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Professional paper

EFFECT OF CELERY ADDITION ON THE OXIDATIVE STABILITY OF COLD-PRESSED RAPESEED OIL UNDER LIGHT AND DARK STORAGE CONDITIONS

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Abstract

Cold-pressed vegetable oils possess high nutritional benefits but are highly susceptible to oxidation due to their high content of unsaturated fatty acids and minimal processing. Oxidation of oils leads to rancidity and nutrient loss, which limits shelf life and compromises the quality. The aim of this study is to investigate the potential of celery (*Apium graveolens*), leaf and root, as natural antioxidants to enhance the oxidative stability of cold-pressed rapeseed oil during storage. The oil samples with added fresh celery leaf or celery root, were stored for one and two weeks in dark and light conditions. The rapeseed oils were stored in bottles with different oil volumes (1 L, 750 mL, 500 mL and 250 mL). In addition, control samples without celery addition were also prepared and stored under the same conditions to compare the effect of celery. Peroxide value (PV) was used to measure the oxidation. Statistical analysis using ANOVA was performed to check if the differences between the groups were significant. Results have shown that PV increased with the storage time in all samples. Oxidation was higher in oils exposed to light and stored in smaller volumes. Compared to the control oil samples, samples with celery addition showed lover peroxide values, especially when stored in dark and in larger oil volume bottles. Oils with celery leaf added have greater oxidative stability than oils with celery root added, in both dark and light storage conditions.

Keywords: rapeseed oil, oxidative stability, celery

1. Introduction

Cold-pressed rapessed oil (*Brasica napus* L.) has a good nutritional composition and is therefore highly valued and widely used in the diet. It contains important polyunsaturated fatty acids such as α-linolenic and linoleic acid (Mao et al., 2020; Symoniuk et al., 2018). These oils contain bioactive compounds that improve health such as tocopherols, phenols, and phytosterols (Szydlowska-Czerniak, A., 2013; Rekas et al. 2017; Wroniak et al., 2008). However, because these oils are not refined and contain high amounts of polyunsaturated fatty acids, they are very unstable. They are subject to oxidation, processes during which they break down and produce many harmful products such as peroxides, aldehydes, and ketones. Due to these undesirable processes, their nutritional quality and shelf life are reduced (Grebenteuch et al., 2021; Redondo-Cuevas et al., 2019).

The oxidation of oils is greatly influenced by light, oxygen, temperature and trace metals (Staroselska et al., Ocieczek et al., 2020). To reduce and prevent oxidation of oils, natural and artificial antioxidants are added to them. Butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) are synthetic antioxidants that, although widely used, have potentially negative effects on human health. Today, the use of natural antioxidants that are a component of plants is increasingly preferred (Nieto et al., 2023; Brewer, 2011; Antonczyk et al., 2023).

Various herbs and spices such as rosemary, garlic, savory, parsley, and celery contain antioxidants that can be very effective in reducing the oxidation of oils. Rosemary, for example,

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contains carnosic acid and carnosol, which have a high ability to neutralize free radicals (Brewer, 2011; Redondo-Cuevas et al., 2019). These compounds have shown great efficacy in reducing oxidation in cold-pressed oils for periods of up to three weeks, maintaining the peroxide value within recommended limits (Temelkovska&Pavlovska, 2021). Garlic, which contains sulfur compounds such as allicin and diallyl sulfide, has shown an even stronger effect in stabilizing lentil oil during storage for four weeks, completely preventing the formation of peroxides (Eftizjijoska & Pavlovska, 2019; Temelkovska et al., 2024). Temelkovska et al., (2023) and Pavlovska et al., (2022) observed that parsley and mint also significantly reduce oxidation, but have lower efficacy compared to garlic and rosemary.

Celery (Apium graveolens), which is often used to enhance the flavor of food due to its aromatic components, has strong antioxidant, anti-inflammatory, and antimicrobial properties. This plant contains flavonoids such as apigenin and luteolin, phenolic acids such as caffeic and chlorogenic acids, and essential oils containing limonene and selenene, which are known for their ability to scavenge free radicals such as peroxides (Nieto et al., 2023; Embuscado, 2015; Kooti & Daraei, 2017). The oxidative stability of cold-pressed rapeseed oil is influenced by the antioxidants present in the oil itself and the antioxidants added through the addition of various herbs and spices (Symoiniuk et al., 2018; Seppanen et al., 2010). Studies have shown that the volume of the container and the duration of storage also affect the oxidation of oils. Smaller volumes oxidized more easily and contained more peroxides due to increased exposure to oxygen. This was observed in various oils when different herbs such as rosemary, savory, and garlic were added (Temelkovska et al., 2024; Pavlovska et al, 2022; Temelkovska & Pavlovska, 2021). Adding different herbs also changed the flavor of the oils. Sensory analyses showed that oils with rosemary and garlic had better sensory characteristics than oils containing parsley and mint (Temelkovska et al., 2023). For better understanding how the celery influence oxidation, control samples of rapeseed oil without celery were included in this study. These helped to measure the baseline oxidation and compare it with the oils with added celery leaf or root.

The aim of this research is to determine the oxidative stability of cold-pressed rapeseed oil with celery leaf and root added under different storage conditions. Oils were stored under light and dark conditions and in different bottle volumes. Peroxide value was used as the primary indicator of oxidation during a 2-week storage period. This work contributes to the growing field of natural antioxidants in oil preservation, giving the accent to how storage time and conditions affect the antioxidant potential of celery. In this study statistical analysis using one way ANOVA and Tukey HSD (Honestly significant difference) test was used to confirm whether the observed differences in peroxide values between the oils with celery addition and control group (oils without addition) were statistically meaningful.

2. Materials and Methods

Sample Selection and Preparation

Rapeseed oil from the producer “Fila” was used in this study. A total of sixteen 1-liter bottles of oil were prepared. In four of these bottles, the full 1-liter volume of oil was retained. In the remaining twelve bottles, specific amounts of oil were removed to obtain volumes of 750 mL, 500 mL and 250 mL (four bottles per volume).

In addition, eight more bottles were prepared as control samples without celery. These control samples were with same oil volumes (1 L, 750 mL, 500 mL and 250mL). Half of these control bottles were stored in light conditions and the rest were stored in dark for 1 and 2 weeks.

The rest of the bottles were divided equally between two treatments: eight bottles enriched with 20 grams of fresh celery leaf and eight bottles enriched with 20 grams of fresh celery root, allowing a comparative analysis of the antioxidant effects of each plant part. The bottles of

celery leaf and celery root oils were further divided based on storage conditions. Four bottles of celery leaf oils and four bottles of celery root oils (with volumes of 1L, 750 mL, 500 mL and 250 mL) were stored in the light, and four bottles of celery leaf and celery root oils were stored in the dark. The peroxide value (PV) indicates the amount of primary oxidation products, namely peroxides and hydroperoxides, present in the edible oil. Therefore, the determination of PV determines the oxidative stability of the oils, i.e. its quality during storage (Popa et al., 2017; Ali et al., 2022). The PV values in this study were determined using the standardized method AOCS Cd 8-53 (Eftinzjijoska, 2020). The PV of the oils was determined for all oils after one and two weeks of storage.

Statistical analysis

For statistical comparison, analysis of variance (ANOVA) was used. Analysis of variance (ANOVA) is a statistical tool used to detect differences between experimental group means. ANOVA is warranted in experimental designs with one dependent variable that is a continuous parametric numerical outcome measure, and multiple experimental groups within one or more independent (categorical) variables (Sawyer, 2009).

The statistical analysis was used to check if there were significant differences in peroxide value between three groups: control, celery leaf and celery root. The test was done using all 48 PV values from different storage oil volumes and conditions (light and dark). In this study one way ANOVA was used for checking if there were differences between the three treatment groups. But since ANOVA only tells if there is difference between the groups but not where exactly, another follow up test called Tukey HSD (Honestly significant difference) was used. This test helped to find which specific groups had statistically different peroxide values.

3. Results and discussion

To understand the oxidation process without celery addition, the control oil bottles without celery addition were analysed. The peroxide value (PV) increased in all control samples, but mostly in those stored in lignt conditions for 1 and 2 weeks. After 2 weeks of storage in light, the smallest oil volume in the bottles (250 mL) was 9.50 mmol O_2/kg which is far above the legal limit of 7.5 mmol O_2/kg. It is important to note that even the oil with 1L of bottle volume is above the permited limits and it is 7.85 mmol O_2/kg. The results are presented in Figure 1.

In control samples which were stored in dark, the PV was lower, but still increased in oil with smaller oil volume in the bottles. The results were slightly different, the oils with 250 mL oil in the botlle was 9.20 mmol O_2/kg, while for the 1L sample the PV was 7.60 mmol O_2/kg. Results from the control samples stored in dark are presented in Figure 2.

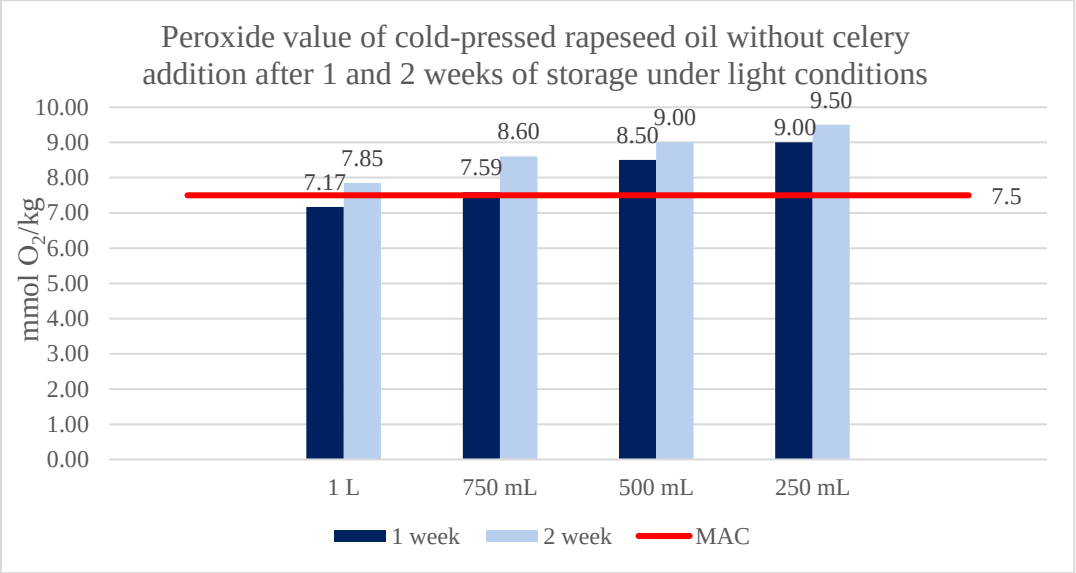

Figure 1. Peroxide value of cold-pressed rapeseed oil without celery addition after 1 and 2 weeks of storage under light conditions

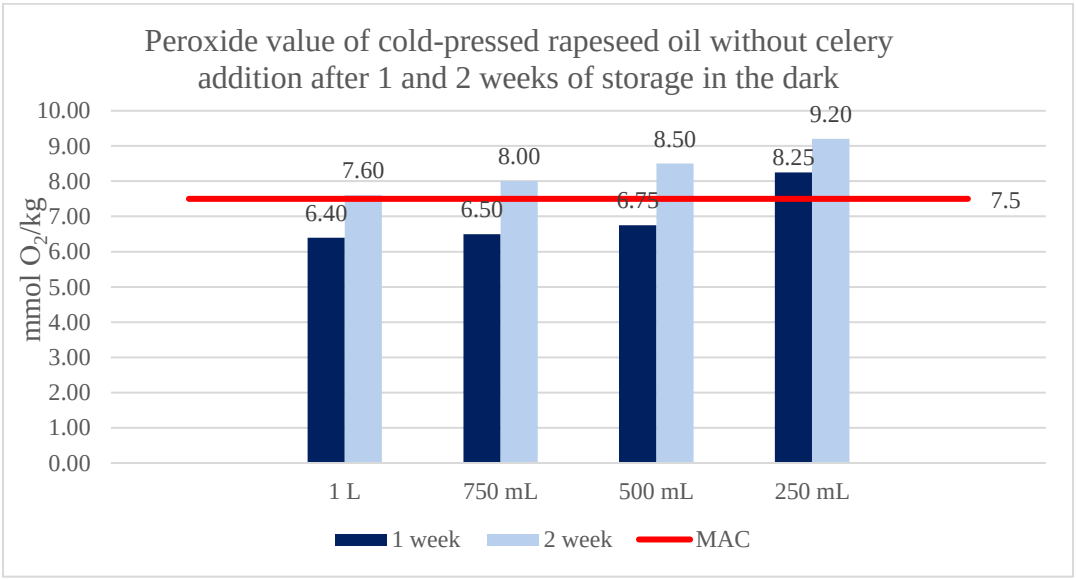

Figure 2. Peroxide value of cold-pressed rapeseed oil without celery addition after 1 and 2 weeks of storage stored in the dark

The results for samples with celery addition revealed that PV increased over time, with light exposure and reduced oil volume significantly accelerating oxidation, as shown in Figures 3 and 5 for celery leaf and celery root, respectively. According to the Rulebook for Fats and Oils of Vegetable Origin, the maximum permitted concentration of peroxides is 7.5 mmol O_2/kg. Under light conditions, the smallest volume (250 mL) exceeded the legal limit in the second week of storage, reaching 7.95 mmol/kg for oils with celery leaf and 10.12 mmol/kg in oil with celery root, while the 500 mL samples approached the threshold. The 1 L samples stored in light remained within maximum allowed concentration in both celery leaf and root addition. Compared to the control samples, celery slowed down oxidation in most cases, especially in bottles with more oil volume in the 1L bottles.

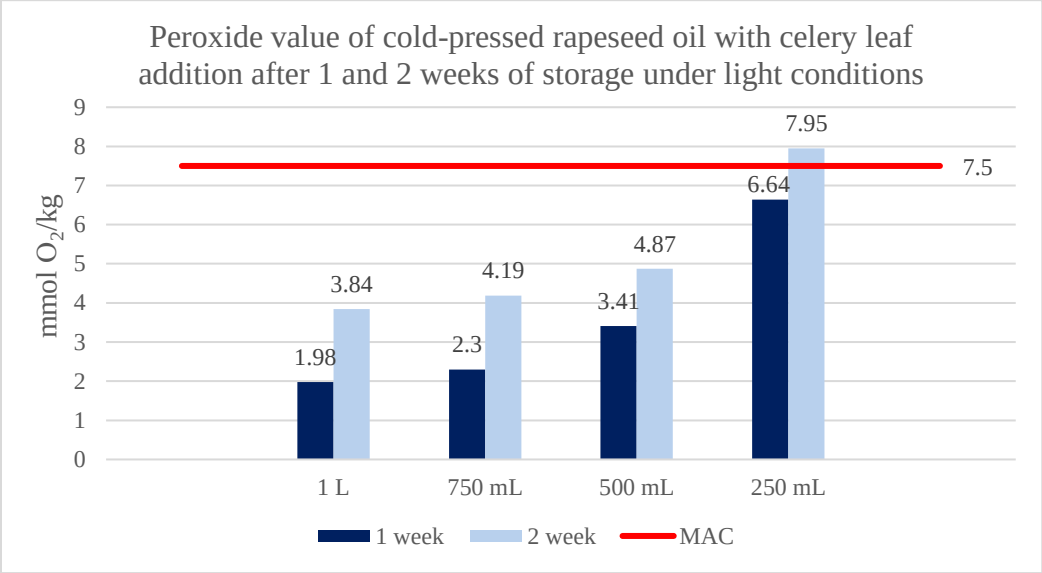

Figure 3. Peroxide value of cold-pressed rapeseed oil with celery leaf addition after 1 and 2 weeks of storage under light conditions

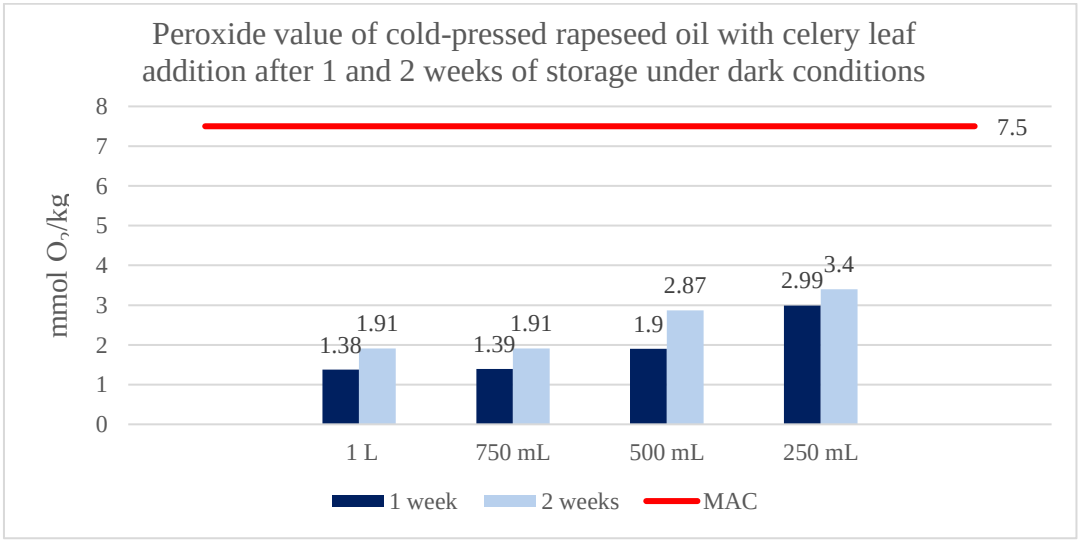

Figure 4. Peroxide value of cold-pressed rapeseed oil with celery leaf addition after 1 and 2 weeks of storage under dark conditions

Under dark storage, PV values were notably lower across all volumes for both treatments. As shown in Figures 4 and 6, the 250 mL samples reached 2.99 mmol O_2/kg (leaf) and similar levels for root by the first week, with modest increases in the second week. The 1 L and 750 mL samples demonstrated greater stability, with PV values remaining well below the threshold. In comparison to the control oil samples stored in the dark, oils with celery addition had lower PV, showing protective effect of celery.

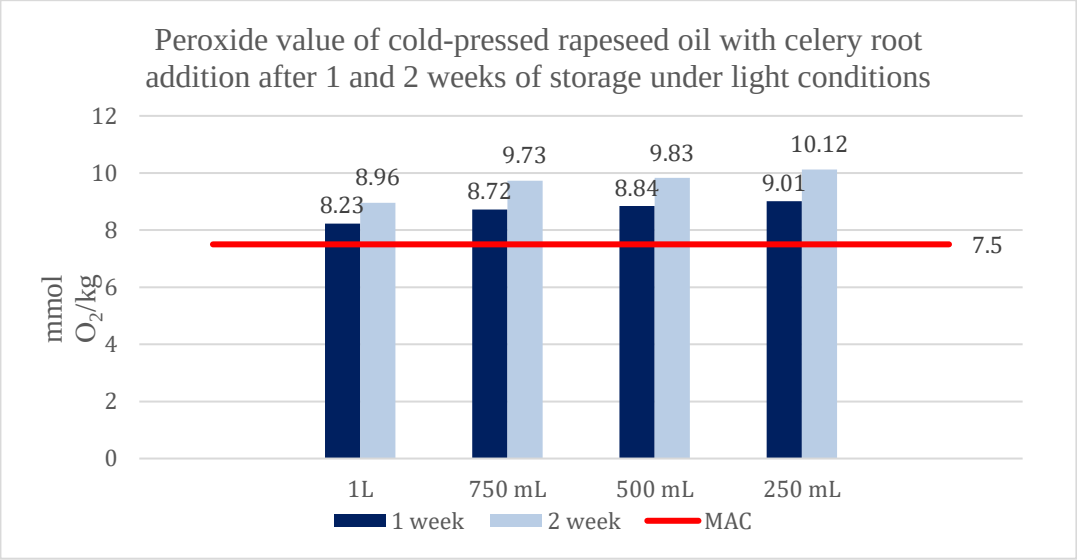

Figure 5. Peroxide value of cold-pressed rapeseed oil with celery root addition after 1 and 2 weeks of storage under light conditions

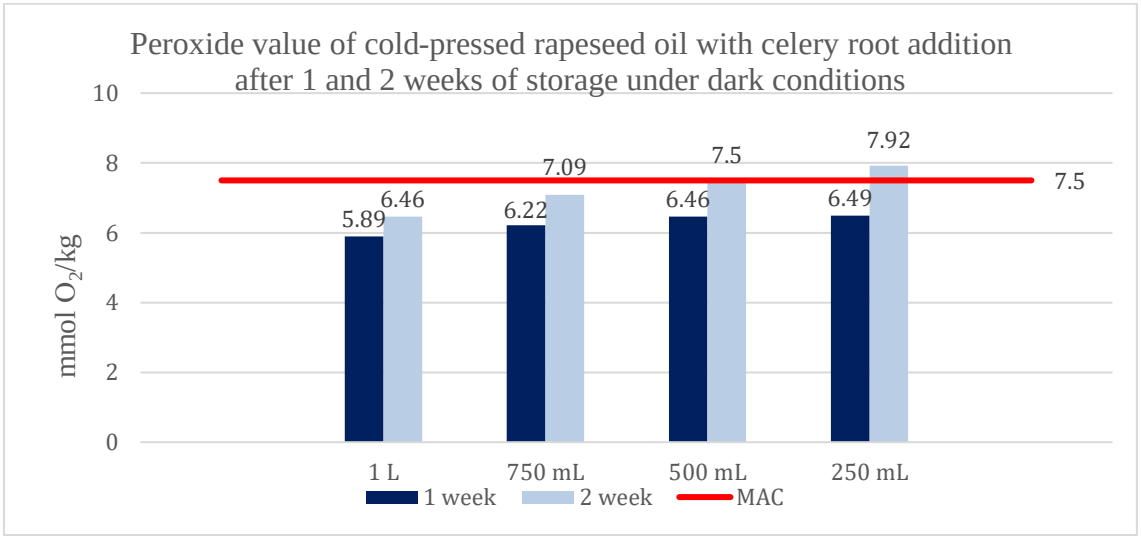

Figure 6. Peroxide value of cold-pressed rapeseed oil with celery root addition after 1 and 2 weeks of storage under dark conditions

These findings suggest that both light and headspace volume play critical roles in oxidative degradation, as increased exposure to oxygen and light initiates peroxidation reactions, confirming earlier studies on rapeseed oil stability (Grebenteuch et al., 2021; Gromadzka et al., 2008). Although celery, in both leaf and root forms, contains antioxidant compounds such as polyphenols and flavonoids, their stabilizing effect was not sufficient under high oxidative stress, especially in samples with larger air to oil ratios. However, when compared to oils without celery addition, both celery leaf and root helped slow oxidation, especially in bottles with larger oil volume and stored in the dark.

In oil samples stored in the dark and with a larger volume of oil in the bottles, celery leaf has a greater antioxidant effect. This is consistent with previous research showing that natural antioxidants from herbs and spices can reduce the oxidation of oils to a greater or lesser extent, but not prevent it (Redondo-Cuevas et al., 2019; Embuscado, 2015; Eftinzjijoska & Pavlovska, 2019). The results show that storage also plays a major role in the oxidation of oils, and not just antioxidants.

The statistical ANOVA test showed significant difference in PV between the three groups

($p<0.05$), showing that the treatment affected the oxidation of oils. Table 2 represents one way ANOVA summary of peroxide values for control, celery leaf and celery root treatments.
Celery leaf group showed the greatest reduction in oxidation compared to the control group, the results are presented in Table 2 using Tukey HSD post-hoc test for comparison the peroxide values between treatment groups.

Table 1. One way ANOVA summary of peroxide values for control, celery leaf and celery root treatments.

Test	**F statistic**	**p-value**
One-way ANOVA (PV across Control, Leaf, Root)	8.5757	0.0007

Table 2. Tukey HSD post-hoc test for comparing peroxide values between treatment groups.

Comparison	**Mean Difference**	**p-value**
Celery Leaf vs Root	1.23	0.2051
Celery Leaf vs Control	**2.93**	**0.0005**
Celery Root vs Control	1.70	0.0532

4. Conclusions

The results of this study show that celery leaf and root can reduce the oxidation of cold-pressed rapeseed oil. Celery leaf showed greater efficiency in reducing the peroxide value, i.e. reducing the oxidation of oils, compared to celery root. However, the study showed that the oxidation of oils depends largely on storage conditions and the amount of oxygen in the bottle, i.e. the oil-to-air ratio in the bottle itself. Compared to the control oil samples without celery addition, both celery leaf and root helped slow down oxidation, especially when stored in the dark and in bottles with larger oil volumes. This confirms that celery is really useful in protecting oils oxidation, but the good storage practices are very important. Statistical analysis using ANOVA also confirmed that there were real differences between groups, showing that the effects of celery and storage conditions were meaningful and not just random.

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