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# DETERMINATION OF THE SHELF LIFE OF SUNFLOWER OIL USING THE OXITEST INSTRUMENT

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**Abstract.** Sunflower oil is a strategically important product for Ukraine. One of the main issues affecting its quality during transportation and storage remains peroxide oxidation. Establishing minimum shelf lives is a key step in ensuring stable quality and safety of sunflower oil throughout all stages of the production and logistics chain. This article discusses modern approaches to assessing the oxidative stability of oils, in particular, the instrumental method of accelerated sample aging using the Oxitest device. It has been shown that traditional chemical methods, such as determining peroxide and anisidine values, are labor-intensive and require the use of reagents, which limits their suitability for rapid quality control. To optimize oil quality monitoring during storage, the effectiveness of a kinetic approach based on the Arrhenius and Eyring equations was investigated. For unrefined sunflower oil, induction periods were determined using OXISoft™ software and used to describe the kinetics, as well as to calculate the oxidation reaction rate constants at temperatures of 363, 373, and 383 K. Based on the temperature dependence of ln k versus 1/T, the activation energy (84.99 kJ/mol) and pre-exponential factor were calculated. The dependence of ln (k/T) on 1/T was used to determine thermodynamic parameters: enthalpy (81.85 kJ/mol), entropy (−41.28 J/(K·mol)), and Gibbs free energy, the values of which increased with temperature, confirming the non-spontaneous nature of the reaction. It was shown that increasing the temperature from 288 to 298 K leads to an increase in the oxidation rate and a reduction in the shelf life of oil samples, calculated based on the dependence of log IP on T. The obtained results confirm the feasibility of using the Oxitest instrument in combination with kinetic analysis for rapid, reagent-free, and environmentally safe assessment of the oxidative stability of oils, which is promising for modeling the minimum shelf life of oil-based products.

**Keywords:** sunflower oil, Oxitest, oxidation, rate constant, kinetics, shelf life.

## Introduction. Formulation of the problem

Sunflower oil is one of the most common vegetable fats, widely used in cooking, cosmetology, and the food industry. Its nutritional value and health benefits have been confirmed by numerous studies [1–5]. Sunflower oil is rich in polyunsaturated fatty acids, particularly ω-6, vitamin E, and other biologically active components that contribute to maintaining a normal blood lipid profile and reducing the risk of cardiovascular diseases. For Ukraine, sunflower oil is a traditional and strategically important product. The country is among the world leaders in its production and export. More than 5–6 million tons of oil are supplied annually to over 120 countries, accounting for about 50% of global exports and playing a significant role in contributing to the state budget. In the 2023/24 marketing year (MY), production and export volumes reached 6.6 and 6.2 million tons, respectively, exceeding the figures of certain pre-war periods. This significant growth was achieved due to the active processing of sunflower seeds in the domestic market – 14.8 million tons were processed. The main export destination for Ukrainian sunflower oil in the 2023/24 MY was the European Union, to which almost 3.7 million tons of the product were shipped – 43% more than in the previous season. This partially offset the decline in supplies to such countries as Turkey, India, and China.

Despite the high production and export figures, peroxide oxidation remains an important issue affecting the quality of sunflower oil during transportation and storage – a process that limits its shelf life. During oxidation, degradation products accumulate, which negatively affect the taste, odor, and most importantly, the safety of the oil. Due to increased quality requirements and prolonged storage conditions, sunflower oil producers are actively seeking effective, rapid, and reliable methods for assessing its oxidative stability in order to predict the minimum shelf life.

The degree of oil oxidation is traditionally determined using classical chemical methods, such as the determination of peroxide and anisidine values. The peroxide value allows for the monitoring of primary oxidation products (peroxides), while the anisidine value indicates secondary oxidation products. However, these methods have several limitations, as they require significant time and the use of chemical reagents. As an alternative, modern instrumental methods that simulate the accelerated aging of samples are increasingly being used, allowing for a significant reduction in research time. One of the promising methods is *Oxitest*, which provides automated and environmentally safe assessment of oxidative stability without the use of toxic substances. Its principle of operation is based on recording the absolute change in oxygen pressure in a sealed thermostated chamber as a result of the reaction between oxygen and unstable oil components. This allows for accurate and objective assessment of the product's susceptibility to oxidation, determination of the induction period – a key parameter that characterizes the time until the onset of intensive oxidative degradation of lipids – and obtaining reliable data for further shelf-life prediction under different temperature conditions.

Based on the above, the determination of lipid oxidative stability and, consequently, the establishment of minimum shelf life are key steps in ensuring the quality and safety of sunflower oil at all stages of its storage, transportation, and distribution.

## Analysis of recent research and publications

The minimum shelf life of oil can be determined using either a direct or an indirect approach. The direct approach is based on monitoring changes in the product under normal storage conditions throughout its entire life cycle. Within this approach, samples are periodically analyzed until signs of spoilage appear. In contrast, the indirect approach relies on predicting shelf life by studying the behavior of the product under accelerated aging conditions (*Accelerated Shelf Life Testing,* ASLT), most often at elevated temperatures, since the reaction rates increase exponentially with temperature [6, 7]. Based on experimental data, kinetic equations describing oil oxidation can be obtained, as well as the parameters of the Arrhenius model, which evaluates the effect of temperature on the oxidation rate. The combined extrapolation of descriptors enables the prediction of the oil's shelf life under various temperature conditions [6, 8]. This method significantly reduces research time, which is especially important for products with a long shelf life [9].

Numerous scientific sources present a wide range of studies on determining the shelf life and storage conditions of oils. The aim of study [10] was to assess the oxidative stability of choiba oil (*Dipteryx oleifera Benth*.) at a temperature of $100 \pm 1$ ºC with aeration (1150 mL of air/min) in the presence of rosemary extract (*Rosmarinus officinalis L*.) at concentrations of 1000 mg/L (RE1000) and 1500 mg/L (RE1500), as well as the synthetic antioxidant butylated hydroxytoluene (BHT) at a concentration of 200 mg/L. Based on the obtained data, the oxidation kinetics and shelf life of choiba oil were evaluated under storage conditions at 35 ºC, 45 ºC, and 55 ºC without antioxidants (control) and with the addition of the established optimal concentration of rosemary extract. Oxidative changes were determined using the peroxide value. The study showed that the use of rosemary extract at a concentration of 1500 mg/L was more effective in inhibiting the formation of primary oxidation products compared to BHT. Based on the relationship between antioxidant concentration (including the control) and changes in peroxide value, the kinetic parameters of oxidation were determined and the shelf life of choiba oil was modeled under real and accelerated storage conditions using the Arrhenius equation. It was shown that the oxidation process of the oil follows a first-order kinetic model with respect to the peroxide value. The rate of hydroperoxide formation was dependent on storage temperature and followed the Arrhenius equation, with an activation energy of 4611.5 J/mol for the control sample and 7409.6 J/mol for the sample with RE1500.

In work [11], the application of a kinetic model was proposed to describe the oxidation rate of oil from red fruit (*Pandanus conoideus*) as a function of time at a fixed temperature. This oil is characterized by a high content of unsaturated fatty acids, which causes its susceptibility to intensive oxidation during storage. To assess stability, oil samples were stored at temperatures of 60 ºC, 75 ºC, and 90 ºC for 15 days, determining the content of free fatty acids and peroxide value. The results of the study showed that increasing temperature and storage duration led to a decrease in oil quality. The accumulation of free fatty acids and increase of peroxide value occurred according to zero-order kinetics with activation energy values of 43318 J/mol·K for free fatty acids and 29437 J/mol·K for primary oxidation products. The shelf life estimation of the oil, based on the dynamics of changes of acid and peroxide values, was carried out using the kinetic equations developed by the authors.

In study [12], the use of a kinetic approach for assessing quality changes of oil from pangasius fish (*Pangasius*) during thermal loading is presented. This oil is distinguished by a significant content of

unsaturated fatty acids, which are characterized by high reactivity and instability during thermal processing. To analyze oxidation stability, samples were heated at temperatures of 70 ºC, 80 ºC, and 90 ºC for 15, 30, 45, 60, and 75 minutes. The study included determination of peroxide and acid values. It was established that increasing temperature and heating duration were accompanied by an increase in the content of primary oxidation products and the level of free fatty acids. The rate of degradation processes was characterized by activation energy values: 111.433 kJ/mol for peroxides and 83.971 kJ/mol for free fatty acids. The obtained data indicate that thermal processing promotes oxidative degradation of pangasius oil, which negatively affects its quality and safety.

The conduction of the above-mentioned studies [6–12] is accompanied by high labor intensity and a significant volume of experimental work within tight timeframes, which is due to the necessity of multiple determinations of the peroxide value at short time intervals in order to construct a linear dependence according to the Arrhenius equation.

However, oxidative stability of oil can be evaluated not only by chemical methods, such as determination of peroxide value, but also by instrumental approaches. In this context, the official method for determining the oil stability index recommended by the American Oil Chemists' Society involves the use of various analytical instruments. Among these are *Rancimat* and *Oxitest*. The assessment of oxidative stability by the *Rancimat* method is based on recording the increase in conductivity of an aqueous solution caused by the transfer of volatile oxidation products from the sample by an air flow, whereas the *Oxitest* method involves determining the induction period by measuring changes in oxygen pressure in a closed chamber during sample oxidation, which helps to avoid operational errors. The aim of study [13] was to determine the induction period of 15 frying oil samples using two accelerated oxidation methods – *Oxitest* and *Rancimat*. In study [14], the oxidative stability of olive oils was investigated using the *Oxitest* and *Rancimat* methods within a temperature range of 90–160 ºC. Kinetic analysis allowed determination of activation energies according to Arrhenius, enthalpy, entropy, Gibbs free activation energy, temperature coefficients, $Q_{10}$ factors, and oxidative stability indices at 20 ºC for different samples. Linear regression analysis showed a high correlation between results obtained both in study [13] and [14] ($R^2 = 0.996$). At the same time, the *Oxites*t method provided shorter induction periods and required smaller sample amounts, indicating its efficiency as a faster alternative for evaluating oxidative stability of oils. Thus, the researchers concluded that *Oxitest* is a simple, fast, and environmentally safe alternative to the official *Rancimat* method for determining the oxidative stability of oil- and fat-containing products.

The authors of study [15] focused on evaluating the effectiveness of the *Oxitest* device for studying the oxidation kinetics of soybean oil at different storage temperatures, as well as analyzing the correlation between results obtained by the *Oxitest* method and data from traditional chemical determination of peroxide value. The research established that the increase in peroxide value and the decrease in induction period duration followed zero-order kinetics at all storage temperatures of the oil. Based on the obtained data, reaction rate constants for each temperature, Arrhenius equation parameters, and the $Q_{10}$ index were calculated. The high degree of correlation between the two methods confirmed that *Oxitest* is a reliable alternative to traditional methods for assessing the oxidative stability of oils.

In studies [16, 17], the authors aimed to investigate the effectiveness of the *Oxitest* device as a modern screening tool for determining the stability of lipids in finished food products. The objects of the study were bakery products – taralini and breadsticks – enriched with powder from grape pomace. It was established that the *Oxitest* device allows for the assessment of oxidative stability of liquid, solid, and paste-like food products without prior lipid extraction and with minimal sample preparation. *Oxitest* demonstrated good repeatability of results (coefficient of variation <5%), confirming its reliability for screening lipid oxidation resistance in complex food matrices, particularly in bakery products. At the same time, the authors emphasized the need for further research to expand the method's applications.

Study [18] is devoted to investigating the potential use of *Oxitest* as a tool for predicting the shelf life of oils. The induction period of pressed oils from nuts (almond, peanut, pecan, walnut, pine nuts) and seeds (black sesame, white sesame, camellia, golden flaxseed, pumpkin, sunflower) was determined using the *Oxitest* method at temperatures of 70 ºC, 90 ºC, and 100ºC. Based on the obtained data, extrapolation was performed to calculate shelf life under room temperature storage conditions.

Oxidative rancidity is the primary cause of quality loss in oils and fats during storage, leading to the development of unpleasant off-flavors and the formation of compounds potentially harmful to health. At the initial stages, the rate of lipid oxidation remains low because free radicals are neutralized by natural or added synthetic antioxidants. Gradually, the antioxidant content decreases until complete depletion, after which intensive oxidation of the food matrix begins. The oxidative stability of fats is usually characterized by the induction period – the time during which oxidation proceeds slowly or remains nearly unchanged under certain conditions. Given the critical role of oxidative processes in the deterioration of oil and fat quality, the development of rapid and reliable methods for assessing their oxidative stability is highly relevant. Over the past decade, scientific interest in studying the shelf life of vegetable fats, particularly their behavior under oxidative testing conditions, has increased. Although the analysis of chemical changes during long-term

storage provides accurate results, it remains labor-intensive and time-consuming. Assessment can be accelerated by applying accelerated aging methods at elevated temperatures; however, these also require significant resources. Instrumental methods are more efficient in this regard. The *Oxitest* device serves as a simple, rapid, and environmentally safe alternative to the official *Rancimat* method for determining the oxidative stability of products containing oils and fats. At the same time, the scientific literature lacks sufficient studies dedicated to predicting the shelf life of oils using the *Oxitest* device. Therefore, conducting relevant research to develop an effective tool for predicting the shelf life of oils, particularly sunflower oil, to prevent errors in determining their compliance with safety and quality standards, is a timely and important task.

**The purpose** of this work is to:

- investigate the oxidative stability of unrefined sunflower oil at temperatures of 363, 373, and 383 K using the *Oxitest* device;
- determine the kinetic parameters of the oxidation reaction of unrefined sunflower oil;
- develop an equation that reliably describes the kinetics of oxidation of unrefined sunflower oil;
- determine the thermodynamic parameters of the oxidation reaction of unrefined sunflower oil;
- evaluate the shelf life of the studied oil.

## Research materials and methods

The following materials were used for the research: unrefined sunflower oil according to DSTU 4492:2017 Sunflower oil. Specifications.

The deterioration of oil quality can lead to its spoilage and reduction of shelf life. Monitoring such changes is possible through the analysis of chemical reactions occurring during storage, taking into account their mechanism and rate. For this purpose, it is appropriate to use kinetic models, in particular the Arrhenius equation in its logarithmic form, which allows describing the dynamics of oil quality changes depending on time and temperature [9]:

$$\ln k = \ln A - (\frac{E_a}{R \cdot T}), \quad (1)$$

where $k$ – rate constant or the inverse value of oxidation induction time, $h^{-1}$; $A$ – pre-exponential factor, $h^{-1}$; $Ea$ – activation energy, J/mol; $R$ – universal gas constant (8.314510 J/(K·mol)); $T$ – temperature, K.

This approach allows for a comprehensive assessment of the impact of hydrolytic and oxidative processes on oil stability during storage and provides a sound basis for determining the minimum shelf life.

To characterize the oxidation kinetics of the oil depending on temperature, this study used the induction period (IP) – the time during which the sample retains resistance to autocatalytic oxidation under conditions of elevated temperature and oxygen pressure.

Oxidative stability of the oil samples was determined using the *Oxitest* device (*Velp Scientifica*, Italy). The *Oxitest* method is a rapid analytical tool used to assess the oxidative stability of fats without prior extraction of the fat fraction under accelerated aging conditions. Thanks to the efforts of *VELP Scientifica*, which developed the device and methodology in collaboration with universities and research institutions, this method has been recognized as an international standard procedure by AOCS (Cd 12c-16). It is included in the "Official Methods and Recommended Practices of AOCS" (7th edition) [19]. The study and determination of induction periods and kinetic parameters of oxidation were conducted at temperatures of 363, 373, and 383 K and an oxygen pressure of 6 bar. The selected temperature range corresponds to the recommendations of the *Oxitest* device manufacturer and the nature of the sample. The experiments were carried out in two independent thermostatic chambers, each loaded with 5.0 g of sample, hermetically sealed, and heated to the set temperature. After oxygen was introduced to the established pressure, changes in pressure during the oxidation process of the sample were recorded in real time. Data processing was performed using the OXISoft™ software (*Velp Scientifica*, Italy). The pressure-versus-time curve, which is automatically generated and has an *S*-shaped form, allowed for the determination of the IP by a graphical method – through constructing tangents to the curve before and after the inflection point. The intersection of these tangents was projected onto the time axis, yielding a numerical value of the induction period. At the specified temperatures, the reaction rate constants, $k$, were calculated as the inverse values of the induction period duration. This approach is based on the assumption that lipid oxidation in the presence of excess oxygen, characteristic of *Oxitest* and *Rancimat*, is described as a first-order exothermic process [20].

Having determined the rate constants, $k$, within the selected temperature range, the activation energy, $Ea$, and the pre-exponential factor, $A$, were calculated from the graphical correlation between ln $k$ and $1/T$ [11, 15, 17].

Using basic kinetic approaches and the Arrhenius equation, an equation was obtained that describes the oxidation kinetics of the oil and allows determining the rate constant of oxidative deterioration, $k$, at any temperature:

$$k = A \cdot e^{\frac{-E_a}{RT}}, \quad (2)$$

The enthalpy, $\Delta H$, and entropy, $\Delta S$, of the oxidation reaction were determined by regression analysis of the dependence of ln ($k/T$) on $1/T$ according to the logarithmic form of the Eyring equation:

$$\ln\left(\frac{k}{T}\right) = \frac{-\Delta H}{R} \cdot \frac{1}{T} + (\ln\left(\frac{k_b}{h}\right) + \frac{\Delta S}{R}), \quad (3)$$

where $k_b$ – Boltzmann constant ($1{,}380649 \cdot 10^{-23}$ J/K); $h$ – Planck constant ($6{,}62607015 \cdot 10^{-34}$ J·s); $\Delta H$ – activation enthalpy, J/mol; $\Delta S$ – activation entropy, J/(K·mol).

Gibbs free energy, $\Delta G$, was calculated using the relationship between $\Delta H$, $\Delta S$, and temperature $T$:

$$\Delta G = \Delta H - \Delta S \cdot T, \quad (4)$$

The minimum shelf life of the oil was estimated based on the IP values determined by the *Oxitest* method at temperatures of 363, 373, and 383 K. The first-order oxidation kinetics equation for any temperature is as follows [18]:

$$\log \text{IP} = \log \text{IP}_0 - k_0 \cdot T, \quad (5)$$

where $\log \text{IP}_0$ – initial value IP, h; $k_0$ – temperature coefficient of IP, $K^{-1}$.

The minimum shelf life, IP of unrefined sunflower oil at temperatures of 288, 293, and 298 K was determined using the equation:

$$\text{IP} = \text{IP}_0 \cdot 10^{(-k_0 \cdot T)}, \quad (6)$$

The temperature acceleration coefficient, or $Q_{10}$ value, which characterizes how many times the reaction rate increases with a 10 ºC or 10 K temperature rise, was calculated using the equation:

$$Q_{10} = 10^{-10 \cdot k_0}, \quad (7)$$

where $k_0$ – temperature coefficient of IP, $K^{-1}$.

Mathematical methods of the Microsoft Excel software package environment were applied for data processing

## Results of the research and their discussion

To extrapolate the minimum shelf life under storage conditions of 15–25 °C (288, 293 та 298 K), the first stage involved determining the induction period of unrefined sunflower oil using the *Oxitest* device in the temperature range of 363–383 K with 10 K intervals. Using the OXISoft™ software (*Velp Scientifica*, Italy), automatic modeling of the *S*-shaped kinetic curves of the oil oxidation process was performed at the respective temperatures. Drawing tangents to the exponential sections of the curves and subsequently projecting the intersection point onto the time axis allowed for the determination of numerical values of the oil's induction period depending on temperature. Based on the obtained induction period values, the rate constants of the oxidation reaction were calculated as their reciprocal values. The corresponding data are presented in Table 1.

**Table 1 – Kinetic parameters of the oxidation reaction of unrefined sunflower oil**

| Temperature, K | Induction period, h | Rate constant, $h^{-1}$ |
|---|---|---|
| 363 | 11.82 | 0.084602 |
| 373 | 5.17 | 0.193424 |
| 383 | 2.72 | 0.367647 |

The results presented in Table 1 confirm the influence of temperature on the intensity of oxidative processes in unrefined sunflower oil: as the temperature increases, the rate constants of the reaction increase, indicating an acceleration of lipid oxidation and, consequently, a decrease in the induction period, which is consistent with the findings of study [21].

Based on the kinetic data presented in Table 1, the Arrhenius plot (ln *k* versus 1/*T*) was constructed and is shown in Fig. 1. The slope of the resulting line was used to calculate the activation energy, while the intercept with the ordinate axis was used to determine the pre-exponential factor. The high coefficient of determination ($R^2 > 0.99$) confirms the reliability of the obtained results.

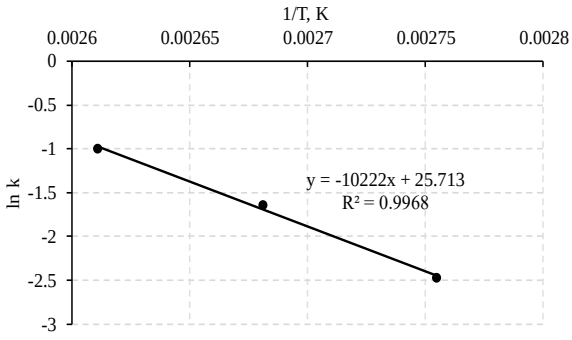


**Fig. 1. Dependence of the logarithm of the reaction rate constant on the reciprocal temperature in Arrhenius plot coordinates**

The obtained dependence allows extrapolating the values of the reaction rate constant over an extended temperature range. Based on this graphical dependence and taking into account equation (1), a kinetic equation for the oxidation process of the studied oil was formulated:

$$\ln k = 25.713 - (\frac{10222}{T}), \quad (8)$$

which can, based on equation (2), be written as:

$$k = 1.47 \cdot 10^{11} \cdot e^{\left[-\frac{84991}{RT}\right]}, \quad (9)$$

From equation (8), the pre-exponential factor and activation energy – the minimum energy required to initiate any reaction – were determined. The obtained results are consistent with literature data on activation energy for oils, which range from 79 to 104 $kJ \cdot mol^{-1}$ [18]. Using equation (9), rate constants were calculated for temperatures of 288, 293, and 298 K. Enthalpy and entropy were calculated by regression analysis of the dependence of ln(*k*/*T*) on 1/*T* (Fig. 2), according to equation (3), as well as the Gibbs free energy of the reaction based on equation (4).

The minimum shelf life, IP, of unrefined sunflower oil at temperatures of 288, 293, and 298 K was determined using equation (6), where $k_0$ and $\log \text{IP}_0$ were established from the graphical dependence of

equation (5), shown in Fig. 3. Using equation (7), the temperature acceleration coefficient of the oxidation reaction was calculated. The calculation results are presented in Table 2.

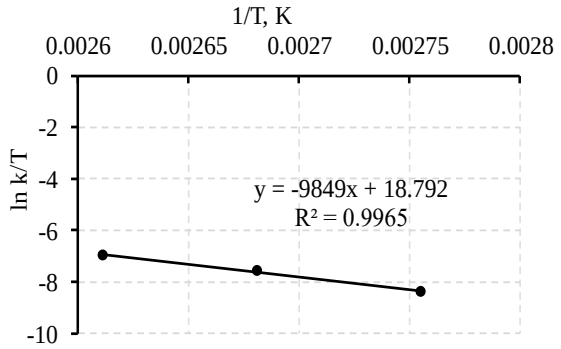


**Fig. 2. Dependence of ln(*k*/*T*) on the inverse temperature in the coordinates of the Eyring equation**

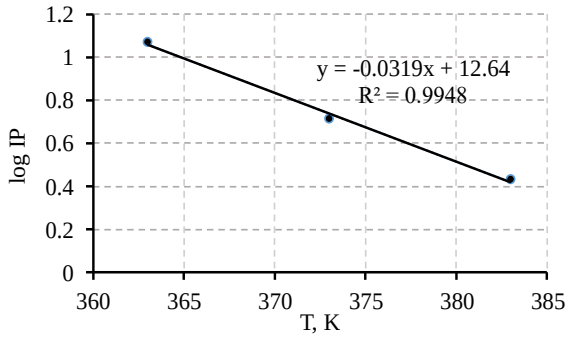


**Fig. 3. Dynamics of the change in the logarithm of the oil oxidation induction period depending on temperature**

In Fig. 3, within the specified temperature range, a high linearity of the dependence between the logarithm of the IP and temperature was observed, indicating the preservation of the oxidation mechanism under elevated temperature conditions. This allows considering the *Oxitest* method, based on oxygen consumption monitoring, as effective for rapid assessment of oil shelf life.

According to the results in Table 2, an increase in temperature from 288 to 298 K leads to a rise in the reaction rate constant from 0.0000566 to 0.0001861 $h^{-1}$, indicating an acceleration of the oxidation process. The activation energy, determined from the temperature dependence in the Arrhenius plot, was 84.99 kJ/mol. The activation enthalpy (81.85 kJ/mol) and activation entropy (–41.28 J/(K·mol)) were determined from the dependence of ln(*k*/*T*) on 1/*T*. The positive value of enthalpy indicates that the process is endothermic, which has also been noted during oil oxidation [22]. The negative value of activation entropy suggests a high degree of order in the transition state. Moreover, the negative entropy combined with positive enthalpy is a sign of a non-spontaneous reaction [23]. Changes in Gibbs free energy during oxidation were positive, confirming the non-spontaneous nature of the oxidation reaction. The Gibbs free energy values increased with rising temperature (from 93.73 to 94.15 kJ/mol), which correlates with a decrease in shelf life from 118 to 57 days. The value of the temperature acceleration coefficient $Q_{10}$ (2.08) confirms the high sensitivity of the oxidation rate to temperature increase: a rise in temperature by every 10 K results in approximately a twofold acceleration of the process. This indicates the thermolability of the oil and necessitates strict control of storage temperature conditions to preserve its stability.

**Table 2 – Kinetic and thermodynamic parameters of the oxidation reaction of unrefined sunflower oil**

| Tempe-rature, K | Rate constant, $h^{-1}$ | A | Activation energy, kJ/mol | Activation enthalpy, kJ/mol | Activation entropy, J/(K·mol) | Gibbs energy, kJ/mol | Shelf life, days | $Q_{10}$ |
|---|---|---|---|---|---|---|---|---|
| 288 | 0.0000566 | $1.47 \cdot 10^{11}$ | 84.99 | 81.85 | -41.28 | 93.73 | 118 | 2.08 |
| 293 | 0.0001037 | | | | | 93.94 | 82 | |
| 298 | 0.0001861 | | | | | 94.15 | 57 | |

## Conclusion

1. The oxidation level of oils is typically determined using traditional chemical methods such as peroxide and anisidine values. However, these approaches have several limitations, including labor intensity and the need for chemical reagents. Consequently, modern instrumental methods that simulate accelerated aging of samples and significantly reduce analysis time are gaining increasing popularity. One promising tool of this type is the *Oxitest* device.

2. To assess changes in oil quality depending on temperature, it is appropriate to apply kinetic models, particularly the Arrhenius equation. This approach allows for a comprehensive analysis of the influence of hydrolytic and oxidative processes on oil stability during storage and provides a scientifically grounded determination of its minimum shelf life. The induction period, determined using the *Oxitest* device (*Velp Scientifi*ca, Italy), was used as the kinetic parameter to characterize oxidation. Based on the temperature dependence of the reaction rate constants, *k*, a plot of ln *k* versus 1/*T* was constructed, from which the activation energy, *Ea* (84.99 kJ/mol), and the pre-exponential factor, *A* ($1.47 \cdot 10^{11}$), were calculated. The linear nature of this dependence and the high coefficient of determination, $R^2$, confirm the consistency of the experimental data with the Arrhenius model.

3. A kinetic equation for the oxidation reaction of unrefined sunflower oil has been developed, enabling the determination of the rate constant, $k$, at various temperatures. Calculations were performed for temperatures of 288, 293, and 298 K, revealing that as temperature increases, the values of $k$ rise from 0.0000566 to 0.0001861 $h^{-1}$, indicating an acceleration of the oxidation process. From the dependence of $\ln(k/T)$ on $1/T$, the activation enthalpy, $\Delta H$ (81.85 kJ/mol), and activation entropy, $\Delta S$ (–41.28 J/(K·mol)), were determined. The enthalpy value indicates an endothermic oxidation mechanism. The negative entropy value reflects an ordered nature of the transition state. Together, these parameters confirm that the reaction is not thermodynamically spontaneous.

4. The Gibbs free energy values during oxidation were positive, confirming the non-spontaneous nature of the reaction. With an increase in temperature from 288 to 298 K, the $\Delta G$ values rose (from 93.73 to 94.15 kJ/mol), which correlates with a reduction in the predicted shelf life – from 118 to 57 days. The temperature coefficient $Q_{10}$ value (2.08) indicates a high sensitivity of the oxidation rate to temperature increase, necessitating strict control of storage conditions to prevent product quality deterioration. Therefore, the *Oxitest* device can serve as an effective tool for rapid, environmentally safe, and automated determination of oil shelf life without the use of toxic reagents..

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# ВИЗНАЧЕННЯ ТЕРМІНУ ПРИДАТНОСТІ СОНЯШНИКОВОЇ ОЛІЇ З ВИКОРИСТАННЯМ ПРИЛАДУ *OXITEST*

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**Анотація.** Соняшникова олія є стратегічно важливим продуктом для України. Однією з основних проблем, що впливає на її якість під час транспортування та зберігання, залишається пероксидне окиснення. Встановлення мінімальних термінів придатності є ключовим етапом у забезпеченні стабільної якості та безпечності соняшникової олії на всіх етапах виробничо-логістичного ланцюга. У статті розглянуто сучасні підходи до оцінювання окисної стабільності олій, зокрема інструментальний метод прискореного окиснення зразків із використанням приладу *Oxitest*. Показано, що традиційні хімічні методи, як визначення пероксидного та анізидинового чисел, є трудомісткими та потребують застосування реагентів, що обмежує їх придатність для оперативного контролю. З метою оптимізації процедури контролю якості олій у процесі зберігання досліджено ефективність кінетичного підходу на основі рівнянь Арреніуса та Ейрінга. Для нерафінованої соняшникової олії за допомогою програмного забезпечення OXISoft™ визначено індукційні періоди, які використано для опису кінетики, а також константи швидкості реакції окиснення при температурах 363, 373 та 383 К. На основі температурної залежності $\ln k$ від $1/T$ розраховано енергію активації (84,99 кДж/моль) та преекспоненційний множник. Залежність $\ln k/T$ від $1/T$ використано для визначення термодинамічних параметрів: ентальпії (81,85 кДж/моль), ентропії (-41,28 Дж/(К·моль)) та енергії Гіббса, значення якої зростали зі збільшенням температури, що підтверджує несамовільний характер реакції. Показано, що підвищення температури від 288 до 298 К супроводжується зростанням швидкості окиснення та скороченням терміну придатності зразків олії, що розраховано на основі залежності $\log IP$ від $T$. Отримані результати підтверджують доцільність використання приладу *Oxitest* у поєднанні з кінетичним аналізом для швидкої, безреагентної та екологічно безпечної оцінки окисної стабільності олій, що є перспективним для моделювання мінімального терміну придатності олійної продукції.

**Ключові слова:** соняшникова олія, *Oxitest*, окиснення, константа швидкості, кінетика, термін придатності.