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EVALUATION AUTO-HEATING TENDENCY OF SOME VEGETABLE OILS USED IN THE VIETNAM'S PAINT AND COATINGS INDUSTRY BY MACKEY TEST

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Abstract. For the paint and coatings industry, vegetable oils play the most important role, as it is the glue to bind the pigments to the surface of the product. Vegetable oils derived from plants are the best oils to help the surface to be covered with a beautiful shine and quick drying. In the process of paint production using many materials with high explosion risk, one of the dangerous problems is the ability of vegetable oil to self-heating during production, transportation, or storage. In the article, the author uses Differential Mackey Test according to ASTM D3523-92 to determine spontaneous heating values of vegetable oils for 3 widely used oils (tung oil, linseed oil, and pine oil). For each type of oil, 20 experiments were conducted and the results were confirmed that tung oil and linseed oil have the ability self-heating. Therefore, the study of the self-heating ability of some vegetable oils used in the paint and coatings industry in Vietnam significance is of great in fire prevention and fighting to take safety measures during use.

Keywords: *Vegetable oils, self- paint industry, Mackey test.*

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1. Introduction

Vegetable oils are mainly extracted from fruits and seeds, and also in leaves, roots, bark, branches... but in a small amount. The main source of vegetable oils is from some short-term plants (peanut, sesame, sunflower, soybean, cotton, rice, corn...), and some perennial plants (coconut, palm, corn…), etc. The process of oil formation in oilseeds occurs when the seeds contain natural organic and inorganic compounds that are transferred to the seed through the leaves and root system. When the seeds are just beginning to ripen, the fat contains a lot of free fatty acids, then the amount of fatty acids decreases and the amount of glycerides and triglycerides increase (Anneken *et al.*, 2000).

In the paint and coatings industry, oils play the most important role, because it is a glue to bind the pigment to the surface of the product. Oils extracted from tung oil, linseed oil, and pine oil... are best oils for polishing and quick drying of surfaces. In addition, it can also be processed in rubber oil, tick oil, coconut oil, corn oil, soybean oil, and sunflower oil... but these types are characterized by long drying times, and not very helpful for covering the surface with a beautiful shine, so people often use to mix a part of them with tung oil, pine oil, or with linseed oil. Linseed oil, also known as flaxseed oil or flax oil, is a colorless to yellowish oil obtained from the dried, ripened seeds of the flax

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plant (*Linum usitatissimum*), which grows mainly in temperate regions. Linseed oil has the advantage when the paint film dries to form a beautiful glossy paint film, and the paint film dries naturally after 24 hours. But its disadvantage is that it is not electrically insulating and insoluble in water. Tung oil and pine oil have beautiful and sharp glossy paint film, durable color and good electrical insulation, good moisture resistance, salt water, and some chemicals. To reduce product costs and use for some products that do not require too high specifications, people can use 15% - 30% oil mixed with slow-drying oil with hybrid oil, or truss oil, but this type of paint lacks have the paint film not shiny and less sharp. The production process in the factory, from the very first steps, contributes to the quality of the pain. The main combustible substances in the workshop include linseed oil, turpentine, rubber, all kinds of natural, synthetic resins, and gasoline… Gas vapor of these substances mixed with air can potentially create an explosion hazard. Gas vapor is likely to escape from the modulation device because the structure of the oil extraction pot is not tight. It escapes through the gap, through the capillary tubes (appearing in the manufacturing process) between the lid and the pot body because the layers are not completely sealed. Adding solvent (gasoline) to the oil extraction pot is the most dangerous step in the paint and oil factory, when the oil in the extraction pot (reaching temperature t = 220 °C) provided a large amount of heat to vaporize the entire blended gasoline, which brought the gaseous vapor to a temperature close to its own boiling point, encountering atmospheric oxygen that could ignite, with no need for heat supplied from outside (Alfred *et al.,* 2002; Baylon *et al.*, 2008; TCVN 6122:2015(ISO 3961:2013) on animal and vegetable fats and oils).

The self-heating of vegetable oils originates from the oxidation of the fatty acids contained in them. Because this oxidation reaction is exothermic, it generates heat directly in the material. The generated heat may be sufficient to provide the energetic activation required to bring the material or its substrate to its self-heating temperature. However, the two main conditions must be:

+ Oxygen must be able to penetrate the core of the clear material to ensure the continuity of the oxidation reaction.

+ The process of heat exchange with the environment is almost isolated to minimize heat loss to the surrounding environment.

In order for oxygen to reach the molecules during oxidation. Such a situation is possible only when the carrier is solid and porous. Oxidation at the surface of the liquid cannot heat the oil on its own. However, if the liquid is absorbed into a solid surface, the liquid phase ratio is increased significantly. As a result, oxygen exposure is facilitated and the reaction heat release rate is increased.

The self-oxidation of vegetable oils is a process that can be described as occurring in three different steps: Initiation phase, propagation phase, and termination phase (Fig. 1, 2 and 3).

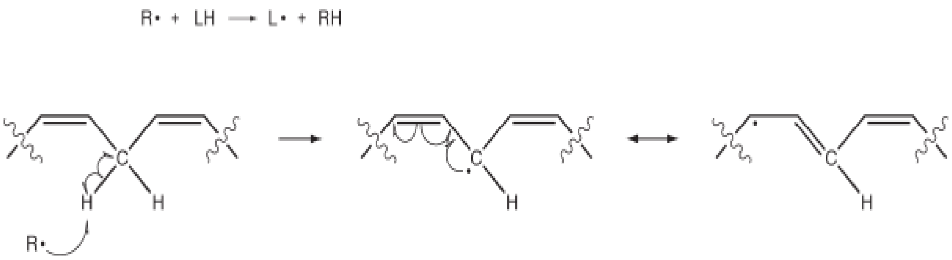

Fig. 1. Initiation phase

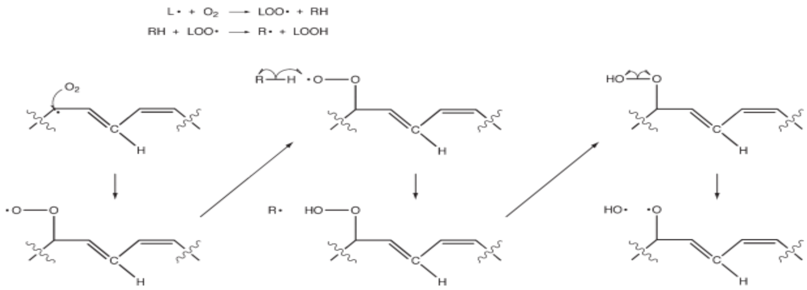

Fig. 2. Propagation phase

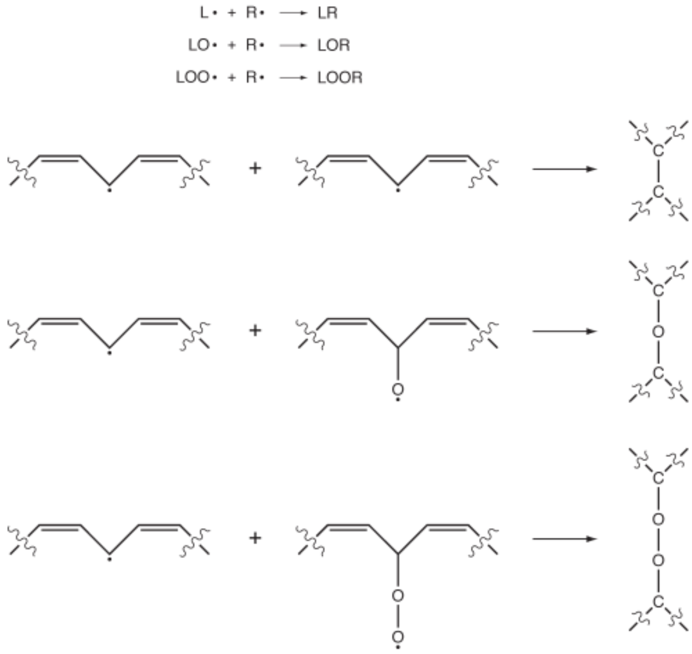

Fig. 3. Termination phase

2. Materials and methods

In the content of this study, we experimented with 3 types of oils widely used in the paint and coatings industry: pine oil, tung oil, and linseed oil. Sampling directly from the supply to paint factories to conduct research.

Between the two shells, fill the tank with water almost to the mouth of the bottle. The bottle cap covers the inner part of the body to reduce heat exchange between the inside and the outside environment. In the middle of the lid, there is a hole to insert the thermometer, at the edge of the lid, there are two small symmetrical tubes. One tube is mounted deep down to provide oxygen for the oxidation reactions, the other is mounted high up to bring the oxidation products of the outlet out. In the middle of the flask, there is a cylindrical tube in the form of a mesh to place a carrier that has been soaked in vegetable oil (cotton, fiber), which can be removed and lifted out of the bottle (ASTM D3523-92, 2012; Bowes, 1984).

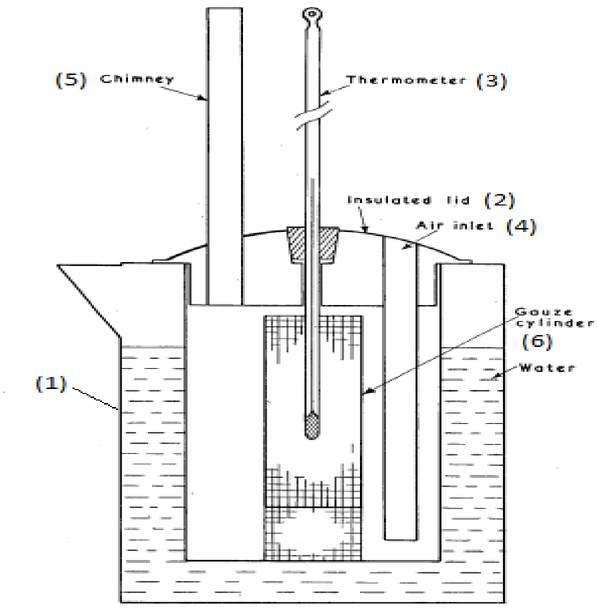

Fig. 4. Diferential Mackey Test

3. Results and Discussion

The way in which the specimen temperature varied throughout a test is shown in Fig.5,6,7 for the typical examples at the different ratios for oil and cotton (Hrusovsky, 2014; Babrauskas, 2003; Tuman *et al.*, 1996; Mosiewicki *et al.*, 2009). Therein the difference in maximum temperature was large.

For Tung oil, conducting 20 experiments with different ratios of oil and cotton obtained the highest temperature of 221°C for an oil and cotton ratio of 2:1, and the time to reach that temperature is 80 min. The experimental results for tung oil are shown in Table 1.

Table 1. Results of Tung oil

Ratio Tung oil: cotton	Number of tests	Maximum temperature °C	Time to maximum mins
1,71:1	5	189 ± 4	90
1,74:1	5	200 ± 3	80
1,87:1	5	210 ± 5	80
2:1	5	221 ± 6	80

Fig. 5 depicts the effect of tung oil on cotton of different proportions heated for a period of 120 min. For torsion oil, the highest temperature of the experiments was reached during the heating period of 80 min**.**

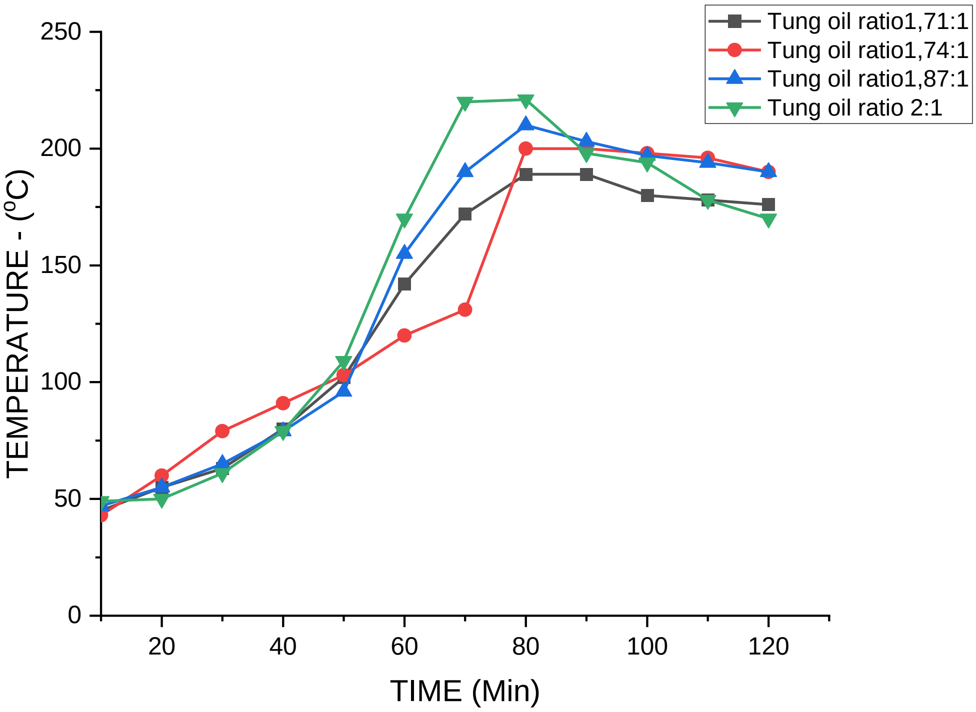

Fig. 5. Effect of Tung oil ratio for cotton of heating by Mackey test

Linseed oil is a triglyceride, like other fats. Linseed oil is distinctive for its unusually large amount of α-linolenic acid, which oxidizes in the air. The triply unsaturated α-linolenic acid (51.9–55.2%)

Table 2. Results of Linseed oil

Ratio Linseed oil: cotton	**Number of tests**	**Maximum temperature °C**	**Time to maximum mins**
1,85:1	5	189 ± 4	90
2:1	5	200 ± 3	80
2,14:1	5	210 ± 5	80
2,28:1	5	223 ± 6	80

As for linseed oil, they quickly reach the highest temperature of 223°C in 80 minutes of heating with a ratio of 2.28:1 between oil and cotton. The variation of cotton temperature on linseed oil content and heating time is shown in Fig. 6.

For pine oil, reaching the maximum temperature of 87 – 89°C requires an average time of 100- 110 minutes. That's a lot longer than it takes to heat tung oil and linseed oil (80 minutes on average).

The results of the experiments for pine oil are shown in Fig. 7. The maximum temperature that can be achieved is 89°C with the ratio of pine oil and cotton is 2:1.

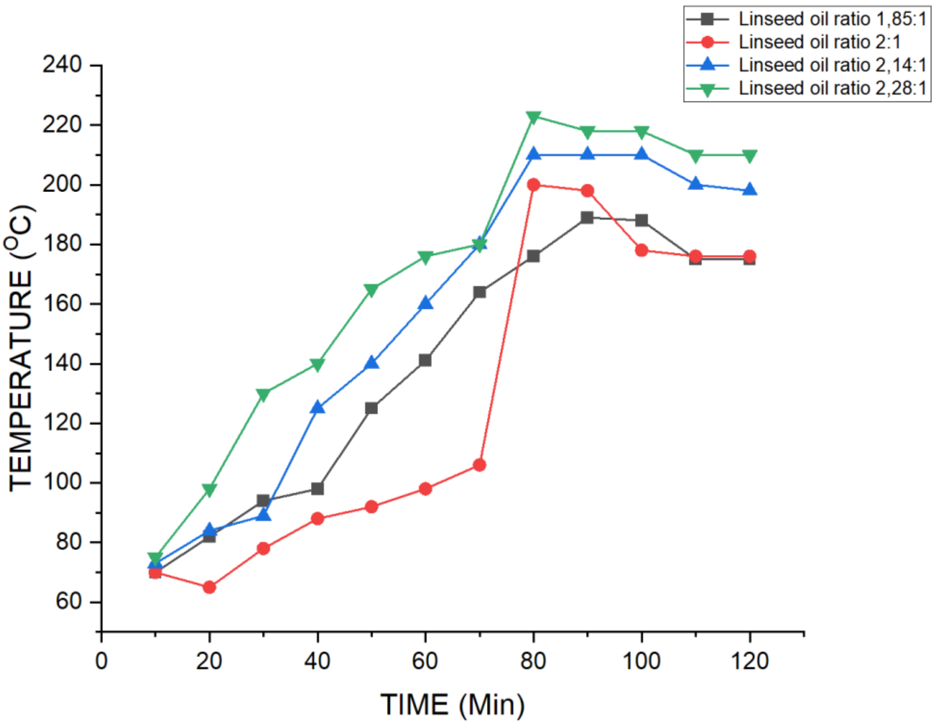

Fig. 6. Effect of Linseed oil ratio for cotton of heating by Mackey test

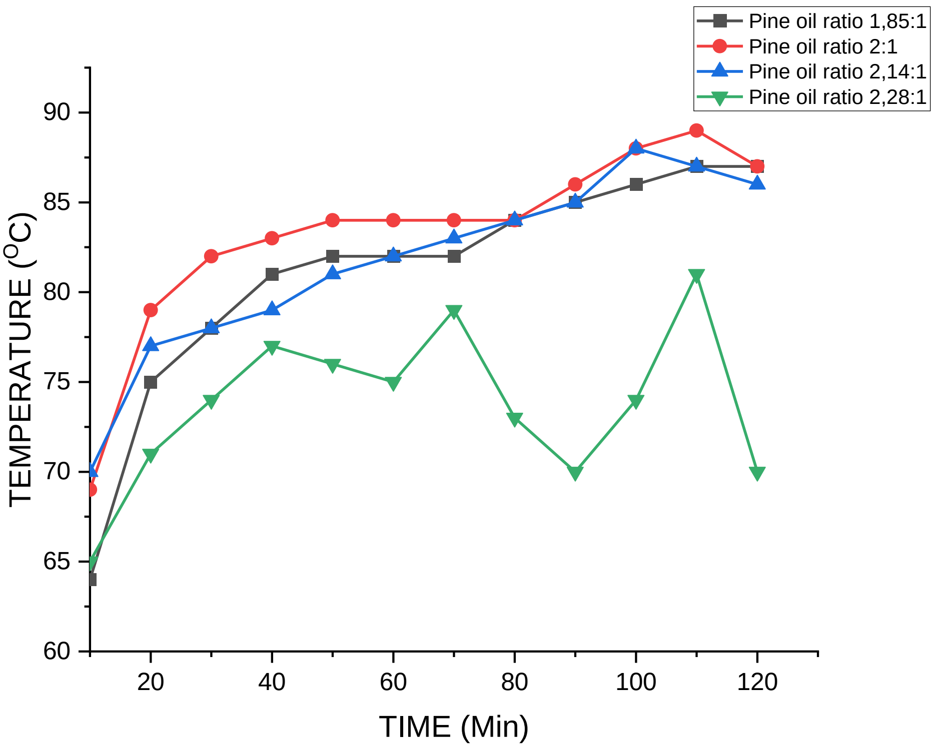

Fig. 7. Effect of Pine oil ratio for cotton of heating by Mackey test

Table 3. Results of Pine oil

Ratio Pine oil: cotton	Number of tests	Maximum temperature °C	Time to maximum mins
1,85:1	5	87 ± 4	110
2:1	5	89 ± 2	110
2,14:1	5	88 ± 4	100
2,28:1	5	81 ± 3	110

For pine oil, although heated for 120 minutes, it cannot exceed 90°C. In contrast, when linseed oil and Tung oil were heated using the Mackey test device for an average of 80 minutes, the cotton temperature exceeded 200°C. That can confirm the self-heating trend of linseed oil and Tung oil used in the paint and coatings industry in Vietnam, which always has potential fire safety risks.

4. Conclusion

Linseed oil and Tung oil , they quickly reach the highest temperature of 221- 223°C in 80-100 minutes of heating between oil and cotton. For pine oil, reaching the maximum temperature of 87 – 89°C requires an average time of 100- 110 minutes. This result proves that only Tung oil and linseed oil have the ability to self-heat. It is urgent to study the properties of vegetable oils, especially their self-heating, in the paint and coating industry in Vietnam. From there, it is possible to propose solutions to prevent fire and explosion risks from Tung oil and linseed oil during transportation, storage, and use in accordance with the actual requirements of Vietnam. This result is a very important step in the future not only for the paint industry but also many other fields that use vegetable oils. With the desire to apply research achievements to fire prevention and fighting propaganda, help improve people's understanding and minimize the damage of fires related to vegetable oil.

References

Alfred, T., Matthäus, B., & Fiebig, H.J. (2002). Fats and fatty oils. *Ullmann's Encyclopedia of Industrial Chemistry*. Weinheim: Wiley-VCH.

Anneken, D.J., Both, S., Christoph, R., Fieg, G., Steinberner, U., & Westfechtel, A. (2000). *Fatty acids.* Ullmann's Encyclopedia of Industrial Chemistry.

ASTM D3523-92, 2012. Standard Test Method for Spontaneous Heating Values of Liquids and Solids (Differential Mackey Test).

Babrauskas, V. (2003). *Ignition handbook: principles and applications to fire safety engineering, fire investigation, risk management and forensic science*. Books by Alumni. 3856. https://works.swarthmore.edu/alum-books/3856

Baylon, A., Stauffer, É., & Delémont, O. (2008). Evaluation of the Self-Heating Tendency of Vegetable Oils by Differential Scanning Calorimetry. *Journal of Forensic Sciences*, *53*(6), 1334-1343.

Bowes, P.C. (1984). *Self-heating: evaluating and controlling the hazards*. Elsevier: HMSO.

Edimecheva, I.P., Sosnovskaya, A.A., & Shadyro, O.I. (2020). The application of natural and synthetic antioxidants to increase theoxidation resistance of linseed oil. *Food Industry: Science and Technology*, 13 (4 (50)), 41–51. doi: https://doi.org/10.47612/2073-4794-2020-13-4(50)-41-51

Feoktistov, D.V., Glushkov, D.O., Kuznetsov, G.V., & Orlova, E.G. (2021). Gel fuels based on oil-filled cryogels: Corrosion of tank material and spontaneous ignition. *Chemical Engineering Journal*, *421*, 127765.

Fu, S., Chen, H., Watt, S. D., Sidhu, H. S., Luangwilai, T., & Shu, Y. (2021). Numerical study on effect of ambient humidity variation on self-heating and spontaneous ignition of the eucalyptus bark pile. *Fire Technology*, *57*, 1803-1825.

Glushkov, D.O., Kuznetsov, G.V., Tabakaev, R.B., Altynbaeva, D.B., & Nigay, A.G. (2020). Kinetic properties of gas-phase combustion of gel fuels based on oil-filled cryogels. *Thermochimica Acta*, *686*, 178553.

Hrusovsky, I. (2014). *Investigation of Self-Heating And Spontaneous Ignition Of Oils*. Dresden: IFW Dresden

Korchak, M., Bragin, O., Petrova, O., Shevchuk, N., Strikha, L., Stankevych, S., ... & Petukhova, O. (2022). Development of transesterification model for safe technology of chemical modification of oxidized fats. *Eastern-European Journal of Enterprise Technologies*, *6*(6), 120.

Krigstin, S., Helmeste, C., Jia, H., Johnson, K. E., Wetzel, S., Volpe, S., ... & Ferrero, F. (2019). Comparative analysis of bark and woodchip biomass piles for enhancing predictability of self-heating. *Fuel*, 242, 699-709.

Kuznetsov, Y.I., Chirkunov, A.A., & Semiletov, A.M. (2019). Progress in the inhibition of metal corrosion and the prospects of its use in the oil and gas industry. *International Journal of Corrosion and Scale Inhibition*, *8*(4), 850-881.

Mosiewicki, M.A., Casado, U., Marcovich, N.E., & Aranguren, M.I. (2009). Polyurethanes from tung oil: polymer characterization and composites. *Polymer Engineering & Science*, *49*(4), 685-692.

Prakash, K., Naik, S.N., & Yadav, U. (2020). Effects of Sesame Seed Oil (Black/White) as a Natural Antioxidant on the Oxidative and Frying Stability of Linseed Oil. *European Journal of Nutrition & Food Safety*, *12*(11), 133-146.

Sheng, C., Yao, C. (2022). Review on self-heating of biomass materials: understanding and description. *Energy & Fuels*, *36*(2), 731-761.

Symoniuk, E., Ratusz, K., & Krygier, K. (2016). Comparison of the oxidative stability of linseed (*Linum usitatissimum* L.) oil by pressure differential scanning calorimetry and Rancimat measurements. *Journal of Food Science and Technology*, *53*, 3986-3995.

TCVN 6122:2015(ISO 3961:2013) on animal and vegetable fats and oils – Determination of iodine index.

Tuman, S.J., Chamberlain, D., Scholsky, K.M., & Soucek, M.D. (1996). Differential scanning calorimetry study of linseed oil cured with metal catalysts. *Progress in Organic Coatings*, *28*(4), 251-258.

Wu, X., Bian, X., Lin, E., Wang, H., Guo, Y., & Tan, X. (2021). Weighted multiscale support vector regression for fast quantification of vegetable oils in edible blend oil by ultraviolet-visible spectroscopy. *Food Chemistry*, *342*, 128245.

Xie, T., Wei, R., Wang, Z., & Wang, J. (2020). Comparative analysis of thermal oxidative decomposition and fire characteristics for different straw powders via thermogravimetry and cone calorimetry. *Process Safety and Environmental Protection*, *134*, 121-130.

Zeng, J., Xiao, T., Ni, X., Wei, T., Liu, X., Deng, Z. Y., & Li, J. (2022). The comparative analysis of different oil extraction methods based on the quality of flaxseed oil. *Journal of Food Composition and Analysis*, *107*, 104373.