ORIENTAL JOURNAL OF CHEMISTRY
An International Open Access, Peer Reviewed Research Journal
www.orientjchem.org

ISSN: 0970-020 X
CODEN: OJCHEG
2025, Vol. 41, No.(4):
Pg. 1377-1382

Oxidative Stability of Rapeseed oil based Lubricants

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http://dx.doi.org/10.13005/ojc/410436

(Received: July 06, 2025; Accepted: August 16, 2025)

ABSTRACT

Rapeseed oil is a promising renewable alternative to mineral-based lubricants due to its excellent lubricating properties, biodegradability, and low toxicity. However, its high content of unsaturated fatty acids makes it particularly vulnerable to oxidative degradation, limiting its application in high-temperature and long-term operations. Oxidation leads to the formation of acidic compounds, sludge, and polymers, which compromise lubricant performance and equipment longevity. This study investigates the oxidative stability of rapeseed oil-based lubricants, focusing on the mechanisms of oxidation, key influencing factors such as temperature and metal catalysts, and methods to enhance stability. Strategies including chemical modification of the oil structure and the use of antioxidants are evaluated for their effectiveness. Results highlight the importance of tailored antioxidant systems and molecular adjustments to improve oxidative resistance, thereby extending the functional life of rapeseed oil as a sustainable lubricant base stock.

Keywords: Rapeseed oil, Dynamic viscosity, Temperature.

INTRODUCTION

Rapeseed has been cultivated since time immemorial-it has been known in culture since four millennia BC. Some researchers consider the homeland of rapeseed, or, as Europeans call it, its representatives, Europe, especially Sweden, Holland and Great Britain, others-the Mediterranean Sea.

In Europe, rapeseed gained popularity in the 13th century for culinary uses and room illumination, as rapeseed oil burns efficiently and produces little smoke. Nonetheless, prior to the advancement of steam power, its application in industry was rather restricted.

However, by the mid-19th century, rapeseed gained significant popularity–it was discovered that rapeseed oil clings more effectively than other lubricants to metal surfaces exposed to water and steam. The emerging oil industry during that period was unable to meet the entire demand for technical oils.

But by the beginning of the 20th century, the appearance of a large number of cheap oil products caused a sharp decrease in the volume of rapeseed cultivation.

A characteristic of rapeseed is the presence of organic sulfur compounds-thioglucosides (glucosinolates), as well as sulfur-containing amino acids. Selection for non-erucism has been shown to be inextricably linked to selection for low glucosinolate content.

Rapeseed meal is a food rich in protein, contains 40-50% protein, balanced in amino acid composition, similar to soy.

In modern varieties of rapeseed, the content of glucosinolates does not exceed 1% by weight of dry matter without fat. Direct detection and quantitative analysis of thiogucosides and isothiocyanates in rapeseed and oil is laborious, time-consuming and not always efficient. For this reason, the presence of the above-mentioned compounds is evaluated by the sulphide sulfur content.

This vegetable oil has an adequate level of vitamin E, the lack of which negatively impacts the health of the skin, hair, nails, and the human reproductive system. Moreover, this vitamin serves as a natural antioxidant essential for preserving youth and wellness, as it inhibits the development and build-up of free radicals within the body.

Besides vitamin E, Rapeseed oil has B vitamins, vitamin A, and a significant quantity of trace elements (such as phosphorus, zinc, calcium, copper, magnesium, etc.) that are essential for everyone's health.

Rapeseed oil is advised for inclusion in the diet of individuals with gastrointestinal tract ailments, due to its regenerative and anti-inflammatory properties, its ability to lower gastric juice acidity, and its gentle laxative effect.

Rapeseed oil is particularly beneficial for women, as the components it contains are essential for the production of female sex hormones. Therefore, consistent use of this product aids in lowering the chances of infertility and conditions affecting the female genital region, including cancer. Rapeseed oil is beneficial for expectant mothers: the components within it aid in the proper development of the fetus[1-11].

With growing environmental concerns and the need for sustainable alternatives to petroleum-based lubricants, vegetable oils have garnered significant attention as promising renewable base stocks. Among these, rapeseed oil stands out due to its favorable fatty acid composition, biodegradability, and excellent lubricity. However, one of the major limitations hindering the broader application of rapeseed oil-based lubricants is their oxidative stability.

Oxidation is a chemical degradation process that occurs when oils are exposed to oxygen, heat, light, and metal catalysts, leading to the formation of peroxides, acids, sludge, and volatile compounds. These oxidative by-products can severely impact the lubricant's performance by increasing viscosity, causing corrosion, and reducing the lifespan of machinery components.

Rapeseed oil contains a high proportion of unsaturated fatty acids-particularly oleic, linoleic, and linolenic acids-which, while beneficial for fluidity and cold-flow properties, make the oil more susceptible to oxidative degradation. Improving the oxidative stability of rapeseed oil-based lubricants is therefore crucial to enhancing their performance and commercial viability.

Research in this area focuses on chemical modification, such as hydrogenation or epoxidation, and the use of antioxidants-both synthetic and natural-to slow down the oxidation process. Furthermore, understanding the oxidation mechanisms and evaluating stability using standardized tests (e.g., Rancimat, Pressure Differential Scanning Calorimetry) is key to developing more robust bio-lubricants.

This paper explores the oxidative stability of rapeseed oil-based lubricants, examining the factors influencing degradation, methods of stabilization, and recent advances in improving their performance in demanding industrial applications[11-18].

MATERIAL AND METHODS

The Rheotest[2] system is manufactured in Germany by RHEOTEST Medingen GmbH. was used to evaluate the shear rate. Rapeseed oil was subjected to oxidation at different temperatures measured at shear rates ranging from 3.3 s^{-1} to 80 s^{-1}.

Results indicated that the dynamic viscosity decreased as the shear rate increased, regardless of oxidation time, temperature, or testing conditions.

RESULTS AND DISCUSSION

Rapeseed oil was oxidized at 120°C for 5 h and at 130°C for 10 hours. Following oxidation, its dynamic viscosity was measured across a temperature range of 30°C to 90°C. Results are illustrated in the two-dimensional plot 1 and 2, where the relationship between and shear rate is depicted for testing. In all cases, dynamic viscosity decreased as shear rate increased, regardless of temperature, oxidation time, or testing condition.

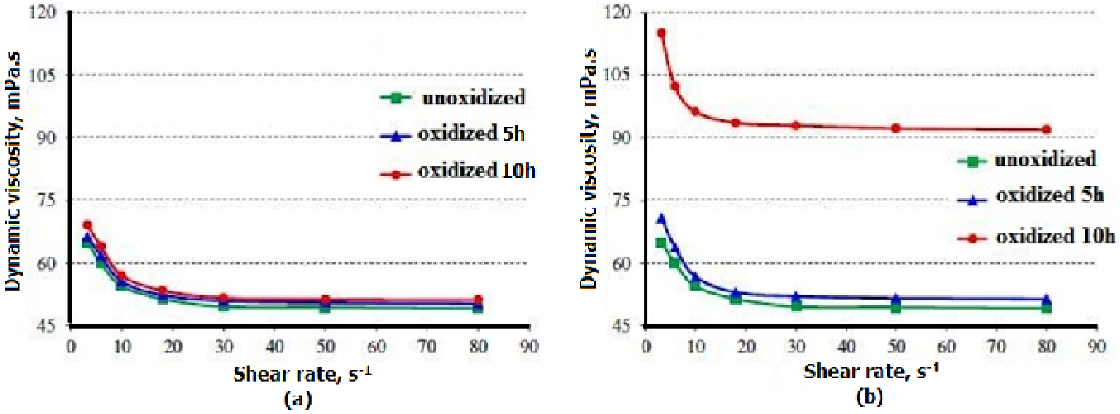

Fig. 1. The two-dimensional plot at a temperature of 30°C for rapeseed oil oxidized at 120°C (a) and at 130°C (b)

Rapeseed oil oxidized at 120°C for 5 and 10 h did not exhibit a notable rise in comparison. This occurrence was noted at both temperatures examined. The oil that oxidized for 10 h exhibited a notable rise in dynamic viscosity.

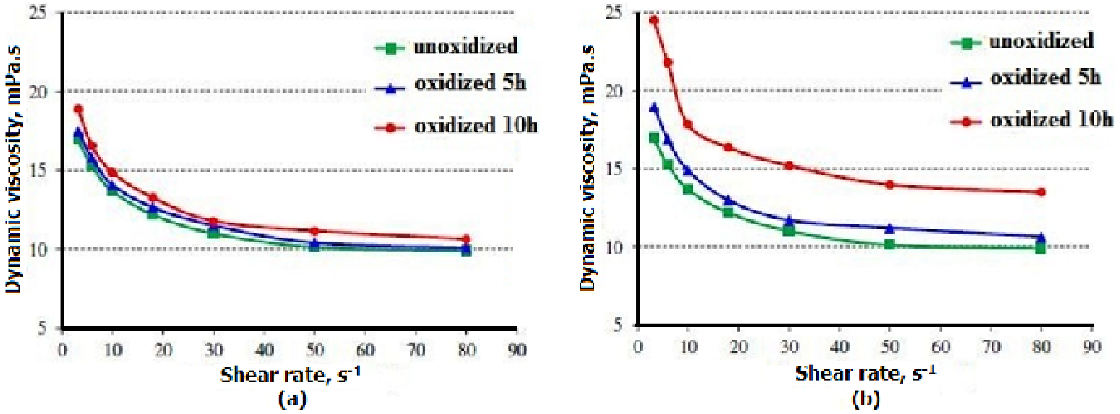

Fig. 2. The two-dimensional graph at a temperature of 90°C, for rapeseed oil oxidized at 120°C (a) and at 130°C (b)

Figures 3 and 4 display the dynamic viscosity curves of rapeseed oil as a function of temperature. At both oxidation temperatures with increasing, independent of oxidation duration or shear rate.

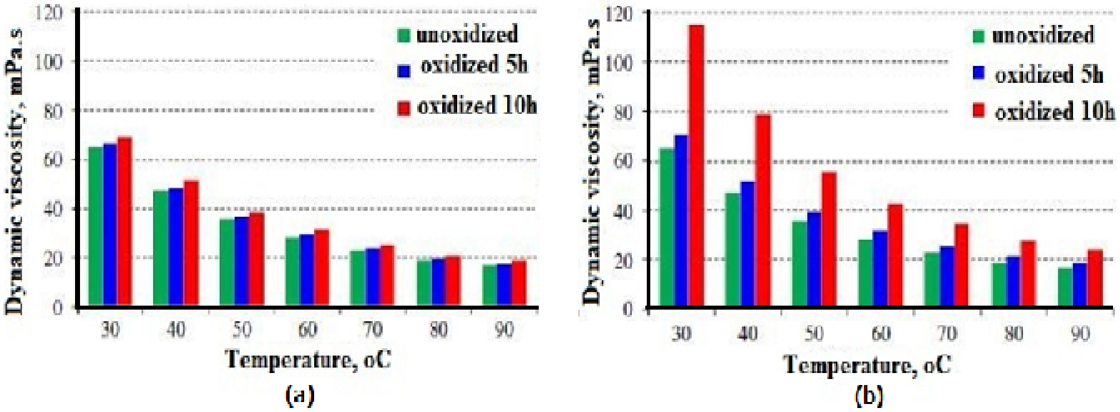

Fig. 3. The two-dimensional graphs at a shear rate of 3.3 s^{-1} show the behavior of Rapeseed oil oxidized at 120°C (a) and 130°C (b)

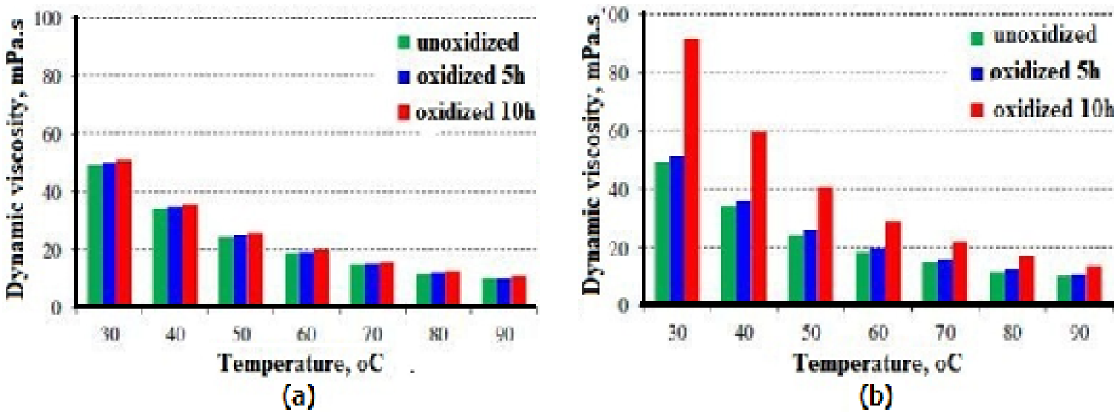

Fig. 4. The two-dimensional graph at a shear rate of 80 s^{-1}, show the behavior of rapeseed oil oxidized at 120°C (a) and 130°C (b)

Compared unoxidized oil, oxidized rapeseed oil heated at 120°C, under shear rates of, does not show a big increase in dynamic viscosity. However, when is raised, the dynamic viscosity increases a lot after 10 hours.

Figures 5, 6 and 7 show viscosity maps that display how both temperature and shear rate together affect the dynamic viscosity of rapeseed oil. These include unoxidized oil, oil oxidized for 5 h, and oil oxidized for 10 h, each at temperatures of 120°C and 130°C.

The results from the experiments, shown as points, along with the surfaces that closely match these results for rapeseed oil that was heated at, are displayed in Figures 8 and 9.

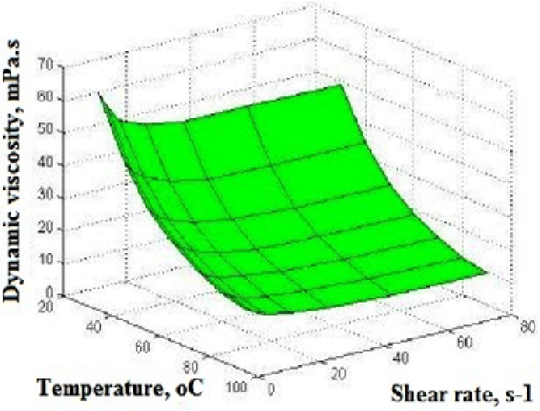

Fig. 5. The three-dimensional graph for non-oxidized rapeseed oil

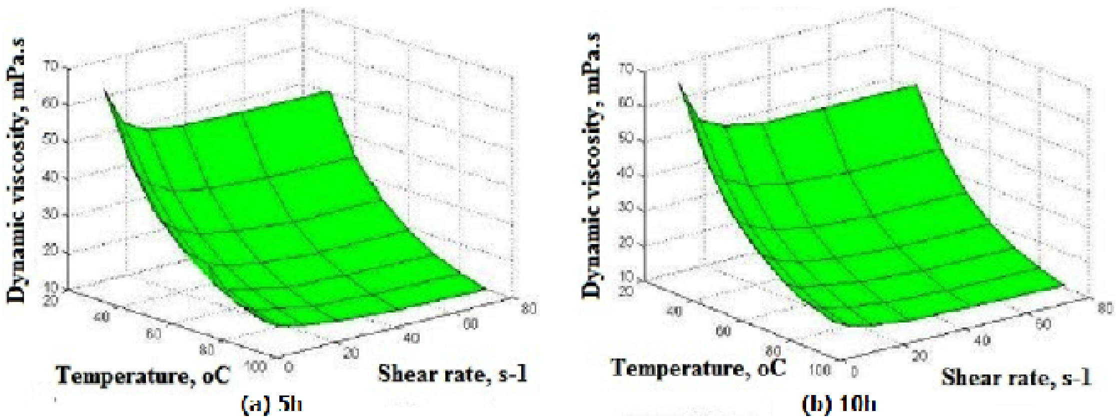

Fig. 6. The 3D graph shows rapeseed oil that has been oxidized at a temperature of 120 degrees Celsius.

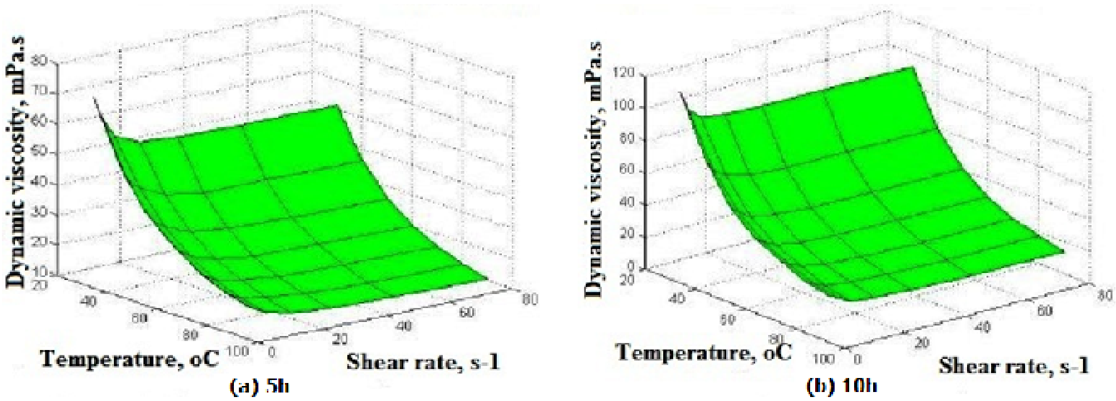

Fig. 7. The 3D graph shows rapeseed oil that has been oxidized at a temperature of 130 degrees Celsius

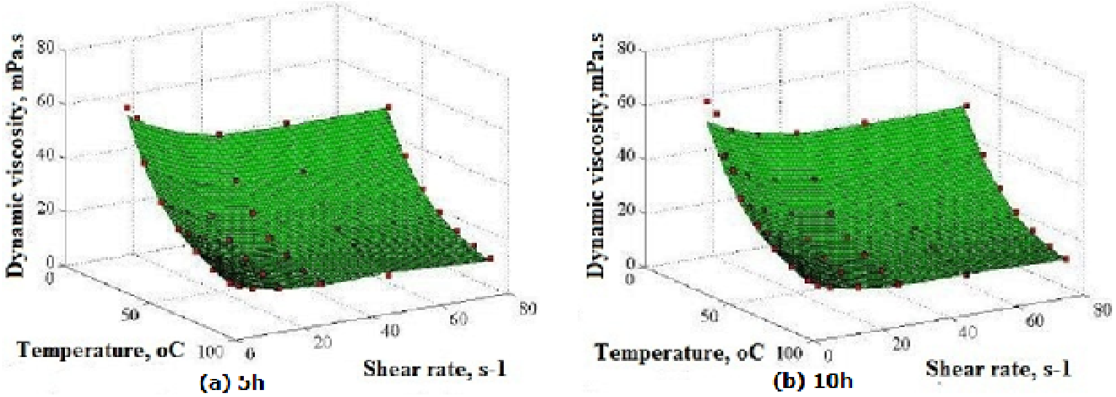

Fig. 8. The 3D graph shows rapeseed oil that has been oxidized for at a temperature of 120°C degrees Celsius

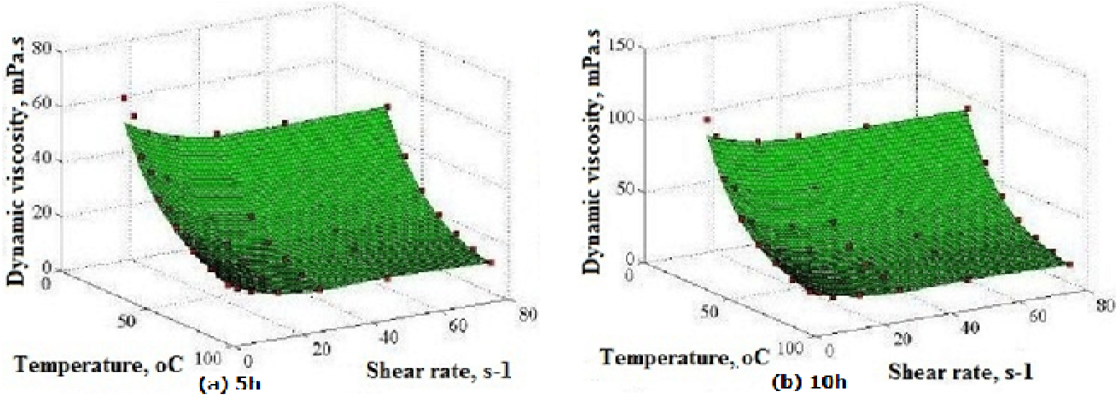

Fig. 9. The 3D graph shows rapeseed oil that has been oxidized for at a temperature of 130°C degrees Celsius

CONCLUSION

A criterion for evaluating vegetable oils is their heightened viscosity throughout the oxidation process.

At both test temperatures, it was observed that the oxidation of rapeseed oil does not notably enhance oils compared. When the oil undergoes oxidation for 10 h instead of 5 h of the rapeseed shows a significant rise.

ACKNOWLEDGMENT

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

The author declare that we have no conflict of interest.

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