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Research Article **Araştırma Makalesi**

Differences in Quality Between Canned and Pouched Yellowfin Tuna (*Thunnus albacares*) Packed with Various Media

Farklı Ortamlarda Paketlenmiş Konserve ve Poşette Sarı Yüzgeçli Orkinos Balığı (*Thunnus albacares*) Arasındaki Kalite Farklılıkları

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Abstract: Canned and pouched tuna products are available in the markets in different liquid media such as brine, different oils and sauces. Limited information is provided about the pouched tuna products in different liquid media available in the Turkish market and the differences between them. The main purpose of this study is to evaluate the differences between two different tuna packaging methods using different packaging media. The pH values of CW (canned tuna in water) and PW (pouched tuna in water) were found to be lower than the others ((CO (canned tuna in olive oil), CS (canned tuna in sunflower oil), PO (pouched tuna in olive oil,) PS (pouched in sunflower oil)). It was observed that the TBA values of all groups were below the limits of developing objectionable odor/taste. The n-6/n-3 ratio was determined to be quite high in CS and PS. On the other hand, higher eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) contents were found in CW and PW compared to the others (CO, CS, PO, PS). It was determined that the tuna products were safe according to the heavy metal contents of arsenic, mercury, lead and cadmium levels. The L* values of all canned tuna (CO, CS, CW) were found to be significantly higher than those of pouched tuna (PO, PS, PW). The b* values of both CW and PW was found to be lower than the other groups. CW had the lowest overall quality, color and taste scores compared to the others. In this regard, pouched tuna products, especially PW, were recommended for health reasons.

Keywords
- Canned tuna
- Pouched tuna
- Sensory evaluation
- Heavy metals
- Fatty acid profile

Özet: Konserve ve poşetlenmiş ton balığı ürünleri piyasalarda salamura, farklı yağ ve soslar gibi farklı sıvı ortamlarda bulunabilmektedir. Türkiye pazarında mevcut olan farklı sıvı ortamlardaki poşetlenmiş ton balığı ürünleri ve aralarındaki farklar hakkında sınırlı sayıda bilgi verilmiştir. Bu çalışmanın temel amacı, farklı paketleme ortamları kullanan iki farklı ton balığı paketleme yöntemi arasındaki farkları değerlendirmektir. CW (suda paketlenmiş konserve) ve PW (suda poşette paketlenmiş) 'nin pH değerleri diğerlerine ((CO (zeytinyağında paketlenmiş konserve, CS (ayçiçek yağında paketlenmiş konserve), PO (zeytin yağında poşette paketlenmiş,) PS (ayçiçek yağında poşette paketlenmiş)) göre daha düşük bulunmuştur. Tüm grupların TBA değerlerinin sakıncalı koku/tat geliştirme sınırlarının altında olduğu görülmüştür. n-6/n-3 oranı CS ve PS'de oldukça yüksek belirlenmiştir. Öte yandan CW ve PW'de diğerlerine (CO, CS, PO, PS) kıyasla daha yüksek eikosapentaenoik asit (EPA) ve dokosaheksaenoik asit (DHA) içeriği bulunmuştur. Ton balığı ürünlerinin ağır metal içeriklerinin arsenik, civa, kurşun ve kadmiyum seviyelerine göre güvenli olduğu belirlenmiştir. Tüm konserve ton balıklarının (CO, CS, CW) L* değerleri, poşetlenmiş ton balıklarından (PO, PS, PW) önemli ölçüde daha yüksek bulunmuştur. Hem CW hem de PW'nin b* değerleri diğer gruplara göre daha düşük bulunmuştur. CW, diğerleriyle karşılaştırıldığında önemli ölçüde en düşük genel kalite, renk ve tat puanlarını almıştır. Bu doğrultuda, sağlık açısından poşetlenmiş ton balığı ürünleri, özellikle de PW önerilmiştir.

Anahtar kelimeler
- Konserve ton balığı
- Poşette ton balığı
- Duyusal değerlendirme
- Ağır metaller
- Yağ asidi profili

1. INTRODUCTION

Fish is a popular dietary choice in various regions worldwide due to its abundant protein content, low levels of saturated fats, and the inclusion of omega fatty acids which are well-documented for their positive impact on health (Ikem & Egiebor, 2005). These fatty acids, essential for human health, are abundant in oily fish such as tuna. They play crucial roles in supporting both structural and regulatory physiological processes and have established links to the prevention of conditions such as cardiovascular diseases, inflammatory responses, neurocognitive disorders, and cancer. (Innes & Calder, 2020).

Numerous conventional and technological approaches for fish preservation, including freezing, smoking, salting, drying, and canning, have been documented. Canning stands out as a highly significant technique for the preservation of fish. The inherent shelf-stability of canned fish greatly enhances accessibility to this essential source of nutrition, eliminating the need for cold chain storage (Barbosa *et al.*, 2019). Canned tuna, characterized by its extended shelf life and convenience in storage, ranks among the most widely consumed seafood globally. Oil serves as a primary medium in canned fish production, not only for its preservative properties but also for enhancing the product's palatability. Olive and refined seed oils represent some of the most commonly employed varieties (Caponio *et al*., 2010). While tuna initially found its place in vegetable oil canning, the advent of brine canning emerged later. Since the 1960s, brine packing has predominated, aligning with consumer preferences for lower-calorie products (Mohan *et al*., 2014).

In recent years, companies that want to increase the consumption of canned tuna have started to develop their product range by using different packaging methods (such as pouch), ingredients (such as vegetables or spices) and media (different sauces, oils, brine or water). The introduction of tuna in pouch packaging represents a relatively recent development in comparison to the traditional canning process. Some studies suggest that pouch-packaged tuna may potentially replace canned tuna in the market within the coming years. The demand for pouched products in Turkiye has increased in recent years.

Indeed, the primary objective of this study was to assess the distinctions between two distinct tuna packaging methods utilizing varying packing media. No studies were available about the comparison of canned and pouched tuna in different liquid media available in Turkish markets.

2. MATERIALS AND METHODS

2.1. Materials

We procured all samples from local supermarkets. A total of seventy-two units of canned tuna and pouched tuna from the same brand (the only firm producing different types of pouched tuna) were obtained. The canned tuna variants included olive oil (CO), sunflower oil (CS), and water (CW), while the pouched tuna options encompassed olive oil (PO), sunflower oil (PS), and water (PW). Each category consisted of twelve samples canned in olive oil, twelve in sunflower oil, and twelve in water. We acquired all samples approximately three months after their production. After opening the cans and pouches, they were drained to remove the packing liquid.

2.2. Analysis

2.2.1. pH and TBA values

The pH measurements of the canned tuna were taken in accordance with the procedures specified by ASU (1980). Five grams of homogenized tuna was mixed with five milliliters of distilled water to get the pH, which was then measured with a pH meter (Cluj-Napoca, Romania). The levels of thiobarbituric acid (TBA, mg malonaldehyde/kg) was calculated by Tarladgis *et al*. (1960).

2.2.2. Fatty acid analysis

The oil, which was obtained in a quantity of 10 milligrams, was dissolved in 2 milliliters of potassium hydroxide (KOH). Then, 2 milliliters of isooctane were added. Following each stage, the tubes were subjected to vortexing for a duration of 2 minutes, followed by centrifugation for 10 minutes at a speed of 4000 revolutions per minute. Subsequently, the bottom layer was meticulously isolated and introduced into the GC-FID system (OIC, 2017). The Fatty Acid Methyl Esters (FAME) were acquired by employing an HP-Agilent 6890 gas chromatograph (GC) that was furnished with a flame ionization detector and outfitted with a SUPELCO SP 2560 capillary column (100 m, 0.25 mm internal diameter, 0.25 μm). The oven was initially set at a temperature of 140°C for a

duration of 5 minutes. Subsequently, the temperature gradually increased by 4°C each minute until it reached 240°C, where it was maintained for a period of 20 minutes. The temperatures of the injector and detector were held at 250°C and 260°C, respectively. The carrier gas used in this experiment was helium, which flowed at a linear velocity of 1 ml/min. The injection volume was 1 µl. Hydrogen was provided at a flow rate of 35 milliliters per minute, while compressed air was given at a rate of 350 milliliters per minute. The identity of fatty acids (FAs) was determined by comparing their retention periods with a standard mixture of FAs (Supelco 37 component FAME mixture). The GC analyses were conducted three times, and the outcomes were expressed as the percentage of the total FAME area, represented as the average value.

2.2.3. Heavy metals analysis

The fish samples were digested for the quantitative analysis of total mercury (Hg), arsenic (As), lead (Pb), and cadmium (Cd). The canned tuna samples were subjected to the extraction of oil and water, resulting in the isolation of only the fish muscles for subsequent examination. The tube was used to collect wet samples and HNO_3, which were then digested following the protocol outlined in EPA Methods (2007). Wet samples were dried at 60°C. 10 ml of concentrated HNO_3 was added to vessel for digestion. Vessel was sealed and placed in microwave system and digestion was carried out at 175°C for 10 min. After the process of digestion, each sample was transferred to a 50 ml volumetric flask and filled to its maximum capacity using deionized water. Afterwards, the sample underwent filtration and was subsequently diluted four times for subsequent analysis using ICP-MS (Agilent 7500CE, USA). The required amount of stock solution provided by Agilent, Germany, was diluted to create standard solutions.

2.2.4. Instrumental color analysis

Using various portions of the surface, the color measurement was repeated ten times after the homogenized samples were placed in glass petri plates. Using a Dr. Lange Spectro Pen®, color measurements were taken. A* indicates the presence of either a positive (+) red or a negative (-) green hue; b* signifies the presence of either a positive (+) yellow or a negative (-) blue hue; and the L* parameter within the CIE Lab* system represents lightness on a scale from 0 to 100, where 0 is black and 100 is white, according to Schubring *et al*. (2003).

2.2.5. Sterility test

To ensure commercial sterility, tuna in cans and pouches were tested in a variety of liquid media (TS 10524, 1992). Every product category had four canned tunas and four pouched tunas chosen at random. Each batch was divided into two groups: one group incubated at 55°C for 7 days and the second group at 35°C for 10 days. This was done to mimic aerobic and anaerobic growth conditions, respectively. Using aseptic techniques, we extracted samples from the incubated cans and transferred them to four tubes of bromocresol purple supplemented glucose tyriptone broth, with a loading of about 2–4 g each tube. Subsequently, two of the tubes that had been inoculated were placed in an incubator set at 35°C for 96-120 hours, while the remaining tubes were kept at 55°C for 24-72 hours. Tubes were observed for a change in color from purple to yellow while they were incubating in order to detect microbial growth.

2.2.6. Sensory evaluation

Ten trained panelists were asked to assess the following sensory aspects: appearance upon opening the package, chunk size, brightness, color, general taste, metallic taste, plastic taste, texture, and overall quality. The evaluation was based on a 9-point hedonic scale that was slightly modified from Mohan *et al*. (2014). For every analysis, three cans and three pouches from each group were utilized. We used sensory scores from 1 to 9, with 1 meaning "dislike extremely" and 9 meaning "like extremely." The cutoff for acceptance was a score higher than 6.0. The samples were given to the panelists in a random order after being anonymised with a random 3-digit code to ensure objectivity.

2.2.7. Statistical analysis

The SPSS software (Version 16.0, Chicago, IL, USA) was employed to evaluate the existence of substantial disparities among average values. The study investigated mean differences using one-way analysis of variance (ANOVA), followed by Tukey and Duncan tests for post-hoc analysis. All statistical evaluations were subject to a significance level of $p = 0.05$. The results are reported as mean values together with their corresponding standard deviations (SD), and each experiment was conducted three times.

3. RESULTS

3.1. pH and TBA values

The pH values for canned tuna in water (CW) and pouched tuna in water (PW) were observed to be lower than those of the other samples (Table1). The highest pH value was detected at 5.88±0.03 in CO and the lowest one was detected at 5.79±0.05 in CW.

Even though canned tuna in water exhibited the highest TBA values (0.71 mg malonaldehyde/kg) among the samples (Table 1).

3.2. Fatty acid profile

Fatty acid profile of the canned and pouched tuna in different liquid media was given in Table 2. Among the saturated fatty acids (SFA), C16:0 was found to be major constituent in samples (12.73, 6.411, 11,445, 6.337 in CO, CS, PO, PS), respectively. On the other hand, C18:0 was found to be major constituent in samples (34.661, 19.630) CW, PW. Within the category of monounsaturated fatty acids (MUFA), oleic acid (C18:1) was identified as the predominant component, with respective proportions of 68.234, 28.879, 11.271, 69.402, 27.515, and 12.331 in CO, SC, CW, PO, PS, and PW, respectively. The significantly higher C18:1 was found in CO and PO.

The highest PUFA/SFA ratio was found in CS. Besides, PUFA/SFA ratio of all samples were higher than 0.45. However, PUFA/SFA and n6/n3 ratio was higher in CS and PS in comparison to CO, CW, PO and PW. EPA+DHA amount was higher in PW and CW than other groups. EPA/DHA ratio were higher in CW and PW, in comparison to CO, CS, PO, and PS.

3.3. Heavy metal content

Heavy metal contents of the canned and pouched tuna in different liquid media were given in Table 3. In this study, the Arsenic contents (As) in canned tuna and pouched tuna samples, measured in milligrams per kilogram that ranged from 0.338to 0.574. The concentration of Cd in group CO, CS, PS and PW expressed in mg/kg were determined as 0.002, 0.015, 0.005, 0.004, respectively. The average Hg values were determined as 0.33 for CO, 0.16 for CS, 0.15 for CW, 0.04 for PO, 0.24 for PS and 0.082 for PW. Pb levels for canned tuna were determined as 0.002, 0.007, 0.000, 0.130, 0.010, and 0.020 for CO, CS, CW, PO, PS and PW.

3.4. Colour values

In the present study; L* values of all canned tunas (CO, CS, CW) were significantly higher than the pouched tunas (PO, PS, PW) ($p<0.05$) (Table 4). Significantly ($p>0.05$) lowest a* value 4.68 was detected in CW samples. However, the highest a* value was measured in PS samples. b* values were determined between 23.33 and 20.65.

3.5. Sterility test and Sensory analysis

Canned tuna and pouched tuna with different packing media were passed through the commercial sterilization process. No microbial growth was observed in any of the samples kept after opening the packages for 10 days at 37°C and 7 days at 55°C.

The sensory analysis results indicated that the quality of the canned and pouched tuna products varied according on the packaging material used (Table 5). In the present study appearance when package opened, colour and taste values of CW and PW were lower than the other products. When the appearance of canned tuna was evaluated upon initial opening, pouch packages received lower scores. In general, products packaged in this manner were found to contain crushed, pureed pieces of tuna meat upon opening. The chunk size of fish in canned tuna products were found biggest in CO and smallest in PW. The use of water as the filling medium in both packaging types has led to a decrease in brightness. According to the scoring by the panelists, the metallic taste originating from the packaging was most pronounced in CW, while the plastic taste was felt in PW. When overall quality, taste and colour values of the canned and pouched tunas were compared, CW got the significantly lowest score when compared with the others. Consequently, depending on the kind of liquid utilized as the filling medium, the final canned and pouched product's quality varied.

Table 1. pH and TBA (mg malonaldehyde/kg) values of canned and pouched tuna in different liquid media.

Analysis	Groups					
	CO	**CS**	**CW**	**PO**	**PS**	**PW**
pH	5.88 ± 0.03^{ab}	5.84 ± 0.04^{ab}	5.79 ± 0.05^{a}	5.86 ± 0.02^{b}	5.85 ± 0.02^{ab}	5.80 ± 0.01^{a}
TBA	0.51 ± 0.02^{a}	0.62 ± 0.01^{b}	0.71 ± 0.01^{c}	0.49 ± 0.02^{b}	0.41 ± 0.02^{a}	0.42 ± 0.02^{a}

*Means within the same line with the same letter is not significantly different at a significance level of 0.05 (P>0.05). CO: Canned tuna in olive oil, CS: Canned tuna in sunflower oil, CW: Canned tuna in brine, PO: Pouched tuna in olive oil, PS: Pouched tuna in sunflower oil, PW: Pouched tuna in water.

Table 2. Fatty Acid Content of Canned and Pouched Tuna in Different Liquid Media.

Fatty acids %	Groups					
	CO	**CS**	**CW**	**PO**	**PS**	**PW**
C14:0	0.045±0.0^{a}	0.076±0.01^{a}	1.238±0.05^{b}	0.056±0.00^{a}	0.088±0.01^{a}	4.762±0.52^{c}
C15:0	0.018±0.00^{a}	0.018±0.01^{a}	0.553±0.07^{b}	0.018±0.00^{a}	0.021±0.00^{a}	1.113±0.14^{c}
C16:0	12.73±1.20^{a}	6.411±0.50^{b}	15.788±1.1^{c}	11.445±0.40^{a}	6.337±0.60^{b}	19.227±1.35^{d}
C17:0	0.133±0.03^{a}	0.046±0.00^{a}	0.833±0.03^{b}	0.101±0.01^{a}	0.051±0.27^{a}	1.190±0.19^{b}
C18:0	4.014±0.23^{a}	3.952±0.42^{a}	34.661±1.46^{b}	3.409±0.41^{a}	4.134±0.09^{a}	19.630±0.87^{c}
C20:0	0.583±0.04^{a}	0.276±0.06^{b}	0.790±0.12^{c}	0.495±0.04^{a}	0.263±0.07^{b}	0.656±0.08^{ac}
C21:0	0.026±0.01^{a}	-	-	0.025±0.01^{a}	-	-
C22:0	0.270±0.06^{a}	0.792±0.09^{b}	0.334±0.06^{a}	0.238±0.04^{a}	0.789±0.10^{b}	0.232±0.04^{a}
C24:0	0.110±0.01^{a}	0.258±0.04^{b}	0.247±0.03^{a}	0.094±0.01^{a}	0.238±0.05^{a}	0.148±0.01^{a}
SFA	**17.93**	**11.83**	**54.44**	**15.88**	**11.92**	**46.96**
C16:1	0.767±0.18^{a}	0.112±0.02^{b}	1.663±0.20^{c}	0.655±0.05^{a}	0.119±0.01^{b}	4.088±0.30^{d}
C18:1n9c	68.234±0.9^{a}	28.879±2.00^{b}	11.271±0.6^{c}	69.402±1.20^{a}	27.515±1.80^{b}	12.331±0.40^{c}
C20:1	0.409±0.11^{ac}	0.193±0.02^{a}	0.990±0.20^{b}	0.445±0.10^{ac}	0.177±0.01^{a}	0.502±0.05^{c}
C22:1n9	-	-	0.166±0.02^{a}	-	-	0.081±0.02^{a}
C24:1	-	-	0.470±0.14^{a}	-	0.018±0.00^{a}	0.239±0.03^{c}
MUFA	**69.41**	**29.18**	**14.56**	**70.5**	**27.83**	**17.24**
C18:2n6c	11.467±1.30^{a}	58.707±2.81^{b}	5.077±0.23^{c}	12.282±1.42^{a}	59.918±2.72^{b}	2.560±0.40^{c}
C20:2	-	-	0.482±0.10^{a}	-	-	1.382±0.20^{b}
C22:2	-	-	0.252±0.07^{a}	-	-	0.297±0.10^{a}
C18:3n3	0.648±0.20^{a}	0.188±0.09^{ac}	-	0.753±0.30^{a}	0.088±0.00^{c}	-
C20:3n6	-	-	0.073±0.00^{a}	-	-	0.122±0.01^{b}
C20:3n3	-	-	0.276±0.08^{a}	-	-	0.146±0.01^{b}
C20:4n6	0.282±0.07^{a}	-	2.233±0.60^{b}	0.228±0.04^{a}	-	2.854±0.50^{b}
C20:5n3	0.046±0.01^{a}	0.018±0.00^{a}	3.307±0.31^{b}	0.085±0.04^{a}	0.016±0.00^{a}	7.612±1.70^{c}
C22:6n3	0.212±0.02^{a}	0.046±0.00^{a}	19.294±1.80^{b}	0.266±0.07^{a}	0.210±0.02^{a}	20.774±1.00^{b}
PUFA	**12.66**	**58.96**	**30.99**	**13.61**	**60.23**	**35.75**
PUFA/SFA	0.71	4.98	0.57	0.86	5.05	0.76
Σn-6	11.75	58.71	7.38	12.51	59.92	5.54
Σn-3	0.91	0.25	22.88	1.1	0.31	28.53
n6/n3	12.912	234.84	0.3225	11.372	193.290	0.194
EPA	0.046	0.018	3.307	0.085	0.016	7.612
DHA	0.212	0.046	19.294	0.266	0.21	20.774
EPA/DHA	0.2170	0.3913	0.1714	0.3195	0.0762	0.3664

Means within the same line with the same letter is not significantly different at a significance level of 0.05 (P > 0.05). CO: Canned tuna in olive oil, CS: Canned tuna in sunflower oil, CW: Canned tuna in brine, PO: Pouched tuna in olive oil, PS: Pouched tuna in sunflower oil, PW: Pouched tuna in water. SFA: Saturated fatty acid, MUFA: Mono unsaturated fatty acid, PUFA: Poly unsaturated fatty acid.

Table 3. Heavy Metal Content of Canned and Pouched Tuna in Different Liquid Media.

Heavy Metals (mg/kg)	Groups					
	CO	**CS**	**CW**	**PO**	**PS**	**PW**
As	0.338±0.007^{a}	0.345±0.005^{a}	0.391±0.008^{b}	0.346±0.004^{a}	0.543±0.003^{c}	0.574±0.001^{d}
Cd	0.002±0.00^{a}	0.015±0.001^{b}	ND	ND	0.005±0.00^{c}	0.004±0.00^{c}
Hg	0.334±0.004^{a}	0.155±0.002^{b}	0.145±0.001^{c}	0.040±0.00^{d}	0.235±0.006^{e}	0.082±0.00^{f}
Pb	0.002±0.00^{a}	0.007±0.00^{ac}	ND	0.130±0.005^{b}	0.010±0.00^{c}	0.020±0.00^{d}

*Means within the same line with the same letter is not significantly different at a significance level of 0.05 (P > 0.05). CO: Canned tuna in olive oil, CS: Canned tuna in sunflower oil, CW: Canned tuna in brine, PO: Pouched tuna in olive oil, PS: Pouched tuna in sunflower oil, PW: Pouched tuna in water.

Table 4. Instrumental Colour Values of Canned and Pouched Tuna in Different Liquid Media.

Colour values	Groups					
	CO	**CS**	**CW**	**PO**	**PS**	**PW**
L*	74.01±1.44^{a}	71.64±1.38^{a}	71.55±1.81^{a}	67.60±1.73^{b}	65.74±1.98$^{b.c}$	65.11±1.39^{c}
a*	4.96±0.35$^{a.d}$	5.47±0.28^{bc}	4. 68±0.32^{d}	5.29 ±0.42$^{a.b}$	6.28±0.43^{c}	5.87 ±0.24^{c}
b*	22.50±0.90$^{a.c}$	21.43±0.67$^{a.b}$	20.65±0.57^{b}	22.49±0.76$^{a.c}$	23.33±0.83^{c}	21.00±0.79^{b}

*Means within the same line with the same letter is not significantly different at a significance level of 0.05 (P > 0.05). CO: Canned tuna in olive oil, CS: Canned tuna in sunflower oil, CW: Canned tuna in brine, PO: Pouched tuna in olive oil, PS: Pouched tuna in sunflower oil, PW: Pouched tuna in water.

Table 5. Sensory evaluation of canned and pouched tuna in different liquid media.

Sensory Analysis	Groups					
	CO	CS	CW	PO	PS	PW
Appearance when package open	8.10±0.50^{a}	7.80±0.74^{ab}	6.60±1.84^{b}	6.80±0.88^{b}	6.65±0.92^{b}	6.10±0.99^{b}
Chunk size	8.85±0.33^{a}	8.20±0.42^{ab}	7.60±0.72^{ab}	6.90±0.55^{bc}	6.81±0.42 ^{bc}	6.60±0.47^{c}
Brightness	8.75±0.51^{a}	8.82±0.28^{a}	7.11±0.35^{b}	7.72±0.61^{bc}	7.40±0.47^{c}	6.82±0.71^{c}
Color	8.20±0.92^{a}	8.20±0.63^{a}	6.70±0.24^{b}	8.10±0.99^{a}	8.10±1.29^{a}	7.70±0.26^{a}
Texture	7.78±0.83^{ab}	8.33±0.50^{a}	6.78±1.92^{b}	7.44±0.88^{ab}	7.22±0.83^{ab}	6.56±0.88^{b}
General Taste	7.89±1.05^{a}	7.56±0.53^{a}	4.44±1.42^{b}	7.78±0.97^{a}	6.44±1.67^{a}	6.44±1.01^{a}
Metalic Tasteless	8.10±0.25^{a}	8.02±0.41^{a}	5.12±0.21^{b}	8.75±0.91^{a}	8.96±0.82^{a}	8.66±0.19^{a}
Plastic tasteless	8.80±0.38^{a}	8.69±0.21^{a}	8.43±0.55^{a}	7.72±0.22 ^{b}	6.55±0.51^{c}	6.05±0.47^{c}
Overall Quality	8.25±0.89^{a}	7.75±0.71^{ac}	5.25±1.67^{b}	7.13±1.55^{ac}	6.88±1.46^{ac}	6.63±0.15^{c}

Means within the same line with the same letter is not significantly different at a significance level of 0.05 (P > 0.05). CO: Canned tuna in olive oil, CS: Canned tuna in sunflower oil, CW: Canned tuna in brine, PO: Pouched tuna in olive oil, PS: Pouched tuna in sunflower oil, PW: Pouched tuna in water.

4. DISCUSSION

The pH values observed in this investigation were comparable to those found in canned tuna without vegetables and with peas, as well as canned tuna with baby corn and canned tuna with broccoli (Mohan *et al*., 2014). The pH values of the fish samples were determined to be within the range (4.0–6.9) that the Turkish Standard Institute recommends (TSİ, 2010). Schormüller (1968) noted that the TBA value must be below 1 mg malonaldehyde/kg to be considered of "excellent" quality. According to this criterion, all samples were found to be of excellent quality. The TBA results indicated a resemblance to the findings of Medina *et al*. (1998), who discovered that canned tuna muscle preserved in brine had higher TBA values. This suggests that the muscle stored in an aqueous media experienced an accelerated rate of oxidative activity.

The fatty acid profile results were comparable to those published by Medina *et al*. (1998), who found that refined olive oil had a high oleic acid level of 72%. Linoleic acid (LA) (18:2ω6) represents omega 6, while α-linolenic acid (ALA) (18:3ω3) represents omega 3. According to Simopoulos (2008), consuming too much omega-6 polyunsaturated fatty acids (PUFA) and having an imbalanced omega-6/omega-3 ratio might lead to the onset of several illnesses, such as cardiovascular disease, cancer, and inflammatory and autoimmune disorders. In the current investigation, it was observed that the levels of linoleic acid (LA) were much lower in both CW and PW, whereas significantly higher levels of LA were observed in CS and PS. Scientific evidence confirms that sunflower oil is mainly composed of linoleic acid (C18:2), with oleic acid (C18:1) being the second most abundant component (Moreiras *et al*., 2013). The results of the current investigation are consistent with those of Shim *et al*. (2004), who noted that both light tuna and white/albacore tuna packed in either vegetable oil or soy oil had elevated levels of LA in comparison to tuna packed in water. The concentration of EPA + DHA was determined following the standards established by the European Food Safety Authority about the recommended dietary intake of lipids. The maximum allowable daily consumption of EPA and DHA for adults should not surpass 250 mg (Kandyliari *et al*., 2020). The current investigation revealed a notable increase in the levels of 20:5n-3 (EPA) and 22:6n-3 (DHA) in CW and PW, in comparison to CO, CS, PO, and PS. This can be explained by the migration of fatty acids, especially EPA and DHA, in fish packaged in oil into the oil packaging medium. Shim *et al*. (2004) observed that white/albacore tuna packed in water had the highest content of EPA plus DHA among other tuna products, such as light tuna in water, light tuna in oil, and white/albacore tuna in oil. Shim *et al*. (2004) reported that consuming arachidonic acid (AA) and linoleic acid (LA) in your diet can increase the risk of cardiovascular disease for individuals with certain genetic variations. On the other hand, consuming eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) can decrease the risk of cardiovascular disease. The study conducted by Mesias *et al*. (2015) found no notable differences in the fatty acid compositions of samples that underwent different treatments (canning in brine, sunflower oil, and olive oil) or between various sterilization methods (conventional retort heating and high-pressure thermal sterilization). Therefore, it seems that the

sterilizing technique did not significantly affect the fatty acid composition of tuna in sunflower oil. The efficacy of canned fish as a source of n-3 LC PUFA is contingent upon factors such as the fish species, quality of the raw material, the kind of liquid used in canning, and the duration of storage (Kolakowska *et.al*., 2006). One often used metric to evaluate the impact of diet on oxidative stress and cardiovascular health is the PUFA/SFA ratio (Biandolino *et al.*, 2023). The range of 0.45–4.00 is ideal for the PUFA/SFA ratio (Peycheva *et al*., 2021). In the current investigation, PUFA/SFA were at between recommended levels in CW, PW, CO and PO (<1), while they were above ideal limits (>4) in CS and PS. Nava *et al.*, (2023) have found that the PUFA/SFA of the canned tuna pate samples packed in corn and olive oil showed a higher value (3.89) like as the CO and PO samples in current investigation.

The PUFA/SFA and n6/n3 ratio in tuna fish packaged in sunflower oil were higher than those packaged in water and olive oil, due to the high level of n-6 fatty acids. In the present study, due to the higher amounts of EPA and DHA, the EPA+DHA was found to be higher in CW and PW compared to CO, CS, PO and PS. EPA+DHA was found lower in canned tuna pate samples packed in corn and olive oil in the research of Nava *et.al*., (2023). When oil is incorporated as a filling medium, a chemical interaction ensues between the fatty acids naturally occurring in the fish and those within the oil, resulting in alterations to the fatty acid composition of both the fish and the oil medium (Garcia-Aries *et al*. 1994; Ruiz-Roso *et al*. 1999). Therefore, tuna packaged in water had higher EPA, DHA and some other fatty acids than tuna packaged in oil. Besides, because of the fatty acid migration from sunflower oil to tuna, PUFA, PUFA/SFA, n6 and n6/n3 values were affected.

Potentially, the processing stages can modify the content of heavy metals in fish before they are consumed (Ganjavi *et al.* 2010). There is presently no universally accepted guideline for the allowable levels of total arsenic in fish (Andayesh *et al*., 2015). Ikem and Egiebor (2005) documented that the concentration of As in canned tuna ranged from 0.0 to 1.72 mg/kg. According to Andayesh *et al*. (2015), the levels of As contamination in canned tuna samples ranged from 0.25 to 1.42 mg/kg. The concentration of Cd was not found in the samples of CD and PO. Ganjavi *et al*. (2010) found that heating and sterilization can reduce the level of Cd in tuna fish during processing. The findings were below those of Mahalakshmi *et al*. (2012), who documented that the concentration of Cd in canned tuna produced in India was 0.025mg/kg, whereas in Canadian-made tuna, it was 0.020mg/kg. In a study conducted by Mol (2011), it was found that the concentration of Cd in all the various brands of canned tuna was 0.09mg/kg. Çelik & Oehlenschlager, (2007) documented elevated levels of Cd that beyond our own findings, which in turn exceeded the permissible limits. The Commission of the European Communities stated that Cadmium (Cd) can build up in the human body and cause harmful health effects, such as kidney failure, bone damage, and reproductive abnormalities. Both the Turkish Food Codex (TFC, 2002) and EC rules (2006) have set a maximum allowable level for Cd at 0.1 mg/kg. The toxicity of mercury (Hg) not only affects children and pregnant women but also poses a health concern to the entire population, as emphasized by Feng (2012).

The prescribed upper limits for mercury (Hg) content in tuna fish are defined as 0.5 and 1.0 mg/kg, as per the European Commission regulations in 2006. The Hg concentration in all samples was much below the established limits. The results were highly consistent with the findings presented by İkem & Egiebor (2005). Voegborlo *et al*. (1999) found that the content of Hg in the analyzed tuna fish samples ranged from 0.2 to 0.66 g/g. Mol (2011) documented that certain canned tuna products exhibited mercury levels exceeding 1.0 mg/kg. In their study, Shim *et al.* (2004) found that light tuna stored in soy oil had considerably higher levels of Hg ($p<0.05$) compared to light tuna stored in water or vegetable oil. The allowable limit for lead (Pb) in fish is 0.2mg/kg according to the EU regulations of 2006. However, the TFC (2002) recommends that the lead level in tuna should not exceed 0.4 mg/kg. The lead content of all canned and pouched tuna in various liquid mediums was found to be below the specified limit. In their study, Andayesh *et al*. (2015) found that the canned tuna samples had a Pb concentration ranging from 0.008 to 0.15 mg/kg, which was consistent with previous research. Mol (2011) reported that the average content of this metal varied between 0.09 and 0.45 mg/kg. The implementation of advanced packaging methods, specifically the use of cans with lacquered

interiors and mechanical seams, has been successful in reducing, and sometimes completely eliminating, the transfer of toxic metals, like lead and tin, into the food, as highlighted by Khansari *et al*. (2005).

One key factor in determining a product's acceptance by consumers is its color (Mohan *et al*. 2014). The observed elevation in lightness values may be attributed to the release of muscle pigments and exudates during the precooking and thermal processing stages, as discussed by Haard (1992). Notably, it is worth mentioning that retort pouch-packaged products require considerably less heat than canned products to attain commercial sterility, a fact highlighted by Jun *et al*. (2006). L* values of canned and pouched tuna samples were detected between 74.01±1.44 to 65.11±1.39 in this study. On the other hand, Rueangwatcharin & Wichienchot (2015) reported L* values of control groups between 91.04 to 73.88. In the present study b* values also known as yellowness value of both CW and PW were lower than the other groups. This could be explained as a result of the colour of oil penetrates the tuna in cans and pouches. Trends were not consistent when comparing a* values of the canned and pouched tuna in different liquid medium.

All samples have passed the sterility test. Results were similar with those of Rueangwatcharin & Wichienchot (2015), who reported that pouched and canned tuna products with added inulin passed the commercial sterilization test and no mesophylls, and no thermophiles aerobe and anaerobe were found in finished products. According to Caponio *et al*. (2010), adjectives linked to the existence of faults were given higher ratings for tuna kept in refined seed oil and olive oil. Conversely, tuna preserved in extra virgin olive oil obtained superior evaluations for characteristics related to color and the firmness of the meat. The study conducted by Caponio *et al*. (2010) found that tuna preserved in extra virgin olive oil received better ratings for its color and flesh cohesion. On the other hand, tuna preserved in olive oil and processed seed oil scored higher for descriptors related to flaws or imperfections. Another conducted study analyzed preserved eels and found that the color of canned fish meat and the filler material were impacted by the production stages and content (Gómez-Limia *et al.*, 2022).

CONCLUSION

The study reported below provides evidence that canned and pouched tuna fish, when ingested in Turkiye, adhere to the permissible levels of cadmium, lead, arsenic, and mercury, thereby ensuring its safety for consumption. The quality of the finished product varied depending on the types of liquid used as media, as indicated by the sensory analysis results and fatty acid profile. Higher content of EPA and DHA, EPA/DHA were found in CW and PW compared to others (CO, CS, PO, PS). The PUFA/SFA ratio in tuna fish packaged in sunflower oil is higher than those packaged in water and olive oil, due to the high level of n-6 fatty acids. According to sensory parameters, CW had significantly lowest overall quality, taste and color values. When comparing appearance (when the package is first opened) and chunk size with other groups, CW and PW obtained the lowest values. Upon opening the packages of all products packaged in puch, a pile of crushing was observed. Based on the findings of this study and the additional advantages of pouched products, such as cost-effective shipping and lower heat requirements for commercial sterility, together with reduced cooking time and energy expenses, it is advised to use pouched canned products. This study is expected to expand the assortment of pouched products.

CONFLICTS OF INTEREST

The authors affirm that there are no identifiable financial or personal conflicts that could impact the research.

AUTHOR CONTRIBUTIONS

Nida Demirtaş Erol: Performed chemical quality analysis, chemical composition analysis, sensory evaluation, color measurement, statistical analyses, writing - original draft.

ETHICS APPROVAL

The study did not require any specific ethical approval.

DATA AVAILABILITY

For inquiries for datasets, please contact the corresponding author.

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