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SOME DETERIORATION PARAMETERS OF EDIBLE OILS AND FATS SOLD IN TÜRKİYE MARKETS

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ABSTRACT
In this study, some deterioration parameters were determined in nine different types of edible fats and oils (46 samples) obtained from the Turkish market, their compliance with the Turkish Food Codex and Standards was evaluated and compared with the literature. Six samples including (3 margarines, 2 shortenings and 1 riviera olive oil) had peroxide value (PV) that exceeded the codex limit. The oils with the highest PVs were found to be fish oils (8.5-27.4 meqO_2/kg), peanut oils (9.2-32.1 meqO_2/kg) and extra virgin olive oils (10.37-17.66 meqO_2/kg). Free fatty acidity (FFA) content of one of the riviera olive oils (1.29%) and extra virgin olive oil (0.81-1.13%) sample were above the limit value of the Codex. The highest conjugated-diene and -triene were determined in fish oils (9.12-12.3 and 2.42-5.60, respectively). The p-Anisidine values in hazelnut and fish oils ranged from 2 to 61.
Keywords: Edible oils, free fatty acidity, deterioration parameters, oxidation, peroxide value, p-Anisidine

TÜRKİYE PAZARLARINDA SATILAN YEMEKLİK SIVI VE KATI YAĞLARIN BAZI BOZULMA PARAMETRELERİ

ÖZ
Bu çalışmada, Türkiye pazarından temin edilen dokuz çeşit yemeklik katı ve sıvı yağda (46 numune) bazı bozulma parametreleri belirlenmiş, bunların Türk Gıda Kodeksi gerekliliklerine uygunluğu değerlendirilmiş ve literatür ile karşılaştırılmıştır. Altı numunede kodeks limitini aşan peroksit sayısı (PS) tespit edilmiştir (3 margarin, 2 katı yağ ve 1 riviera zeytinyağı). En yüksek PS'na sahip yağlar balık yağları (8.5-27.4 meqO_2/kg), yer fıstığı yağları (9.2-32.1 meqO_2/kg) ve natürel sızma zeytinyağı (10.37-17.66 meqO_2/kg) olmuştur. Serbest yağ asitliği (SYA) oranları riviera zeytin yağlarının birinde ve sızma zeytinyağının tamamında sınır değerin üzerinde çıkmıştır. En yüksek konjuge-dien ve -trien balık yağlarında belirlenmiştir (sırasıyla 9.12-12.3 ve 2.42-5.60). SYA oranları riviera zeytinyağının birinde (%1.29) ve natürel sızma zeytinyağının tamamında (%0.81-1.13) sınır değerin üzerinde çıkmıştır. Fındık ve balık yağlarında bulunan p-Anisidin değerleri 2 ile 61 arasında değişmiştir.
Anahtar kelimeler: Yemeklik yağlar, serbest yağ asitliği, bozulma parametreleri, oksidasyon, peroksit değeri, p-Anisidin

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INTRODUCTION

Fats and oils are vital food components in human nutrition. When stored under inappropriate conditions, they decompose as a result of oxidative and hydrolytic reactions. All fats and oils may undergo oxidation during storage. The level of oxidation depends primarily on external factors such as storage temperature, air (oxygen) concentration and light, as well as minor components such as fatty acid profile, moisture and other impurities, and processing quality. Fat oxidation does not only cause changes in taste, odor and color in foods, but also causes harmful effects on human health by reducing the nutritional quality and safety due to decomposition products (Das, 1991; Rodriguez-Estrada and Caboni, 2002; Zhang et al., 2010). Edible oils with higher unsaturated fatty acids content, especially polyunsaturated fatty acids, are more susceptible to oxidation (Kapich et al., 2010). The oxidation of edible oils begins with the double bonds of fatty acids in the triacylglycerol molecule. The first products of lipid oxidation are hydroperoxides, which are tasteless and odorless and therefore do not significantly impair the sensory quality of the oil (Reindl and Stan, 1982). Since hydroperoxides are generally unstable compounds, they are converted to secondary products of oxidation such as ketones, aldehydes, alcohols, lactones, hydrocarbons and esters. Some of these components, even at very low levels, significantly impair the taste and odor of the oils and fats. Hydrolytic reactions are measured by determining the FFA content in fats and oils. PV, conjugated diene (K_{232}) and conjugated triene (K_{270}) as primary oxidation products; p-Anisidine value (p-AV) and TBARS analyzes are used as secondary oxidation products (Baştürk, 2019; Chinprahast et al., 2016; Shahidi, 1998; Shi et al., 2015) in determining the oxidation rate in fats and oils.

Within the scope of this study, sunflower oil (7 brands), hazelnut oil (4 brands), corn oil (6 brands), natural extra virgin olive oil (7 brands), riviera olive oil (7 brands), margarine and shortening (9 brands), peanut oil (2 brands), and fish oil capsules (4 brands) which are sold and consumed widely in the markets of Türkiye were investigated. PV, K_{232} and K_{270} measured to monitor the primary products of oxidation, p-AV and Totox values were determined to measure secondary products of oxidation, and FFA was measured as an indicator of hydrolytic degradation in all oils and fats samples. The results obtained were evaluated according to the Turkish Food Codex and compared with the literature.

MATERIALS AND METHODS

Material

Different cooking oils, fish oils, margarines and shortenings used in the study were obtained in 2019 from Türkiye local markets. Their names and number of brands are shown in Table 1. Extra virgin olive oil is obtained by cold pressing, that is, it is not refined. Riviera olive oil consists of 20% extra virgin olive oil and 80% refined olive oil. Diethyl ether, methanol, sodium hydroxide, sodium bromide, ethyl acetate, glacial acetic acid, acetone and sodium thiosulfate were obtained from Sigma-Aldrich (Steinheim, Germany). The purity of the chemicals was ensured.

Methods

Preparation of samples

The lipid fractions of margarine and fats were obtained by melting the fats and centrifuged and then filtered through anhydrous sodium sulfate by removing the upper oil phase. In margarines and shortenings, analysis were performed only in the lipid phase. Encapsulated fish oils were removed from the capsules with a sterile needle. Edible oils were obtained from the market. All oils and fats samples were stored at 4 °C in dark until the experiments. Sample brand numbers, types, production dates and codes are presented in Table 1.

Determination of free fatty acidity

FFA of oil samples were determined according to AOCS Official Method Ca 5a-40 (AOCS, 2004). Experiments were performed in triplicate and the mean value was used.

Table 1. Description of the samples

Sample names	The number of brands	Production date	Packaging type	Sample code
Sunflower oil (Refined)	seven different brands	March-June 2019	plastic oil bottle (1 liter)	SO1, SO2, SO3, SO4, SO5, SO6, SO7
Hazelnut oil (Refined)	four different brands	September-December 2018	metal tin can (1 liter)	HO1, HO2, HO3, HO4
Peanut oil (Refined)	two different brands	June-August 2018	plastic oil bottle (1 liter)	PO1, PO2
Corn oil (Refined)	six different brands	January-May 2019	plastic oil bottle (1 liter)	CO1, CO2, CO3, CO4, CO5, CO6
ExtraVirgin Olive Oil (Cold-pressed)	seven different brands	4 of them 2018, 3 of them 2019	2 plastic oil bottles (1 liter), 4 glass oil bottles (250 ml), 1 glass oil bottle (150 ml)	EVOO1, EVOO2, EVOO3, EVOO4, EVOO5, EVOO6, EVOO7
Riviera olive oil (Blend from refined and cold pressed)	seven different brands	5 of them 2018, 2 of them 2019	2 plastic oil bottles (1 liter), 4 glass oil bottles (250 ml), 1 glass oil bottle (750 ml)	ROO1, ROO2, ROO3, ROO4, ROO5, ROO6, ROO7
Pastry oil (Shortening) (Refined)	three different brands	March-July 2019	paper package (250 gr, 1 kg, 2.5 kg)	S1, S2, S3
Margarine (Refined)	six different brands	March-May 2019	Package (250 gr)	M1, M2, M3, M4, M5, M6
Fish oil (capsule) (Native-Refined)	four different brands	2 of them July-December 2018, 2 of them January-June 2019	capsule in a capped bottle	FO1, FO2, FO3, FO4

Peroxide value

Peroxide values were determined according to AOCS Official Method Cd 8-53 (AOCS, 1989a). All samples were analysed in triplicate. PVs were calculated according to Equation 1.

$$PV = \frac{V \times T \times 1000}{m} \quad (1)$$

where PV= Peroxide value ($meqO_2/kg$ oil), V= Used sodium thiosulfate solution (mL), T= normality of sodium thiosulfate solution, m = sample weight (g)

p-Anisidine value

The p-AV analysis was carried out according to AOCS Official Method Cd 18-90 (AOCS, 1998). 0.5 g oil sample was weighed into a 25 mL graduated flask, completed with hexane up to the scale line. The absorbance of the test tube filled with hexane without sample was read at 350 nm (A_1). 5 mL oil (m) was taken into the test tube. 1 mL p-AV (0.25 g/100 mL glacial acetic acid) was added to the test tube. After 10 minutes the absorbance (A_2) of the sample was read at 350 nm against the reference cell prepared with hexane and p-AV without sample. The value of p-AV was calculated according to the Equation 2.

$$\text{p-AV} = \frac{25 \text{ x } [(1.2xA_2) - A_1]}{\text{m}} \quad (2)$$

m: Sample weight (g)

Total oxidation value

The total oxidation value (Totox) was calculated by adding 2 times PV with the p-AV value (Equation 3) (Shahidi and Wanasundara, 2002).

$$\text{Totox} = (2 \text{ x PV}) + \text{p-AV} \quad (3)$$

Conjugated-diene and -triene

Analysis was done according to AOCS Official Method Ch 5-91 (AOCS, 1989b). Specific absorption values were calculated by Equation 4.

$$E_{1cm}^{\%1} = K_\lambda = \frac{A_\lambda}{c \; x \; l} \quad (4)$$

where K_λ = Specific absorption value, A_λ = Absorbance value, c = Concentration of solution (g/100 mL), l = Quartz cuvette length (cm)

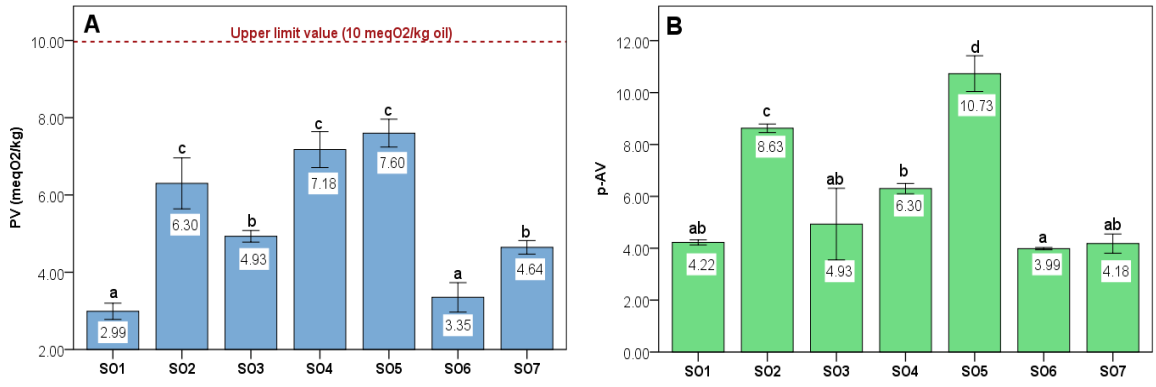
Statistical analysis

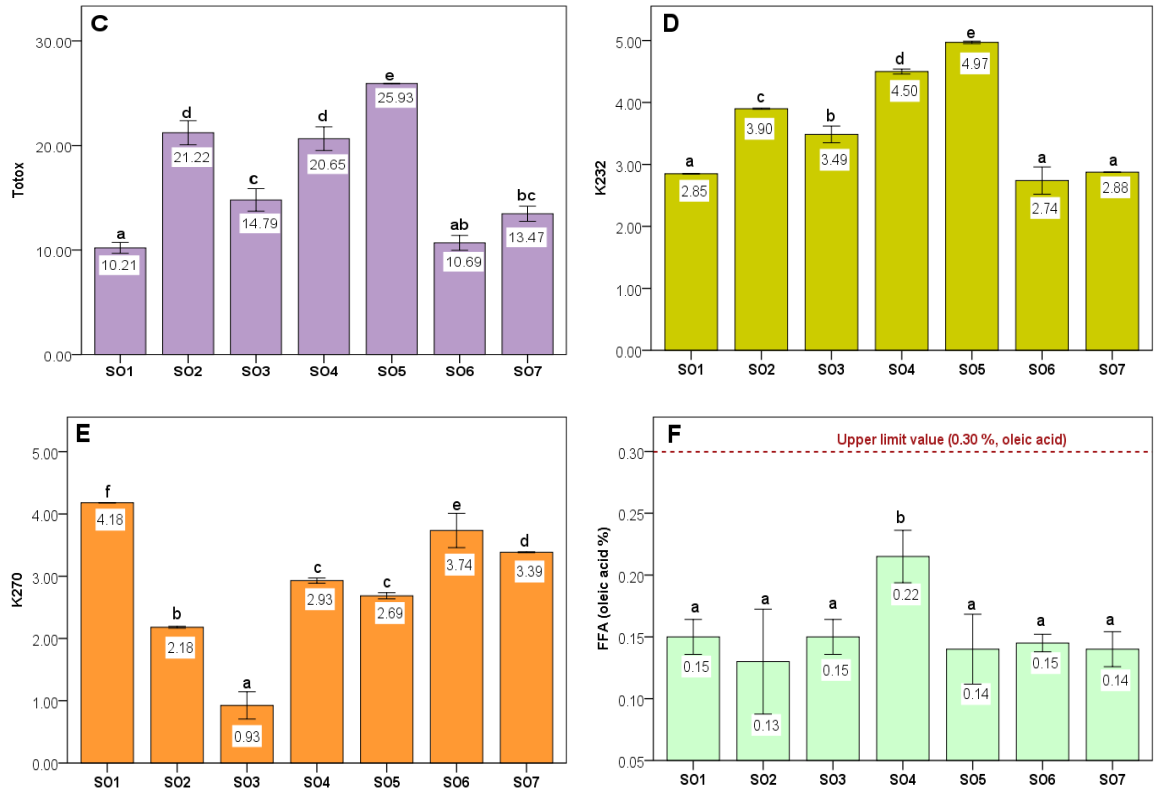
All data were statistically analyzed using SPSS (version 20.0 for Windows, SPSS Inc., Chicago, Illinois) package program by conducting one-way analysis of variance (ANOVA), and defining a significant difference at P <0.05 by Duncan test. Besides, the experiments were evaluated by performing three independent measurements for all treatment and expressed as the mean ± standard deviation (SD).

RESULTS AND DISCUSSION

Sunflower oils

The PV, p-AV, totox, K_{232}, K_{270}, and FFA values found in samples of sunflower oil from seven different brands are shown in Figure 1.





SO1-SO7: Sunflower oils (different brands). Different lowercase letters indicate the difference between the mean values of the samples (P <0.05). The upper limit values are the values specified by the "Turkish Food Codex Communiqué on Oils Called by Plant Name" (TGK, 2012).

Figure 1. Certain properties determined in sunflower oils

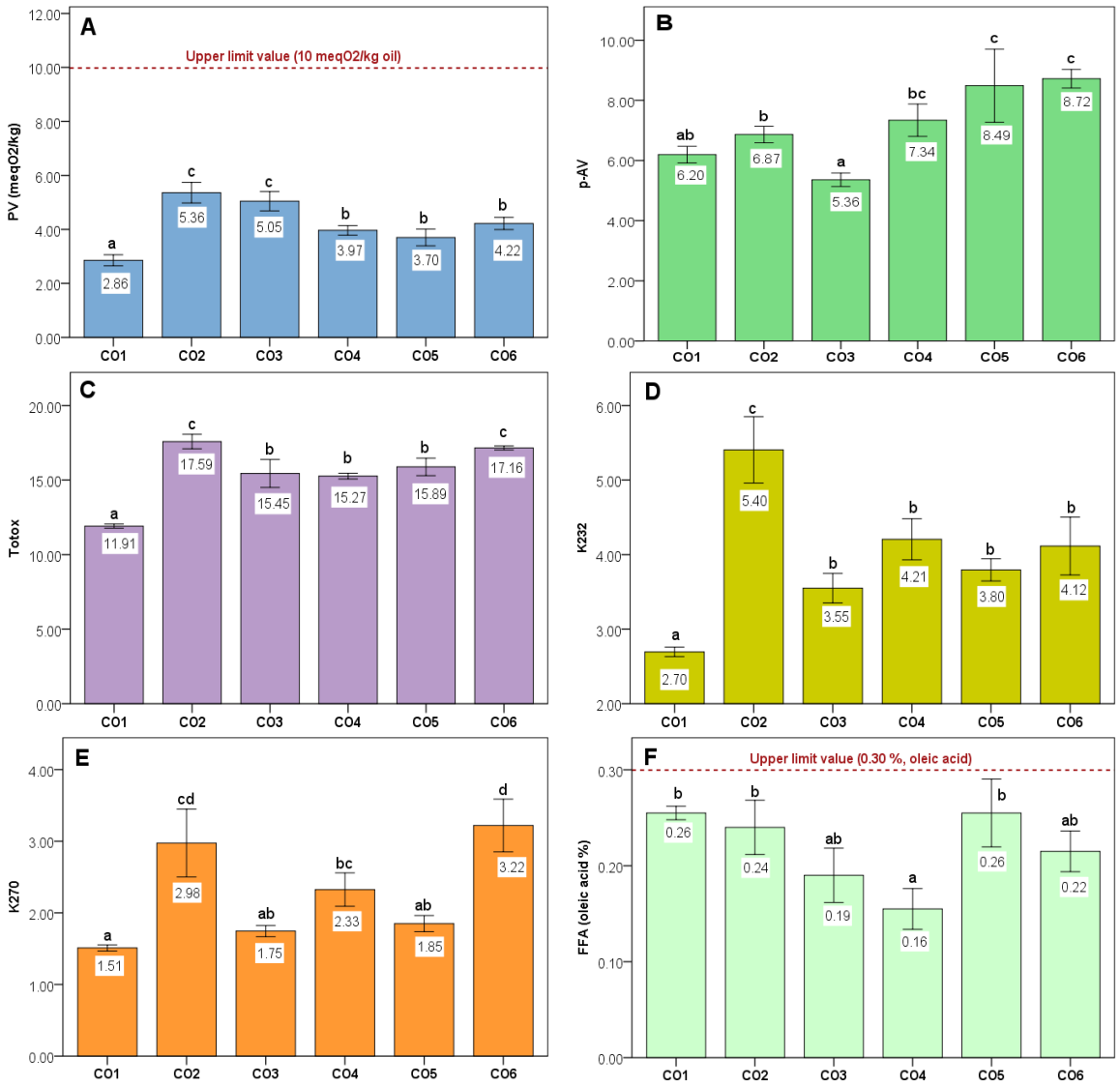
PV values of the samples were determined the range between 2.99-7.60 meqO_2/kg (P <0.05). These values are below the 10 meqO_2/kg PV upper limit value specified in the Turkish Food Codex Communiqué on Oils with Plant Name (TGK, 2012). PV is the primary oxidation product formed by storage of oils under unsuitable conditions (exposure to factors such as heat, light, heavy metal ions, etc.). The PVs of sunflower oils coded with SO2, SO4, and SO6 showed no significant differences.

The p-AV value is a colorimetric measurement (350 nm) based on the color change produced by the reaction between the p-AV reagent and secondary oxidation components (aldehydes, ketones, alcohols and acids). p-AV is a secondary oxidation parameter that occurs as a result of the breakdown of peroxides in the later stages of oxidation in oils and fats. p-AVs of oils and fats ranged between 3.99 to 10.73. The SO5 sample revealed the greatest level, and the SO6 sample revealed the lowest amount. The p-AVs of SO1, SO3 and SO7 sunflower oils were close to each other. However, the values of these and other samples were significantly different (P <0.05). Totox values of SOs varied in the range of 10.21-25.93 (P <0.05). In a previous study, PV, p-AV and totox values in sunflower oil were reported as 4.6 meqO_2/kg, 5.12 and 14.32, respectively (Ali et al., 2013). Anjum et al. (2006) determined the PVs of 3.77 and 2.60 meqO_2/kg and p-AVs as 3.24 and 4.99, respectively, in two different sunflower oils. These findings are consistent with the results of our study. Totox values in SO samples were in the range of 10.2 to 25.9 (P <0.05). There was no significant difference between SO2 and SO4 totox values (Figure 1C). K_{232} value was determined in the range of 2.74-4.97 (P <0.05) (Figure 1D), and K_{270} was determined in the range of 0.93-4.18 (P <0.05) (Figure 1E). K_{232} and K_{270} values were reported by Ali et al. (2014) as 1.14

and 0.55, and as 13.18 and 1.66 respectively, by Javidipour et al. (2017) in sunflower oils. Anjum et al. (2006) determined the K_{232} value as 4.10 and 9.66, and the K_{270} value as 0.60 and 0.58 in two different sunflower oils. FFA was determined in the range of 0.13-0.22 % in terms of oleic acid in sunflower oil samples (Figure 1F). According to the Turkish Food Codex Communiqué on Oils with Plant Name (TGK, 2012), FFA (in oleic acid, %) in edible sunflower oils should be at most 0.3%. In this case, all the sunflower oil samples were found to comply with the standard in terms of FFA. This value was determined as 0.16% by Ali et al. (2013) and as 0.10% by Javidipour et al. (2017). Our results were in accordance with the literature.

Corn oils

PV, p-AV, totox, K_{232}, K_{270} and FFA values determined in six different brands of corn oil samples are shown in Figure 2.



CO1-CO6: Corn oils (different brands). Different lowercase letters indicate the difference between the mean values of the samples (P <0.05). The upper limit values are the values specified by the "Turkish Food Codex Communiqué on Oils Called by Plant Name" (TGK, 2012).

Figure 2. Certain properties determined in corn oils

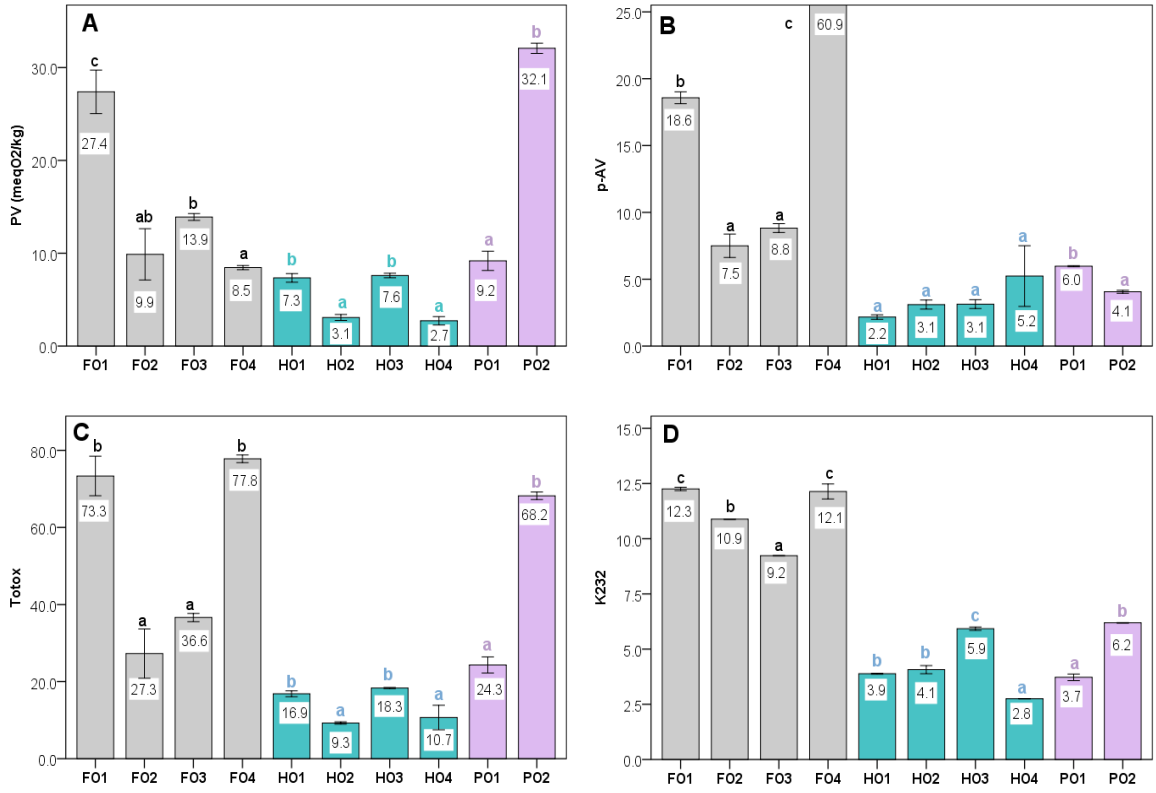
PVs varying between 2.86-5.36 meqO_2/kg in the samples (P <0.05) were found appropriate in the codex (Maximum 10 meqO_2/kg). There were no significant differences between the PVs of CO4, CO5, and CO6 samples. In previous studies, PV in corn oil was determined as 0.8 meqO_2/kg by Ahmad et al. (2011), 2.55 meqO_2/kg by Inanc Horuz and Maskan (2015), 4.34 meqO_2/kg by Ali et al. (2016), 10.2 meqO_2/kg by Bantchev et al. (2011), 9.96 meqO_2/kg Baştürk et al. (2018), 2.26 meqO_2/kg El Boulifi et al. (2010), 3.3 meqO_2/kg Günç Ergönül and Nergiz (2014) and 3.02 meqO_2/ kg Karakaya and Simsek (2011). Some of these findings were in accordance with our results.

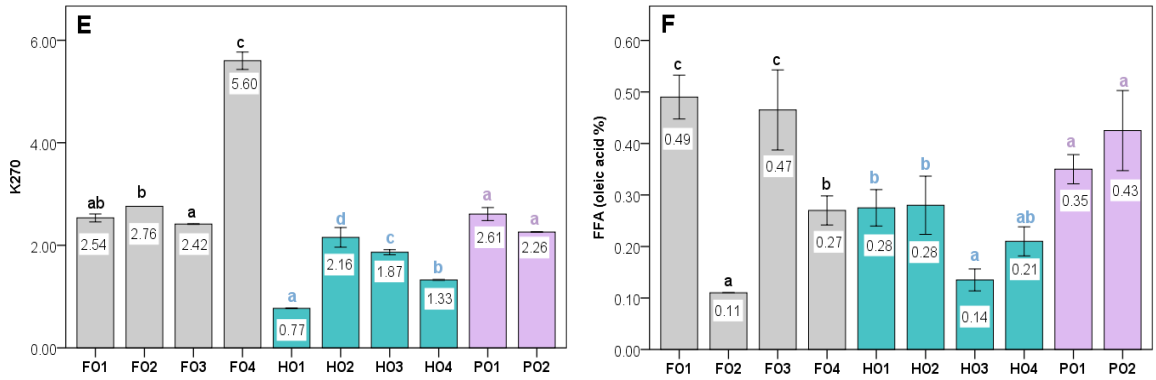
As seen in Figure 2B, p-AVs were found in the range of 5.36-8.72 (P <0.05). In corn oil, p-AV was determined as 2.85 by Inanc Horuz and Maskan (2015), 1.44 by Günç Ergönül and Nergiz (2014), and 1.36 by Inanc and Maskan (2013). Totox values in the samples were determined in the range of 11.91-17.59. Totox values did not differ significantly in CO3, CO4 and CO5 samples. Ali et al. (2016) determined PV, p-AV and totox values in corn oil as 4.34 meqO_2/kg, 1.22 and 8.90, respectively.

K_{232} values of CO3, CO4, CO5 and CO6 samples were quite similar (Figure 2D) however, K_{270} values of corn oils samples varied in the range of 1.51-3.22 (P <0.05). K_{232} was found to be 1.96 and K_{270} to be 0.05 in corn oil by Baştürk et al. (2018). FFA was determined in the range of 0.16-0.26% (Figure 2F). These values are within the limit (0.3% oleic acid) stated in the Turkish Food Codex Communiqué on Oils Called by Plant Name (TGK, 2012). In previous studies, FFA in CO was reported as 0.15% (Ali et al., 2016), and 0.12% (Inanc and Maskan, 2013). Our findings are similar to these results reported in the literature.

Fish oils, hazelnut oils, and peanut oils

Figure 3 displays the findings for FOs (4 brands), HOs (4 brands), and POs (2 brands) in terms of PV, p-AV, totox, K_{232}, K_{270}, and FFA.





FO1-FO2: Fish Oils (different brands), HO1-HO2: Hazelnut Oils (different brands), PO1-PO2: Peanut Oils (different brands). Different lowercase letters indicate the difference between the mean values of the samples (P <0.05).

Figure 3. Certain properties determined in fish, hazelnut, peanut oils

In FOs, the following values for PV, p-AV, totox, K_{232}, and K_{270} were found: 8.45–27.39 $meqO_2/kg$ for PV, 7.50–60.90 for p-AV, 27.3–77.8 for K_{270}, and 0.1-0.49% for FFA. The possible reason for the high levels of some of these parameters is that fish oils are rich in polyunsaturated fatty acids and therefore they are more susceptible to oxidation compared to other edible oils. Fazel et al. (2009) determined the PV levels of 2.7 and 2.3 $meqO_2/kg$ in carp and tuna fish, which are two important commercial and industrial fish in the Caspian Sea in the north of Iran. The p-AV value was reported as 1.12 and the totox value as 2.48 in New Zealand hoki fish oil (Kindleysides et al., 2012). The PV, p-AV and totox values of the 3 best-selling dietary supplements fish oil in the United States were determined in the range of 25-60 $meqO_2/kg$, 15-85 and 55-210, respectively (Mason and Sherratt, 2017). In a study evaluating the content of lipid oxidation products in various seafood omega-3 supplements in Norway, their PV was found in the range of 1.04-10.38 $meqO_2/kg$ (Halvorsen and Blomhoff, 2011). Sixteen of the best-selling liquid fish oil products in the American market were analyzed by Ritter et al. (2013) and their PV were found to be in the range of 1.0-14.8 $meqO_2/kg$. PV of encapsulated fish oil supplements marketed in New Zealand, was detected in the range of 1.09-33.34 and p-AV 3.14-72.63, totox in the range of 16.17-82.58 (Albert et al., 2015). Our results partially overlap with all these literature findings. However, it should kept in mind that many factors such as fish oil types, purity, packaging, and storage conditions will sure affect these results.

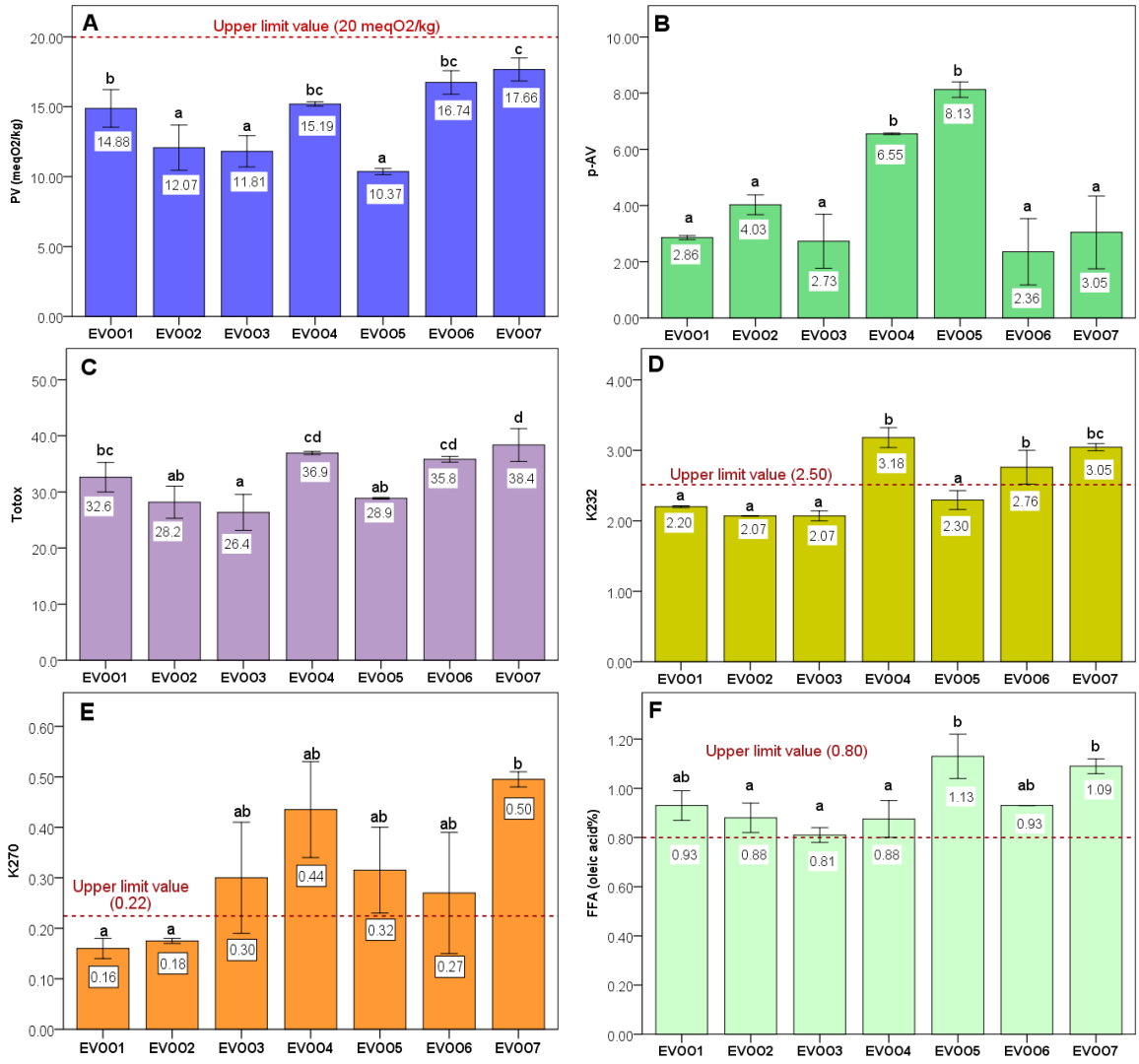
If HOs are evaluated, the difference between the mean values of the parameters other than p-AV was found to be statistically significant (P <0.05). Their PV ranged from 2.7 to 7.6 $meqO_2/kg$ (Figure 3A). There were no significant differences between p-AVs of HOs. Their PVs did not exceed the upper limit (10 $meqO_2/kg$) which is specified in the Turkish Food Codex Communiqué on Oils Called by Plant Name (TGK, 2012). Totox value was the highest in HO3. K_{232} values were higher than K_{270} in all samples. FFA values were determined in the range of 0.14-0.28 % in terms of oleic acid. FFA was found to be equal in HO1 and HO2 samples. Tekin et al. (2009) determined the FFA, PV and K_{232} values in HO as 0.33%, 1.02 $meqO_2/kg$ and 0.09, respectively. In HOs, FFA, p-AV, and K_{232} values were reported by Tohma and Turan (2015) to be 0.07 (% oleic acid), 2.0, and 0.11, respectively.

The PV, p-AV, totox, K_{232}, K_{270}, and FFA findings of two different brands of PO are presented in Figure 3. The difference between the mean in parameters other than K_{270} and FFA was found to be significant (P <0.05). The PV of PO2 was above the limit (10 $meqO_2/kg$) specified in the codex. In comparison to PO1, PO2's totox value was about 2.8 times higher. While the difference between the K_{232} values of the POs was

found to be significant, the K_{270} values were similar. The FFA of the POs was determined as 0.35% and 0.45% in terms of % oleic acid. FFA in both peanut oils exceeded the upper limit (0.3%) specified in the Turkish Food Codex Communiqué on Oils with Plant Name (TGK, 2012). According to Zhang et al. (2020), PVs and FFAs in peanut oils ranged from 3.36 to 14.93 mmol/kg and 0.35 to 0.69 mgKOH/g, respectively. Tanriverdi (2011) determined PV and FFA values in peanut oil as 9.41 $meqO_2/kg$ and 16.67% (in terms of oleic acid), respectively. According to Shi et al. (2015), K_{232} and K_{270} levels in peanut oil were 2.28 and 0.32, respectively. In two separate peanut oils, Özcan and Seven (2003) found that the FFA and PV values were 1.45-1.53 (% oleic acid) and 2.08-2.49 $meqO_2/kg$, respectively.

Extra virgin olive oils

Figure 4 shows PV, p-AV, totox, K_{232}, K_{270}, and FFA values of EVOOs.



EVOO1-EVOO7: Extra virgin olive oils (different brands). Different lowercase letters indicate the difference between the mean values of the samples (P <0.05). The upper limit values are the values specified by the "Turkish Food Codex Communique on Olive Oil and Olive Pomace Oil" (TGK, 2017).

Figure 4. Certain properties determined in extra virgin olive oils

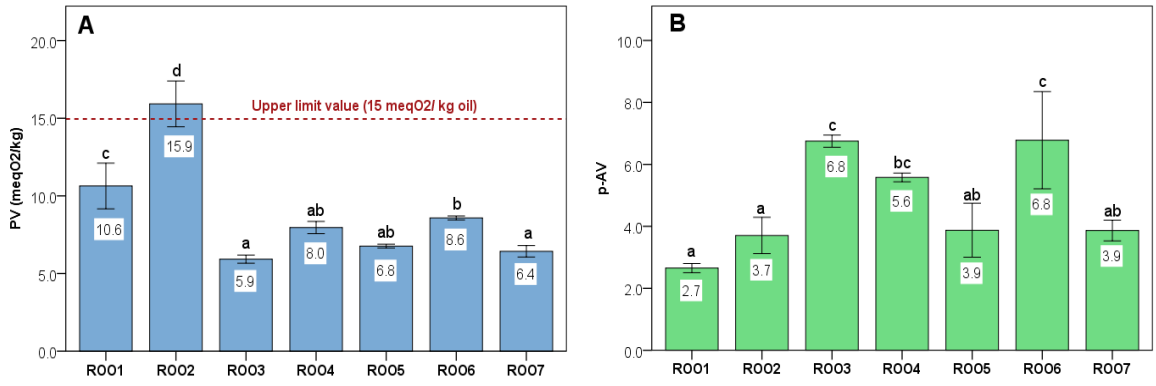
As seen in Figure 4A, PVs of EVOOs differed in the range of 10.4-17.7 meqO_2/kg (P <0.05). According to Turkish Food Codex Communiqué on Olive Oil and Olive Pomace Oil (TGK, 2017), the PV of EVOO should not be more than 20 meqO_2/kg. As a result, the EVOOs used in the study did not have PVs above the threshold set as the quality requirement. The lowest PVs were in EVOO2, EVOO3, and EVOO5, and the difference between them was not significant (P >0.05). PVs of EVOOs were found to be 17.9 meqO_2/kg by Ghanbari Shendi et al. (2018), 6.34-11.45 meqO_2/kg by Jabeur et al. (2022), 4.36 meqO_2/kg by Keramat and Golmakani (2016), and 15.37 meqO_2/kg by Tanrıverdi (2011).

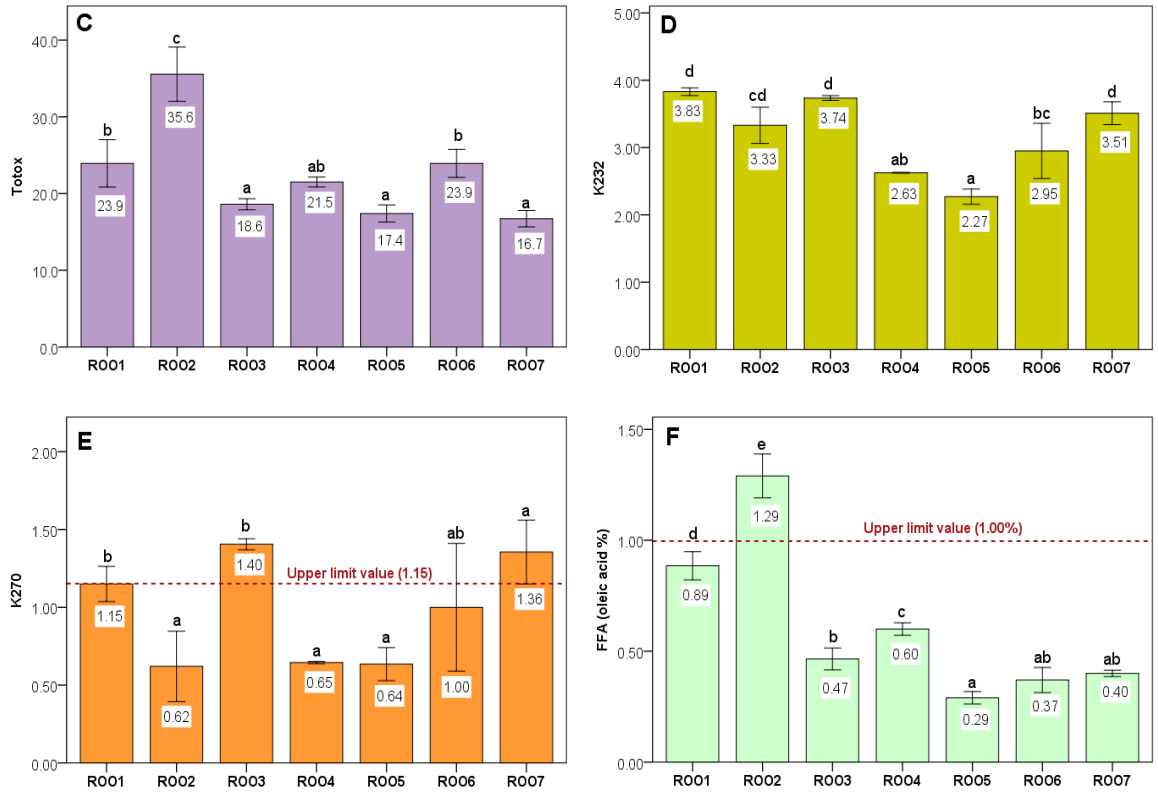
p-AV values in EVOOs were determined in the range of 2.36-8.13 (Figure 4B). p-AVs were close to each other in EVOO4 and EVOO5. There was no significant difference between the PVs of the other EVOOs (P >0.05). By Keramat and Golmakani (2016) p-AV was determined in EVOO at a level of 3.92. Totox values ranged from 26.35 to 38.37 (P <0.05). The lowest was at EVOO3, and the highest was at EVOO7. While K_{232} values in EVOOs differed between 2.07 and 3.18, K_{270} values were at lower levels (between 0.16-0.50) (P <0.05). Turkish Food Codex Communiqué on Olive Oil and Olive Pomace Oil (TGK, 2017) has specified the upper limits of K_{232} and K_{270} for EVOOs as 2.5 and 0.22, respectively. EVOO1, EVOO2, EVOO3, and EVOO5 samples for K_{232} and EVOO1 and EVOO2 samples for K_{270} were found to be appropriate for the communiqué. In EVOOs, K_{232} and K_{270} were determined as 1.49 and 0.14 by Keramat and Golmakani (2016), 1.75 and 0.09 by Benmoussa et al. (2016), 1.90-2.21 and 0.06-0.11 (Di Stefano and Melilli, 2020), 1.9 and 0.15 (Ghanbari Shendi et al., 2018), 1.84-2.44 and 0.12-0.15 (Jabeur et al., 2022) respectively.

The FFA (% oleic acid) in EVOOs should be ≤0.8, according to the same communiqué. Seven different brands of EVOO contained FFAs that ranged from 0.81% to 1.13. All EVOOs had FFA in excess of the legal maximum as a result. FFAs (% oleic acid) of EVOOs were reported as 1.75% (Keramat and Golmakani, 2016), 1.56-2.49% and 0.30–0.42% (Di Stefano and Melilli, 2020), 0.3% (Benmoussa et al., 2016; Ghanbari Shendi et al., 2018), 0.24-0.32% (Jabeur et al., 2022) and 1.45% (Tanrıverdi, 2011).

Riviera olive oils

Riviera olive oil is obtained by mixing natural olive oil in different proportions ranging from 5 to 20% with refined olive oil (Türkoğlu et al., 2012). Seven different brands of ROO were used in the study and the parameters determined for them are shown in Figure 5.





ROO1-ROO7: Riviera olive oils (different brands). Different lowercase letters indicate the difference between the mean values of the samples (P <0.05). The upper limit values are the values specified by the "Turkish Food Codex Communique on Olive Oil and Olive Pomace Oil" (TGK, 2017).

Figure 5. Certain properties determined in Riviera olive oils

According to the Turkish Food Codex Communique on Olive Oil and Olive Pomace Oil (TGK, 2017), the limit values of some criteria in ROO are; PV ≤15 meqO_2/kg, FFA (% oleic acid) ≤1 and K_{270} ≤1.15. PVs of ROOs differed in the range of 5.93-15.93 (P <0.05). Brands other than ROO2 were found to comply with the communiqué. The fact that parameters such as PV, K_{270} and FFA are above the limit in ROO2 is probably because it was produced a year earlier than other ROOs. PV in ROO was determined as 4.71 meqO_2/kg (Yüzereroğlu, 2021). Inanç (2022) detected PVs of twenty-two ROOs in the range of 1.8 to 13.05 meqO_2/kg oil. Most of the PV results we obtained are in line with these findings.

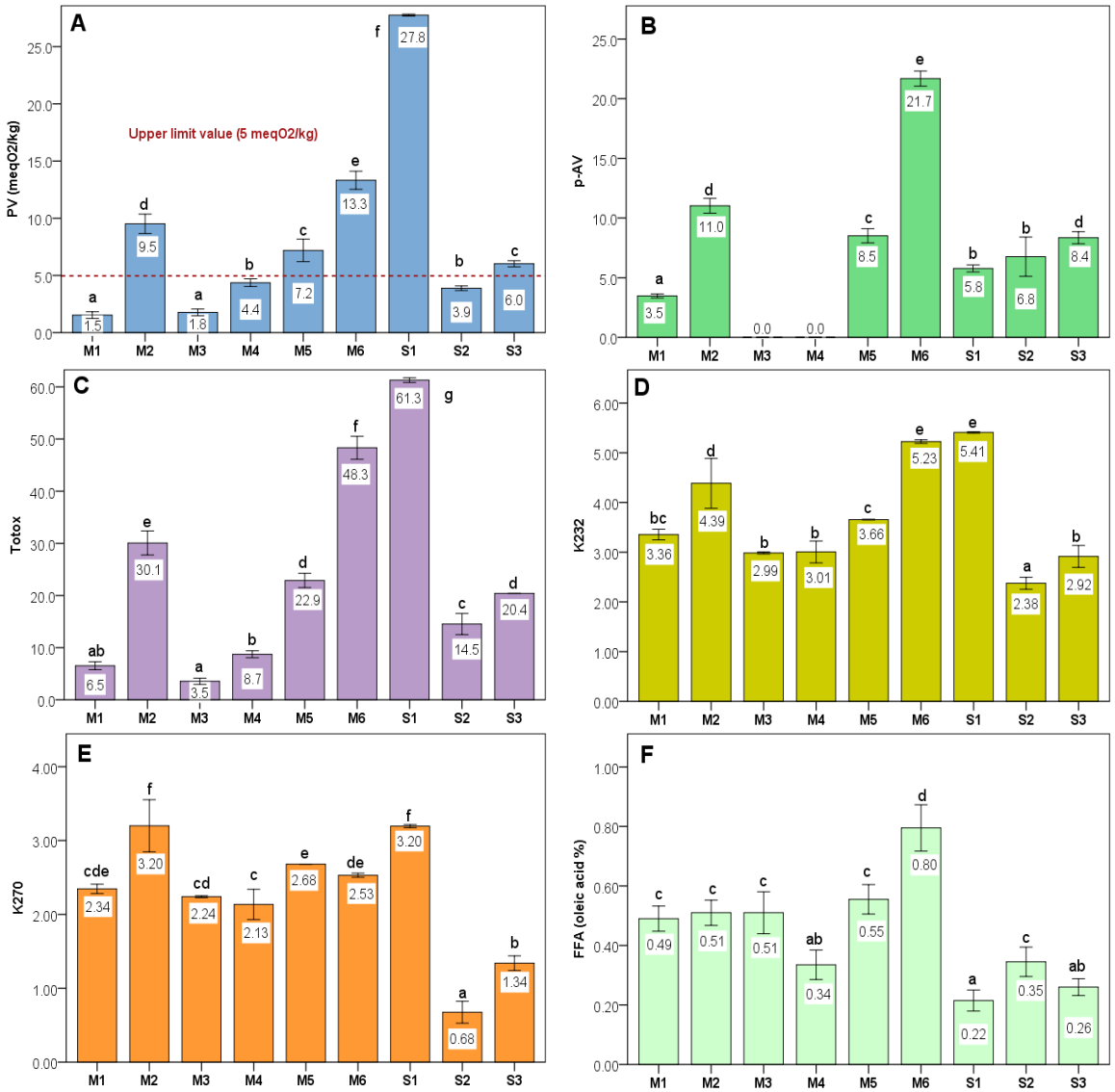
p-AVs, which are indicators of secondary oxidation products, were determined in the range of 2.66-6.78 (P <0.05). Totox values calculated from PV and p-AV values showed variation in the range of 16.73-35.56 (P <0.05). K_{232} was found in the range of 2.27 to 3.83 in ROOs, while K_{270} was found in the range of 0.62 to 1.40 (Figure 5D and E). K_{232} values were higher than K_{270} values in all samples. K_{270}, ROO3 and ROO7 samples exceeded the limit specified in the communiqué (≤ 1.15). Inanç (2022) found the K_{270} of twenty-two ROOs in the range of 0.17 to 1.57. According to Yüzereroğlu (2021), K_{232} and K_{270} values in ROOs were 3.50 and 0.78, respectively. These findings were consistent with some of our ROO results.

FFA values ROOs were determined as in the range of 0.29-1.29%. In the samples other than ROO2, FFA was found suitable according to the communiqué. The ROO2 sample was not found in accordance with the communiqué in terms of both PV and FFA. Possible reason for this may be transportation and storage in unsuitable conditions. Yüzereroğlu (2021) determined the FFA rate in ROO to be 0.26%. The FFA of the

twenty-two ROOs, according to Inanç (2022), was 2.09% in one and 0.10% to 0.90% in the others.

Margarines and shortenings

Margarines (M) and shortenings (S), like other edible oils and fats, may deteriorate by oxidation under the influence of some factors including temperature, light, heavy metal ions, etc. under inappropriate storage conditions. As a result of deterioration, properties such as color, smell and taste may change in margarines and this significantly reduces the quality of the product. The results of PV, p-AV, totox, K_{232}, K_{270} and FFA determined in six margarine (M1-M6) and three shortening (S1-S3) samples used in the study are presented in Figure 6.



M1-M6: Margarines (different brands), S1-S3: Shortenings (different brands). Different lowercase letters indicate the difference between the mean values of the samples (P <0.05). The upper limit values are the values specified by the " TS 2812 Standard of Spreadable margarine/margarine " (TSE, 2022).

Figure 6. Certain properties determined in margarine and shortenings

Their PVs varied in the range of 1.53-27.76 meqO_2/kg (P <0.05). In the TS 2812 Standard of Spreadable margarine/margarine (TSE, 2022), PV is accepted as 5 meqO_2/kg at most. Accordingly, M2, M5, M6, S1 and S3 samples were found above the PV limit determined in the standard (Figure 6A). This could possibly be caused by transportation or storage in unsuitable conditions. While p-AV was not detected in M3 and M4 samples, it differed in the range of 3.47-21.69 in other samples (P <0.05). The totox value representing total oxidation was found in the range of 3.54-61.30 in margarine and shortening samples (P <0.05). The increase in K_{232} formation during oxidative reactions is considered an important parameter since it provides information about the degradation status of oils. While K_{232} was determined in the range of 2.38-5.41 (Figure 6D), K_{270} was determined in the range of 0.68-3.20 (Figure 2E). Bozkurt and Baştürk (2018) determined the K_{232} value in the range of 2.55-5.72% in five different brands of kitchen margarine, which they obtained from the markets of Iğdır/Türkiye province. The FFA values of the samples varied between 0.22-0.80% (P <0.05). There was no significant difference between the FFA rates determined in the M1, M2, M3, M5 and S2 brands (Figure 6F). Similarly, M4 and S3 values were close to each other. According to Engler Ribeiro et al. (2017) Brazil's margarine has PV, p-AV, K_{232}, and K_{270} values of 0.24 meqO_2/kg, 1.38, 3.54, and 0.20 respectively. In another study, the PV of two different margarines sold in Tehran markets were 1.69 and 1.47 meqO_2/kg, and the p-AV values were 1.5 and 1.6 (Bahmaei and Eshratabadi, 2016). The FFA of the margarines and shortenings varied between 0.22-0.80% in terms of oleic acid (P < 0.05).

CONCLUSIONS

Many factors such as storage conditions, packaging materials, transportation conditions, chemical composition of oils and fats can affect the shelf life of fats and oils offered to the consumer. Therefore, consumers should pay attention to these conditions and label information when they chose a product from the market shelves. The parameters determined in some edible oils and fats examined within the scope of the study were above the limits specified in the codex and standards Oils and fats may exhibit various deteriorating behaviors depending on their fatty acid composition and the properties of the raw materials from which they are obtained. For this, variables including the type of packing and the storage environment should be optimized. Additionally, limit values for each parameter for each type of oil and fat should be distinctly established in national and international codex. In this regard, more research is required.

DECLARATION OF COMPETING INTEREST

The authors have declared no conflict of interest.

AUTHORS' CONTRIBUTIONS

Ali Osman GÜNDÜZ: Conceptualization, methodology, investigation, formal analysis, writing-review and editing. Ayhan BAŞTÜRK: Project administration, supervision, conceptualization, methodology, writing review and editing. All authors read and approved the final manuscript.

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