

Oxidation stability assessment of food products demonstrated on chia seed derivatives



Dr. Carolin Edinger, Anton Paar GmbH

Oxidation is one of the main degradation processes affecting food quality and shelf life. In particular, the autoxidation of lipids and other oxidation-prone components of food products can generate compounds that can cause off-flavours, discoloration, loss of nutritional value, and reduced consumer acceptance. Understanding oxidation mechanisms and accurately assessing oxidation stability are therefore essential for product development and quality control.

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The oxidative stability of a food product is influenced by numerous factors, including the raw materials used, processing history, packaging system, and storage conditions. Because these interact in complex ways, manufacturers require analytical methods that can rapidly and reliably compare products, ingredients, formulations, and stabilisation strategies under controlled conditions.

Traditional oxidation stability methods often require long testing times and may involve extensive sample preparation, limiting their usefulness for rapid product development and routine quality control.

Anton Paar's RapidOxy 100 provides an efficient solution for accelerated and quick oxidation testing using a fully automatic Rapid Small-Scale Oxidation Test (RSSOT). The method determines oxidation stability by monitoring oxygen consumption in a closed measuring chamber under precisely controlled temperature and oxygen pressure conditions. A key advantage is its versatility: liquids, semi-solids, powders, seeds, raw materials, ingredients, supplements, and finished products can be analysed directly without any sample preparation regardless of sample consistency. This enables the investigation of products in their original state and allows oxidation stability to be assessed across a wide range of food matrices.

For deeper insights into the oxidative behaviour of food products, the OxyLogger 100 software provides advanced data evaluation tools, including automatic determination of oxidation induction times, comparison of oxidation curves, Arrhenius plot generation,

calculation of activation energy, and shelf-life estimation.

The following article demonstrates the capabilities of RapidOxy 100 using chia seed oil and chia seed samples as model systems. The studies illustrate how the method can be used to evaluate antioxidant effectiveness, investigate oxidation mechanisms, estimate shelf life, and assess the influence of physical product characteristics on oxidative stability.



Rapid small-scale oxidation test

Typical test conditions for a measurement using RapidOxy 100 range from 60°C to 140°C, with an initial oxygen pressure of 700 kPa. Under these conditions, oxidation is initiated and proceeds rapidly. During the test, the closed system continuously records the pressure decrease resulting from oxygen consumption of the sample until either a predefined pressure drop is reached or a specified test duration has elapsed. The result of a measurement is either the time required to reach a defined pressure drop or, alternatively, the magnitude of the pressure decrease within a fixed time period. Both results are directly related to the amount of oxygen consumed by the sample and therefore provide a reliable basis for assessing its oxidation stability.

A standard Rapid Small-Scale Oxidation Test (RSSOT) conducted according to ASTM D8206 – which is well suited for determining the oxidation stability of fats, oils, and various food samples – measures the induction period (IP). This is defined as the time elapsed from the start of the heating process until the breakpoint is reached, corresponding to a pressure decrease of 10 % below the maximum pressure (Figure 1). The underlying principle is straightforward: the longer the induction period, the higher the oxidative stability of the sample.

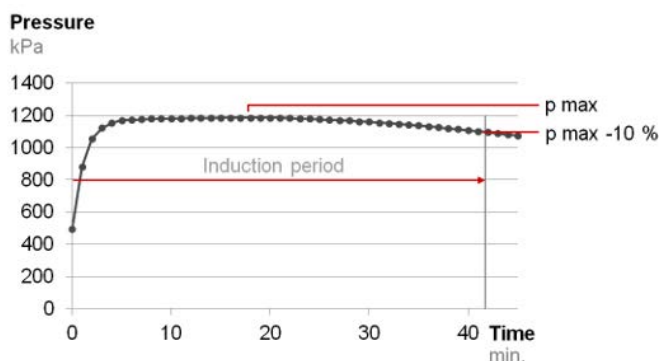


Figure 1: RSSOT (ASTM D8206) induction period, defined as time elapsed between starting the heating procedure of the sample pressure vessel and a pressure drop of 10% from p_{max} .

Compared with traditional oxidation stability methods, RSSOT provides substantially shorter analysis times. Instrument setup and post-test cleaning with RapidOxy 100 are simple and can in total be completed in less than five minutes. In addition, only small sample quantities are required (typically 5 mL or 1 g to 4 g), and samples can be analysed without prior preparation. These advantages enable direct investigation of products in their original state, facilitating realistic assessments of oxidation behaviour and shelf-life stability.

Investigating the influence of antioxidants demonstrated on chia seed oil

Chia seed oil is highly susceptible to oxidation, making the use of antioxidants generally necessary to achieve an acceptable shelf life. The effectiveness of individual antioxidants or antioxidant systems can be evaluated quickly and efficiently with RapidOxy 100 in simple screening experiments.

Whereas more oxidation-stable vegetable oils – such as rapeseed,

sunflower oil, and soybean oil – are typically analysed at 120°C, the present study was conducted at 100°C due to the lower oxidative stability of chia seed oil. Apart from the reduced test temperature, the standard conditions of RSSOT were applied: a sample volume of 5 mL, an initial oxygen pressure of 700 kPa, and a pressure-drop criterion of 10%.

To demonstrate the speed and effectiveness of RSSOT for antioxidant screening, the induction period (IP) of chia seed oil was determined with different antioxidants. Samples containing no antioxidant, 0.5% salvia fructose (SF), and 0.5% tocopherol were analysed at 100°C, with a pronounced difference in oxidation stability observed depending on the presence and type of antioxidant used.

The oxidation stabilities are illustrated in Figure 2, which presents the pressure-time curves obtained with RapidOxy 100. These results clearly demonstrate the suitability of RSSOT as a rapid screening tool for evaluating antioxidant performance in oxidation-sensitive oils.

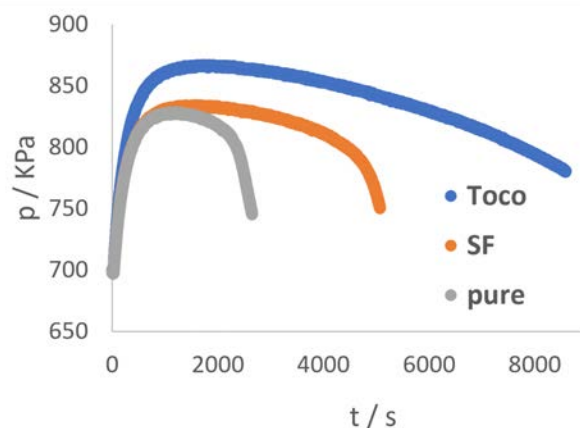


Figure 2: RSSOT screening the effect of antioxidants on chia seed oil. Blue pressure curve = 0.5 % tocopherol; orange pressure curve = 0.5 % SF, grey pressure curve = pure chia seed oil.

As expected, the lowest oxidation stability was observed for the untreated chia seed oil, which exhibited an induction period (IP) of 44 minutes. The addition of salvia fructose (SF) significantly improved the oxidation stability, increasing the IP to 1 hour and 25 minutes. However, tocopherol proved to be the most effective antioxidant, providing the greatest enhancement in oxidation stability and extending the IP to 2 hours and 23 minutes.

These results demonstrate the strong influence of antioxidant selection on the oxidative stability of chia seed oil and highlight the suitability of RSSOT as a rapid method for comparing antioxidant performance.

Oxidation induction time, Arrhenius dependency, and shelf-life estimation

The oxidation induction time (OIT) represents an additional evaluation parameter that can be derived from the pressure curve obtained with RapidOxy 100. This is characterised by a distinct change in the rate of pressure decrease during the measurement and is defined as the point at which this change in slope begins. Such a pressure-curve profile may occur when an antioxidant has been depleted or has lost its effectiveness, allowing oxidation of the previously protected material to proceed at an accelerated rate.

The OIT can be determined automatically using the OxyLogger 100 software. OxyLogger 100 applies tangents to the two sections of the pressure curve exhibiting different slopes and calculates the OIT from the intersection of these tangents. *Figure 3* illustrates this evaluation method for chia seed oil containing 0.5% SF.

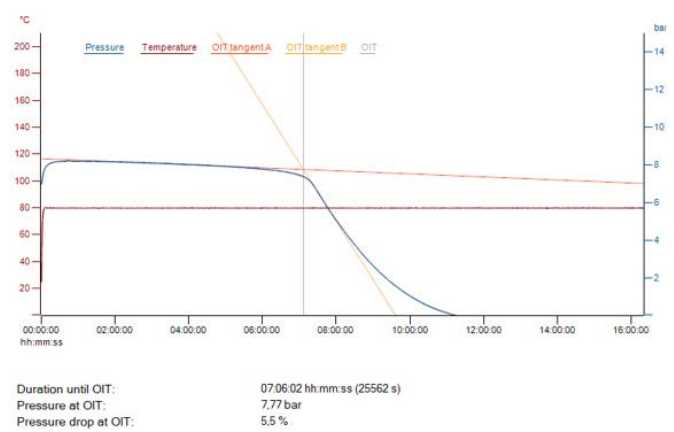


Figure 3: OIT determined automatically with the desktop software OxyLogger 100 for chia seed oil with 0.5% SF.

Another advantage of the method is that, for most samples, both the induction period (IP) and the oxidation induction time (OIT) exhibit an Arrhenius-type dependence on the measurement temperature. The corresponding Arrhenius plot can be generated automatically using the OxyLogger 100 software, providing additional insights into the oxidation behavior of the sample.

Based on the slope of the Arrhenius plot and other input parameters, the software automatically calculates the activation energy of the oxidation process. The software also enables shelf-life estimation of oils and fats under practical conditions by extrapolating the linear Arrhenius relationship to room temperature or other relevant temperatures, such as storage or transport conditions. *Figure 4* illustrates this approach using chia seed oil containing 0.5% SF. OxyLogger 100 automatically provides shelf-life estimates at 40°C, 25°C, and 20°C, with additional temperatures able to be entered as required. To obtain the most realistic predictions, the temperature sensitivity of the sample should be considered when selecting the measurement temperatures used for the Arrhenius evaluation. In general, lower test temperatures tend to yield more reliable shelf-life estimates because they more closely reflect the oxidation mechanisms occurring under actual storage conditions. For the relatively oxidation-sensitive chia seed oil examined in this study, for example, a measurement temperature of 120°C was found to be too high for generating realistic shelf-life predictions.

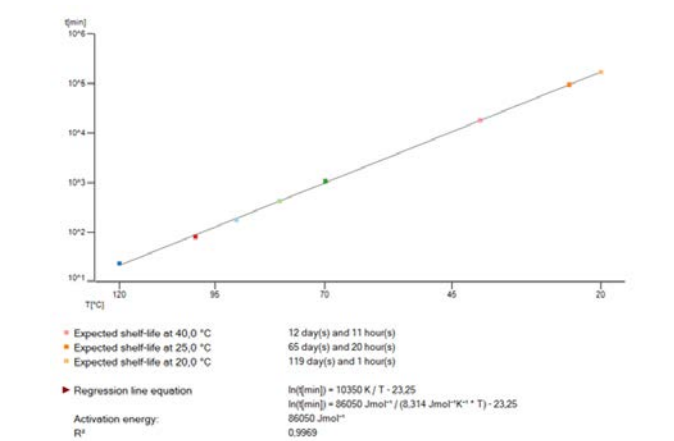


Figure 4: Shelf-life estimation of chia oil containing 0.5% Salvia fructosa using the OxyLogger 100 software.

When the results of the antioxidant screening are included in the shelf-life estimation, the method provides added value beyond the simple comparison of antioxidant performance. The predicted shelf lives of the samples investigated were:

- Pure chia seed oil: 12 days
- Chia seed oil containing SF: 105 days
- Chia seed oil containing tocopherol: 338 days

These results demonstrate the substantial impact of antioxidant addition on the expected shelf life of chia seed oil.

Investigating the oxidation stability of chia seed variations

A major advantage of RapidOxy 100 is its ability to analyse samples in their original state, regardless of their physical consistency. To demonstrate the applicability of the Rapid Small-Scale Oxidation Test (RSSOT), the oxidation stability of whole and ground chia seeds from different batches was investigated.

In this study, five different chia seed samples were analysed using two RapidOxy 100 instruments (Device 1 and Device 2, *Table 1*). Samples 1, 2, and 4 consisted of ground chia seeds, whereas samples 3 and 5 were analysed in their whole-seed form.

For each sample, two replicate measurements were performed on each instrument. This experimental design allowed the assessment of both repeatability and reproducibility of the oxidation stability measurements.

The induction period (IP) was determined at a test temperature of 100°C using 3 g of sample. To facilitate handling and minimise the time between sample preparation and measurement, the samples were placed in the measuring chamber using a glass sample dish.

Table 1: Results of the measurements for various chia seed samples.

Sample	Device 1 Run 1 [min]	Device 2 Run 1 [min]	Mean [min]
1	245.13 247.16	238.60 245.65	244.14
2	263.53 255.95	252.56 256.31	257.09
3	326.10 308.50	307.60 313.63	313.96
4	266.30 263.43	270.90 271.01	267.91
5	318.73 306.88	315.30 317.75	314.67

Because the induction period is directly related to oxidation stability, the following stability ranking was obtained:

$$1 < 2 < 4 < 3 < 5$$

The differences in oxidation stability are illustrated in *Figure 5* using the pressure curves from Device 1, run 1. The ranking indicates that the physical condition of the chia seeds, and consequently their exposed surface area, influences oxidation stability. As

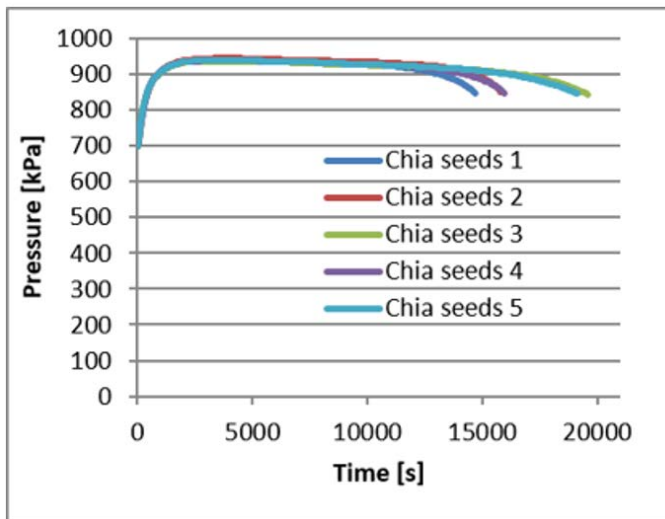


Figure 5: Pressure curve of the chia seed samples 1 to 5 (Device 1, run 1).

expected, Samples 3 and 5 exhibited the highest oxidation stability, demonstrating that oxygen uptake occurs more slowly in case of intact chia seeds. In contrast, Samples 1, 2, and 4 showed lower oxidation stability, indicating that grinding the seeds accelerates oxidation reactions by increasing the surface area exposed to oxygen.

Conclusion

The Rapid Small-Scale Oxidation Test (RSSOT) performed with RapidOxy 100 provides a fast, reliable, and most of all versatile method for evaluating the oxidation stability of oils, fats, and food products. Compared with conventional oxidation stability tests, RSSOT significantly reduces analysis time and requires

only small sample quantities with no sample preparation. The ability to analyse materials in their original state further enhances its applicability for realistic product characterisation and quality assessment.

The studies presented here demonstrate the broad analytical capabilities of the method. In chia seed oil, RSSOT enabled rapid screening of antioxidant performance, clearly differentiating the effectiveness of salvia fructose and tocopherol. The measured induction periods showed the substantial impact of the suitable antioxidant selection, with tocopherol providing by far the greatest stabilisation effect. Combining oxidation stability measurements with derived Arrhenius-based evaluations also enabled shelf-life estimation under practical storage conditions.

In addition to induction period determination, the evaluation of the oxidation induction time (OIT) provides further insight into oxidation processes and antioxidant depletion behaviour. Automated data analysis with the OxyLogger 100 software simplifies the determination of OIT, activation energy, Arrhenius relationship, and shelf-life predictions, extending the value of RSSOT beyond routine stability testing.

The investigation of whole and ground chia seeds highlighted the flexibility of the method. RSSOT successfully differentiated between samples with different physical characteristics based on their oxidative stability, demonstrating the influence of particle size and exposed surface area on oxidation behaviour. Whole chia seeds exhibited markedly higher oxidation stability than ground samples, confirming the importance of maintaining seed integrity during storage and processing.

Overall, the results demonstrate that RapidOxy 100 is a powerful tool for rapid oxidation stability assessment, antioxidant screening, product development, quality control, and shelf-life prediction. The combination of speed, ease of use, reproducibility, and comprehensive data evaluation makes it a highly valuable solution for both research and routine industrial applications in the food and edible oil sectors.