in the spectra of the phenolipids, which proves the quercetin encapsulation by SL.

As presented in Fig. 3, quercetin shows its characteristics peaks in the range of 1600 – 1100 cm^{-1} (at 1662 cm^{-1} corresponding to C=O aryl ketonic stretch, 1608 cm^{-1} corresponding to C-C aromatic ring stretch, 1379 cm^{-1} corresponding to O-H bending of phenol, 1317 cm^{-1} corresponding to C-H bond in aromatic hydrocarbon, 1259 cm^{-1} corresponding to C-O stretch of aryl ether, 1214 cm^{-1} corresponding to C-O stretch of phenol and 1166 cm^{-1} corresponding to C-CO-C stretch and bending in ketone) and OH – phenolic bending:

1400 – 1200 cm⁻¹ [39]. SL shows characteristic peaks in the range of 1765 - 970 cm⁻¹ (at 1765 - 1720 cm⁻¹ corresponding to C=O, 1200 - 1145 cm⁻¹ corresponding to P=O, 1145 – 970 cm⁻¹ corresponding to P-O-C, and 1200 – 970 cm⁻¹ corresponding to (P-O-C and PO₂) [40].

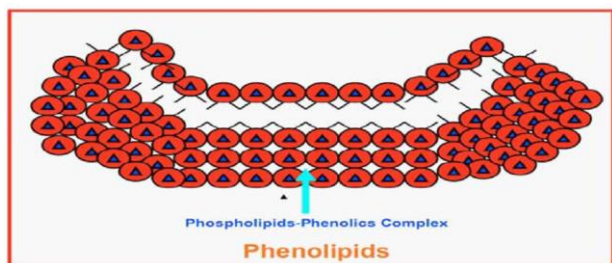


Fig. 4. Structure of phenolipids shows the encapsulation of phenolic compound by phospholipids.

From FT-IR spectra presented on Fig. 3, it can be observed that the characteristic peaks of quercetin are missing in the spectra of the phenolipids (1) and (2). This data indicates that in the phenolipids (1) and (2), quercetin is encapsulated by SL as presented in Fig. 4 [41] and it is not present as segregated crystals [42].

3.2 Evaluation of the addition of Soy Lecithin (SL) to mineral base oils as anti-rust additive for petroleum lubricating oils

SL was blended with mineral base oils and evaluated as anti-rust according to standard method ASTM D 665 – B. Different mass % of SL was added, then its rust inhibition characteristic was evaluated and the optimum mass % of SL as anti-rust was determined.

Table 1. Evaluation results of SL addition with different mass percentage.

Blend Components	Blend number				
	(1) Blank	(2)	(3)	(4)	(5)
SL, mass %	-----	5	3	1	0.5
Test	Results				
Rust test	Moderate	Nil	Nil	Nil	Light
RPVOT (minutes)	68	27	30	33	-----

From results reported in Table 1, the blank blend, which is mineral base oils without addition of SL, showed a moderate rusting on a test rod as shown in Fig. 5, but when SL was added to a blend of mineral base oils with different mass percent 5, 3 and 1 mass % respectively, there are no rusting

found in test rods as shown in Fig. 5. By adding 0.5 mass % of SL, there is a light rusting, so the optimum mass percent of SL to be used as anti-rust additive is 1 mass %.



Fig. 5. Rods of Rust preventing characteristic test: Blank sample mineral base oils without Soy Lecithin shows a moderate rusting and blend contained 1 % of Soy Lecithin shows no rusting.

It was concluded that SL has excellent anti-rust characteristic in addition to it is eco-friendly and locally available. It can be explained by the molecular polarity of SL, so the SL molecules can easily adsorb onto the metal surface and forms a protective film which cannot be easily removed and prevents transport of water from contacting with the metal surface. According to the mechanism of corrosion inhibition, SL can be classified as mixed inhibitor [8], which can absorb on the metal surface and prevent both anodic and cathodic reactions, and hence exhibit excellent rust inhibition properties.

3.3 Evaluation of the addition of Soy Lecithin (SL) to mineral base oils as anti-oxidant additive for petroleum lubricating oils

Oxidation stability of blends with different mass percent of SL was evaluated according to standard method ASTM D 2272 (RPVOT).

Results of oxidation stability evaluation were reported in Table 1. From RPVOT results, the addition of SL to mineral base oils decreased oxidation stability. It can be explained by the high degree of unsaturation of SL which accelerates the rate of the oxidation.

The addition of SL to mineral base oils decreased oxidation stability, so some experiments were carried out to improve the oxidation stability of SL such as modification of SL, addition of eco-friendly antioxidants and addition of different mixtures of prepared additives.

3.4 The effect of using modified Soy Lecithin to improve oxidation stability

SL was modified according to three modification processes: fractionation, de-oiling and hydroxylation to enhance its oxidation stability.

RPVOT results of the addition of phosphatidylcholine (PC), which was fractionated from SL, and de-oiled Soy Lecithin showed no observed difference in oxidation stability between SL, PC and de-oiled Soy Lecithin. Iodine value of SL and hydroxylated Soy Lecithin showed significantly drop in iodine value of SL from 143 to 74 mg. KOH/g. (iodine value of the product of SL hydroxylation) which mean that hydroxylation decreased the unsaturation of SL but RPVOT result of blend contained the product of SL hydroxylation showed no improvement of oxidation stability. It was concluded that addition of prepared modified soy lecithin didn't improve SL oxidation stability.

3.5 The effect of using lecithin borate to improve oxidation stability

Lecithin borate was prepared and added to mineral base oils to enhance oxidation stability.

Results of addition of lecithin borate showed that was no improvement in oxidation stability in comparison to blend contained SL.

3.6 The effect of using eco-friendly antioxidants to improve oxidation stability

Some eco-friendly antioxidants were added to SL such as lactic acid, citric acid, vitamin E and quercetin to enhance oxidation stability of SL. Results of addition of lactic acid, citric acid and vitamin E showed that was no improvement in oxidation stability of SL.

Addition of quercetin to blends of SL and mineral base oils showed an excellent improvement in oxidation stability, it increased

oxidation stability time of blend contained 1 % of SL from 33 min. to 248 min. but quercetin wasn't completely soluble in mineral base oils, so different oils were used to dissolve quercetin to be suitable to blend with lubricating oils.

Different base oils and essential oils (natural liquid aroma compounds) were used. From results, quercetin solubility wasn't increased by the addition of essential oils but by the addition of different base oils, it was showed that quercetin solubility was increased as the aromatic content of the base oils increased and the oxidation stability of the blend increased but quercetin still not completely soluble.

3.7 The effect of using prepared phenolipids (lecithin enriched quercetin) to improve oxidation stability

A mixture of SL and quercetin was prepared. Each of SL and quercetin was added with different mass percent to determine the ratio of (SL to quercetin) to achieve complete solubility of quercetin. The typical ratio was determined and was referred to it as phenolipid (1) and it was added with different mass percent to mineral base oils. Oxidation stability of blends was evaluated and reported in Table 2.

Table 2. Evaluation results of phenolipid (1) addition with different mass percentage.

Blend Components	Blend number			
	(6)	(7)	(8)	(9)
Phenolipid (1), mass %	1.6	3.2	4.8	8
Test	Results			
RPVOT (minutes)	160	160	155	146

From RPVOT results in Table 2, the addition of phenolipid (1) improved the oxidation stability of SL from 33 minutes (blend contained 1 mass% of SL) to 160 minutes (blend contained 1.6 mass % of phenolipid (1)) stability against oxidation but it was observed that as a mass percent of phenolipid (1) was increased, the oxidation stability wasn't increased. It can be explained that as percent of phenolipid was increased, each of SL and quercetin also increased to achieve the typical ratio of quercetin solubility and the increase of SL affected negatively on oxidation stability. It can be concluded that the preparation of phenolipid

achieved the complete solubility of quercetin in the blend of mineral base oils but it was important to replace a part of SL mass percent with another substance which allowed quercetin to be completely soluble and to improve oxidation stability.

3.8 The effect of using lecithin - oleyl alcohol mixtures

Oleyl alcohol was added to SL. The effect of adding oleyl alcohol to SL with different mass percent was evaluated. Each of oleyl alcohol, SL and prepared additives packages was added individually to mineral base oils, the oxidation stability of blends was evaluated and results were reported in Table 3.

Table 3. Evaluation results of the addition of lecithin – oleyl alcohol mixtures with different mass percentage.

Blend Components	Blend number					
	(10)	(11)	(12)	(13)	(14)	(15)
Additives package (1), mass %	----	----	----	----	4.5	----
Additives package (2), mass %	----	----	----	4.5	----	7.5
Additives package (3), mass %	----	----	4.5	----	----	----
SL, mass %	4.5	----	----	----	----	----
Oleyl alcohol, mass %	----	4.5	----	----	----	----
Test	Results					
RPVOT (minutes)	30	56	56	75	60	46

From RPVOT results in Table 3, addition of additives package (2) has better oxidation stability than each of SL, oleyl alcohol and other prepared additives packages. From results, it was concluded that lecithin – oleyl alcohol mixture with a ratio (1:1), which was referred to it as additives package (2), was a typical ratio to be added to quercetin in phenolipid preparation because of its better oxidation stability.

So lecithin-oleyl alcohol mixture with the best oxidation stability was selected and added to quercetin with the same ratio which was determined before to allow phenolipid preparation with achievement of a complete

solubility of quercetin in mineral base oils and SL. Prepared phenolipid was referred to it as phenolipid (2) and it was added with different mass percent to mineral base oils. Oxidation stability of blends was evaluated and reported in Table 4.

Table 4. Evaluation results of phenolipid (2) addition with different mass percentage.

Blend Components	Blend number	
	(16)	(17)
Phenolipid (2), mass %	4.8	8
Test	Results	
RPVOT (minutes)	357	407
Rust test	-----	Nil

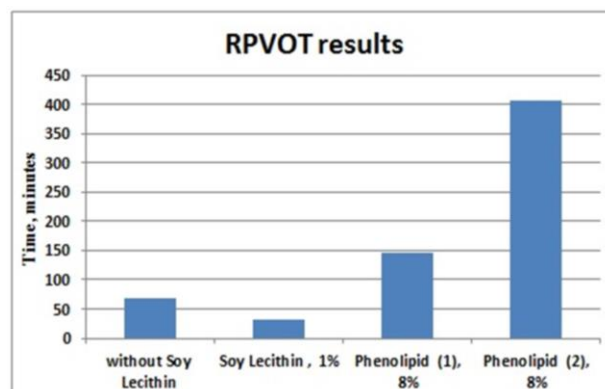


Fig. 6. Comparison chart of RPVOT results of different blends shows a significantly stability against oxidation in blend contained phenolipid (2).

From RPVOT results in Table 4, the addition of phenolipid (2) improved the oxidation stability from 146 minutes (blend contained 8 mass% of phenolipid (1)) to 407 minutes (blend contained 8 mass % of phenolipid (2)) stability against oxidation. It was considered a significantly improvement of the oxidation stability of mineral base oils in comparison to other additives which were used as showed in comparison chart in Fig. 6 and by applying rust preventing characteristic test, rod of the test showed no rusting which was referred to a powerful ability of phenolipid (2) to be added to mineral base oils and to be used as environmentally friendly anti-rust, anti-oxidant additive in lubricating oils.

4. CONCLUSION

In this study, Soybean Lecithin (SL) was used as a multifunctional additive in lubricating oils as an

alternative of already used additives due to its low toxicity to the environment. The evaluation of SL as anti-rust showed excellent rust inhibition characteristic when it was used with a concentration of 1 mass % but it showed a low oxidation stability. The oxidation stability of SL was improved by preparation of phenolipids by a combination of SL and polyphenols through the formation of chain like structure linked by hydrogen bonds and form phenolipids. Phenolipids were prepared with different methods and the oxidation stability of different concentrations of prepared phenolipids was evaluated. Evaluation of prepared phenolipids blended with mineral base oils in a lubricating oil formulation proves a significantly success of this study to show a remarkable improvement of the oxidation stability of SL in addition to its powerful rust inhibition characteristic which allows a widely usage of vegetable oils and its derivatives in petroleum industry.

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