# Oxidative stability of Commercial Omega-3 Supplements

– A comparative study of three products available on the Swedish market

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Degree Project in Analytical Chemistry, 2026
Department of Chemistry
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BSc, 15 hp


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# Fishy Business: Are omega-3 capsules as fresh as they promise?

Omega-3 fatty acids are important for the body, especially the brain and heart. They are mainly found in oily fish, but taking it in the form of a supplement might be easier than eating salmon twice a week, as Livsmedelsverket suggests. Fish oil, however, whether in food or supplements, is delicate and spoils (oxidizes) easily, especially when exposed to air, light or heat. This causes the oil to break down, which can smell fishy and could affect its quality.

In this degree project, I investigated how fresh three popular omega-3 supplements available on the Swedish market really are, and how different storage conditions affect their quality over four weeks. The three tested products were: Elixir Pharma Omega-3 Forte, Biosalma Omega-3 Forte 70%, and Puori O3 Fish Oil, a more expensive option with lemon flavor.

For the experiment, I measured two oxidation markers using standard laboratory methods: peroxide value (PV), indicating early-stage spoilage, and anisidine value (AV), indicating later-stage spoilage. PV and AV were combined into a total oxidation value TOTOX. Capsules were stored for four weeks under four conditions: fridge (5°C), room temperature in the dark, room temperature with sunlight, and an elevated temperature in GC-oven (37°C).

The results showed all three products started with acceptable or good oxidation levels when first opened, except Puroi, which had a high AV because of its natural lemon flavoring, not poor oil quality. Puori, nevermind the high AV, had the lowest early oxidation value, PV. Elixir Pharma showed moderate increases, especially when kept warm or in sunlight. Biosalma was a clear winner, for staying very stable with almost no increase in oxidation regardless of storage.

Overall, the omega-3 supplements in Sweden are generally of good quality at purchase, but storage at home matters. Keeping them in the fridge is the best way to maintain freshness. Warm temperatures clearly speeds up spoilage.

# Abstract

**Introduction**: Omega-3 fatty acid supplements are widely used as an alternative to eating oily fish. However the polyunsaturated oils they contain are highly susceptible to oxidation, which can lead to rancidity and possibly decreased quality of the supplement.

**Background**: Despite the convenience of omega-3 supplementation, there is limited independent information on the oxidative quality of products available on the Swedish market and how everyday storage conditions affect their stability over time.

**Aim(s):** The aim of this study was to compare initial oxidation status of three commercial omega-3 supplements (Elixir Pharma, Biosalma and Puori) and evaluate how different storage conditions affect the peroxide value (PV), anisidine value (AV) and the total oxidation value (TOTOX) over four weeks.

**Methods**: Oxidation parameters were measured in triplicates using established titration and spectrophotometric methods from European Pharmacopoeia. Capsules were stored under four conditions: fridge (5°C), room temperature in darkness, room temperature with sunlight exposure, and elevated temperature (37°C).

**Results**: All products, except for Puori, showed acceptable initial oxidation levels. Biosalma showed highest stability with minimal changes across conditions. Elixir Pharma exhibited moderate increases in PV and TOTOX, under warmth and sunlight. Puori displayed significantly elevated AV, likely attributed to presence of aldehydic compounds from the flavoring agents, but presented lowest PV value of all. Most values remained within GOED recommended limits (PV ≤ 5 milliequivalents peroxide oxygen per kilogram oil (meq $O_2$/kg), AV ≤ 20, TOTOX ≤ 26), none exceeded drastically.

**Conclusion**: The tested commercial omega-3 supplements are generally of acceptable oxidative quality upon purchase and when stored properly, with refrigeration being most effective.



**Keywords:** omega-3, fish oil, oxidative stability, peroxide value, anisidine value, TOTOX

## Acknowledgement

I would sincerely like to thank the teachers of this course, Peter Spégel, Margareta Sandahl and Kuria Ndungu, for allowing me to perform my own idea for this degree project and for their guidance throughout the project. I would also like to thank all of the PhD students in CAS who were always ready to help whether with a minor or a major problem I encountered. Lastly I would like to thank my close ones, who have been supporting, motivating me and more often than not been inspiring me throughout this project.

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# 1 List of abbreviations

Anisidine value (AV)

Docosahexaenoic acid (DHA)

Docosapentaenoic acid (DPA)

Eicosapentaenoic acid (EPA)

Peroxide value (PV)

Polyunsaturated fatty acid (PUFA)

Total oxidation value (TOTOX)

Volatile organic compound (VOC)

# 2 Introduction

Omega-3 supplements are a great alternative for those who do not eat a sufficient amount of oily fish on a regular basis. According to Livsmedelsverket only 30% of the population in Sweden eat fish twice, or more, times a week, which is considered baseline to sustain a good intake of omega-3 through the diet.[1] On top of that, in recent years the consumption of fish in Sweden has decreased even further, which has been suggested to be caused by price increase.[2] Omega-3 is related to various health aspects such as proper brain function, childhood development and is important in the prevention of cardiovascular diseases.[3,4]

Although omega-3 supplements are often presented as a convenient and cost-effective way to increase intake of beneficial fatty acids, their susceptibility to oxidation remains an important quality and safety consideration. Because omega-3 polyunsaturated fatty acids (PUFAs) contain multiple double bonds, they are prone to oxidative degradation.[5]

Several rat studies have suggested that highly oxidized fish oils may have harmful biological effects including increased newborn mortality, insulin resistance in pregnant rats, lower body weight and increased liver and kidney weight in male rats.[6–8] The relevance of these findings to humans remains uncertain. Existing human studies are limited and have not provided conclusive evidence that oxidized omega-3 supplements cause toxicity.[9–11] As of today, oxidation is not regarded as a major human health concern and there are no strict guidelines, neither in the US nor in the EU, for oxidation limits that apply to the supplements.

Despite this, some industries follow the voluntary recommended limits from organizations such as Global Organization for EPA and DHA Omega-3 but these practices are not universally enforced.[12] The fact that industries adhere to the recommended limits is more likely to be motivated by commercial concerns, as oxidation makes the product rancid and develop unpleasant fishy odor and taste.[13]

The omega-3 fatty acids are one of the main groups of PUFAs, alongside omega-6 fatty acids. The main omega-3 fatty acids found in marine oils are docosahexaenoic acid (22:6n-3, DHA), eicosapentaenoic acid (20:5n-3, EPA) and docosapentaenoic acid (22:5n-3, DPA). These fatty acids are highly susceptible to oxidation, which can be accelerated from exposure to oxygen, light or elevated temperature. In the early stage, the lipid reacts with oxygen and undergoes

free radical induced lipid peroxidation leading to formation of hydroperoxides, also referred to as primary oxidation products. Because hydroperoxides are unstable, they can further decompose into secondary oxidation products such as aldehydes, ketones or volatile organic compounds (VOCs). The radical reaction mechanism of hydroperoxide formation is shown in Figure 1. Both oxidation products contribute to the rancidity of the oil, associated with an unpleasant fishy smell and taste.[14,15]

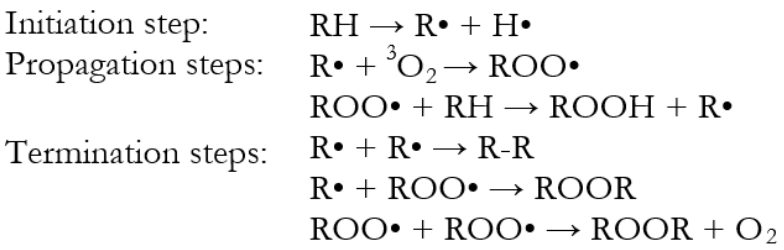


*Figure 1* The peroxidation reaction mechanism of polyunsaturated fatty acids. Redrawn based on Zhang et. al.[15]

In fish oil analysis, peroxide value (PV) is commonly used to assess the primary oxidation status of a product. For fish oil supplements, secondary oxidation products are typically estimated with anisidine value (AV), although this method does not account for ketones or VOCs.[16] According to GOED recommendations, the suggested limits for oxidation are 5 milliequivalents peroxide oxygen per kilogram oil (meq $O_2$/kg ) for PV, 20 for AV and 26 for TOTOX.[12]

The common PV method is iodometric titration. Hydroperoxides oxidize iodide ions, freeing it in the form of iodine and thus giving it a yellow/brown color. During titration, sodium thiosulphate reduces iodine back to colorless iodide and the volume used for titration is converted to peroxide value, expressed as meq $O_2$/kg.[15]

AV is a spectrophotometric method that measures the aldehydic secondary oxidation products. The amine group of p-anisidine undergoes a condensation reaction with the aldehydes present to form an imine. The imine double bond creates a conjugated system which leads to higher absorbance in the spectrophotometric measurement.[17,18]

Both PV and AV are calculated relative to the weight of the sample, allowing comparison between products. PV and AV are then combined into the total oxidation value (TOTOX), which provides a broader indication of the overall oxidation status of the supplement, and is expressed as TOTOX = 2PV + AV.[16] The reasoning behind the factor 2 of PV in the TOTOX formula is that a peroxide group has twice the oxygen of an aldehyde group.[19] The TOTOX interpretation can however be challenging. AV reflects only the aldehydic compounds from the secondary oxidation products and does not account for ketones or VOCs. Additives such as flavoring agents can also interfere with AV if the compounds contains aldehydic groups, by reacting with p-anisidine and elevating the absorption.[20]

Alternative analytical methods are therefore being explored. Proton nuclear magnetic resonance ($^{1}$H-NMR) can be used to identify specific aldehydes and to quantify their concentrations, providing a more detailed assessment of secondary oxidation products.[21]

Regardless of whether highly oxidized fish oil products pose a risk to human health, supplement manufacturers commonly add antioxidant agents to fish oil supplements, to slow further oxidation and prevent the supplement from going rancid. One of the most common classes of antioxidants used in this context are tocopherols, a group of compounds that constitute vitamin E. Tocopherols have proven to be effective in the prevention of further oxidation but only in small concentrations.[22] Other antioxidant agents commonly used are rosemary extract and ascorbyl palmitate.[23]

The aim of this study was to compare the fatty acid composition and oxidation status of three commercial omega-3 supplements, available on the Swedish market. The study also investigated how different storage conditions, under a four-week period, affected PV, AV and TOTOX and if higher oxidation levels can be correlated to the perceived fishy odor of the supplements.

# 3 Materials and Methods

## 3.1 Choice of samples and overview of the method

Three commercially available omega-3 supplements were selected for this study: Elixir Pharma Omega-3 Forte, Biosalma Omega-3 Forte 70%, and Puroi O3 Fish Oil Capsules. The products were chosen to represent supplements available on the Swedish market, including two most commonly sold brands and one product marketed as a higher-quality alternative, also at a higher price. Commonly available products were identified by searching Swedish online pharmacies and consumer-oriented websites ranking omega-3 supplements. An overview of the declared compositions, per 1000 mg of fish oil, of the three products is presented in table 1.

Table 1 Data collection of the three commercial omega-3 supplement products, Elixir Pharma "Omega-3 Forte 132 capsules", Biosalma "Omega-3 Forte 70% 1000 mg" and Puori "O3 - Fish Oil Capsules", that will undergo oxidation profile evaluation. The concentrations of the antioxidant agents are stated only if this information is available in the ingredients list.

| | Total (mg) | DHA (mg) | EPA (mg) | DPA (mg) | Other (mg) | Omega-3 total (mg) | Antioxidant agents | Flavoring agents |
|---|---|---|---|---|---|---|---|---|
| Elixir Pharma | 1000 | 200 | 300 | 30 | 100 | 630 | Rosemary extract (5 mg) | - |
| Biosalma | 1000 | 200 | 300 | 30 | 100 | 630 | DL-alpha-tocopherol | - |
| Puori | 1000 | 200 | 500 | - | 100 | 800 | Mixed tocopherols (Soy) | Natural lemon oil |

To evaluate the supplements, oxidation status was measured using peroxide value (PV) and anisidine values (AV) to obtain the total oxidation value (TOTOX). All measurements were done in triplicate and evaluated against the voluntary GOED limits: PV $\leq$ 5 meq $O_2$/kg, AV $\leq$ 20 and TOTOX $\leq$ 26.

Before initial measurements, unopened samples were stored in a cool area protected from sunlight. After the initial measurements, capsules were divided into glass containers and stored for four weeks under different conditions and their used abbreviations in the results section: room temperature with exposure to sunlight (Sun), room temperature without the exposure to sunlight (Shadow), refrigeration at 5°C (Fridge), temperature-controlled storage

in the GC-oven at 37°C (Oven). All glass containers, except for the capsules that were supposed to be subjected to sunlight, were ambered glass flasks.

### 3.2 Method validation and statistical analysis

To validate the modifications made to the standard procedures for PV and AV, measurements were first performed using the reagent and solvent volumes specified in the original standard procedures. The overall results were statistically analysed by calculating the standard deviation between triplicate measurements to ensure sufficient experimental precision. ANOVA followed by Tukey's post hoc test was subsequently used to evaluate the trueness of the modified method. In addition, one-sample one-tailed t-tests were performed to evaluate whether the measured oxidation values of PV, AV and TOTOX were significantly below the voluntary GOED limits. The tests were performed separately for each product and storage condition. A significance level of $p < 0.05$ was used.

### 3.3 Peroxide value

Peroxide value, PV, was determined according to the European pharmacopoeia, C-1.1 Ph. Eur. Method 2.5.5 (Method A), with minor modifications. The procedure was scaled down to half of the volumes used, to reduce solvent and chemical waste, while preserving the same reagent ratios like in the original method. Chloroform was replaced with dichloromethane, and not all chemicals were reagent grade. Starch was purchased at a local store, dichloromethane was anhydrous and chloroform for method validation was pro analysis.

Distilled water was pre-boiled and cooled before use to minimize dissolved carbon dioxide. All samples were prepared immediately before analysis by extracting oil from the capsules using a syringe. The syringe was weighed after injection to account for any residual oil left in the syringe.

Sodium thiosulphate ($Na_2S_2O_3$, 0.0632 g, 4 mmol) was dissolved in distilled water (40 ml). This solution with the concentration of 0.01 M was used as a titrant. A saturated KI solution in water (3 ml) was prepared. The sample (2.5 g) was extracted from the capsule with a syringe and added to a mixture of dichloromethane (6 ml) and glacial acetic acid (9 ml). KI solution (0.25 ml) was added and the mixture was mixed for exactly 1 min. Water (15 ml) was then added and the titration began. The sample was titrated until the color of the mixture

became pale. Once pale, a starch solution (2.5 ml, 1g/ml) was added to facilitate the end-point determination of the titration, by increasing the saturation of the color of the solution. The blank was conducted as the samples, but without the use of sample material, to ensure that the KI used is not degraded in any way. The volume of the used titrant is equivalent to the amount of hydroperoxides in the sample. The peroxide value was calculated according to:

$$Peroxide\ value\ I_p = \frac{10(n_1 - n_2)}{m}$$

Where $n_1$ is the volume of titrant used on the sample in ml, $n_2$ is the volume of titrant used in the blank, m is mass of the sample in grams and the peroxide value is given in meq $O_2$/kg, as explained in the standard procedure.

### 3.4 Anisidine value

Anisidine value, AV, was determined according to the European Pharmacopoeia, C-1.1 Ph. Eur. Method 2.5.36, with minor modifications. As for PV, the procedure was scaled down. All reagent and solvent volumes were reduced to 40% of the specified volumes, while keeping the original reagent ratios.

For the initial measurement p-anisidine (0.0625 g, 50.8 mmol) was dissolved in glacial acetic acid (25 ml) in an ambered volumetric flask, to reduce light exposure. For the second measurement, a larger stock was prepared (0.125 g, 50.8 mmol) in glacial acetic acid (50 ml). Fish oil samples (approx. 0.2 g) were measured in the syringes, and the leftover weight was subtracted.

Each sample was properly mixed in trimethylpentane (10 ml). A portion of this solution was used as test solution A. Test solution B was prepared by mixing 5 ml from test solution A with p-anisidine solution (1 ml). The blank for test solution A consisted of trimethylpentane, while the blank for test solution B consisted of trimethylpentane (5 ml) and p-anisidine solution (1 ml).

Exactly 10 min after addition of p-anisidine solution, the absorbance of test solution B was measured at 350 nm using a single-beam spectrophotometer, as referred to in the standard procedure. Test solution A was measured at the same wavelength. The anisidine value was calculated according to:

$$Anisidine\ value = \frac{25\left(1.2A_b - A_a\right)}{m}$$

Where $A_b$ is the absorbance of the test solution B, $A_a$ is the absorbance of test solution A and m is the mass of the sample in grams and the anisidine value is a dimensionless value. The absorbances $A_a$ and $A_b$ have already subtracted blanks, blank for solution A and solution B respectively, in the spectrophotometer. Together with the peroxide value, they result in the total oxidation value (TOTOX):

$$TOTOX = 2PV + AV$$

The TOTOX is treated as an index value, therefore it is also dimensionless.

### 3.5 Sensory test

At the end of the experiment, Elixir Pharma and Puori contained in the fridge at 5°C and stored at 37°C for four weeks, were used for a sensory study in which the participants would compare which of the capsules, within the same brand, smelled more fishy. The study was single-blind.

# 4 Results and discussions

Oxidative stability differed between the three commercial omega-3 supplements, Elixir Pharma, Biosalma and Puori. Oxidation was assessed from PV, AV and TOTOX at purchase and after four weeks of storage.

Puori requires separate consideration as it contains natural lemon oil. Flavoring agents may contain aldehydic compounds that react in the p-anisidine assay, increasing AV. The complete composition was not disclosed in correspondence with Puori, therefore Puori's AV and TOTOX values should be interpreted as apparent values instead of direct measure of lipid oxidation.

## 4.1 Initial oxidation status

The initial PV measurements, Figure 2, showed low levels of primary oxidation across all three supplements. Elixir Pharma and Biosalma showed relatively similar PVs of approximately 4-5 meq $O_2$/kg, whereas Puori had an even lower initial PV of approximately 2- 3 meq $O_2$/kg. The mean values of all products were under the recommended limit of 5 meq $O_2$/kg from GOED at the time of purchase. However One-sample one-tailed t-tests, against GOED limits, showed that only the PV of Puori was significantly below the limit of 5 meq $O_2$/kg ($p = 0.00178$, see appendix).

Statistical analysis confirmed that there was a significant difference in the initial PV between the products, by one-way ANOVA (see appendix). Tukey's post hoc test showed that Puori had significantly lower initial PV than both Elixir Pharma and Biosalma, while no significant difference was found between Elixir Pharma and Biosalma.

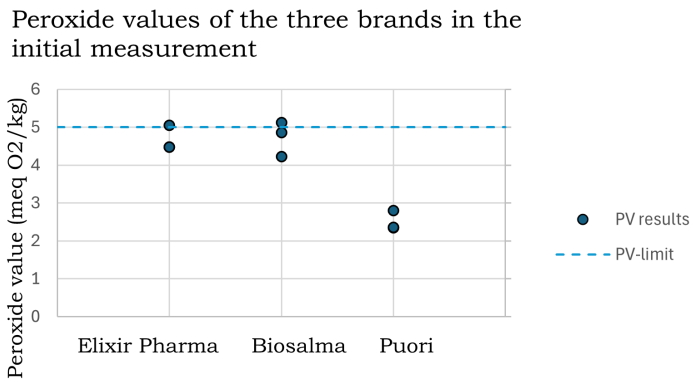


*Figure 2* Peroxide values (meq $O_2$/kg) of the three omega-3 supplements, Elixir Pharma, Biosalma and Puori, measured in triplicates at the initial time point.

Larger differences appeared in secondary oxidation products, Figure 3. Elixir Pharma and Biosalma had anisidine values of approximately 7–8, well below the voluntary GOED limit of 20. In contrast, Pouri showed markedly higher results around 110–120. The ANOVA showed statistically significant difference in initial AV between the products, and Tukey's post hoc test confirmed that Puori differed significantly from both Elixir Pharma and Biosalma. Elixir Pharma and Biosalma did not differ significantly from each other. Both Elixir Pharma and Biosalma were significantly below the GOED limit of 20 ($p = 7.68 \times 10^{-5}$ and $p = 0.00019$, respectively).

Puori however, requires separate interpretation because it contains natural lemon oil. Flavoring agents may contain aldehydic compounds that react with p-anisidine and thereby increase the apparent AV. Therefore the significantly higher AV observed for Puori cannot be concluded to originate solely from secondary oxidation products.

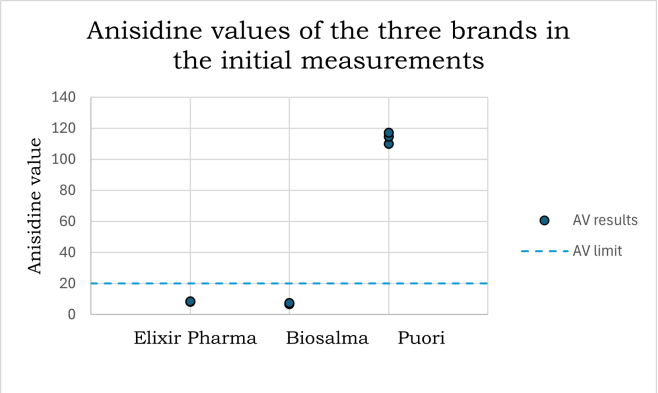


*Figure 3* Anisidine values of the three omega-3 supplements, Elixir Pharma, Biosalma and Puori, measured in triplicates at the initial time point. Note that the markedly higher values for Puori are possibly influenced by its natural lemon flavoring agents.

## 4.2 Effects of storage conditions on oxidation

After four weeks of storage, the changes in oxidation status depended on both product and storage conditions, Figures 4-6. The clearest increase in PV was observed for Puori after oven-storage at 37°C, where the value increased from 2.50 to 3.92 meq $O_2$/kg, corresponding to an increase of approximately 56%. Despite this increase, the final PV still remained significantly below the GOED limit ($p = 0.01577$). The ANOVA analysis showed significant differences between storage conditions. Tukey's post hoc showed that the oven-stored samples differed significantly between all of the other storing conditions. Meanwhile no significant difference was observed between refrigerated samples and samples kept at room temperature. The remaining PV of Puori were also significantly below the GOED limit ($p = 0.00064$ for refrigeration, $p = 0.00071$ for shadow stored samples, $p = 0.00044$ for samples exposed to sunlight).

For Elixir Pharma, Figure 4a, storage conditions had a statistically significant effect on PV. The highest PV was observed after oven-storage at 37°C, where the mean value of PV increased from 4.67 to 5.58 meq $O_2$/kg, corresponding to an increase of approximately 20% and thus exceeding the voluntary GOED limit. Tukey's post hoc showed that the oven stored sample differed significantly from the refrigerated, shadow-stored and sun-exposed samples. This supports the interpretation that elevated temperature accelerated primary oxidation for Elixir Pharma. The sample exposed to sunlight also showed a moderate increase in PV, compared with refrigeration, although only storage at 37°C showed a statistically significant

increase. The one-sample t-tests showed that PV of Elixir Pharma was significantly below the GOED limit for refrigerated samples and samples kept at room temperature without and with exposure to sunlight ($p = 0.00461$, $p = 0.01338$ and $p = 0.01259$, respectively). The oven-stored samples at 37°C were significantly over the GOED limit ($p = 0.04816$).

Biosalma, Figure 5a, showed the smallest changes in PV across all storage conditions, all within the voluntary GOED limit. The ANOVA analysis and Tukey's post hoc showed that the largest increase was observed after sunlight exposure, from 4.42 to 4.73 meq $O_2$/kg, corresponding to approximately 11%. For Biosalma, PV remained below the GOED limit for all storage conditions, including refrigeration, shadow storage, sunlight exposure and oven storage ($p = 0.03504$, $p = 0.00357$, $p = 0.00876$ and $p = 0.00969$, respectively). This suggests comparatively high oxidative stability of Biosalma over the four-week period.

The PV results should nonetheless be interpreted with some caution. The titrimetric method requires visual endpoint determination, which is subject to subjective assessment. While the starch solution was to aid end-point determination, variations in the natural colour of oils from different brands, together with the persistence of their hues during titration, may have affected the accuracy of end-point detection. This could explain why some results did not follow the expected trend, such as slightly higher PV in refrigerated Biosalma samples than in the samples stored at 37°C.

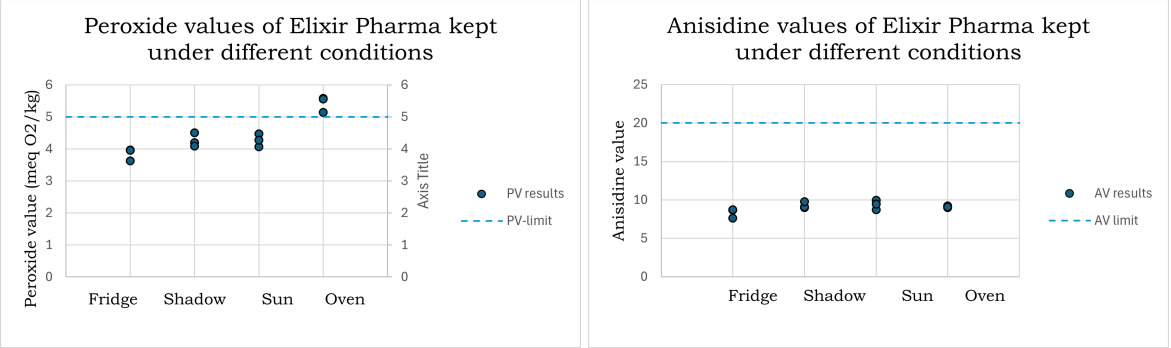


*Figure 4* Peroxide values (A) and anisidine values (B) of Elixir Pharma omega-3 supplements after 4 weeks of storage under different conditions (Fridge at 5°C, room temperature away from sunlight, room temperature with exposure to sunlight, oven-storage at 37°C in the GC-oven). Values are shown as triplicates.

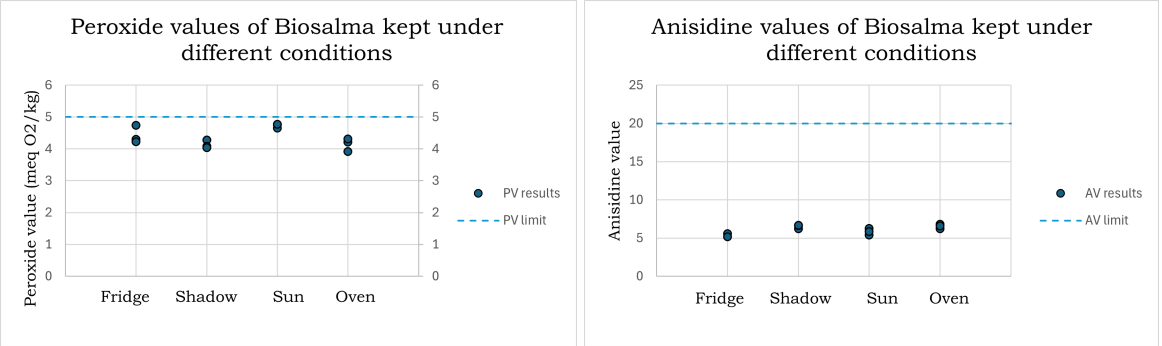


*Figure 5* Peroxide values (A) and anisidine values (B) of Biosalma omega-3 supplements after 4 weeks of storage under different conditions (Fridge at 5°C, room temperature away from sunlight, room temperature with exposure to sunlight, oven-storage at 37°C in the GC-oven). Values are shown as triplicates.

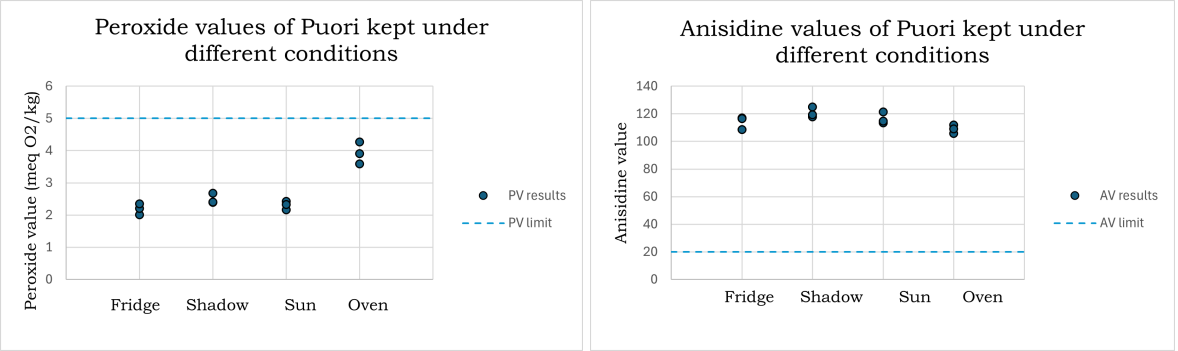


*Figure 6* Peroxide values (A) and anisidine values (B) of Puori omega-3 supplements after 4 weeks of storage under different conditions (Fridge at 5°C, room temperature away from sunlight, room temperature with exposure to sunlight, oven-storage at 37°C in the GC-oven). Values are shown as triplicates. The markedly higher values for Puori are probably influenced by its natural lemon flavoring agents.

The AV of Elixir Pharma, Figure 4b, showed no statistically significant difference between different storage conditions, suggesting that the increase in oxidation during the four-week period is mainly reflected by primary oxidation products. The AV values remained significantly below the GOED limit of 20 under all tested conditions.

The AV values of Biosalma, Figure 5b, showed statistically significant differences between storage conditions. The refrigerated samples generally had lower AV values than the samples stored at room temperature or at 37°C. Tukey's post hoc showed a significant difference between the refrigerated samples and samples kept at room temperature without sunlight exposure and samples stored in the oven at 37°C respectively. However all values remained significantly below the GOED limit.

For Puori, AV remained high under all storage conditions, Figure 6b, generally within the range of approximately 100 – 130. A statistically significant difference in AV was observed between storage conditions but the pattern did not show a clear storage-dependent increase. Since the AV was already elevated at the initial measurement, and because natural lemon oil may contribute to the p-anisidine response, these values should not be interpreted as direct evidence of extensive secondary lipid oxidation. The only significant difference was observed between samples kept at room temperature without sunlight exposure and samples stored at 37°C, with an increase in the mean value from approximately 108.81 (oven) to 120.73 (shadow) corresponding to an 11% increase.

While AV assessment is a more objective measurement, not requiring a visual interpretation, several methodological factors may have contributed to variation in AV. The p-anisidine reagent is sensitive to light, and the color-forming reaction must be measured exactly 10 minutes after reagent addition. The small differences in timing, light exposure or reagent preparation could therefore influence absorbance values.

### 4.3 Total oxidation values

TOTOX was calculated as 2PV + AV and used as an overall index of oxidation status. For Elixir Pharma, Figure 7, storage conditions had a statistically significant effect on TOTOX. Tukey's post hoc test showed that the oven-stored samples differed significantly from all the other storing conditions. Four-week period of storage of Elixir Pharma has resulted in an increase from the mean TOTOX of 17.73 (initial measurement) to 19.51 (oven-stored), corresponding to a 10% increase in TOTOX. The largest difference, however, is observed between the oven-stored samples and the refrigerated samples, corresponding to a 21% increase. It is unlikely that the oxidation, after the initial measurement, would decrease during refrigeration, and this difference is likely attributed to uncertainty in titration end-point determination. Because the PV measurements after 4 weeks of storage were done on the same day, it seems more likely that the difference in PV is more true between the refrigerated samples rather than the samples in the initial measurement. Overall the one-sample t-tests showed that TOTOX values were significantly below the limit of 26 under all conditions, including the initial measurement.

For Biosalma, Figure 8, TOTOX values differed significantly between groups, but all values remained significantly below the GOED limit. Interestingly, some stored samples showed lower TOTOX values than the initial measurement. Since the differences were small and both PV and AV remained low, this should not be interpreted as a true improvement in oxidative quality, but rather as normal experimental variation within a low oxidation range. Biosalma showed overall highest oxidative stability among the tested products.

Puori, Figure 9, had high TOTOX values at all the time points. However, these values were dominated by the elevated AV and therefore cannot be interpreted as a reliable measure of total lipid oxidation. The ANOVA showed no statistically significant difference in TOTOX between the initial and stored Puori samples. This supports the interpretation that the high TOTOX values were mainly caused by a consistently high apparent AV, overshadowing any observed difference in PV.

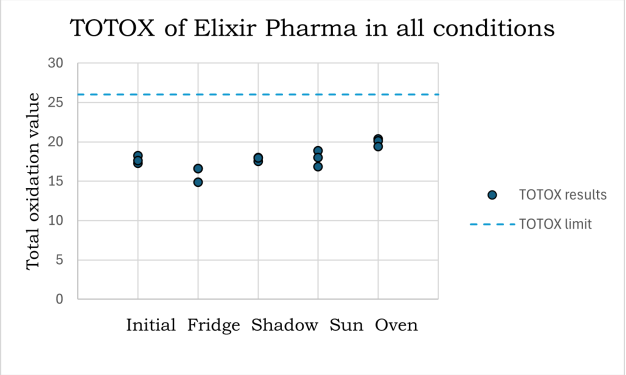


*Figure 7* Total oxidation (TOTOX) values of Elixir Pharma omega-3 supplements at the initial measurement and after 4 weeks of storage under different conditions (Fridge at 5°C, room temperature away from sunlight, room temperature with exposure to sunlight, oven-storage at 37°C in the GC-oven).

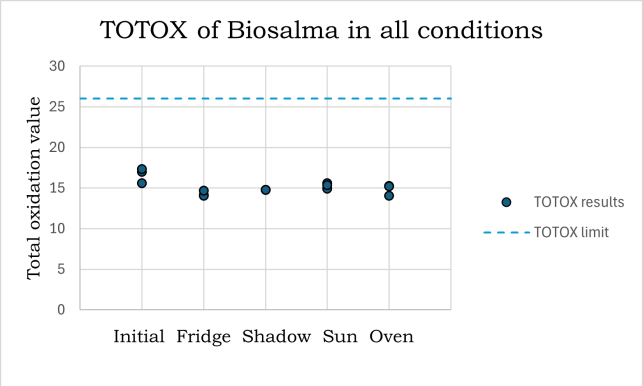


*Figure 8* Total oxidation (TOTOX) values of Biosalma omega-3 supplements at the initial measurement and after 4 weeks of storage under different conditions (Fridge at 5°C, room temperature away from sunlight, room temperature with exposure to sunlight, oven-storage at 37°C in the GC-oven).

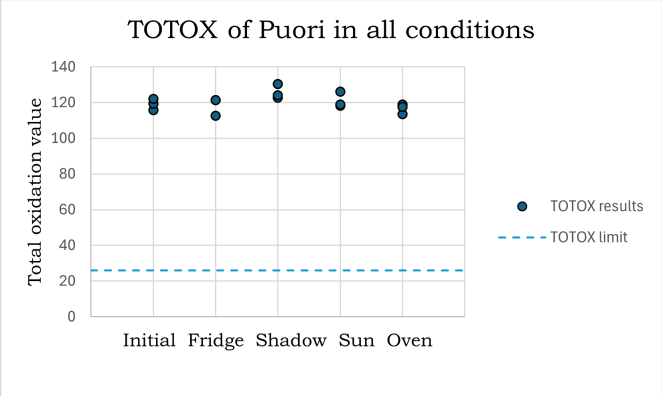


*Figure 9* Total oxidation (TOTOX) values of Puori omega-3 supplements at the initial measurement and after 4 weeks of storage under different conditions (Fridge at 5°C, room temperature away from sunlight, room temperature with exposure to sunlight, oven-storage at 37°C in the GC-oven). *The TOTOX cannot be determined with full certainty due to elevated anisidine value likely caused by flavouring agents.

## 4.4 Sensory study

A small-scale, single blind sensory study was carried out to assess whether differences in oxidative status, induced by storage conditions, were perceptible as fishy/unpleasant odor by human participants. Only the most contrasting storage conditions (refrigeration at 5°C vs. storage in the GC-oven at 37°C for four weeks) were tested for only the brands that had a significant increase in oxidation whether by AV or PV values (Elixir Pharma and Puori).

Participants (n = 6) were asked to smell from the bottles, from the same brand and indicate which sample had a stronger odor, whether fishy or generally unpleasant. Because Puori uses flavoring agents, it did not deem adequate to do an inter-brand comparison.

For Puori, Table 2, all six participants perceived the capsules stored at 37°C as having a more pronounced fishy odor compared to the refrigerated samples.

Table 2 Sensory evaluation results for Puori Omega-3 capsules.

| | Puori (Fridge, 5°C) | Puori (Oven, 37°C) |
|---|---|---|
| Votes | 0 | 6 |

For Elixir Pharma, Table 3, five out of six participants perceived the capsules stored at 5°C as having a more pronounced fishy odor compared to the oven-stored samples. One participant found the difference inconclusive, also commenting that the capsules stored at 37°C had a more of a smoky odor, rather than fishy.

Table 3 Sensory evaluation results for Elixir Pharma Omega-3 capsules.

| | Inconclusive | Elixir Pharma (fridge, 5°C) | Elixir Pharma (oven, 37°C) |
|---|---|---|---|
| Votes | 1 | 5 | 0 |

### 4.5 General interpretation and limitations

The products showed distinct oxidative profiles. Although Elixir Pharma and Biosalma had no significant differences in oxidation levels upon purchase, the four week storage suggests Biosalma having greater chemical stability than Elixir Pharma. Elixir Pharma remained within the recommended limits in most cases, but heat exposure caused an increase in PV above the GOED limit. Puori showed the lowest PV initially and remained below the PV limit after storage, but had the highest observed increase in PV from the initial measurement. Puori's AV and TOTOX values were not trustworthy indicators of oxidation because of probable interference from natural lemon flavoring.

Differences in oxidative behaviour may be related to product formulation. The products contain different antioxidant systems, including rosemary extract, DL-alpha-tocopherol and mixed tocopherols. Puori also differs in fatty acid composition, with a higher declared omega-3 concentration and higher EPA content than the other two products. Because highly unsaturated fatty acids are more susceptible to oxidation, the differences in EPA and DHA content may influence oxidative stability.

Analytical constraints should also be considered. PV determination can be affected by subjective end-point detection, while AV determination requires strict timing and protection from light. In addition, expectation bias may have influenced visual endpoint assessment during PV titration, since the products differed in price, marketing claims and perceived quality. Although the measurements were performed carefully, complete elimination of subjective influence cannot be guaranteed. A blinded study would have been beneficial in this context, but due to only three supplements being used, all distinct in their appearance from each other, it was not possible. The results also provide short-term comparison of selected products, rather than a comprehensive assessment of all omega-3 supplements available on the Swedish market.

To summarize, the storage condition affected oxidation, with refrigeration providing the best protection and storage at 37°C promoting the greatest increase in oxidation markers. Biosalma showed the highest oxidative stability, Elixir Pharma was moderately affected by heat and light, and Puori could not be fully evaluated using AV or TOTOX because of likely flavoring interference. Overall, the tested supplements were generally of acceptable oxidative quality when stored appropriately, but the results point out the importance of storage factors and the limitations of p-anisidine analysis for flavored fish oil products.

The sensory results were only partially consistent with the chemical oxidation data. For Puori, the stronger fishy odor detected in the oven-stored samples aligned with the observed increase in peroxide value under elevated temperature. In contrast, for Elixir Pharma the sensory test results showed an unexpected pattern. Five out of six participants perceived the refrigerated capsules as having a stronger fishy odor, while oven-stored capsules were not selected by any participant as fishier. One participant described the heated sample as smelling more “smoky” than classically fishy. The discrepancy in the results for Elixir Pharma, could be related to the effect of prolonged storage at 37°C in the GC-oven. Elevated temperature could have given rise to a “smoky” odor, possibly masking the fishy odor.

Although the sensory test was a single-blind study under non-ideal conditions, it illustrates nonetheless that relatively modest changes in oxidation status can influence perceived sensory quality.

# 5 Conclusions

The experiment showed that the oxidation status of the three commercial omega-3 supplements was acceptable at the time of purchase. Different storing conditions, over the four-week period, proved to have a significant effect on TOTOX of the supplements. The sensory study did not result in direct correlation between oxidation levels and a fishy odor. However it did show that moderate changes in oxidation affect how the smell of the supplements was perceived by the participants.

# 6 Future aspects

Further studies should include a full assessment of the oxidation status of all commercial omega-3 supplements available on the Swedish market. An $^{1}$H-NMR, or other alternative analytical method, should be performed on supplements containing flavoring agents to obtain true anisidine value for the supplements. It would also be of interest to investigate whether the oxidation status would differ depending on what time of the year the supplements were purchased and tested at. Regarding oxidation stability, a longer-term study should be conducted, for example by tracking both PV and AV over a period of one year. Since the present study was conducted in a laboratory environment, subsequent research might also aim to simulate storage handling in a typical home environment. This could include repeatedly opening the supplement containers, as would occur during regular consumer use.

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# 8 Appendix

## 8.1 ANOVA and Tukey's post hoc tests

Statistical analysis of the results, ANOVA and Tukey's post hoc test.

TOTOX For Elixir (left) and Biosalma (right) in the initial measurement and conditions during 4 weeks.

| | TOTOX ELIXIR | | | | |
|---|---|---|---|---|---|
| | Initial | Fridge | Shadow | Sun | Oven |
| 1 | 18,2688 | 14,8846 | 17,9867 | 18,8808 | 20,3659 |
| 2 | 17,2958 | 16,613 | 17,5058 | 16,83 | 20,1094 |
| 3 | 17,6118 | 16,6148 | 17,9532 | 18,0093 | 19,384 |

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Initial | 3 | 53,1764 | 17,7255 | 0,24638 |
| Fridge | 3 | 48,1124 | 16,0375 | 0,9968 |
| Shadow | 3 | 53,4457 | 17,8152 | 0,07209 |
| Sun | 3 | 53,7201 | 17,9067 | 1,05934 |
| Oven | 3 | 59,8593 | 19,9531 | 0,25934 |

ANOVA

| *Source of Varia* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between G | 23,1636 | 4 | 5,7909 | 10,9928 | 0,00111 | 3,47805 |
| Within Grc | 5,26789 | 10 | 0,52679 | | | |
| Total | 28,4315 | 14 | | | | |

| treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inferfence |
|---|---|---|---|
| A vs B | 4.0282 | 0.0989754 | insignificant |
| A vs C | 0.2142 | 0.8999947 | insignificant |
| A vs D | 0.4325 | 0.8999947 | insignificant |
| A vs E | 5.3160 | 0.0242321 | * p<0.05 |
| B vs C | 4.2425 | 0.0785604 | insignificant |
| B vs D | 4.4607 | 0.0618991 | insignificant |
| B vs E | 9.3443 | 0.0010053 | ** p<0.01 |
| C vs D | 0.2183 | 0.8999947 | insignificant |
| C vs E | 5.1018 | 0.0306303 | * p<0.05 |
| D vs E | 4.8835 | 0.0389152 | * p<0.05 |

| | TOTOX BIOSALMA | | | | |
|---|---|---|---|---|---|
| | Initial | Fridge | Shadow | Sun | Oven |
| 1 | 16,978 | 14,1593 | 14,8003 | 14,9258 | 14,0427 |
| 2 | 15,583 | 14,0476 | 14,7949 | 15,5924 | 15,2684 |
| 3 | 17,3231 | 14,6672 | 14,7666 | 15,3826 | 15,2021 |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Initial | 3 | 49,8841 | 16,628 | 0,8488 |
| Fridge | 3 | 42,8742 | 14,2914 | 0,10907 |
| Shadow | 3 | 44,3617 | 14,7872 | 0,00033 |
| Sun | 3 | 45,9009 | 15,3003 | 0,11618 |
| Oven | 3 | 44,5132 | 14,8377 | 0,47519 |

ANOVA

| *Source of Varia* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between G | 9,51512 | 4 | 2,37878 | 7,67566 | 0,00427 | 3,47805 |
| Within Grc | 3,09912 | 10 | 0,30991 | | | |
| Total | 12,6142 | 14 | | | | |

| treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inferfence |
|---|---|---|---|
| A vs B | 7.2700 | 0.0031155 | ** p<0.01 |
| A vs C | 5.7273 | 0.0155049 | * p<0.05 |
| A vs D | 4.1310 | 0.0885395 | insignificant |
| A vs E | 5.5702 | 0.0183746 | * p<0.05 |
| B vs C | 1.5428 | 0.7886716 | insignificant |
| B vs D | 3.1390 | 0.2478112 | insignificant |
| B vs E | 1.6998 | 0.7316065 | insignificant |
| C vs D | 1.5962 | 0.7692460 | insignificant |
| C vs E | 0.1571 | 0.8999947 | insignificant |
| D vs E | 1.4392 | 0.8263085 | insignificant |

TOTOX For Puori in the initial measurement and conditions during 4 weeks.

| | TOTOX Initial | PUORI Fridge | Shadow | Sun | Oven |
|---|---|---|---|---|---|
| 1 | 115,672 | 112,696 | 122,615 | 118,211 | 118,953 |
| 2 | 119,291 | 121,315 | 124,069 | 118,938 | 113,465 |
| 3 | 121,951 | 121,294 | 130,437 | 126,135 | 117,521 |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Initial | 3 | 356,915 | 118,972 | 9,9349 |
| Fridge | 3 | 355,305 | 118,435 | 24,6991 |
| Shadow | 3 | 377,121 | 125,707 | 17,3098 |
| Sun | 3 | 363,284 | 121,095 | 19,186 |
| Oven | 3 | 349,939 | 116,646 | 8,10333 |

ANOVA

| *Source of Varia* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between G | 145,131 | 4 | 36,2827 | 2,28962 | 0,13135 | 3,47805 |
| Within Grc | 158,466 | 10 | 15,8466 | | | |
| Total | 303,597 | 14 | | | | |

| treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inferfence |
|---|---|---|---|
| A vs B | 0.2335 | 0.8999947 | insignificant |
| A vs C | 2.9306 | 0.3021645 | insignificant |
| A vs D | 0.9238 | 0.8999947 | insignificant |
| A vs E | 1.0117 | 0.8999947 | insignificant |
| B vs C | 3.1641 | 0.2418075 | insignificant |
| B vs D | 1.1573 | 0.8999947 | insignificant |
| B vs E | 0.7783 | 0.8999947 | insignificant |
| C vs D | 2.0068 | 0.6200578 | insignificant |
| C vs E | 3.9424 | 0.1085822 | insignificant |
| D vs E | 1.9355 | 0.6459748 | insignificant |

Peroxide and anisidine values for the initial measurements (left) and Elixir (right).

PEROXIDE

| | INITIAL | | |
|---|---|---|---|
| | EL | BS | PU |
| 1 | 5,045017 | 5,1167 | 2,802354 |
| 2 | 4,478817 | 4,225146 | 2,346133 |
| 3 | 4,472272 | 4,85693 | 2,362484 |
| Average | 4,665369 | 4,732925 | 2,503657 |

Tukey HSD results

| treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inferfence |
|---|---|---|---|
| A vs B | 0.3265 | 0.8999947 | insignificant |
| A vs C | 10.4471 | 0.0010053 | ** p<0.01 |
| B vs C | 10.7736 | 0.0010053 | ** p<0.01 |

Anova: Single Factor Peroxide value initial

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| EL | 3 | 13,99611 | 4,665369 | 0,10811 |
| BS | 3 | 14,19878 | 4,732925 | 0,21025 |
| PU | 3 | 7,510971 | 2,503657 | 0,066982 |

ANOVA

| *Source of Varia* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between G | 9,647201 | 2 | 4,823601 | 37,55313 | 0,000405 | 5,143253 |
| Within Gr | 0,770684 | 6 | 0,128447 | | | |
| Total | 10,41789 | 8 | | | | |

ANISIDINE

| | INITIAL | | |
|---|---|---|---|
| | EL | BS | PU |
| 1 | 8,178774 | 6,744555 | 110,0672 |
| 2 | 8,338161 | 7,132754 | 114,5992 |
| 3 | 8,667246 | 7,609263 | 117,2265 |
| Average | 8,394727 | 7,162191 | 113,9643 |

Tukey HSD results

| treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inferfence |
|---|---|---|---|
| A vs B | 1.0114 | 0.7514486 | insignificant |
| A vs C | 86.6288 | 0.0010053 | ** p<0.01 |
| B vs C | 87.6402 | 0.0010053 | ** p<0.01 |

Anova: Single Factor

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| EL | 3 | 25,18418 | 8,394727 | 0,062051 |
| BS | 3 | 21,48657 | 7,162191 | 0,18758 |
| PU | 3 | 341,8928 | 113,9643 | 13,11617 |

ANOVA

| *Source of Varia* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between G | 22553,13 | 2 | 11276,56 | 2531,064 | 1,66E-09 | 5,143253 |
| Within Gr | 26,73159 | 6 | 4,455266 | | | |
| Total | 22579,86 | 8 | | | | |

PEROXIDE

| | 4 WEEKS LATER ELIXIR | | | |
|---|---|---|---|---|
| | Fridge | Shadow | Sun | Oven |
| 1 | 3,626541 | 4,502108 | 4,471363 | 5,584368 |
| 2 | 3,968726 | 4,20159 | 4,062233 | 5,555776 |
| 3 | 3,951476 | 4,091486 | 4,275498 | 5,141388 |
| Average | 3,848914 | 4,265061 | 4,269698 | 5,427177 |

Tukey HSD results

| treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inferfence |
|---|---|---|---|
| A vs B | 3.3455 | 0.1619709 | insignificant |
| A vs C | 3.3828 | 0.1561826 | insignificant |
| A vs D | 12.6882 | 0.0010053 | ** p<0.01 |
| B vs C | 0.0373 | 0.8999947 | insignificant |
| B vs D | 9.3427 | 0.0010053 | ** p<0.01 |
| C vs D | 9.3054 | 0.0010053 | ** p<0.01 |

Anova: Single Factor

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Fridge | 3 | 11,54674 | 3,848914 | 0,037162 |
| Shadow | 3 | 12,79518 | 4,265061 | 0,045174 |
| Sun | 3 | 12,80909 | 4,269698 | 0,041872 |
| Oven | 3 | 16,28153 | 5,427177 | 0,061461 |

ANOVA

| *urce of Varia* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* | *Sc* |
|---|---|---|---|---|---|---|---|
| Between G | 4,148584 | 3 | 1,382861 | 29,79198 | 0,000108 | 4,066181 | |
| Within Gr | 0,371338 | 8 | 0,046417 | | | | |
| Total | 4,519922 | 11 | | | | | |

ANISIDINE

| | 4 WEEKS LATER ELIXIR | | | |
|---|---|---|---|---|
| | Fridge | Shadow | Sun | Oven |
| 1 | 7,631534 | 8,982459 | 9,938064 | 9,197147 |
| 2 | 8,675511 | 9,10262 | 8,705528 | 8,99786 |
| 3 | 8,711864 | 9,770262 | 9,458321 | 9,101242 |
| Average | | | | |

| treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inferfence |
|---|---|---|---|
| A vs B | 3.3560 | 0.1603320 | insignificant |
| A vs C | 3.6477 | 0.1204485 | insignificant |
| A vs D | 2.6945 | 0.2982026 | insignificant |
| B vs C | 0.2917 | 0.8999947 | insignificant |
| B vs D | 0.6615 | 0.8999947 | insignificant |
| C vs D | 0.9532 | 0.8999947 | insignificant |

Anova: Single Factor

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Fridge | 3 | 25,01891 | 8,339636 | 0,376387 |
| Shadow | 3 | 27,85534 | 9,285114 | 0,180136 |
| Sun | 3 | 28,10191 | 9,367304 | 0,386 |
| Oven | 3 | 27,29625 | 9,098749 | 0,009933 |

ANOVA

| *urce of Varia* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* | *Sc* |
|---|---|---|---|---|---|---|---|
| Between G | 1,979918 | 3 | 0,659973 | 2,771665 | 0,110681 | 4,066181 | |
| Within Gr | 1,904914 | 8 | 0,238114 | | | | |
| Total | 3,884832 | 11 | | | | | |

Peroxide and anisidine values for Biosalma (left) and Puori (right).

PEROXIDE

| | 4 WEEKS LATER BIOSALMA | | | |
|---|---|---|---|---|
| | Fridge | Shadow | Sun | Oven |
| 1 | 4,297882 | 4,281155 | 4,76096 | 3,917881 |
| 2 | 4,226952 | 4,085637 | 4,657481 | 4,2186 |
| 3 | 4,742896 | 4,042854 | 4,770803 | 4,316603 |

Anova: Single Factor

SUMMARY

| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Fridge | 3 | 13,26773 | 4,422577 | 0,078211 |
| Shadow | 3 | 12,40965 | 4,136549 | 0,016141 |
| Sun | 3 | 14,18924 | 4,729748 | 0,003941 |
| Oven | 3 | 12,45308 | 4,151028 | 0,043169 |

ANOVA

| Source of Variati | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Grou | 0,702687 | 3 | 0,234229 | 6,623091 | 0,014659 | 4,066181 |
| Within Group | 0,282924 | 8 | 0,035366 | | | |
| Total | 0,985612 | 11 | | | | |

| treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inferfence |
|---|---|---|---|
| A vs B | 2.6344 | 0.3144746 | insignificant |
| A vs C | 2.8291 | 0.2639976 | insignificant |
| A vs D | 2.5010 | 0.3533936 | insignificant |
| B vs C | 5.4635 | 0.0200301 | * p<0.05 |
| B vs D | 0.1334 | 0.8999947 | insignificant |
| C vs D | 5.3301 | 0.0227758 | * p<0.05 |

PEROXIDE

| | 4 WEEKS LATER PUORI | | | |
|---|---|---|---|---|
| | Fridge | Shadow | Sun | Oven |
| 1 | 2,004249 | 2,391304 | 2,429937 | 3,583373 |
| 2 | 2,204586 | 2,399904 | 2,156355 | 3,902287 |
| 3 | 2,35248 | 2,679528 | 2,326033 | 4,265384 |

Anova: Single Factor

SUMMARY

| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Fridge | 3 | 6,561314 | 2,187105 | 0,030545 |
| Shadow | 3 | 7,470737 | 2,490246 | 0,026889 |
| Sun | 3 | 6,912325 | 2,304108 | 0,019072 |
| Oven | 3 | 11,75104 | 3,917015 | 0,116448 |

ANOVA

| urce of Varia | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between G | 5,827468 | 3 | 1,942489 | 40,26832 | 3,57E-05 | 4,066181 |
| Within Gro | 0,385909 | 8 | 0,048239 | | | |
| Total | 6,213377 | 11 | | | | |

Tukey HSD results

| treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inferfence |
|---|---|---|---|
| A vs B | 2.3906 | 0.3883345 | insignificant |
| A vs C | 0.9227 | 0.8999947 | insignificant |
| A vs D | 13.6423 | 0.0010053 | ** p<0.01 |
| B vs C | 1.4679 | 0.7167424 | insignificant |
| B vs D | 11.2517 | 0.0010053 | ** p<0.01 |
| C vs D | 12.7196 | 0.0010053 | ** p<0.01 |

ANISIDINE

| | 4 WEEKS LATER BIOSALMA | | | |
|---|---|---|---|---|
| | Fridge | Shadow | Sun | Oven |
| 1 | 5,563563 | 6,23797 | 5,403886 | 6,206912 |
| 2 | 5,593707 | 6,623581 | 6,277474 | 6,831233 |
| 3 | 5,181451 | 6,680904 | 5,841019 | 6,56888 |

Average

Anova: Single Factor

SUMMARY

| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Fridge | 3 | 16,33872 | 5,44624 | 0,052812 |
| Shadow | 3 | 19,54245 | 6,514151 | 0,058029 |
| Sun | 3 | 17,52238 | 5,840793 | 0,190789 |
| Oven | 3 | 19,60703 | 6,535675 | 0,098271 |

ANOVA

| Source of Variati | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Grou | 2,564783 | 3 | 0,854928 | 8,551388 | 0,007069 | 4,066181 |
| Within Group | 0,799803 | 8 | 0,099975 | | | |
| Total | 3,364586 | 11 | | | | |

| treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inferfence |
|---|---|---|---|
| A vs B | 5.8499 | 0.0138857 | * p<0.05 |
| A vs C | 2.1613 | 0.4665693 | insignificant |
| A vs D | 5.9678 | 0.0124403 | * p<0.05 |
| B vs C | 3.6886 | 0.1156619 | insignificant |
| B vs D | 0.1179 | 0.8999947 | insignificant |
| C vs D | 3.8065 | 0.1028481 | insignificant |

ANISIDINE

| | 4 WEEKS LATER PUORI | | | |
|---|---|---|---|---|
| | Fridge | Shadow | Sun | Oven |
| 1 | 108,6879 | 117,8325 | 113,3514 | 111,7862 |
| 2 | 116,906 | 119,269 | 114,6251 | 105,6604 |
| 3 | 116,5886 | 125,0783 | 121,483 | 108,9903 |

Average

Anova: Single Factor

SUMMARY

| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Fridge | 3 | 342,1824 | 114,0608 | 21,67648 |
| Shadow | 3 | 362,1797 | 120,7266 | 14,71879 |
| Sun | 3 | 349,4596 | 116,4865 | 19,12957 |
| Oven | 3 | 326,4369 | 108,8123 | 9,405094 |

ANOVA

| urce of Varia | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between G | 222,5141 | 3 | 74,17135 | 4,569316 | 0,038085 | 4,066181 |
| Within Gro | 129,8599 | 8 | 16,23248 | | | |
| Total | 352,3739 | 11 | | | | |

| treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inferfence |
|---|---|---|---|
| A vs B | 2.8656 | 0.2552846 | insignificant |
| A vs C | 1.0428 | 0.8705105 | insignificant |
| A vs D | 2.2563 | 0.4334199 | insignificant |
| B vs C | 1.8228 | 0.5883606 | insignificant |
| B vs D | 5.1220 | 0.0278729 | * p<0.05 |
| C vs D | 3.2992 | 0.1694462 | insignificant |

## 8.2 T-tests

One-sample one-tailed t-tests for PV, AV and TOTOX. Blue rubrics for measurements below the limits, orange for measurements over the limit.

T-test for the initial measurements of PV (left) and AV (right) compared against recommended limits of 5 for PV and 20 for AV.

| INITIAL PV | Elixir | Biosalma | Puori |
|---|---|---|---|
| 1 | 5,04502 | 5,1167 | 2,80235 |
| 2 | 4,47882 | 4,22515 | 2,34613 |
| 3 | 4,47227 | 4,85693 | 2,36248 |
| AVERAGE | 4,66537 | 4,73293 | 2,50366 |
| STDEV.S | 0,3288 | 0,45853 | 0,25881 |
| t-value | -1,76276 | -1,00885 | -16,7065 |
| Significanc | 0,11 | 0,20963 | 0,00178 |

| INITIAL AV | Elixir | Biosalma | Puori |
|---|---|---|---|
| 1 | 8,1787738 | 6,74456 | 110,067 |
| 2 | 8,3381611 | 7,13275 | 114,599 |
| 3 | 8,66724553 | 7,60926 | 117,226 |
| AVERAGE | 8,39472681 | 7,16219 | 113,964 |
| STDEV.S | 0,24910021 | 0,43311 | 3,62162 |
| t-value | -80,6941212 | -51,3403 | 44,9386 |
| Significance | 7,6769E-05 | 0,00019 | 0,00018 |

T-test for the measurements of PV (left) and AV (right) of Elixir Pharma after 4 weeks of storage, compared against recommended limits of 5 for PV and 20 for AV.

| 4 WEEK | PV | Elixir Pharma | | Oven |
|---|---|---|---|---|
| | Fridge | Shadow | Sun | 5,58437 |
| 1 | 3,62654 | 4,50211 | 4,47136 | 5,55578 |
| 2 | 3,96873 | 4,20159 | 4,06223 | 5,14139 |
| 3 | 3,95148 | 4,09149 | 4,2755 | 5,42718 |
| AVERAGE | 3,84891 | 4,26506 | 4,2697 | 0,24791 |
| STDEV.S | 0,19277 | 0,21254 | 0,20463 | 2,98448 |
| t-value | -10,3424 | -5,98918 | -6,18161 | 0,04816 |
| Significanc | 0,00461 | 0,01338 | 0,01259 | |

| 4 WEEK | AV | Elixir Pharma | | |
|---|---|---|---|---|
| | Fridge | Shadow | Sun | Oven |
| 1 | 7,631533736 | 8,98245931 | 9,93806 | 9,19715 |
| 2 | 8,675511292 | 9,10261993 | 8,70553 | 8,99786 |
| 3 | 8,711863924 | 9,77026194 | 9,45832 | 9,10124 |
| AVERAGE | 8,339636317 | 9,28511372 | 9,3673 | 9,09875 |
| STDEV.S | 0,613504138 | 0,4244246 | 0,62129 | 0,09967 |
| t-value | -32,9196513 | -43,7267953 | -29,6422 | -189,446 |
| Significanc | 0,000460743 | 0,0002613 | 0,00057 | 1,4E-05 |

T-test for the measurements of PV (left) and AV (right) of Biosalma after 4 weeks of storage, compared against recommended limits of 5 for PV and 20 for AV.

| 4 WEEK | PV | Biosalma | | |
|---|---|---|---|---|
| | Fridge | Shadow | Sun | Oven |
| 1 | 4,29788 | 4,28116 | 4,76096 | 3,91788 |
| 2 | 4,22695 | 4,08564 | 4,65748 | 4,2186 |
| 3 | 4,7429 | 4,04285 | 4,7708 | 4,3166 |
| AVERAGE | 4,42258 | 4,13655 | 4,72975 | 4,15103 |
| STDEV.S | 0,27966 | 0,12705 | 0,06278 | 0,20777 |
| t-value | -3,5762 | -11,7716 | -7,45626 | -7,07728 |
| Significanc | 0,03504 | 0,00357 | 0,00876 | 0,00969 |

| 4 WEEK | AV | Biosalma | | |
|---|---|---|---|---|
| | Fridge | Shadow | Sun | Oven |
| 1 | 5,56356257 | 6,23796966 | 5,40389 | 6,20691 |
| 2 | 5,593707079 | 6,62358083 | 6,27747 | 6,83123 |
| 3 | 5,181451483 | 6,68090399 | 5,84102 | 6,56888 |
| AVERAGE | 5,446240377 | 6,51415149 | 5,84079 | 6,53568 |
| STDEV.S | 0,229808707 | 0,24089166 | 0,43679 | 0,31348 |
| t-value | -109,690583 | -96,965478 | -56,1465 | -74,393 |
| Significanc | 4,15506E-05 | 5,317E-05 | 0,00016 | 9E-05 |

T-test for the measurements of PV of Puori after 4 weeks of storage, compared against recommended limits of 5 for PV and 20 for AV.

| 4 WEEK | PV | Puori | | |
|---|---|---|---|---|
| | Fridge | Shadow | Sun | Oven |
| 1 | 2,00425 | 2,3913 | 2,42994 | 3,58337 |
| 2 | 2,20459 | 2,3999 | 2,15636 | 3,90229 |
| 3 | 2,35248 | 2,67953 | 2,32603 | 4,26538 |
| AVERAGE | 2,1871 | 2,49025 | 2,30411 | 3,91701 |
| STDEV.S | 0,17477 | 0,16398 | 0,1381 | 0,34124 |
| t-value | -27,8767 | -26,5094 | -33,8114 | -5,4969 |
| Significanc | 0,00064 | 0,00071 | 0,00044 | 0,01577 |

| 4 WEEK | AV | Puori | | |
|---|---|---|---|---|
| | Fridge | Shadow | Sun | Oven |
| 1 | 108,6878758 | 117,83251 | 113,351 | 111,786 |
| 2 | 116,9059893 | 119,268957 | 114,625 | 105,66 |
| 3 | 116,5885547 | 125,078277 | 121,483 | 108,99 |
| AVERAGE | 114,0608066 | 120,726581 | 116,487 | 108,812 |
| STDEV.S | 4,655800735 | 3,83650722 | 4,37374 | 3,06677 |
| t-value | 34,99249759 | 45,4745805 | 38,2098 | 50,1594 |
| Significanc | 0,000407839 | 0,00024161 | 0,00034 | 0,0002 |

T-test for TOTOX of Elixir Pharma under all conditions, compared against recommended limit of 26 for TOTOX.

| ALL | TOTOX | Elixir | | | |
|---|---|---|---|---|---|
| | Initial | Fridge | Shadow | Sun | Oven |
| 1 | 18,2688 | 14,8846 | 17,9867 | 18,8808 | 20,3659 |
| 2 | 17,2958 | 16,613 | 17,5058 | 16,83 | 20,1094 |
| 3 | 17,6118 | 16,6148 | 17,9532 | 18,0093 | 19,384 |
| AVERAGE | 17,7255 | 16,0375 | 17,8152 | 17,9067 | 19,9531 |
| STDEV.S | 0,49637 | 0,9984 | 0,2685 | 1,02924 | 0,50925 |
| t-value | -28,8737 | -17,2833 | -52,7984 | -13,6197 | -20,5665 |
| Significanc | 0,0006 | 0,00167 | 0,00018 | 0,00267 | 0,00118 |

T-test for TOTOX of Biosalma under all conditions, compared against recommended limit of 26 for TOTOX.

| ALL | TOTOX | Biosalma | | | |
|---|---|---|---|---|---|
| | Initial | Fridge | Shadow | Sun | Oven |
| 1 | 16,9779555 | 14,1593 | 14,8003 | 14,9258 | 14,0427 |
| 2 | 15,5830469 | 14,0476 | 14,7949 | 15,5924 | 15,2684 |
| 3 | 17,3231237 | 14,6672 | 14,7666 | 15,3826 | 15,2021 |
| AVERAGE | 16,628042 | 14,2914 | 14,7872 | 15,3003 | 14,8377 |
| STDEV.S | 0,92130147 | 0,33025 | 0,01808 | 0,34086 | 0,68934 |
| t-value | -17,619322 | -61,4072 | -1074,39 | -54,3702 | -28,0466 |
| Significance | 0,00160287 | 0,00013 | 4,3E-07 | 0,00017 | 0,00063 |

T-test for TOTOX of Puori under all conditions, compared against recommended limit of 26 for TOTOX.

| ALL | TOTOX | Puori | | | |
|---|---|---|---|---|---|
| | Initial | Fridge | Shadow | Sun | Oven |
| 1 | 115,671877 | 112,696 | 122,615 | 118,211 | 118,953 |
| 2 | 119,29143 | 121,315 | 124,069 | 118,938 | 113,465 |
| 3 | 121,951421 | 121,294 | 130,437 | 126,135 | 117,521 |
| AVERAGE | 118,971576 | 118,435 | 125,707 | 121,095 | 116,646 |
| STDEV.S | 3,15196758 | 4,96982 | 4,16051 | 4,38019 | 2,84663 |
| t-value | 51,0891973 | 32,2149 | 41,5088 | 37,6032 | 55,1543 |
| Significanc | 0,00019145 | 0,00048 | 0,00029 | 0,00035 | 0,00016 |