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Research Article
Araştırma Makalesi

# Seasonal and Reproductive Period Changes in Nutrient composition of *Nemipterus randalli* (Russell, 1986) and *Boops boops* (Linnaeus, 1758) from Northwest Mediterranean, Türkiye

## Türkiye Kuzeybatı Akdeniz'deki, *Nemipterus randalli* (Russell, 1986) ve *Boops boops* (Linnaeus, 1758) Balıklarının Besin Kompozisyonunda Mevsim ve Üreme Periyodundaki Değişiklikler

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**Abstract:** In recent years, Mediterranean fish species such as *Nemipterus randalli* and *Boops boops* have been increasingly preferred by consumers when commonly consumed species are expensive or not present. Furthermore, the commercialization of these species has been affected by their reaching large-scale populations and becoming a target species in the catch composition. Therefore, the purpose of this study was to determine changes in the proximate content and fatty acid levels during the seasonal and reproductive periods of *N. randalli* and *B. boops* caught from the Northwest Mediterranean. This study showed that the biochemical components of these fish varied significantly with season and maturity stage ($P < 0.05$). While the highest protein level was found to be 18.99% in winter out of the reproductive season, the highest lipid level was 3.85% in spring at the beginning of the reproductive season for *N. randalli*. The highest protein and lipid levels were 21.81% and 3.10% in summer at the end of the reproductive season for *B. boops,* respectively. As a result, the consistent presence of low eicosapentaenoic acid (EPA) levels, predominantly low ratios of polyunsaturated fatty acids to saturated fatty acids (PUFA/SFA), and the prevalence of saturated fatty acids (SFAs) throughout the year in the muscle composition of *N. randalli* and *B. boops* species has an adverse impact on the overall quality of the food derived from these species. However, low n6/n3 ratios, high protein, and a low lipid content are important for food quality.

**Keywords**
- *Nemipterus randalli*
- *Boops boops*
- Seasonal fatty acids
- Proximate composition
- Gonadosomatic index

**Özet:** Son yıllarda Kılkuyruk mercan, *Nemipterus randalli,* ve Kupez, *Boops boops* gibi Akdeniz balık türleri, yaygın olarak tüketilen türlerin pahalı olması veya bulunmaması nedeniyle tüketiciler tarafından giderek daha fazla tercih edilmektedir. Bu nedenle bu çalışmanın amacı, Kuzeybatı Akdeniz'den yakalanan *N. randalli* ve *B. boops*'un mevsimsel ve üreme dönemlerinde yaklaşık içerik ve yağ asidi düzeylerindeki değişimleri belirlemektir. Bu çalışma, bu balıkların biyokimyasal bileşenlerinin mevsim ve olgunluk aşamasına göre önemli ölçüde değiştiğini göstermektedir ($P < 0.05$). *N. randalli* de en yüksek protein düzeyi %18,99 ile üreme mevsimi dışında kışın, en yüksek lipit düzeyi ise üreme mevsimi başlangıcında %3,85 ile ilkbaharda tespit edilmiştir. *B. boops* ta en yüksek protein ve lipid düzeyleri sırasıyla %21,81 ve %3,10 ile üreme mevsimi sonunda yaz aylarında görülmüştür. Sonuç olarak, düşük eikosapentaenoik asit (EPA) seviyelerinin varlığı, çoklu doymamış yağ asitlerinin doymuş yağ asitlerine (PUFA/SFA) oranının düşük olması ve kas bileşiminde yıl boyunca doymuş yağ asitlerinin (SFA) yaygınlığı bu türlerin genel gıda kalitesi üzerinde olumsuz bir etki yaratmaktadır. Ancak gıda kalitesi açısından; düşük n6/n3 oranı, yüksek protein ve düşük lipit içeriğinin önemli olduğu tespit edilmiştir.

**Anahtar kelimeler**
- *Nemipterus randalli*
- *Boops boops*
- Mevsimsel yağ asitleri
- Besin bileşenleri
- Gonadosomatik indeks

## 1. INTRODUCTION

Fish play a crucial role as a vital food source, offering essential lipid, protein, vitamin, and mineral in the human food (Balami et al., 2019; Reale et al., 2006). The immunoglobulins found in fish proteins serve as a protective mechanism against both bacterial and viral infections. The lipids, especially long chain omega-3 polyunsaturated fatty acids such as EPA and DHA, which are not synthesized by the human body, play a crucial role in preventing cardiovascular diseases and coronary heart diseases. They also contribute to maintaining healthy blood pressure in humans and support neurodevelopment in children (Balami et al., 2019).

In Türkiye, a gradual decrease was observed in the production of prominent species such as anchovy, sardine and horse mackerel obtained through natural hunting between 2021 and 2023 (TÜİK, 2024). As a result of changes in these population dynamics, changes in the local ecosystem and fisheries management may occur in the future. The development of alien species such as *N. randalli* on native biota may cause some positive or negative situations on fisheries (Özen & Çetinkaya, 2020). Consumers tend to favor these species, especially when the more commonly consumed ones become either expensive or scarce according to obtained knowledge from the Antalya fisherman.

According to data from the Turkish Statistical Institute, *B. boops* catches reached a record high of 2 140 tons in 2023. There is no certain data on the number of *N. randalli* catches so far.

*N. randalli* is one of the widespread Lessepsian species observed along the Türkiye coast. It has recently become abundant at the beginning of the catch and is a commercially important fish species in Türkiye (Yemişken et al., 2014; Akgun et al., 2023). After its first appearance in Haifa Bay in 2005 (Golani and Sonin, 2006), it has been observed around Lebanon (Lelli et al., 2008), Iskenderun Bay (Bilecenoglu 2008; Gurlek et al., 2010; Tartar and Yeldan, 2022; Yazici et al., 2024), Gökova Bay (Gülşahin and Kara, 2013), Izmir Bay (Aydın et al., 2016; Uyan et al., 2019) and Antalya marine region (Gökoğlu et al., 2009; Özen and Çetinkaya, 2020; Akgun et al., 2023). *N. randalli* is a species known to live on sandy and muddy surfaces between 22-450 m depths of tropical waters and generally feed on crustaceans, mollusks, and small fish (Ay et al., 2022). *B. boops* is a common sea bream (*Sparidae*), native to the Eastern Atlantic, found in Portuguese coastal waters and has a broad distribution, ranging from Norway to Angola in the Eastern Atlantic. Additionally, it is found throughout the Mediterranean Sea and the Black Sea. The bogue's presence extends to the Western Atlantic, including the Gulf of Mexico and the Caribbean Sea. This wide geographical distribution indicates the adaptability and habitat range of the species (Monteiro et al., 2006). The bogue is a gregarious semi pelagic species found as deep as 300 m on a variety of bottoms, but it is more common at depths <150 m, moving up to the surface during the night (Cunha et al., 2022; Monteiro et al., 2006).

There has been insufficient research on the food quality of *B. boops* and *N. randalli*. Most studies in literature have been conducted in the Northeast Mediterranean Sea on *N. randalli* (Bakan et al., 2020; Durmuş, 2019; Göçmen et al., 2018) and *B. boops* (Uçar, 2020). The current study differs from the literature which investigates the seasonal and reproductive period changes in the proximate and fatty acid composition of *N. randalli* and *B. boops*.

## 2. MATERIALS AND METHODS

### 2.1. Sample capture

*N. randalli* and *B. boops* samples were collected monthly from commercial trawl 84 catches in the Northwest Mediterranean between 2020 and 2021. In total, 392 *N. randalli* individuals and 641 *B. boops* individuals were caught (Table 1). The fish samples gathered were promptly transported to the laboratory in an ice cooler. The total length (TL) of each fish was measured to the nearest 0.01 mm, and the weight was determined with an accuracy of 0.01 g digital balance. The mean total length, weight, and sample numbers for both *N. randalli* and *B. boops* were provided in Table 1. The species identifications were carried out according to Özen (2021). The original photographs of *N. randalli* and *B. boops* species are given in Figure 1.


**Figure 1.** *Nemipterus randalli* (Russell, 1986) and *Boops boops (Linnaeus 1758)*

**2.2. Gonadosomatic index (GSI)**

The ventral of the fish samples was opened by cutting with a sharp scissor, and the muscle and digestive organs were removed. The left and right gonads were measured together as gonad weights with a digital balance to an accuracy of 0.01g. The spawning period was determined according to the monthly variation of the gonadosomatic index.

The gonadosomatic index (GSI) was determined through the following calculation: GSI = (GW/BW) × 100 (1)

Gonad weight GW (g), body weight BW (g) (Park & Jeong, 2020).

**2.3. Proximate composition**

The present study was conducted to determine proximate composition and fatty acid analyses during the following seasons: autumn in October 2020, winter in January 2021, spring in April 2021, and summer in July 2021. A total of 10 fish were randomly chosen as triplicates in every season. The fish were filleted by removing their skin, fin, skeleton, visceral, and head. Then, the 10 fish fillets in the replicate were minced and mixed for proximate and fatty acid analyses.

Proximate analysis, except crude lipid, was conducted in accordance with the methods of AOAC (1990) at 104°C. The ash content was determined by subjecting the sample to incineration in a muffle furnace at a temperature of 600°C for a duration of 2 hours. Crude protein content (calculated as N × 6.25) was analyzed using the Dumas method, employing a Dumas Nitrogen Analyzer (Velp NDA 701-Monza, Brianza-Italy). The device was calibrated using Ethylene Diamine Tetra-acetic Acid (EDTA). The lipid concentrations in the samples were analyzed through ether extraction, utilizing the ANKOMXT15 Extractor, an automated extraction system provided by composition ANKOM Technology in Macedon, USA.

**2.4. Fatty acid composition**

Determination of fatty acid composition, the lipids samples were extracted following the procedure outlined by Jakobsen et al. (2008). Wet tissue samples weighing between 50 to 100 mg were placed in a test tube with a secure screw cap and suspended in 0.7 mL of 0.1 M Tris HCl (pH 7.5 at 50°C). Two mL methanol and 1.0 mL chloroform were added to the tube, and the mixture was homogenized vigorously for 1 min using a DATHANN HG-15A homogenizer (DAIHAN Scientific Co. Ltd.). Chloroform (1 mL) was introduced, and the mixture was homogenized for 20 seconds. Subsequently, 1.0 mL of distilled water was added, and the homogenization process continued for another 20 seconds. Following centrifugation (3,200 × g, 5 min, 4°C), a precisely measured quantity of the lower layer in the tube was extracted and subjected to drying through N2 flushing at 40°C. Fatty acid methyl esters (FAME) were synthesized in accordance with the procedures described by Ichihara et al. (1996). In a small glass tube, 20–40 mg of lipid, 2 mL of hexane, and 4 mL of 2 M methanolic KOH were placed. In a typical reaction, the tube was vortexed at room temperature for 2 min. After centrifugation (3,200 × g, 10 min, 4°C), an aliquot of the upper hexane layer was directly injected into gas chromatography (GC) (Focus GC, Thermo Electron, Waltham, MA). The fatty acid analysis was conducted using gas chromatography (GC) with an autosampler, flame ionization detector, and a fused silica capillary column (30 m × 0.32 mm, internal diameter × 0.25 µm film). The oven temperature commenced at 140°C for 5 minutes, then increased to 200°C at a rate of 4°C/min, followed by a further increase to 220°C at a rate of 1°C/min. The injector and detector temperatures were maintained at 220°C and 280°C, respectively. Fatty acid methyl esters (FAMEs) were identified by comparing retention times with those of the SUPELCO standard (Sigma-Aldrich). The outcomes were expressed as a percentage of the total lipid content.

### 2.5. Statistical analysis

The proximate and fatty acid compositions were assessed based on analyzes using one-way analysis of variance (ANOVA) in the SPSS 13.0 computer program (SPSS Inc., Chicago, USA). Subsequently, the Duncan test was employed to identify significant differences between the samples at a significance level of P = 0.05. Additionally, the Pearson correlation test was utilized to explore potential correlations between GSI values and the seasonal protein-lipid, as well as certain fatty acid levels in *N. randalli* and *B. boops*.

## 3. RESULT AND DISCUSSION

### 3.1. The proximate composition

Length-weight parameters of fish are affected by several factors such as gonadal maturity, habitat, season, sex, diet, stomach fullness, health, water temperature, salinity and conservation techniques (Hossain et al., 2006). This study showed all total length and weight presented in Table 1 were highly significant (P<0.05). Kara & Bayhan (2008) investigated that monthly the length-weights of *B. boops* vary between 2.475 (January) and 3.194 (November) in males, between 2.304 (January) and 3.487 (October) in females and between 2.909 (October) and 3.298 (August) in hermaphrodites. Karakulak and Bilgin (2006) in their study, while the height-weight relations did not differ significantly according to the season for *B. boops* (P>0.05), they differed significantly for *Diplodus annularis*, *Mullus surmuletus* and *Spicara maena* (P<0.05). Significant variations were observed in the protein and lipid levels across different seasons for both species (P < 0.05) (Table 1). The highest protein level was identified in winter for *N. randalli* (18.99%), while for *B. boops*, the highest protein level was observed in the summer (21.81%). The lipid contents ranged from 0.52% to 3.85% for *N. randalli*, and from 0.52% to 3.10% for *B. boops* between seasons. The lipid content was found to be much higher in the spring for *N. randalli* (3.85%) and in the summer for *B. boops* (3.10%) than in the other seasons. It was interesting that the lipid difference between seasons was high in both species. The reason for the high seasonal difference in the lipid contents of species may be nutrient quality and diversity rather than the other known causes. The fish can be categorized based on total fat content into different classes, namely lean fish (<2%), low fat (2–4%), medium fat (4–8%), and high fat (>8%) as defined by Ackman 1990.

The muscles of the two species in the present study have a high protein and a low lipid content according to Martin et al. (2000).

**Table 1.** Seasonal, the numbers of sample, total length, weight and proximate composition of *N. randalli and B. boops* (Mean ± SE).

| | | | | | Proximate composition (N=3) | | | |
|---|---|---|---|---|---|---|---|---|
| | **Season** | **N** | **Total length (cm)** | **Weight (g)** | **Moisture (%)** | **Protein (%)** | **Lipid (%)** | **Ash (%)** |
| *N. randalli* | Autumn | 124 | 16.48±0.19[b] | 60.57±3.24[d] | 79.26±0.20[a] | 18.42±0.08[b] | 0.81±0.05[c] | 1.68±0.01[ab] |
| | Winter | 96 | 17.42±0.23[ab] | 71.62±3.26[c] | 78.71±0.10[ab] | 18.99±0.06[a] | 0.52±0.01[d] | 1.65±0.01[b] |
| | Spring | 74 | 18.46±0.27[a] | 92.10±4.82[a] | 76.75±0.38[c] | 16.97±0.10[c] | 3.85±0.12[a] | 1.49±0.04[c] |
| | Summer | 98 | 18.74±0.24[a] | 89.57±3.39[b] | 78.18±0.07[b] | 18.82±0.12[ab] | 1.18±0.02[b] | 1.72±0.01[a] |
| *B. boops* | Autumn | 237 | 15.89±0.10[d] | 37.27±0.79[d] | 76.09±0.26[b] | 21.16±0.07[b] | 0.52±0.02[bc] | 1.92±0.03[a] |
| | Winter | 171 | 22.26±0.91[a] | 58.00±2.72[a] | 77.88±0.06[a] | 19.53±0.09[c] | 0.71±0.09[b] | 1.61±0.01[b] |
| | Spring | 108 | 17.12±0.16[b] | 54.37±1.56[b] | 78.98±0.05[a] | 19.12±0.02[d] | 0.27±0.01[c] | 1.59±0.01[b] |
| | Summer | 125 | 16.49±0.12[c] | 50.94±3.43[c] | 73.19±0.43[c] | 21.81±0.09[a] | 3.10±0.14[a] | 0.91±0.45[c] |

N, numbers of sample; SE, standard error.
The results are presented as a percentage of dry matter. Intraspecific comparisons reveal that values in the same column with different letters are statistically significant in relation to seasonality.

Similarly, Bakan et al. (2020) reported that the total lipid levels of *N. randalli* from Mersin Bay varied between 0.63% and 3.17%, and the highest lipid levels were found in the spring season. Göçmen et al. (2018) detected that the total lipid levels of *N. randalli* from Mersin Bay changed between 2.75% and 2.85% with different ages. Durmuş (2019) determined a lipid content of 1.12% in the muscles of *B. boops* from the Northeastern Mediterranean coast. Orban et al. (2011) reported total lipid levels of 2.54% and 1.02% and protein contents of 20.32% and 18.40% for *B. boops* caught from the Southern Adriatic Coast of Italy in September and March, respectively. Simat et al. (2015) revealed that lipid and protein contents were 2% and 18.8% in the muscles of *B. boops* from the Eastern Adriatic Sea. The variations observed in studies are likely due to a combination of factors, with the biochemical composition of fish being a key influencer. The reasons for the discrepancy between studies are likely multifaceted and could include the biochemical composition of fish, which is influenced by several factors such as biological variations (species, sex, size, and age), natural diet, geographical location of the catch, and seasonal changes (Chuang et al. 2012; Orban et al. 2011).

### 3.2. The relationship between GSI values with seasonal protein-lipid levels

Variability in growth and GSI of *N. randalli* and *B. boops* can be caused by a variety of factors, including differences in mortality, sexual maturity, genetic variations or environmental conditions (Dutka-gianelli and Murie 2001). In the present study, the monthly variation of gonadosomatic index (GSI) was given for the two species in Table 2.

**Table 2.** Correlation between seasonal fatty acids and protein, lipid with GSI of *N. randalli* and *B. boops*.

| | *N.randalli* | | | *B.boops* | | |
|---|---|---|---|---|---|---|
| | **Mean±SD** | **r** | **p** | **Mean±SD** | **r** | **p** |
| PROTEİN | 20.41±1.29 | -0.76 | 0.24 | 18.30±0.92 | 0.27 | 0.73 |
| LİPİD | 1.15±1.31 | -0.21 | 0.79 | 1.59±1.53 | -0.05 | 0.95 |
| SFA | 55.74±10.99 | 0.69 | 0.32 | 43.09±10.67 | 0.45 | 0.55 |
| MUFA | 15.69±10.81 | -0.79 | 0.21 | 20.42±8.62 | -0.45 | 0.55 |
| PUFA | 22.73±2.95 | 0.88 | 0.12 | 24.71±2.39 | -0.24 | 0.76 |
| PUFA/SFA | 0.42±0.07 | -0.28 | 0.72 | 0.61±0.20 | -0.44 | 0.56 |
| n6 | 5.89±3.18 | 0.31 | 0.69 | 9.63±4.19 | -0.54 | 0.45 |
| n3 | 16.84±4.49 | 0.36 | 0.64 | 15.05±2.11 | 0.82 | 0.18 |
| n6/n3 | 0.41±0.35 | 0.15 | 0.85 | 0.68±0.37 | -0.40 | 0.40 |
| DHA | 13.64±4.78 | 0.39 | 0.61 | 8.40±1.99 | 0.51 | 0.50 |
| EPA | 2.15±1.28 | -0.71 | 0.29 | 2.89±0.82 | 0.93 | 0.07 |
| DHA/EPA | 7.19±3.62 | 0.86 | 0.15 | 2.95±0.45 | -0.76 | 0.24 |

According to the GSI, *N. randalli* spawns in the period from April to October, with a peak in July, and *B. boops* spawns during the period from January to April, with a peak in March. However, for *N. randalli*, the lipid level in muscles was very high in April, the beginning of gonad development, but the lowest protein level was in this month. In other words, it could be said that

*N. randalli* stores lipid in muscles before entering the reproductive period. For *B. boops*, protein and lipid levels increased in muscles when the reproduction period finished in July (summer). It could be said that the species goes through a period of intense feeding between the end of the reproductive season and the beginning of summer. The lowest protein and lipid levels were observed in April, when reproduction was high (Figure 2).

Variability in growth and GSI of *N. randalli* and *B. boops* can be caused by a variety of factors, including differences in mortality, sexual maturity, genetic variations or environmental conditions. This may be because, during reproductive periods, there is a transfer of lipids and proteins from muscles to gonads, playing crucial roles in supporting embryonic development. The main source of ovarian protein is the muscle, while lipids may be sourced from both the liver and muscle. This process is essential for providing energy and fulfilling structural functions necessary for successful embryonic development (Tolussi et al., 2018). The results of the current study were similar to the results of previous studies (Soykan et al. 2015; Taylan and Bayhan 2015; Demirci et al. 2018; Özen 2021). In both species, no positive or negative correlation was detected between seasonal proximate composition and GSI levels in the present study ($P > 0.05$) (Table 2).

### 3.3. Fatty acid composition

In this study, a significant variation in fatty acids (FAs) was observed across seasons ($P < 0.05$), as indicated in Table 3. For both species, the predominant fatty acid composition consistently ranked as SFAs > PUFAs > MUFAs (monounsaturated fatty acids) throughout all seasons. The primary fatty acid in this category was stearic acid (C18:0), with palmitic acid (C16:0) following closely. Specifically, stearic acid (C18:0) exhibited peak levels, 29.77% during winter for *N. randalli* and 44.97% during summer for *B. boops*. Palmitic acid (C16:0) was found high at 19.63% in winter for *N. randalli* and 20.22% in autumn for *B. boops*. The high levels of saturated fatty acids (SFAs) in human foods are considered undesirable due to the potential health risks associated with SFAs. Increased consumption of SFAs has been linked to harmful effects, such as elevated total cholesterol levels, which can lead to the formation of arterial blockages in the heart and other parts of the body (Mensink, 2016). It is recommended that 5% to 6% of calories be derived from SFA, and the percent of calories from SFA be reduced (Kris-Etherton and Krauss 2020). Simat et al. (2015) pointed out that SFAs were dominant fatty acids for *B. boops*. According to Orban et al. (2011), SFAs were dominant in September while PUFAs were dominant in March for *B. boops*.

The n-3 long-chain polyunsaturated fatty acids (PUFAs), including C20:5 n-3 (eicosapentaenoic acid, EPA) and C22:6 n-3 (docosahexaenoic acid, DHA), play a crucial role in reducing the risk of cardiovascular diseases and other chronic non-communicable diseases (Merdzhanova et al., 2021). The European Food Safety Authority recommends that infants >6 months to 2 years should consume 100 mg/d of DHA, while the adult population should have a daily DHA and EPA intake of approximately 250 mg (Carlson et al., 2013). In the present study, PUFAs emerged as the predominant fatty acids, following SFAs. DHA was found to be a major PUFA for both species. The highest DHA content was detected in the winter for *N. randalli* (10.33%) and in the spring for *B. boops* (19.46%). Generally, EPAs were low for two species. EPA levels were high in the summer for *N. randalli* (4.00%) and in the autumn for *B. boops* (4.04%). Similarly, Bakan et al. (2020) determined that the highest DHA and EPA contents were 23.00% in autumn and 5.34% in the summer in the muscles of *N. randalli*, respectively. Göçmen (2018) determined DHA contents ranging from 20.16% to 22.02% and EPA contents varying from 3.75% to 5.49% in muscles of *N. randalli* specimens at different ages. The DHA ratio in total fatty acids was lower in both species in the present study. Diraman & Dibeklioğlu (2009) reported an EPA content of 4.53% and a DHA content of 20.66% in *B. boops* from the Aegean Sea in February.

In the current investigation, the DHA/EPA ratio reached the highest level 3.49 during the winter for *N. randalli* and 10.96 in the spring for *B. boops*. Bakan et al. (2020) reported that the highest DHA/EPA ratio was 5.30 in the autumn for *N. randalli*. Diraman & Dibeklioğlu (2009) and Simat et al. (2015) reported DHA/EPA ratios of 4.56 and 3.37 for *B. boops*, respectively.

PUFA/SFA ratio is recommended to be a minimum of 0.45 for human health (HMSO, 1994). In this study, generally the

PUFA/SFA ratios were below 0.45 for both fish species. The highest PUFA/SFA ratio was found to be 0.78 during both the autumn and spring seasons for *N. randalli*. Additionally, for *B. boops*, the highest ratio of 0.50 was observed specifically during the autumn season. Bakan et al. (2020) determined the highest PUFA/SFA ratio for *N. randalli* as 0.81 in the spring. The highest PUFA/SFA ratios for *B. boops* were detected in the winter as 1.51 (Uçar, 2020), 1.25 (Diraman & Dibeklioğlu, 2009), and 1.38 (Durmuş, 2019).

The UK Department of Health (HMSO, 1994) recommends 4.0 of maximum n6/n3 ratio. Exceeding this threshold is considered detrimental to health and may contribute to the promotion of cardiovascular diseases, as highlighted by Moreira et al., (2001). In the present study, the n6/n3 ratios were generally low for each of the two species. The highest of the n6/n3 ratio was observed at 1.02 in the autumn for *N. randalli* and 0.92 in the winter for *B. boops* in this study. In a previous study by Bakan et al. (2020), the highest n6/n3 ratio for *N. randalli* was reported as 0.18 in the spring.

### 3.4. The relationship between GSI values with seasonal fatty acid levels

No significant difference and correlation were detected between seasonal fatty acid and GSI values in both species. (P > 0.05) (Table 3).

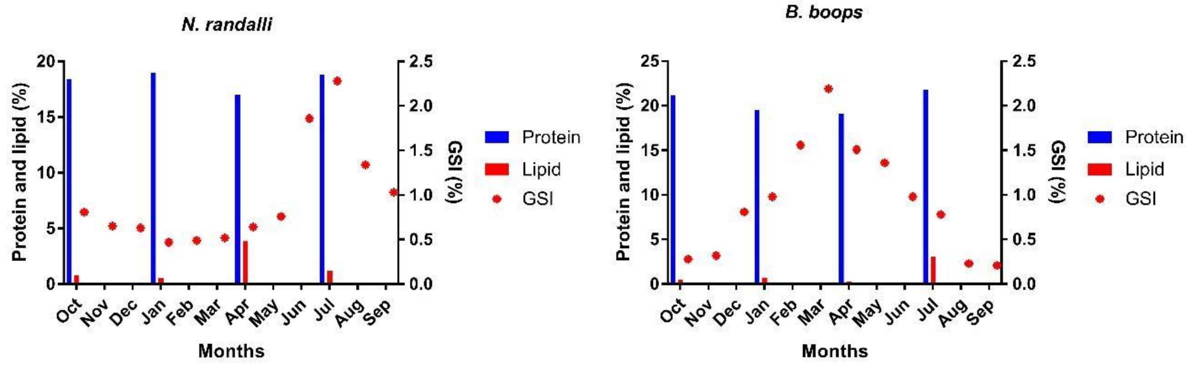


**Figure 2.** Relationship between GSI values with seasonal protein-lipid levels of *N. randalli* and *B. boops.*

**Table 3.** The seasonal changes in the fatty acid composition of *N. randalli and B. boops* (% of total lipid, N=3).

| **Fatty acid** | | ***N. randalli* Mean ± SE** | ***B. boops* Mean ± SE** |
|---|---|---|---|
| Myristic acid (C14:0) | Autumn | 2.15±0.00$^{b}$ | 5.22±0.03$^{a}$ |
| | Winter | 2.46±0.10$^{a}$ | 1.97±0.01$^{b}$ |
| | Spring | 1.67±0.00$^{c}$ | 1.44±0.02$^{c}$ |
| | Summer | 2.20±0.00$^{b}$ | 1.08±0.02$^{d}$ |
| Pentadecanoic acid (C15:0) | Autumn | 0.56±0.01$^{c}$ | 0.83±0.01$^{a}$ |
| | Winter | 0.96±0.01$^{a}$ | 0.35±0.01$^{c}$ |
| | Spring | 0.48±0.01$^{d}$ | 0.53±0.01$^{b}$ |
| | Summer | 0.65±0.01$^{b}$ | 0.36±0.01$^{c}$ |
| **Continuation of The Table 3.** | | | |
| **Fatty acid** | | ***N. randalli* Mean ± SE** | ***B. boops* Mean ± SE** |
| Palmitic acid (C16:0) | Autumn | 15.23±0.06$^{b}$ | 22.29±0.03$^{a}$ |
| | Winter | 19.63±0.09$^{a}$ | 16.82±0.08$^{d}$ |
| | Spring | 15.57±0.08$^{b}$ | 18.07±0.07$^{b}$ |
| | Summer | 19.11±0.08$^{a}$ | 17.36±0.08$^{c}$ |
| Heptadecanoic (margaric) acid (C17:0) | Autumn | 1.15±0.01$^{c}$ | 1.84±0.01$^{a}$ |
| | Winter | 2.24±0.01$^{a}$ | 0.86±0.01$^{d}$ |

| | | | |
|---|---|---|---|
| | Spring | 0.97±0.01$^{d}$ | 1.54±0.01$^{b}$ |
| | Summer | 1.65±0.01$^{b}$ | 1.21±0.01$^{c}$ |
| Stearic acid (C18:0) | Autumn | 14.14±0.10$^{d}$ | 11.12±0.06$^{d}$ |
| | Winter | 29.77±0.11$^{a}$ | 31.55±0.06$^{c}$ |
| | Spring | 14.74±0.06$^{c}$ | 40.28±0.09$^{b}$ |
| | Summer | 25.85±0.14$^{b}$ | 44.97±0.06$^{a}$ |
| Arachidic acid (C20:0) | Autumn | 0.66±0.00$^{c}$ | 0.42±0.01$^{c}$ |
| | Winter | 1.06±0.01$^{a}$ | 0.92±0.01$^{b}$ |
| | Spring | 0.58±0.00$^{d}$ | 0.93±0.01$^{b}$ |
| | Summer | 0.91±0.01$^{b}$ | 1.04±0.02$^{a}$ |
| ∑SFA | Autumn | 33.90±0.07$^{c}$ | 41.72±0.10$^{d}$ |
| | Winter | 56.12±0.13$^{a}$ | 52.47±0.15$^{c}$ |
| | Spring | 33.99±0.06$^{c}$ | 62.79±0.18$^{b}$ |
| | Summer | 50.36±0.22$^{b}$ | 66.01±0.11$^{a}$ |
| Palmitoleic acid (C16:1) | Autumn | 3.49±0.01$^{b}$ | 5.85±0.04$^{a}$ |
| | Winter | 2.46±0.01$^{d}$ | 1.67±0.02$^{b}$ |
| | Spring | 3.34±0.02$^{c}$ | 0.77±0.02$^{d}$ |
| | Summer | 3.70±0.01$^{a}$ | 1.11±0.02$^{c}$ |
| Cis-10-heptadecanoic acid (C17:1) | Autumn | 0.05±0.01$^{a}$ | 0.06±0.00$^{c}$ |
| | Winter | 0.05±0.01$^{a}$ | 0.09±0.00$^{a}$ |
| | Spring | 0.05±0.01$^{a}$ | 0.06±0.00$^{bc}$ |
| | Summer | 0.05±0.01$^{a}$ | 0.07±0.00$^{b}$ |
| Oleic acid (C18:1n9) | Autumn | 23.20±0.03$^{b}$ | 22.51±0.04$^{a}$ |
| | Winter | 8.54±0.01$^{d}$ | 18.00±0.07$^{b}$ |
| | Spring | 23.83±0.01$^{a}$ | 4.40±0.05$^{d}$ |
| | Summer | 10.25±0.04$^{c}$ | 6.84±0.02$^{c}$ |
| Erucic acid (C22:1n9) | Autumn | 0.53±0.01$^{a}$ | 0.07±0.00$^{d}$ |
| | Winter | 0.24±0.00$^{c}$ | 0.18±0.00$^{a}$ |
| | Spring | 0.52±0.01$^{a}$ | 0.11±0.00$^{b}$ |
| | Summer | 0.28±0.00$^{b}$ | 0.09±0.00$^{c}$ |
| Nervonic acid (C24:1) | Autumn | 0.35±0.01$^{a}$ | 0.27±0.01$^{b}$ |
| | Winter | 0.24±0.00$^{ab}$ | 0.34±0.09$^{a}$ |
| | Spring | 0.26±0.00$^{b}$ | 0.18±0.09$^{c}$ |
| | Summer | 0.24±0.00$^{ab}$ | 0.11±0.00$^{d}$ |

**Continuation of The Table 3.**

| **Fatty acid** | | ***N. randalli* Mean ± SE** | ***B. boops* Mean ± SE** |
|---|---|---|---|
| ∑MUFA | Autumn | 27.63±0.03$^{b}$ | 28.76±0.06$^{a}$ |
| | Winter | 11.53±0.02$^{d}$ | 20.28±0.09$^{b}$ |
| | Spring | 27.99±0.02$^{a}$ | 5.53±0.05$^{d}$ |
| | Summer | 14.52±0.03$^{c}$ | 8.22±0.01$^{c}$ |
| Linoleic acid (C18:2n6) | Autumn | 7.59±0.02$^{a}$ | 0.83±0.01$^{b}$ |
| | Winter | 0.67±0.01$^{b}$ | 7.28±0.02$^{a}$ |

| | | | |
|---|---|---|---|
| | Spring | 7.64±0.02[a] | 0.69±0.01[c] |
| | Summer | 0.63±0.00[b] | 0.69±0.01[c] |
| (alfa) linolenic acid (ALA)(C18:3n3) | Autumn | 2.19±0.01[a] | 0.63±0.01[b] |
| | Winter | 0.86±0.01[c] | 1.26±0.01[a] |
| | Spring | 2.17±0.01[a] | 0.32±0.01[d] |
| | Summer | 1.32±0.01[b] | 0.47±0.01[c] |
| Stearidonic acid (C18:4n3) | Autumn | 0.13±0.00[c] | 0.72±0.01[a] |
| | Winter | 0.16±0.01[b] | 0.16±0.01[c] |
| | Spring | 0.13±0.00[c] | 0.11±0.01[d] |
| | Summer | 0.18±0.01[a] | 0.28±0.01[b] |
| Cis-11,14-eicosadienoic acid (C20:2n6) | Autumn | 2.24±0.01[a] | 0.15±0.03[d] |
| | Winter | 0.45±0.01[c] | 0.47±0.07[a] |
| | Spring | 2.24±0.01[a] | 0.22±0.08[b] |
| | Summer | 0.58±0.01[b] | 0.18±0.06[c] |
| Eicosatrienoic acid (C20:3n6) | Autumn | 0.48±0.01[c] | 0.19±0.01[d] |
| | Winter | 0.62±0.01[a] | 0.39±0.01[a] |
| | Spring | 0.47±0.01[c] | 0.25±0.01[c] |
| | Summer | 0.53±0.01[b] | 0.29±0.01[b] |
| Arachidonic acid (C20:4n6) | Autumn | 2.24±0.04[c] | 1.46±0.02[c] |
| | Winter | 2.70±0.01[b] | 1.32±0.01[d] |
| | Spring | 2.11±0.01[d] | 1.62±0.01[b] |
| | Summer | 3.22±0.06[a] | 2.03±0.01[a] |
| cis-13,16-docosadienoic acid (C22:2n6) | Autumn | 0.19±0.00[a] | 0.06±0.00[d] |
| | Winter | 0.14±0.00[b] | 0.23±0.01[a] |
| | Spring | 0.15±0.00[b] | 0.15±0.00[b] |
| | Summer | 0.10±0.01[c] | 0.11±0.00[c] |
| Eicosapentaenoic acid (EPA) (C20:5n3) | Autumn | 2.10±0.01[d] | 4.04±0.04[a] |
| | Winter | 2.96±0.05[b] | 1.32±0.01[d] |
| | Spring | 2.52±0.04[c] | 1.78±0.02[b] |
| | Summer | 4.00±0.07[a] | 1.44±0.02[c] |
| Docosatetraenoic acid (C22:4n6) | Autumn | 0.63±0.01[c] | 0.54±0.01[d] |
| | Winter | 1.24±0.01[a] | 0.82±0.01[c] |
| | Spring | 0.55±0.01[d] | 1.92±0.01[a] |
| | Summer | 1.15±0.01[b] | 1.64±0.01[b] |

**Continuation of The Table 3.**

| **Fatty acid** | | ***N. randalli* Mean ± SE** | ***B. boops* Mean ± SE** |
|---|---|---|---|
| Docosapentaenoic acid (C22:5n3) | Autumn | 2.16±0.02[b] | 1.12±0.01[a] |
| | Winter | 1.57±0.02[d] | 0.82±0.01[b] |
| | Spring | 1.89±0.02[c] | 0.59±0.01[d] |
| | Summer | 2.26±0.01[a] | 0.76±0.01[c] |
| Docosahexanoic acid (DHA) (C22:6n3) | Autumn | 6.57±0.05[d] | 11.13±0.05[c] |
| | Winter | 10.33±0.05[a] | 7.80±0.02[d] |

| | | | |
|---|---|---|---|
| | Spring | 6.81±0.01[c] | 19.46±0.03[a] |
| | Summer | 9.89±0.04[b] | 13.15±0.05[b] |
| ∑PUFA | Autumn | 26.52±0.10[a] | 20.88±0.07[c] |
| | Winter | 21.71±0.14[c] | 21.87±0.04[b] |
| | Spring | 26.66±0.09[a] | 27.11±0.05[a] |
| | Summer | 23.86±0.14[b] | 21.05±0.06[c] |
| Total | Autumn | 88.05±0.09[b] | 91.37±0.10[c] |
| | Winter | 89.36±0.32[a] | 94.63±0.26[b] |
| | Spring | 88.65±0.08[ab] | 95.43±0.23[a] |
| | Summer | 88.74±0.38[ab] | 95.29±0.17[a] |
| PUFA/SFA | Autumn | 0.78±0.00[a] | 0.50±0.49[a] |
| | Winter | 0.39±0.00[c] | 0.42±0.40[c] |
| | Spring | 0.78±0.00[a] | 0.43±0.43[b] |
| | Summer | 0.47±0.00[b] | 0.32±0.32[d] |
| ∑n6 | Autumn | 13.37±0.06[a] | 3.24±0.03[d] |
| | Winter | 5.82±0.02[d] | 10.51±0.02[a] |
| | Spring | 13.15±0.06[b] | 4.85±0.02[c] |
| | Summer | 6.21±0.09[c] | 4.95±0.03[b] |
| ∑n3 | Autumn | 13.15±0.05[d] | 17.64±0.08[b] |
| | Winter | 15.88±0.12[b] | 11.36±0.04[d] |
| | Spring | 13.51±0.05[c] | 22.26±0.03[a] |
| | Summer | 17.65±0.08[a] | 16.10±0.04[c] |
| n6/n3 | Autumn | 1.02±0.00[a] | 0.18±0.00[d] |
| | Winter | 0.37±0.00[c] | 0.92±0.00[a] |
| | Spring | 0.97±0.01[b] | 0.22±0.00[c] |
| | Summer | 0.35±0.00[d] | 0.31±0.00[b] |
| DHA/EPA | Autumn | 3.14±0.03[a] | 2.75±0.02[d] |
| | Winter | 3.49±0.06[b] | 5.92±0.09[c] |
| | Spring | 2.71±0.04[c] | 10.96±0.15[a] |
| | Summer | 2.47±0.04[d] | 9.12±0.16[b] |
| Others | Autumn | 11.95±0.09[a] | 8.63±0.10[a] |
| | Winter | 10.64±0.32[b] | 5.37±0.26[b] |
| | Spring | 11.35±0.08[ab] | 4.57±0.23[c] |
| | Summer | 11.26±0.38[ab] | 4.71±0.17[c] |

Seasonal differences in fatty acids of the same species are indicated by vertical lettering.

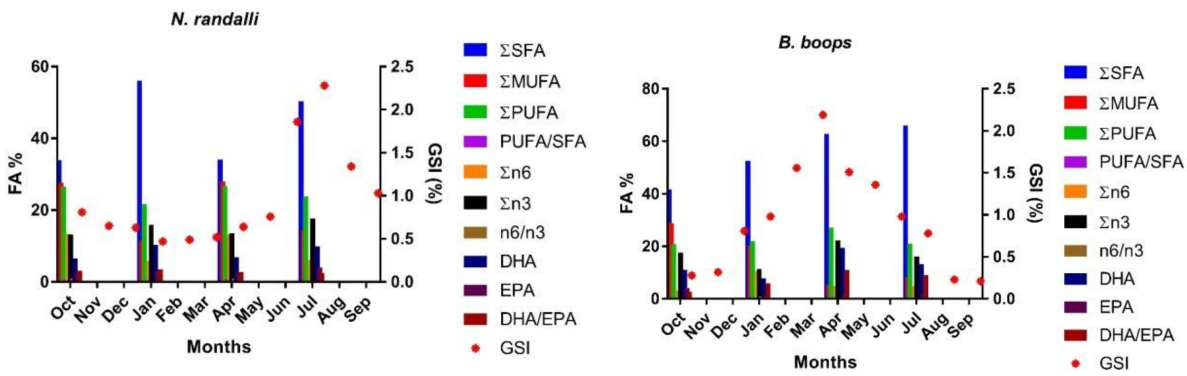


**Figure 3.** Relationship between GSI values with seasonal fatty acid levels of *N. randalli* and *B. boops*.

However, PUFA, MUFA, PUFA/SFA, and lipid levels increased in April at the beginning of gonad development for *N. randalli*. The lipid levels in the muscles of *B. boops* increased in July when the reproduction period finished, but the highest PUFA, DHA, and DHA/EPA ratios were observed in April when reproduction was high for *B. boops* (Figure 3).

Dobroslavić et al. (2017) reported that the gonadosomatic index and histological examination indicated the spawning season of the Bogue in the Adriatic region occurs from January to May, with the peak observed in February.

## CONCLUSIONS

Fish, an important source of PUFA, has the unique advantage that many seafood species are available, and consumers have a wide choice. Because Turkiye is surrounded by sea with different characteristics on three sides, it hosts a rich biodiversity of fish, which differ significantly in their nutritional composition. In the present study, SFAs were high in *N. randalli* and *B. boops* in all seasons. Therefore, excessive consumption is not recommended in the spring for *N. randalli* and in the summer for *B. boops* when their lipid contents are high. Consumption is recommended when protein and DHA content is high in winter for *N. randalli* and in the autumn and spring for *B. boops*. In addition, introducing these species as DHA-rich species would increase their nutritional benefits in terms of public health.

## AUTHOR CONTRIBUTIONS

All authors contributed to this research. The idea for the experiments came from H.U Koca. H.U Koca gathered the raw material and set up the plans for experiments. Ö. Aktaş and F. Pak performed the analyses of the samples. S. Bahadır Koca and G. Sürengil analyzed the data and wrote the article. G. Sürengil researched the literature, participated in drafting of the article and critical revision. All authors approved the final version of the manuscript.

## CONFLICT OF INTERESTS

The authors declare no conflict of interests.

## ETHICS STATEMENT

The paper is not requiring ethics committee approval.

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**Research Article** **Araştırma Makalesi**

# Effectiveness of Anchor Borrowers' Program on Fish Farming in Osun State, Nigeria

## Nijerya'nın Osun Eyaletinde Balık Çiftçilerine Yönelik Sabit Borçlular Destek Programı Etkililiği

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**Abstract:** The main objective of this study is to ascertain the effectiveness of Anchor Borrowers' Program (ABP) on fish farming (FF) in Osun State, Nigeria.120 smallholder fish farmers Participating in ABP (PABP) were chosen using a multi-stage sampling approach. Data were obtained between January and March of 2023. Interview schedule was used to collect data on respondents' demographic characteristics, sources of information on FF (SIFF), benefits derived (BD) from PABP, constraints to PABP, and effectiveness of ABP (EABP) in FF. Data were analyzed using frequency count, percentage, mean, Chi-square, and Pearson Product Moment Correlation. Most respondents' were males (75.8%), members of fish farmers association (68.3%), and aged 46.0±9.0years. The FF information was accessed mostly through ABP representatives ($\bar{x}$=1.7). Access to SIFF was moderate (63.3%), and BD was moderate (66.7%). Increase production ($\bar{x}$=1.7) was the most BD from PABP. Poor access to water ($\bar{x}$=1.8) was the highest constraint to PABP. Constraints to PABP were moderate (74.2%), and EABP in FF was moderate (68.3%). EABP in FF was influenced by SIFF (r=-0.15). ABP representatives (r=-0.22), family and friends (r=-0.28), newspaper (r=0.16), cell phone calls (r=0.20) and extension agents (r=-0.21) information source types significantly influenced EABP in FF. The anchor borrowers' program was moderately effective in fish farming and this was influenced by sources of information on fish farming.

**Keywords**
- Anchor borrowers
- Aquaculture
- Effectiveness
- Fish farmers
- Fish farming

**Özet:** Bu çalışmanın temel amacı, Nijerya'nın Osun Eyaletindeki Sabit Borçlular Destek Programının balık yetiştiriciliği üzerindeki etkililiğini tespit etmektir. Sabit Borçlular Destek Programına katılan 120 küçük ölçekli balık çiftçisi çok aşamalı bir örnekleme yaklaşımı kullanılarak seçilmiştir. Veriler 2023 yılının Ocak ve Mart ayları arasında elde edilmiştir. Katılımcıların demografik özellikleri, balık çiftçileri hakkındaki bilgi kaynakları, sabit borçlular destek program katılımından elde edilen faydalar, katılımla ilgili kısıtlamalar ve programın etkililiği hakkındaki verileri toplamak için görüşme program kullanıldı. Veriler frekans sayısı, yüzde, ortalama, Ki-kare ve Pearson Ürün Moment Korelasyonu kullanılarak analiz edildi. Ankete katılanların çoğu erkek (%75,8), balık yetiştiricileri derneği üyesi (%68,3) ve 46,0±9,0 yaşındaydı.. Balık çiftçilerinin bilgilerine çoğunlukla sabit borçlular destek program temsilcileri aracılığıyla ulaşıldı ($\bar{x}$ = 1,7). Balık yetiştiricileri ile ilgili bilgi kaynaklarına erişim orta düzeydeydi (%63,3) ve elde edilen fayda da orta düzeydeydi (%66,7). Üretim artışı ($\bar{x}$=1,7) sabit borçlular destek programına katılımdan elde edilen en büyük faydaydı. Suya erişimin zayıf olması ($\bar{x}$=1,8) sabit borçlular destek programı katılımındaki en büyük kısıtlamaydı. Sabit borçlular destek program katılımındaki kısıtlamalar orta düzeydeydi (%74,2) ve program etkililiği de orta düzeydeydi (%68,3). Destek programının etkililiği balık yetiştiriciliği ile ilgili bilgi kaynaklarına erişimden etkilenmiştir (r=-0,15). Ayrıca program temsilcileri (r=-0,22), aile ve arkadaşlar (r=-0,28), gazete (r=0,16), cep

**Anahtar kelimeler**
- Sabit borçlular
- Su ürünleri yetiştiriciliği
- Verimlilik
- Balık çiftçileri
- Balık çiftçiliği

telefonu görüşmeleri (r=0,20) ve dahili acenteler (r=-0,21) bilgi kaynağı türleri de destek programına katılımı anlamlı olarak etkiledi. Bu destek program orta düzeyde etkiliydi ve bu etki durumunda balık yetiştiriciliği konusundaki bilgi kaynaklarına erişimin etkisi olmuştur.

## 1. INTRODUCTION

Aquaculture is the farming/cultivation of various aquatic species (aquatic animals and plants) in fresh, brackish and saltwater (Kaleem and Sabi, 2021). The aquaculture industry is a worldwide or global phenomenon. The industry, compared to all other animal food production industries, continues to develop at an average global annual growth rate of 8.8 percent annually (Onada and Ogunola, 2017). Approximately 424 aquatic species, including aquatic plants and animals, crustaceans, mollusks and fish, are cultivated around the world, which benefits millions of people by its production acting as a viable economic activity for nutrition, food security, sustainable livelihood, and poverty alleviation (Galappaththi et al., 2020). World aquaculture has grown significantly over the past 20 years to become a key economic sector that produces more than half of the world's seafood (Joseph**,** 2023). Fish farming (FF) is a segment of the aquaculture business that focuses on raising fish under controlled conditions for market and/or personal use (Samuel, 2020).

Nigeria is one of the Africa's leading producers of aquaculture and the leading producer in Sub-Saharan Africa (SSA). The country's aquaculture industry mostly concentrates on freshwater fish, with catfish species accounting for 64% of production (WorldFish, 2018). In the country, fish farming is without a doubt one of the agricultural and aquaculture industries with the quickest rate of growth (FAO, 2020; FAO, 1991). The country produces the most farmed fish in SSA, making about 52% of the overall production (Kaleem and Bio SingouSabi, 2021). Fish production in the country has increased 12% annually, over the past 35 years, rising from just over 6000 metric tons in 1980 to approximately 307,000 metric tons in 2016 (Kaleem and Bio SingouSabi, 2021). Nigeria's artisanal fisheries have been the focus of federal government efforts for the past 20 years because they are known to account for more than 95% of the nation's fish production.

Nigeria offers the largest market for fish and fisheries products in Africa (Samuel, 2020). Nigerians are high fish consumers. For the average Nigerian, fish makes up roughly 41% of their entire animal protein consumption. Thus, in an effort to boost aquaculture and/or fish productivity in order to meet the high increase in fish demand in the country, the Nigerian federal government over the years established fish production interventions (programs, projects and policies). The Unsubsidized Revolving Loan Scheme to Fishermen, International Assistance for Fisheries Development in Nigeria, and National Accelerated Fish Production (NAFP) are a few of the interventions. Despite these foregoing interventions as well as a lot of opportunities and possibilities, Nigeria is yet to completely explore its aquaculture and/or fish farming (FF) potentials. According to Samuel (2020), by comparison, the FF business is still in its infancy compared to the vast market potential for its production and commercialization. The country's fish supply and demand still experience a deficit (FMARD, 2015). Joseph **(**2023) affirmed that the country has a significant production deficit in fish.

Lately, the Anchor Borrowers' Program (ABP) was established and launched on November 17, 2015. The ABP is an agricultural program introduced by the Nigerian government through the Central Bank of Nigeria (CBN) to help Smallholder Farmers (SHFs) makes better use of inputs while also assuring credit performance (CBN, 2016). It provides farm inputs in-kind and in-cash to participant farmers to increase agricultural production and links them to already available markets. Through the inclusion of private sectors that act as input suppliers, the ABP increases the availability and affordability of inputs and improves the output market (CBN, 2016). The essential agricultural commodities promoted by ABP, among others, include cereals, roots and tuber crops, tree crops, legumes, and livestock. The principal objective of anchor borrowers' program is about credit access and improving farm finance as it provides farm inputs in-kind and in-cash support (for farm labour) to SHFs. This is expectedly to boost production and lower the importation of a specific commodity of interest (CBN, 2016).

In order to assist fish farmers in meeting the country's need for fish, the Fisheries Cooperative Federation of Nigeria (FCFN), a cooperative representing the Nigerian fisheries sector, requested and/or advocated that the CBN include fisheries in its ABP (Ashagye, 2019). As a result, fish farmers from various geopolitical regions and states (including Osun State) of Nigeria have been included in the ABP, with the idea that, with help from the anchor borrower's program, they will be able to meet the nation's annual fish demand of 2.6 million tons. The inclusion in the CBN agriculture program would assist fish producers in overcoming other obstacles impeding increased fish production. Osun State, as one of the states in the Southwestern region, has benefitted from the ABP, with a total sum of ₦167,364,862.50 disbursed to them and farming activities spanned through the fishery value chain with these farmers going through the cycle of the program successfully. Notwithstanding, local production of fish in the State is still relatively low, which has created a demand-supply gap. More so, there is no empirical evidence that the participating farmers' enterprises have recorded significant growth in fish production. In addition, there are limited studies that have focused attention on how participating farmers in ABP have fared in the study area. This formed the motivation of this study, which aims to investigate the effects of ABP on aquaculture production in Osun state. Hence, accessing the effectiveness of ABP (EABP) among fish farmers in Osun State of Nigeria becomes pertinent. It is against this backdrop that this study investigates the EABP for FF among farmers in Osun State of Nigeria.

The study's primary objective is to determine the EABP in FF among farmers in Osun state, Nigeria. The specific objectives are to: describe the demographic characteristics of ABP fish farmers; ascertain the extent of accessing information on FF by ABP participants; ascertain the benefits derived (BD) from ABP; identify constraints faced by fish farmers participating in ABP (PABP); and determine the level of EABP in FF. The study's objectives led to the testing of the following hypotheses: a significant relationship cannot be found between the selected demographic parameters of respondents and EABP in FF; extent of accessing information sources on FF and EABP in FF do not significantly correlate with one another; BD from ABP and EABP in FF does not significantly correlate with one another; and constraints to PABP and EABP in FF do not significantly relate to one another.

## 2. MATERIAL AND METHODS

### 2.1. Work area and working schedule

The study was conducted in Osun State, which is located in the Southwestern region of Nigeria. The study area lies between longitudes 4° 00' and 30° 00'East of the Greenwich Meridian and latitudes 7°00' and 30°0' North of the equator. The period of data collection was January through March of 2023

### 2.2. Population and sampling procedure

All of the registered smallholder fish farmers in Osun State who are taking part in ABP consist of the population under investigation. The study's respondents were chosen through a multi-phase sampling procedure. Two out of the thirty (30) Local Government Areas-LGAs of Osun State were purposively selected based on the high predominance of registered smallholder fish farmers who participated in ABP. These selected LGAs were Ife-Central and Osogbo. Two communities from each of the selected LGA were purposively sampled based on prominence in FF and participation in ABP. These selected communities were Eleyele and Iremo from Ife-Central LGA, and Dada Estate and Okefia from Osogbo LGA. From the list of registered smallholder fish farmers PABP in the selected communities, 60% of the smallholder fish farmers PABP were selected at random, using the proportionate sample technique, from each of the communities that had been selected for analysis. Thus, the sample size for the study was 120 respondents.

### 2.3. Data collection

This research used primary data, which were collected through the use of quantitative research methods. Pre-tested structured interview schedule was used to obtain quantitative data. This covered information on demographic characteristics of fish farmers' PABP, extent of accessing information on FF, benefits fish farmers derived from ABP, constraints PABP and level of EABP in FF.

### 2.4. Measurement of variables

The three-point rating scale of Odebode et al. (2021) was adopted to measure extent of accessing information, benefits associated with PABP, barriers to ABP participation, and effectiveness of ABP in FF. Extent of accessing information on FF by ABP participants was measured at the interval level. Fifteen information sources, which include ABP representatives, family and friends, radio, television and extension agents, among others were presented to the respondents. The respondents were requested to indicate the frequency with which they individually obtained information on FF from the previously stated sources. This was rated on a three-point rating scale of ‘Always/Regularly (2)’, ‘Sometimes/Occasionally (1)’, and Never (0). Every respondent's scores were added together. The highest and lowest scores were obtained. Using the mean and standard deviation, the respondents were categorized into: low access to information on FF, scores between minimum and slightly below mean – 1SD; moderate access to information on FF, scores between mean – 1SD and slightly below mean +1SD, and high access to information on FF, scores between mean +1SD and maximum. Also, the information sources were ranked from the most to the least used based on the computed and/or mean scores of each item rating.

Benefits associated with PABP were measured at interval level. Benefits fish farmers derived from PABP were measured by providing respondents with a list of ten probable benefits derivable from PABP which include increased production, improved income and increased sales output, among others. Respondents were asked to indicate the benefits they derived from PABP. Response options were measured on a 3-point rating scale of high benefit, moderate benefit, and not a benefit with scores of 2, 1 and 0 assigned, respectively. Each respondent's scores were added together. The lowest and highest scores were obtained. The average and standard deviation scores were utilized to divide the respondents into three groups: those with low benefits, ranging from minimum to slightly below mean – 1SD; moderate benefits, ranging from the mean – 1SD to slightly below mean +1SD; and those with high benefits, ranging from the mean +1SD to maximum scores. Also, the weighted mean score of each BD from PABP item ratings was calculated/computed and utilized to rank BD from the most derived benefits to the least derived benefits.

Measurement of barriers to ABP participation was made at the interval level. A list of 15 potential limitations (which include poor access to water, security related issues, and poor marketing facilities) associated with ABP participation were provided to respondents. Measurement was the degree to which participation in ABP was restricted. The choices and/or options of not a constraint, mild constraint, and severe constraint were used to measure the severity of the constraints to participation in ABP, with scores of 0, 1, and 2 assigned for each option, respectively. Each respondent’s scores were summed together, with an obtained maximum score and a minimum score. The composite scores mean and standard deviation were utilized as a benchmark to categorize the respondents into three: high constraints category, scores between mean +1SD and maximum; moderate constraints category, scores between mean – 1SD and slightly below mean +1SD; and low constraints category, scores between minimum and slightly below mean – 1SD. Also, each constraint item’s weighted mean score was calculated and utilized to rank the ABP participation constraints in order of severity.

Effectiveness of ABP in FF is the dependent variable of the study. This was measured at interval level. Effectiveness of ABP in FF were measured by providing respondents with a list of fifteen effectiveness items which include linkages to off-takers, farm input provision and postharvest management, among others. Respondents were asked to indicate the improvement seen in FF with their participation in the ABP. Response options were measured on a 3-point rating scale of greatly improved, improved and not improved with scores of 2, 1 and 0 assigned, respectively. For every respondent, the scores were totaled. The scores that were obtained ranged from minimum to maximum. Index of EABP was generated by adding all responses and the mean and standard deviation indexes were computed. The mean index and standard deviation index were used to categorize EABP in FF into: high effectiveness, scores between slightly above mean +1SD and maximum; moderate effectiveness, scores between slightly above mean – 1SD and mean +1SD; and low effectiveness, scores between minimum and mean – 1SD.

### 2.6. Statistical analyses

The collected data were entered into version 20 of the Statistical Package for Social Science. Descriptive statistics (mean, percentages, frequency) as well as inferential statistics (spearman rho, Chi-square, and Pearson Product Moment Correlation-PPMC) were used to analyze the generated data.

# 3. RESULTS

## 3.1. Demographic characteristics of respondents

The results in Table 1 reveal that the mean age of fish farmers who participated in ABP was 46.05±8.94years. The sex distribution shows that most (75.8%) of the respondents were male. As regards the respondents' main sources of farmland, 47.5% of the fish farmers acquired land for fish production by lease, while 35.8% obtained farmland by inheritance. The majority (67.5%) of the respondents belong to FF association.

## 3.2. Frequency (extent) of access to sources of information on FF (SIFF)

Table 2 show results of respondents' extent of access to SIFF. The findings show that 73.3% of respondents said that they always accessed information on FF through ABP representatives. The results further reveal that most (65.0%) of the respondents indicated that they always accessed FF information through family and friends. Regarding radio, a higher percentage of respondents (90.0%) consented to sometimes receiving information on FF from radio. In terms of television, 95.8% of the respondents indicated that they sometimes received information on FF from television.

Table 2 reveals the respondent's access to all the SIFF. Most of the respondents (63.3%) had moderate access to SIFF and/or production.

**Table 1.** Distribution of respondents according to demographic characteristics.

| Characteristics | Frequency | Percentage (%) | Mean± SD / Mode |
|---|---|---|---|
| **Age (years)** | | | |
| ≤40 | 9 | 7.5 | |
| 41-50 | 73 | 60.8 | |
| 51-60 | 32 | 26.7 | 46.05 ± 8.94 |
| >60 | 6 | 5.0 | |
| **Sex** | | | |
| Male | 91 | 75.8 | Male* |
| Female | 29 | 24.2 | |
| **Sources of farmland** | | | |
| Inherited | 43 | 35.8 | |
| Rented | 20 | 16.7 | Lease* |
| Lease | 57 | 47.5 | |
| **Membership of fish farmers association** | | | |
| Member/yes | 82 | 68.3 | Member/yes* |
| Non-member/no | 38 | 31.7 | |

Values in asterisks implies mode.

**Table 2.** Distribution of respondents according to their frequency (extent) of access to sources of information on fish farming.

| Sources of information | Never f (%) | Sometimes f (%) | Always f (%) | Mean | Rank |
|---|---|---|---|---|---|
| ABP representative | 0 (0.0) | 32 (26.7) | 88 (73.3) | 1.73 | 1 |
| Family and friends | 1 (0.8) | 41 (34.2) | 78 (65.0) | 1.64 | 2 |
| Radio | 5 (4.2) | 108 (90.0) | 7 (5.8) | 1.01 | 3 |
| Television | 3 (2.5) | 115 (95.8) | 2 (1.7) | 0.99 | 4 |
| Newspapers | 14 (11.7) | 104 (86.7) | 2 (1.7) | 0.90 | 5 |
| Cell phone calls | 29 (24.2) | 88 (73.3) | 3 (2.5) | 0.78 | 6 |
| Extension agents | 43 (35.8) | 61 (50.8) | 16 (13.3) | 0.77 | 7 |
| Whatsapp | 38 (31.7) | 82 (68.3) | 0 (0.0) | 0.68 | 8 |
| Newsletter | 81 (67.5) | 39 (32.5) | 0 (0.0) | 0.32 | 9 |
| Short Message Service (SMS) | 94 (78.3) | 24 (20.0) | 2 (1.7) | 0.23 | 10 |
| Facebook | 101 (84.2) | 19 (15.8) | 0 (0.0) | 0.15 | 11 |
| Twitter | 102 (85.0) | 18 (15.0) | 0 (0.0) | 0.15 | 11 |
| Email | 111 (92.5) | 9 (7.5) | 0 (0.0) | 0.07 | 13 |
| Instagram | 111 (92.5) | 9 (7.5) | 0 (0.0) | 0.07 | 13 |

**Table 3.** Categorization of respondent's access to sources of information on fish farming.

| Access to information | Frequency | % | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|---|---|
| Low (4.00 – 7.39) | 18 | 15.0 | 4.00 | 14.00 | 9.54 | 2.14 |
| Moderate (7.40 – 11.67) | 79 | 63.3 | | | | |
| High (11.68 – 14.00) | 26 | 21.7 | | | | |

### 3.3. Benefits derived from ABP by fish farmers

Table 4 presents BD from ABP. The result shows that increased production ($\bar{x}$=1.74), improved income level ($\bar{x}$=1.70), improved future potential of the enterprise ($\bar{x}$=1.52), increased sales output ($\bar{x}$=1.49), improved performance and progress of the enterprise ($\bar{x}$=1.45) and increased access to market ($\bar{x}$=1.35) were the benefits mostly derived from ABP by fish farmers.

Table 5 presents categorization of BD by fish farmers from ABP. The result reveals that most respondents (66.7%) had moderate benefit from ABP.

### 3.4. Constraints on fish farmers' participation in ABP

Table 6 shows the ranking of various constraints on fish farmers' participation in ABP. Poor access to water ($\bar{x}$=1.83) and security related issues ($\bar{x}$=1.81) ranked first and second, respectively. Poor marketing facilities ($\bar{x}$=1.74), difficulty in accessing the anchors ($\bar{x}$=1.71) and stress of accessing loan ($\bar{x}$=1.60) ranked third, fourth and fifth, respectively.

Table 5 presents categorization of respondents based on constraints to participation in ABP. The result reveals that the majority of respondents (74.2%) faced moderate constraints on participation in ABP.

**Table 4.** Distribution of respondents based on benefits derived from anchor borrowers' program.

| Benefits derived from ABP | Not a Benefit f (%) | Moderate Benefit f (%) | Major Benefit f (%) | Mean | Rank |
|---|---|---|---|---|---|
| Increased production | 7 (5.8) | 17 (14.1) | 96 (80.1) | 1.74 | 1 |
| Improved income level | 6 (5.0) | 24 (20.0) | 90 (74.9) | 1.70 | 2 |
| Improve the future potential of the enterprise | 0 (0.0) | 57 (47.5) | 63 (52.5) | 1.52 | 3 |
| Increased sales output | 10 (8.3) | 41 (34.2) | 69 (57.5) | 1.49 | 4 |
| Improved performance and progress of the enterprise | 0 (0.0) | 65 (54.2) | 55 (45.8) | 1.45 | 5 |
| Increased access to the market | 7 (5.8) | 64 (53.3) | 49 (40.8) | 1.35 | 6 |
| Stimulate expertise | 7 (5.0) | 93 (77.5) | 21 (17.5) | 1.12 | 7 |
| Enhance access to better service delivery | 29 (24.2) | 72 (60.1) | 19 (15.8) | 0.91 | 8 |
| Ease of access to quality fish feed | 27 (22.5) | 80 (66.7) | 13 (10.8) | 0.88 | 9 |
| Ease access to insurance service | 63 (52.5) | 54 (44.9) | 3 (2.6) | 0.50 | 10 |

**Table 5.** Categorization of respondents based on benefits derived from anchor borrowers' program.

| Benefit derived | Frequency | % | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|---|---|
| Low (4.00 – 9.91) | 11 | 9.2 | 4.00 | 19.00 | 12.69 | 2.77 |
| Moderate (9.92 – 14.68) | 80 | 66.7 | | | | |
| High (14.69 – 19.00) | 29 | 24.2 | | | | |

**Table 6.** Distribution constraints on respondents' participation in anchor borrowers' program.

| Constraints to participation in ABP | NC f (%) | MC f (%) | SC f (%) | Mean | Rank |
|---|---|---|---|---|---|
| Poor access to water | 1(0.8) | 18(15.1) | 101(84.2) | 1.83 | 1 |
| Security related issues | 3(2.5) | 16(13.3) | 101(84.2) | 1.81 | 2 |
| Poor marketing facilities | 0(0.00) | 31(25.8) | 89(74.2) | 1.74 | 3 |
| Difficulty in accessing the anchor | 4(3.3) | 26(21.7) | 90(75.0) | 1.71 | 4 |
| Stress of accessing the loan | 4(3.3) | 40(33.3) | 76(63.4) | 1.60 | 5 |
| Late distribution of loans | 0(0.00) | 50(41.7) | 70(58.3) | 1.58 | 6 |
| High cost of inputs | 0(0.00) | 50(41.7) | 70(58.3) | 1.58 | 6 |
| Untimely delivery of inputs | 0(0.00) | 51(42.5) | 69(57.5) | 1.57 | 7 |
| Insufficient loans | 10(8.3) | 34(28.3) | 76(63.3) | 1.55 | 8 |
| Delay in payment by off-takers | 9(7.5) | 49(40.8) | 62(51.7) | 1.44 | 9 |
| High cost of labour | 15(12.5) | 40(33.3) | 65(54.2) | 1.41 | 10 |
| Insufficient land | 17(14.2) | 44(36.7) | 59(49.2) | 1.35 | 11 |
| Poor extension contact | 56(46.8) | 52(43.3) | 12(10.0) | 0.63 | 12 |
| Unfavourable government policies | 65(54.2) | 41(34.2) | 14(11.7) | 0.57 | 13 |
| Flood or excessive rain | 74(61.8) | 36(30.0) | 10(8.3) | 0.46 | 14 |

NC = Not a Constraint, MC = Mild Constraint, SC = Severe Constraint

**Table 7.** Categorization of respondents according to constraints to participation in anchor borrowers' program.

| Constraints on participation in ABP | Frequency | % | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|---|---|
| Low (11.00 – 17.75) | 12 | 10.0 | 11.00 | 30.00 | 20.88 | 3.12 |
| Moderate (17.76 – 23.87) | 89 | 74.2 | | | | |
| High (23.88 – 30.00) | 19 | 15.8 | | | | |

### 3.5. Effectiveness of ABP for FF

Table 8 shows data on EABP in fish production as provided by fish farmers in the study area. The results reveal that the majority (53.2%) of the respondents agreed that they had greatly improved the level of increased production and advice. Increased production and advice ranked highest ($\bar{x}$=1.51) amongst all the effectiveness statements. Access to advisory services ranked second ($\bar{x}$=1.45) on the list, with a slight majority of respondents (51.7%) expressed agreement on improved level of access to advisory services. In terms of linkage to various markets and marketing strategies, 60.7% of the respondents indicated that they had improved level of linkage to various markets and marketing strategies. Linkage to various markets and marketing strategies came in third on the list of EABP experienced with a mean score of 1.10. Linkages to off-takers ($\bar{x}$=0.91) ranked fourth on the list of EABP experienced, with the majority (63.3%) of the respondents indicating they had improved linkages to off-takers.

Table 9 presents categorization of EABP on FF. The results reveal that more than half (68.3%) of the participants adjudged the EABP on FF to be moderate.

### 3.6. Relationship between demographic characteristics of ABP fish farmers and the EABP on FF

Results in Table 6 show that ABP fish farmers age (r= -0.02,p=0.81), sex ($\chi^2$=0.57, p = 0.45), source of farmland ($\chi^2$ = 4.34, p = 0.11) and membership of fish association (r = -0.02, p=0.85) were not significantly (p ≥ 0.10) associated to EABP on FF.

**Table 8.** Distribution of effectiveness of anchor borrowers' program in fish production.

| Effectiveness items | NA f (%) | IL f (%) | GIL f (%) | Mean | Rank |
|---|---|---|---|---|---|
| Increased production and advice | 2 (1.7) | 54 (45.1) | 64 (53.2) | 1.51 | 1 |
| Access to advisory services | 2 (1.7) | 62 (51.7) | 56 (46.6) | 1.45 | 2 |
| Linkage to various markets and marketing strategies | 17 (14.2) | 73 (60.7) | 30 (25.1) | 1.10 | 3 |
| Storage facilities | 68 (56.7) | 48 (40.1) | 4 (3.2) | 0.95 | 4 |
| Linkages to off-takers | 27 (22.5) | 76 (63.3) | 17 (14.2) | 0.91 | 5 |
| Farm input provision | 44 (36.7) | 69 (57.5) | 7 (5.8) | 0.69 | 6 |
| Availability of general production practices | 34 (28.3) | 57 (47.5) | 29 (24.2) | 0.56 | 7 |
| Postharvest management | 54 (51.7) | 64 (46.6) | 2 (1.7) | 0.50 | 8 |
| Access to harvesting process technical services | 62 (53.4) | 56 (45.7) | 2 (0.8) | 0.47 | 9 |
| Availability and good marketing facilities | 68 (56.7) | 49 (40.8) | 3 (2.5) | 0.45 | 10 |
| Guaranteed market price | 74 (61.7) | 41 (34.2) | 5 (4.2) | 0.42 | 11 |
| Fish disease control | 64 (61.7) | 55 (46.6) | 1 (0.8) | 0.40 | 12 |
| Ease of access to required input | 78 (65.2) | 37 (30.8) | 5 (4.2) | 0.39 | 13 |
| Value addition process | 82 (68.4) | 34 (28.3) | 4 (3.3) | 0.35 | 14 |

NA = Not at all; IL= Improved Level; GIL= Greatly Improved Level.

**Table 9.** Categorization of effectiveness of anchor borrowers' program in fish farming.

| Effectiveness of ABP | Frequency | % | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|---|---|
| Low (3.00-6.88) | 13 | 10.8 | 3.00 | 22.00 | 10.68 | 3.79 |
| Moderate (6.89 – 13.67) | 82 | 68.3 | | | | |
| High (13.68-22.00) | 25 | 20.8 | | | | |

**Table 10.** Relationship between selected demographic characteristics of fish farmers and effectiveness of anchor borrowers' program in fish farming.

| Variables | Df | $\chi^2$ | r-value | p-value |
|---|---|---|---|---|
| Age | - | - | -0.02 | 0.81 |
| Sex of respondents | 1 | 0.57 | - | 0.45 |
| Source of farmland | 2 | 4.34 | - | 0.11 |
| Membership of fish association | - | | -0.02 | 0.85 |

df = Degree of Freedom, $\chi^2$ = Chi-square Coefficient, r = Correlation coefficient.

### 3.7. Correlation between SIFF and EABP in FF

Table 7 indicates that there was a significant association between SIFF and EABP in FF (r = -0.15, p < 0.10). Also, ABP representative (r= -0.22), family and friends (r= -0.28), newspaper (r=0.16), cell phone calls (r=0.20) and extension agents (r= -0.21) were significantly (p ≤0.10) related to EABP in FF.

### 3.8. Relationship between BD from ABP and EABP in FF

The result (Table 8) reveals no significant correlation (p > 0.10) between BD from ABP and EABP in FF (r = 0.33).

### 3.9. Correlation between constraints to participation in ABP and EABP in FF

The result (Table 9) shows that no significant correlation existed between the constraints associated with participation in ABP and EABP in FF(r = 0.12, p ≥ 0.10).

**Table 11.** Correlation between sources of information on fish farming and effectiveness of anchor borrowers' program in fish farming.

| Variables | r-value | p-value |
|---|---|---|
| Sources of information | -0.15* | 0.10 |
| ABP representative | -0.22* | 0.02 |
| Family and friends | -0.28* | 0.00 |
| Radio | -0.07 | 0.48 |
| Television | -0.01 | 0.88 |
| Newspapers | 0.16* | 0.07 |
| Cell phone calls | 0.20* | 0.03 |
| Extension agents | -0.21* | 0.02 |
| Whatsapp | 0.05 | 0.62 |
| Newsletter | 0.08 | 0.40 |
| Short Message Service (SMS) | 0.04 | 0.67 |
| Facebook | -0.14 | 0.13 |
| Twitter | -0.01 | 0.89 |
| Email | -0.00 | 1.00 |

r = Correlation coefficient. *Significant at p≤0.10.

**Table 12.** Relationship between benefits derived from anchor borrowers' program and effectiveness of anchor borrowers' program in fish farming.

| Variable | r-value | p-value |
|---|---|---|
| Benefits derived from participation in ABP | 0.09 | 0.33 |

r = Correlation coefficient.

**Table 13.** Correlation analysis of constraints to participation in anchor borrowers program and effectiveness of anchor borrowers program in fish farming.

| Variable | r-value | p-value |
|---|---|---|
| Constraints to participation in ABP | 0.12 | 0.18 |

r = Correlation coefficient.

## 4. DISCUSSION

The responders were relatively middle-aged and active, which implies that ABP fish farmers had the energy to satisfy the demands of improving and/or increasing the production of fish. The result is also suggestive of a greater dominance of more mature fish farmers who participated in ABP amongst farmers involved in the fish production business. This finding is consistent with Maina et al. (2014) who reported that the majority of fish farmers were below the age of 50 years. The result is also consistent with Oyibo and Odebode (2024) and Oyibo (2020) who found a mean age of 42.7±11.9 years and 46.37±9.24 years among rural farming households and farmers in Niger-Delta Area and Delta State of Nigeria, respectively. That most of the respondents were male implies that more males were engaged in FF than females. The implication is that FF involvement in the study area is gender sensitive. This finding is in consonance with Samuel (2020) and Oluwasola and Ige (2015) findings that 85.6% and 80.0% of fish farmers were males in Southwestern Nigeria and Ibadan Metropolis of Oyo State, respectively. However, the result disagrees with Ofuoku (2015) who found that over half (63.1%) of rural farmers in Delta State's Central Agricultural Zone were females. The high proportion of males compared to females among the respondents could be due to the patrilineal nature of Africa which gave the males more access to resources than the females (Balogun et al., 2021). Male dominance could also be attributed to the fact that women are risk averse, and fish farming is faced with a lot of uncertainties and risks.

It could be inferred that the predominant land sources for fish production were lease and inheritance. The implication of lease as a major source of farmland is that respondents get it with conditions. In addition, the implication is that respondents had less control over their fish production lands, because they did not have absolute control over the leased land. The presence of respondents who had access to farmland through inheritance could be attributed to older farmers relinquishing farmlands to the younger generation to continue with agricultural activities. The resource poor farmers can have access to land when it is acquired by inheritance, which may encourage more people to engage in farming (Oyibo, 2021). The fish farmers generally had a high level of membership in fish associations. Membership of the FF association could influence EABP in FF, because FF association serves as a source of ABP information and influences the adoption of new farming practices as well as enhances networking, access to the market, government initiatives, resources and credit facilities, and sharing of ideas, knowledge and information. This result agrees with Samuel (2020) who found that 60.0% of fish farmers belong to fish associations in Southwestern Nigeria. The result also corroborates Belewu et al (2023) who found that 100% of ABP beneficiaries belong to agricultural organizations.

It was observed that access to information through ABP representative ($\bar{x}$=1.73), and family and friends ($\bar{x}$=1.64) ranked highest and second on the list of FF information sources, respectively. Furthermore, information access from radio ($\bar{x}$=1.01) and television ($\bar{x}$=0.99) ranked third and fourth among FF information sources, respectively. The result reflects the high status of respondents in terms of always accessing FF information through ABP representatives as well as family and friends. The result also reflects the relatively high status of ABP fish farmers concerning accessing FF information through radio and television. Furthermore, the result indicates that the predominant information sources on FF for ABP fish farmer beneficiaries were family and friends, and ABP representatives. The implication is that FF and/or production information is communicated and/or disseminated to ABP participants through ABP representatives as well as family and friends. The implication is also that ABP representatives as well as family and friends can be used to create awareness about ABP *vis a vis* of a technology as well as enable technology dissemination. The result is similar to the findings of Odebode et al (2021) and Eforuoku (2018) that friends and relatives were the most frequently used sources of information by rural farming households. The access through family and friends might be because of strong family and social ties as well as interpersonal relationships.

It could be deduced that there was moderate access of fish farmers' to SIFF, which suggests that they had relatively moderate access to available information sources on FF business. The implication is that respondents had a moderate level of information on fish production and/or farming technology. In addition, the implication is that fish farmers participating in ABP received information on FF from marginally few sources.

It could be deduced that the fish farmers' need for increased production, improved income level and increased access to market as well as improved future potential of the fish enterprise were clearly provided by ABP participation. The implication is that ABP has enabled fish farmers to increase production sales output and access to the market as well as improved income level *vis a vis*performance and progress of their enterprise. This may probably be the reason for fish farmers' continuous participation in ABP, despite all odds of high-level constraints to their participation in ABP (Table 7). These findings corroborate Umeh et al. (2019) that ABP has a positive effect on farmers which translates to increased income and improvement in the standard of living for the farmers, and achievement of food security of the nation in the long run. The result also supports the finding of Balogun et al (2021) that ABP beneficiaries had high revenue and profit. A closer look at the BD from ABP showed that there are many benefits attached to fish farmers' participation in ABP. It could be inferred that fish farmers' had a moderate benefit from PABP, which is suggestive that the fish farmers relatively benefitted from PABP. The moderate benefit from PABP is expected to affect EABP in fish production.

Poor access to water, security related issues, poor marketing facilities, difficulty in accessing the anchors and stress of accessing loans were the most severe constraints to fish farmers' participation in ABP. These findings are in line with Ayinde et al (2018) who reported administration, technical difficulty and accessibility, as common constraints of ABP. In an earlier study in Nigeria, Samuel (2020) found inadequate access to credit as the greatest obstacle in FF. Constraint to participation in ABP due to poor access to water implies that fish farmers have difficulties in accessing quality water in sufficient quantity, which is a single and important factor in FF enterprise. Hence, fish farmers were discouraged from participating in ABP. The constraint of stress of accessing loans indicates that fish farmers have difficulties in accessing credit facilities to engage in productive FF. This may be due to the unavailability and inadequacy of sources of credit as well as credit/loans. The stress of accessing a loan could result in inadequate capital and low production levels as credit sources have shown to have a positive relationship with capital and technical efficiency. Hence, it discouraged participation in ABP. Okotie (2018) reported that despite funding from government and international agencies, farmers are still faced with difficulty in accessing credit facilities. Furthermore, the constraint of poor marketing facilities could be because of extreme difficulties in getting buyers as well as delay in payment by off-takers.

A closer look at the constraints showed that fish farmers faced moderate constraints to participation in ABP, which invariably might slightly negatively influence EABP in FF. The result disagrees with Oyibo and Odebode (2023) who found high constraints among rural farmers in Nigeria's Niger-Delta Area. The moderate constraint to fish farmers' participation in ABP is aligned with earlier findings of this study where the BD from ABP is moderate (Table 5), indicating that there is likely an indirect relationship between BD from ABP and constraint to the participation in ABP. This suggests that the constraints faced by the fish farmers were slightly strong enough to hinder them from deriving high benefits from participation in ABP.

It was observed that increased production and advice ($\bar{x}$=1.51), and improved level of access to advisory services ($\bar{x}$=1.45) ranked highest and second amongst all the effectiveness statements, respectively. These findings show that most of the respondents experienced improvement in production and access to advisory services. The implication is that participation in ABP can increase fish production *vis a vis* access to fish production advisory services. Furthermore, the implication is that increased production and access to advisory services, which are two extremely fundamental enterprise necessities, are not obstacles or trouble to fish farmers PABP. This is quite good, because of the importance of increasing production and advisory services access to the EABP for FF. The result is similar to Onoja et al (2024) who found that ABP was effective in increasing rice production and/or yield. A closer look at the effectiveness statements showed that linkage to various markets and marketing strategies came in third on the list of EABP experienced with a mean score of 1.10, while linkages to off-takers ($\bar{x}$=0.91) ranked fourth. The results suggest that more of the respondents had a linkage to various markets and marketing strategies as well as off-takers. The implication is that many of the fish farmers PABP had no issues with linkage to off-takers *vis a vis* various markets and marketing strategies. This further implies that fish farmers PABP can comfortably link fish products to off-takers and various markets. In addition, the results imply that linkages to off-taker and various markets and marketing strategies were more reliable and improved during ABP. This result corroborates Akingbade (2019) who posited that timely off-take of rice paddy under ABP was reliable.

It could be deduced from a closer look at the EABP on FF that ABP was averagely effective in FF and/or production. The inference is that ABP to a marginal extent was achieving its objectives as related to fish production in the study area. The result is dissimilar to Elugbaju (2019) who found high EABP on fish production (63.6) in Ogun State. The moderate EABP on fish production may be connected to the moderate access to SIFF and/or production as well as moderate constraints to participation in ABP.

The non-relationship between demographic characteristics of fish farmers and EABP in FF depicts that age, sex, source of farmland and membership in the fish association had no significant relationship with EABP in FF.

The negative correlation between SIFF and EABP in FF implies that the more SIFF, the less EABP in FF. This implies that ABP was more effective in FF for fish farmer beneficiaries who had and/or utilized less SIFF, which further suggests that SIFF could influence the EABP in FF. In addition, the implication is that with increased information sources on FF, the effectiveness status of ABP decreases. According to Oyibo (2021), the SI determines the reliability and accuracy of the information on agricultural production. The relationship between ABP representative, family and friends, newspaper, cell phone calls and extension agents' information source types with EABP in FF implies that ABP representatives, family and friends, newspaper, cell phone calls and extension agents' information source types had a significant relationship with effectiveness status of ABP in FF.

The negative relationship of information source types (ABP representatives, family and friends, and extension agents') with the effectiveness status of ABP in FF implies that ABP representatives, family and friends, and extension agents' information source types negatively influence the effectiveness status of ABP in FF. This implies that the more information from family and friends, ABP representatives and extension agents, the less effective the ABP in FF. This could be because of information overload; the farmers become confused when they are too loaded with information, hence decreasing effectiveness. The positive relationship of newspaper and cell phone calls information source types with the effectiveness status of ABP in FF implies that newspaper and cell phone call information source types positively influence the effectiveness status of ABP in FF. The positive correlation of newspaper and cell phone call information source types implies that the more information from newspapers and cell phone calls, the more effective the ABP in FF. This could be because when the fish farmers are confused, they can easily go back to the newspapers to check as the information is in print or check the cell phone calls in case of cell phones.

There was no association between BD from ABP and EABP in FF, indicating that BD from ABP had no significant relationship with the effectiveness status of ABP in FF. It could be deduced that the BD from ABP does not necessarily influence and/or decide EABP in FF. The effectiveness status of ABP in FF is influenced by sources of information; ABP representatives, family and friends, newspapers, cell phone calls and extension agents.

There was no correlation between the constraints associated with participation in ABP and EABP in FF, implying that fish farmers' constraints to participation in ABP had no significant relationship with the effectiveness status of ABP in FF. One could infer that the respondents' constraints to participation in ABP do not necessarily impact the effectiveness level of ABP in FF. Also, this depicts that the EABP in FF was not determined by the constraints faced. The implication of this is that constraints faced by participating farmers were not strong enough to influence the EABP in their FF.

## 5. CONCLUSION

Fish farmers participants of ABP were relatively mature and middle aged with the energy to meet with the demands of improving fish production. Although both male and female fish farmers participated in ABP, ABP is dominated by male fish farmers. Most of the ABP fish farmers belonged to cooperative societies and utilized leases as predominant source of farmland. The farmers had relatively moderate access to available information sources on FF business. Fish farmer's sources of information were mainly ABP representatives, family and friends, and radio. Fish farmers had a moderate benefit from participation in ABP with moderate constraints to participation in ABP. The effectiveness of ABP on FF was moderate which was influenced by sources of information *vis a vis*ABP representative, family and friends, newspapers, cell phone calls, and extension agents information source types**.** Finally, sources of information as well as ABP representative, family and friends, and extension agents information source types reduced EABP on FF, while newspaper and cell phone call information source types enhanced effectiveness.

In light of the conclusion, the following suggestions are made: The dominance of males over females in FF should be tackled. Platform for sensitization of female gender about FF should be created to allow for more gender balance in FF. Newspaper information source type had a significant positive effect on EABP in FF; therefore, stakeholders are encouraged to utilize newspapers as information sources. Anchor borrower program should be subjected to periodic review, adequate monitoring and evaluation to ensure its effectiveness on FF. Considering the positive influence of cell phone call as an information source type in ensuring EABP on FF, the intervention program should embrace and offer sensitization on the importance of cell phone calls as a source of information to beneficiaries. Poor access to water is one of the major constraints identified in this study; therefore, the government should make available quality water facilities that both the fish farmers and the entire community can have access to. In addition, alternative sources of water supply should be provided by the fish farmers and the community to complement efforts made by the government or other agencies.

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## CONFLICT OF INTEREST

The authors of this article declare that they have no known competing personal relationships and/or financial interests that could have appeared to influence the work reported in this paper.

## AUTHOR CONTRIBUTIONS

Fiction: AAE, JOC, OO; Literature: JOC; Methodology: JOC, OO, AAE; Performing the experiment: JOC; Data analysis: JOC, OO; Manuscript writing: JOC, OO, Supervision: OO, AAE. All authors approved the final draft.

## ETHICAL STATEMENTS

The University of Ibadan's Department of Agricultural Extension and Rural Development's Ethical Committee gave its approval for this study's conduct, on 04/01/2023 (Ethic committee approval number: AERD/01-2023/0020).

## DATA AVAILABILITY STATEMENT

The data used in the present study are available from the corresponding author upon reasonable request.

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**Research Article** | **Araştırma Makalesi**

# Spatial and Temporal Analysis of the Relationship between Phytoplankton Community Structure and Environmental Parameters of Yuvacık Reservoir

# Yuvacık Rezervuarı Fitoplankton Topluluk Yapısı ile Çevresel Parametreler Arasındaki İlişkinin Mekansal ve Zamansal Analizi

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**Abstract:** In the present study, in order to determine the local (sampling stations) and temporal (seasonal) distribution phytoplankton in the Yuvacık Reservoir sampling was carried out in four seasons from two stations: from the entrance area of the streams to the dam (Y2) and from the dam embankment front (Y1). A total of 52 taxa were identified in the phytoplankton composition, including 30 Heterokontophyta, 9 Chlorophyta, 1 Cryptista, 4 Cyanobacteria, 5 Dinoflagellata and 3 Euglenophyta. *Anabaena* sp.1, *Chlorella vulgaris*, *Fragilaria crotonensis*, *Prestauroneis crucicula*, *Melosira varians* and *Ulnaria ulna* were recorded as the dominant species according to relative abundance of total biovolume. Nitrate nitrogen ($NO_3$-N) values varied between stations, while sulfate ($SO_4$), temperature (T) and pH values differed across seasons. According to Canonical Correspondence Analysis (CCA); *Chlorella vulgaris* and *Melosira varians* were associated with $NO_3$-N and $SO_4$; while *Ulnaria ulna*, *Prestauroneis crucicula*, phytoplankton total biovolume (TBV), species richness (RICH), and species diversity (DIVERS) were correlated with temperature (T), nitrite nitrogen ($NO_2$-N) and silica (Si). Moreover, *Anabaena* sp. 1 and *Fragilaria crotonensis* were related with electrical conductivity (EC), ortho-phosphate ($PO_4$-P), total phosphorus (TP) and pH. In the Yuvacık Reservoir, when the riverine region (Y2) and the lacustrine region (Y1) compared, it was observed that the total biovolume, species number and diversity of phytoplankton were generally higher at station Y1 than station Y2.

**Keywords**
- Yuvacık Reservoir
- Environmental parameters
- Phytoplankton

**Özet:** Bu çalışmada Yuvacık Barajının fitoplankton yersel (örnekleme istasyonları) ve zamansal (mevsimsel) dağılımının belirlenmesi amacıyla baraja derelerin giriş bölgesinden (Y2) ve baraj set önünden (Y1) olmak üzere iki istasyondan 4 mevsim örneklenme yapılmıştır. Fitoplankton tür kompozisyonunda 30 Heterokontophyta, 9 Chlorophyta,1 Cryptista, 4 Cyanobacteria, 5 Dinoflagellata ve 3 Euglenophyta grubuna ait olmak üzere toplamda 52 takson tespit edilmiştir. Toplam biyohacimin nispi bolluğu açısından *Anabaena* sp.1, *Chlorella vulgaris*, *Fragilaria crotonensis*, *Prestauroneis crucicula*, *Melosira varians* ve *Ulnaria ulna* türleri dominant olmuştur. İstasyonlar arasında nitrat azotu ($NO_3$-N), mevsimler arasında ise sülfat ($SO_4$), sıcaklık (T) ve pH istatiksel olarak anlamlı bulunmuştur. Kanonik uyum analizi (CCA) sonuçlarına göre $NO_3$-N ve $SO_4$ ile *Chlorella vulgaris*, *Melosira varians*; sıcaklık (T), nitrit azotu ($NO_2$-N) ve silika (Si) ile *Ulnaria ulna* ve *Prestauroneis crucicula* türleri, fitoplankton toplam biyohacmi (TBV), tür sayısı (RICH) ve tür çeşitliliği (DIVERS) ilişkili bulunmuştur. Ayrıca elektriksel iletkenlik (EC), orto-fosfat ($PO_4$), toplam fosfor (TP) ve pH ile *Anabaena* sp 1 ve *Fragilaria crotonensis* türleri ilişkili bulunmuştur. Yuvacık Barajında, derelerin bağlantılı olduğu riverin bölgesi (Y2) ile durgun su kütlesinin bulunduğu lakustrin (Y1)

**Anahtar kelimeler**
- Yuvacık Rezervuar
- Çevresel parametreler
- Fitoplankton

bölgesi karşılaştırıldığında, fitoplankton toplam biyohacimi, tür sayısı ve çeşitliliğinin Y1 istasyonunda çoğunlukla Y2 istasyonuna göre daha fazla olduğu görülmüştür.

# 1. INTRODUCTION

Lakes and reservoirs constitute a significant portion of the Earth's freshwater. Lakes are unique ecosystems characterized by their distinct physical, chemical, and biological features. They can be fresh, salty, shallow, deep, permanent or temporary. The interactions between physical, chemical and biological processes in lake ecosystems differ quantitatively and qualitatively from those in other ecosystems (Bhateria and Jain, 2016). One of the most important types of lakes is the reservoir, which is built to collect streams within a specific area. Reservoirs are used for agriculture, drinking water, fish farming, flood control and energy production. Of all reservoirs, 48% are used for irrigation, 20% are energy production, and the remainder for urban and industrial water supply (Özyalın and Ustaoğlu, 2008; Kutlu et al. 2020). On the horizontal plane extending from the stream entrance to the reservoir embankment, the reservoirs are generally divided into three distinct regions based on their physical, chemical and biological differences. These three regions are known as riverine (stream region), transition (transition region) and lacustrine (lake region) (Geddes, 1984).

Pollution of water resources plays a crucial role in the degradation of these ecosystems, and to detect the pollution and ecological quality of freshwaters, chemical analyzes alone may not be sufficient. Bioindicators, on the other hand, are important for monitoring both environmental quality and the health of organisms living in ecosystems (Ozmen et al., 2008). Phytoplankton, along with benthic algae and macrophytes, are responsible for primary production in aquatic ecosystems. Planktonic algae are valuable indicators of water quality due to their short life cycle and rapid response to environmental changes and are used as biological quality elements in monitoring studies (European Union, 2000, Wu et al., 2014).

There are many phytoplankton studies conducted on reservoirs in Türkiye (Baykal and Açıkgöz, 2004; Sömek et al., 2005; Atıcı et. al. 2005; Taş and Gönülol, 2007; Atıcı and Çalışkan 2007; Özyalın and Ustaoğlu, 2008; Atıcı and Obalı, 2010; Sevindik, 2010; Akin et. al. 2011; Sevindik et al. 2011; Atıcı and Alaş, 2012; Ersanlı and Gönülol, 2014; Çelik and Sevindik, 2015; Ongun Sevindik et. al. 2022; Aksoy and Soylu, 2023). The species composition and community ecology of phytoplankton in Yuvacık Reservoir have not been studied before. As a result of quantitative estimates of the hydrological effects of climate change, Özdemir (2021) has stated that there would be a decrease in the flow rates of Kazandere, Kirazdere and Serindere streams which feed the Yuvacık Reservoir. Additionally, Kalıpcı et al. (2020) reported that the water quality of Yuvacık Reservoir was between Class I and Class II quality, and its trophic level was mesotrophic. This study aims to determine the spatial (sampling stations) and temporal (seasons) distribution of phytoplankton and to understand their relationship with environmental parameters in the riverine and the lacustrine regions of Yuvacık Reservoir.

# 2. MATERIAL and METHODS

## 2.1. Work area

Yuvacık Reservoir was established to supply drinking water to Kocaeli province and its surroundings. Its basin covers parts of Kocaeli, Sakarya and Bursa provinces, with an area of 257.86 $km^2$. The Kirazdere, Serindere and Kazandere streams along with their basins, contribute significantly to the reservoir (Figure 1). The largest sub-basin is Serindere with a recharge area of 120.53 $km^2$, followed by Kirazdere with 79.54 $km^2$, Kazandere with 23.10 $km^2$ and intermediate basins with 34.69 $km^2$. Additionally, many ground waters also feed the reservoir. Of the reservoir water, 0.41% is discharged and sent to Lake Sapanca, and 67% is purified and used as drinking water (Kalıpcı et al., 2020; Özdemir, 2021).

## 2.2. Sampling and Analysis of Phytoplankton

Water samples for phytoplankton were collected seasonally at a depth of 10 cm below the water surface between August 2022 and May 2023. Sampling stations were designated as the reservoir embankment area-Y1 (lacustrine region) and the streams inlet-Y2 (riverine region) (Table 1). Samples taken from each station were fixed with lugol and formaldehyde solution. In the laboratory, the samples were allowed to settle in a 50 mL graduated cylinder for 24 hours. After the settling period, the remaining 45 mL of water was discarded, and the 5 mL of the precipitated material at the bottom was transferred to small glass bottles for microscopic examination (Utermöhl, 1958). Phytoplankton species identified using an Olympus BX 51 microscope and counting was performed with Olympus IX81 inverted microscope using standard methods (Utermöhl 1958). The current names of phytoplankton species were verified according to Guiry and Guiry (2024). The biovolume of the cells were calculated from cell numbers and cell size measurements according to Wetzel and Likens (1991) and Sun and Liu (2003).

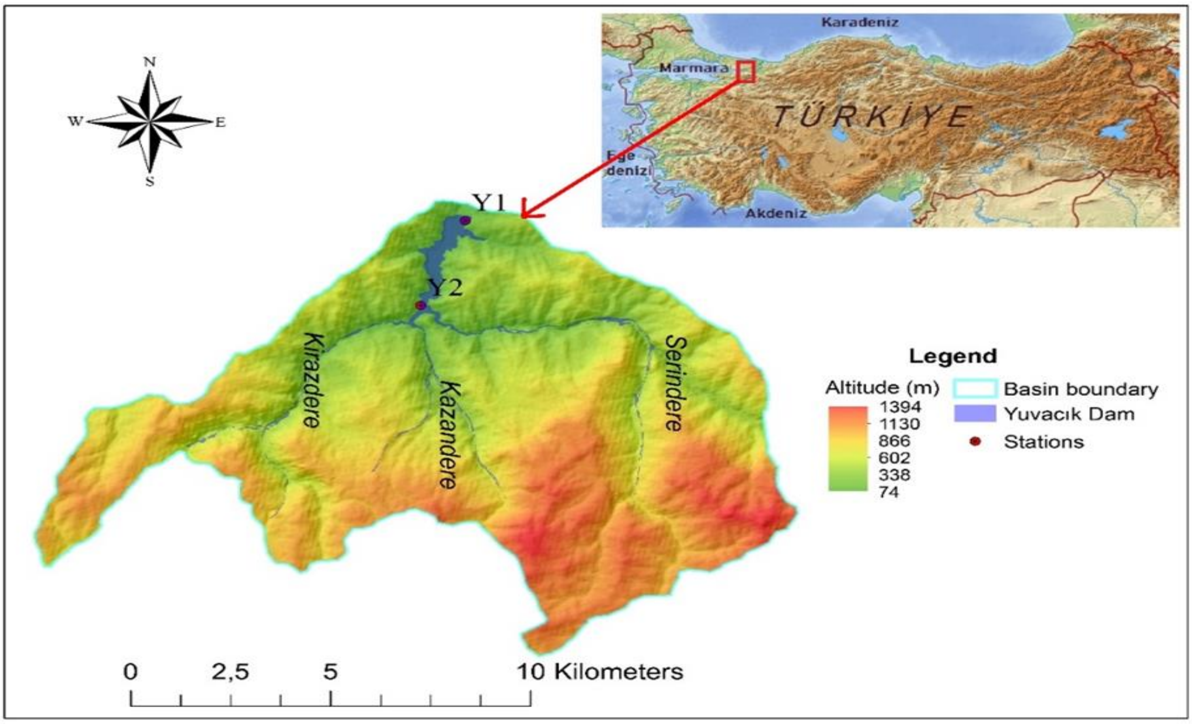


**Figure 1.** Map of the Yuvacık Reservoir and location of the sampling stations.

**Table 1.** Coordinates of the sampling stations in Yuvacık Reservoir.

| No | Position | Station Code | Coordinate | |
|---|---|---|---|---|
| | | | UTM Easting | UTM Northing |
| 1 | Yuvacık Reservoir (Lacustrine) | Y-1 | 29.970366 | 40.672875 |
| 2 | Yuvacık Reservoir (Riverine) | Y-2 | 29.958227 | 40.649050 |

**2.3. Sampling and Analysis of Environmental Parameters**

Sampling for physical and chemical variables was conducted alongside phytoplankton sampling. Electrical conductivity (EC), pH, dissolved oxygen (DO) and water temperature (T) were measured using a YSI multi-probe device at 10 cm below the water surface. For chemical analysis, water samples were collected from 10 cm below the water surface in 1000 mL polyethylene bottles and stored at +4 C° until analysis. Total phosphorus (TP), ortho-phosphate ($PO_4$-P), nitrite nitrogen ($NO_2$-N), nitrate nitrogen ($NO_3$-N), silica (Si) and sulfate ($SO_4$) were analyzed according to methods described by Strickland and Parsons (1972) and Technicon Industrial Methods (1977a, 1977b).

**2.4. Data analysis**

The species diversity index (H) was calculated according to Shannon and Weaver (1963). To detect differences among stations and seasons, (one-way ANOVA), t-test (two-sided, independent samples) or Mann-Whitney U-test (two-sided) were applied depending on the normality of data distribution using SPSS 20.0 software. Data were logarithmically transformed for Pearson correlation analysis. Pearson correlations between physicochemical parameters and phytoplankton biovolume, diversity and species richness were done using SPSS 20.0 software. ArcMap 10.0 and Google Earth Pro, both geographical information system programs, were used for map creation. Since the gradient length was found as 3.226 SD by Detrended Correspondence Analysis (DCA), Canonical Correspondence Analysis (CCA) was performed using CANOCO software (Ter Braak and Smilauer 2002). Phytoplankton species used in CCA were selected from those with a relative abundance higher than 10% (6 taxa) (Weilhoefer and Pan, 2006). The statistical significance of the determinants of environmental parameters was evaluated with 999 restricted Monte Carlo permutations. The relationship between six dominant species, phytoplankton biovolume, species richness, diversity and nine environmental parameters (T, pH, EC, $NO_3$-N, $NO_2$-N, TP, $PO_4$-P, Si, $SO_4$) was performed with CCA. Initially, CCA was performed on phytoplankton data with all environmental parameters. The results showed that 8 (T, pH, Si, $PO_4$-P, TP, $SO_4$, $NO_3$-N and $NO_2$-N) out of 10 environmental factors significantly contributed to phytoplankton biovolume, richness and diversity.

## 3. RESULTS

### 3.1. Environmental Parameters

The amount of $NO_3$-N was higher at station Y2 than at station Y1 in every season ($U$=0.00, $Z$=-2.309, $p$<0.05). The highest $NO_3$-N concentration was measured at station Y2 in winter (0.234 mg/L), while the lowest was measured at station Y1 in summer (0.007 mg/L) (Figure 2). $SO_4$, T and pH values were found statistically significant across seasons. There was a significant increase in $SO_4$ values in winter compared to spring and summer ($F$ = 14.89, $df$ = 3, $p$ < 0.05). T values varied significantly between seasons ($F$ = 161.27, $df$ = 3, $p$ < 0.05). Additionally, there was a significant increase in pH values in fall compared to spring and summer ($F$ = 21.69, $df$ = 3, $p$ < 0.05). The highest $NO_2$-N (fall, 0.015 mg $L^{-1}$), EC (fall, 699.00 µS $cm^{-1}$) and $PO_4$-P (fall, 0.068 mg $L^{-1}$) values were recorded at station Y1, while the highest Si (winter, 11.32 mg $L^{-1}$) and TP (spring, 0.405 mg $L^{-1}$) were recorded at station Y2 (Figure 2, 3). Pearson correlation results among environmental parameters are given in Table 2.

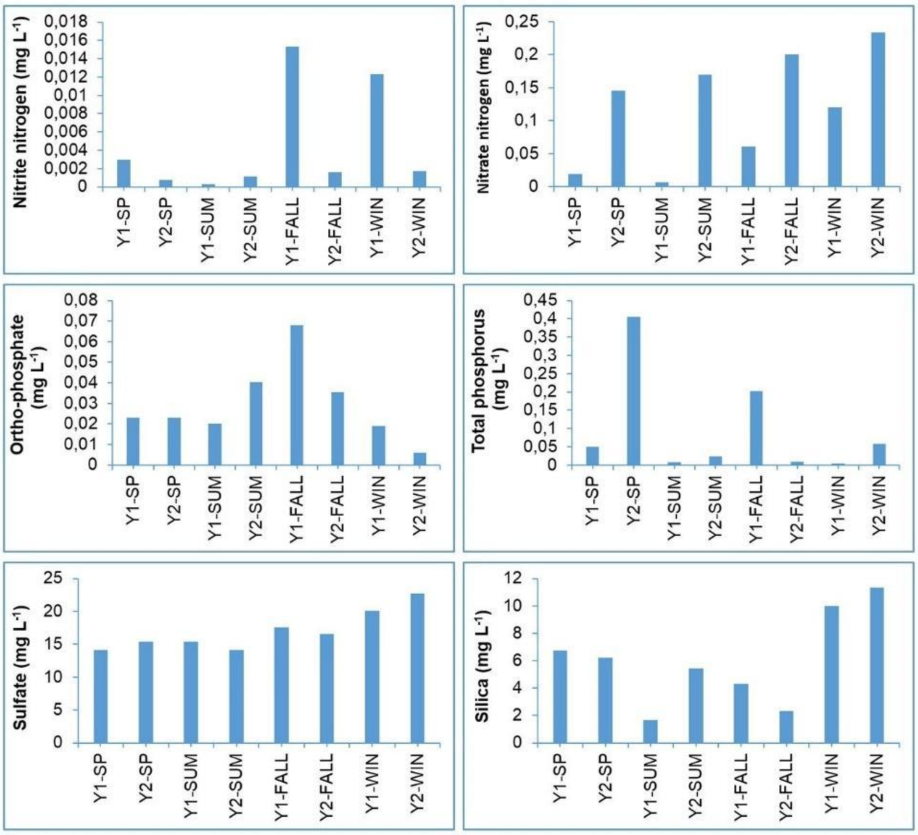


**Figure 2.** Seasonal distribution of some environmental parameters (nitrite nitrogen, nitrate nitrogen, ortho-phosphate, total phosphorus, sulfate, and silica) measured at two stations in Yuvacık Reservoir.

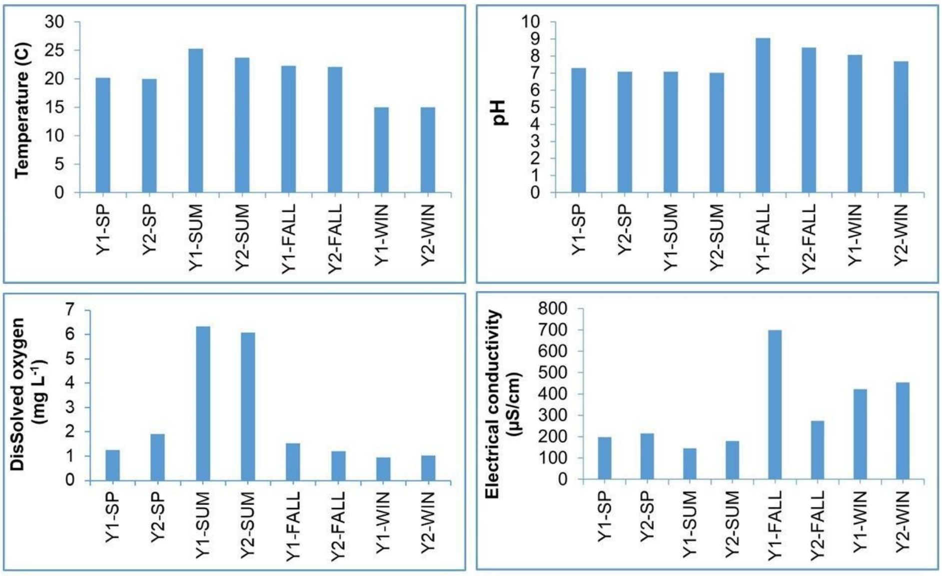


**Figure 3.** Seasonal distribution of some environmental parameters (temperature, pH, dissolved oxygen, and electrical conductivity) measured at two stations in Yuvacık Reservoir.

**Table 2.** Pearson correlation results among some environmental parameters and phytoplankton total biovolume (**TBV**), species richness (**RICH**) and Shannon diversity (**DIVERS**) (**$PO_4$-P**: orto-phosphate**;** **TP:** total phosphorus, **$NO_3$-N:** nitrate-nitrogen, **$NO_2$-N:** nitrite–nitrogen, **Si:** soluble silica, **$SO_4$:** sulfate, **EC:** electrical conductivity, **T:** water temperature).

| | TBV | SHNN | RICH | $NO_2$-N | $NO_3$-N | TP | $PO_4$-P | Si | $SO_4$ | T | EC | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TBV | 1 | 0,681 | **0,720**$^{*}$ | 0,500 | -0,490 | -0,107 | 0,462 | -0,184 | -0,186 | 0,088 | 0,151 | 0,370 |
| SHNN | 0,681 | 1 | **0,852**$^{**}$ | 0,063 | -0,275 | -0,032 | 0,166 | -0,264 | 0,007 | 0,009 | 0,024 | 0,142 |
| RICH | **0,720**$^{*}$ | **0,852**$^{**}$ | 1 | 0,281 | -0,303 | 0,277 | -0,002 | 0,093 | 0,129 | -0,242 | 0,228 | 0,168 |
| $NO_2$-N | 0,500 | 0,063 | 0,281 | 1 | 0,250 | 0,073 | 0,279 | 0,471 | 0,419 | -0,449 | **0,822**$^{*}$ | **0,750**$^{*}$ |
| $NO_3$-N | -0,490 | -0,275 | -0,303 | 0,250 | 1 | 0,185 | -0,104 | 0,507 | 0,430 | -0,475 | 0,422 | 0,269 |
| TP | -0,107 | -0,032 | 0,277 | 0,073 | 0,185 | 1 | 0,132 | 0,281 | -0,094 | 0,029 | 0,247 | 0,014 |
| $PO_4$-P | 0,462 | 0,166 | -0,002 | 0,279 | -0,104 | 0,132 | 1 | -0,461 | -0,581 | 0,679 | 0,031 | 0,356 |
| Sİ | -0,184 | -0,264 | 0,093 | 0,471 | 0,507 | 0,281 | -0,461 | 1 | 0,492 | **-0,835**$^{**}$ | 0,425 | -0,038 |
| SUL | -0,186 | 0,007 | 0,129 | 0,419 | 0,430 | -0,094 | -0,581 | 0,492 | 1 | **-0,803**$^{*}$ | **0,742**$^{*}$ | 0,473 |
| T | 0,088 | 0,009 | -0,242 | -0,449 | -0,475 | 0,029 | 0,679 | **-0,835**$^{**}$ | **-0,803**$^{*}$ | 1 | -0,526 | -0,168 |
| EC | 0,151 | 0,024 | 0,228 | **0,822**$^{*}$ | 0,422 | 0,247 | 0,031 | 0,425 | **0,742**$^{*}$ | -0,526 | 1 | **0,838**$^{**}$ |
| pH | 0,370 | 0,142 | 0,168 | **0,750**$^{*}$ | 0,269 | 0,014 | 0,356 | -0,038 | 0,473 | -0,168 | **0,838**$^{**}$ | 1 |

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

## 3.2. Phytoplankton

A total of 52 taxa were identified in the phytoplankton of Yuvacık Reservoir, including 30 Heterokontophyta, 9 Chlorophyta, 1 Cryptista, 4 Cyanobacteria, 5 Dinoflagellata and 3 Euglenophyta (Table 3). *Anabaena* sp. 1, *Chlorella vulgaris* Beyerinck [Beijerinck], *Fragilaria crotonensis* Kitton, *Prestauroneis crucicula* (Smith) Genkal & Yarushina, *Melosira varians* C.Agardh and *Ulnaria ulna* (Nitzsch) Compère were recorded as the dominant taxa based on the relative abundance of the total biovolume (Figure 4).

Total biovolume (TBV) was higher at station Y1 than station Y2 in all seasons ($U$=0.00, $Z$=-2.309, $p$<0.05) (Figure 5). The highest TBV was recorded at station Y1 in winter (2.868 $mm^3$ $L^{-1}$), and the lowest was recorded in winter at station Y2 (0.033 $mm^3$ $L^{-1}$). The highest species richness (RICH) was recorded at station Y2 in spring (21), and lowest was recorded at station Y2 in summer (2). The highest Shannon diversity (DIVERS) was recorded at station Y2 in spring (2.131), and lowest was recorded at station Y2 in summer (0.367) (Figure 5). Based on the Pearson correlation results, DIVERS showed a significant positive correlation with TBV ($R$ = 0.72, $p$<0.05) and RICH ($R$ = 0.85, $p$<0.01) (Table 2).

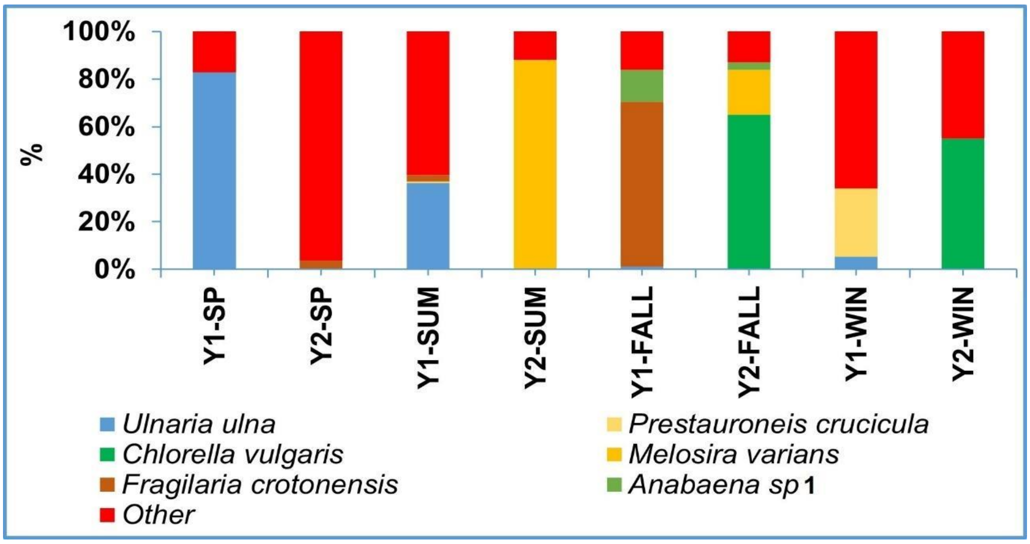


**Figure 4.** Seasonal distribution of dominant phytoplankton species in two stations of Yuvacık Reservoir.

**Table 3.** List of phytoplankton species identified in Yuvacık Reservoir between August 2022 and May 2023.

| **HETEROKONTOPHYTA** | **CHLOROPHYTA** |
|---|---|
| **Bacillariophytina** | **Chlorophytina** |
| *Amphora pediculus* (Kützing) Grunow | *Chlamydomonas elegans* West |
| *Asterionella formosa* Hassall | *Chlamydomonadopsis klinorostris* (Skuja) Fott |
| *Cocconeis pediculus* Ehrenberg | *Chlamydomonas* sp. |
| *Cyclotella affinis* Makarova & Genkal | *Chlorella* sp. 1 |

**Continuation of the Table 3.**

| **HETEROKONTOPHYTA** | **CHLOROPHYTA** |
|---|---|
| *Cymbella* sp. | *Chlorella* sp. 2 |
| *Diatoma ehrenbergii* Kützing | *Chlorella vulgaris* Beyerinck [Beijerinck] |
| *Encyonema caespitosum* Kützing | *Monoraphidium circinale* (Nygaard) Nygaard |
| *Fragilaria crotonensis* Kitton | *Coenochloris fottii* (Hindák) Tsarenko |
| *Gomphocymbellopsis ancyli* (Cleve) Krammer | *Papenfussiomonas cordata* (Pascher&Jahoda) Desikachary |
| *Gomphonema parvulum* (Kützing) Kützing | |
| *Gyrosigma acuminatum* (Kützing) Rabenhorst | **CRYPTISTA** |
| *Lindavia radiosa* (Grunow) De Toni & Forti | **Rollomonadia** |
| *Navicula* sp. 1 | *Chroomonas pochmannii* Huber-Pestalozzi |
| *Navicula* sp. 2 | |
| *Nitzschia acula* (Kützing) Hantzsch | **CYANOBACTERIA** |
| *Nitzschia costei* Tudesque, Rimet & Ector | *Dolichospermum* sp. |
| *Nitzschia dissipata* (Kützing) Rabenhorst | *Anabaena* sp. 1 |
| *Nitzschia umbonata* (Ehrenberg) Lange-Bertalot | *Anabaena* sp. 2 |
| *Prestauroneis crucicula* (Smith) Genkal & Yarushina | *Anabaena sphaerica* var. *attenuata* Bharadwaja |
| *Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot | |
| *Surirella librile* (Ehrenberg) Ehrenberg | **DINOFLAGELLATA** |
| *Tabularia fasciculata* (Agardh) Williams & Round | **Myzozoa** |
| *Tryblionella apiculata* Gregory | *Parvodinium centenniale* (Playfair) Carty |
| *Tryblionella calida* (Grunow) Mann | *Parvodinium lubieniense* (Woloszynska) Carty |

| | |
|---|---|
| *Ulnaria acus* (Kützing) Aboal | *Parvodinium cunningtonii* (Lemmermann) Pandeirada ve diğ. |
| *Ulnaria delicatissima* var. *angutissima* (Grunow) Aboal & Silva | *Peridinium willei* Huitfeldt-Kaas |
| *Ulnaria ulna* (Nitzsch) Compère | *Naiadinium polonicum* (Woloszynska) Carty |
| **Coscinodiscophytina** | |
| *Aulacoseira italica* (Ehrenberg) Simonsen | **EUGLENOPHYTA** |
| *Melosira varians* C.Agardh | **Euglenoida** |
| **Ochrophytina** | *Phacus* sp. |
| *Phacomonas pelagica* Lohmann | *Euglena chlamydophora* Mainx |
| | *Trachelomonas crebea* var. *brevicollaris* Prescott |

### 3.3. Relationships Between Phytoplankton and Environmental Parameters

The first two eigenvalues of the CCA axes are 0.92 and 0.15. While 81.40% of the cumulative percentage values of phytoplankton species (axis 1: 37.7%, axis 2: 43.7%) are explained by the first two CCA axes, the variance of the phytoplankton species-environment relationship is explained as 92.90% (Figure 6).

According to the CCA results, three regions were grouped on the axes. In the positive part of the first axis, summer, fall and winter seasons at station Y2 were associated with $SO_4$, $NO_3$-N, *Chlorella vulgaris* and *Melosira varians*. In the negative part of the first axis, RICH, DIVERS, TBV, $NO_2$-N, T and Si were associated with the spring, summer and winter seasons at station Y1 as well as *Ulnaria ulna* and *Prestauroneis crucicula*. In the positive part of the second axis, EC, $PO_4$, TP and pH were associated with the spring season at Y2 and the fall season at Y1, as well as *Anabaena* sp.1, and *Fragilaria crotonensis*.

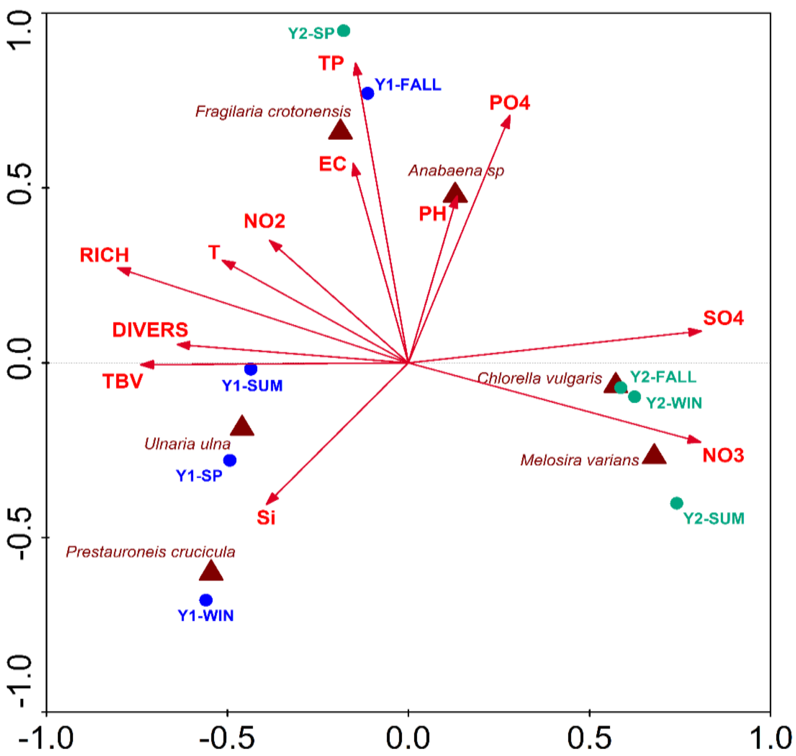


**Figure 5.** Ordination diagram of the canonical correspondence analysis (CCA) with the scores of dominant phytoplankton species, total biovolume (**TBV**), species richness (**RICH**), Shannon diversity (**DIVERS**) and environmental variables in different seasons and stations in Yuvacık Reservoir. Environmental variables: **T:** temperature, **$SO_4$:** sulfate, **TP:** total phosphorus, **$PO_4$**: orto-phosphate, **EC:** electrical conductivity, **$NO_3$:** nitrate-nitrogen, **$NO_2$:** nitrite–nitrogen, **Si:** soluble silica (**blue:** Y1, **light blue:** Y2, **SP:** spring, **SUM:** summer, **FALL:** fall, **WIN:** winter).

## 4. DISCUSSION

While reservoirs generally exhibit high electrical conductivity, alkaline pH, average temperature, varying dissolved oxygen concentrations (Ariyadej et al., 2004; Chellappa et al., 2008; Moura et al., 2021), seasonality and local differences can have impact on environmental factors (Moura et al., 2021). When the environmental parameters of Yuvacık Reservoir were examined, the highest temperature was recorded in summer and the lowest in winter, while there was a temperature difference in every season. In Yuvacık Reservoir, the highest temperature was recorded in summer and the lowest in winter, with noticeable temperature differences across seasons. The reservoir's water is characterized as alkaline based on pH values, a finding supported by Kalıpcı et al. (2020). Generally, the reservoir pH values are alkaline, which is crucial for maintaining biological and chemical balance (Şengül and Müezzinoğlu, 2008). The alkaline nature of Yuvacık Reservoir's water is thought to be influenced by surface water discharge (Kalıpcı et al., 2020). The fall discharge of surface waters is believed to contribute to the water's alkaline nature. Electrical conductivity (EC) is the potential of water to conduct electric current (Güler and Çobanoğlu, 1997). The geological structure and the precipitation level affect the EC (Temponeras et al., 2000). Although the EC values of Yuvacık Reservoir are recorded on average, precipitation, evaporation, temperature and water inputs play important roles in fluctuations in EC values. An increase in sulfate ion concentration is a symptom of chemical pollution. Sulfate concentration in natural waters typically ranges from 3 to 30 mg $L^{-1}$ (Giritlioğlu, 1975; Svobodá et al., 1993). Despite seasonal fluctuations, the highest $SO_4$ concentration at station Y2 in winter was 22.7 mg/L, which is consistent with natural water values. Depending on the geological structure, surface runoff during rainy periods may have been effective in the increase of sulfate values in winter (Kalıpcı et al., 2017). Ortho-phosphate values in water typically range from 0.05 to 0.30 mg/L, but higher values can increase primary production (Cirik and Cirik, 2005). In Yuvacık Reservoir, $PO_4$-P value was recorded as 0.41 mg $L^{-1}$ in spring at station Y2. Since agriculture, animal husbandry and other pollution activities are prohibited in the Yuvacık Reservoir basin (Anonymous, 2018), the increase of $PO_4$-P values at Y2 (riverine region) during spring when the precipitation increases, was likely due to allochthonous inputs with the effects of precipitation and erosion. Nitrogen can be found in freshwater in different forms such as nitrite ($NO_2^-$) and nitrate ($NO_3^-$) (Wetzel 1983). The amount of $NO_3$-N was higher at station Y2 than at station Y1 in every season. Conversely, $NO_2$-N levels were higher at both stations. It is thought that the high $NO_3$-N amount at Y2 station is due to stream inflows, while high $NO_2$-N in Y1 may result from anoxic sediments (Wetzel 1983). Total phosphorus (TP) is a key indicator of production capacity (Clark et al., 2010). The highest TP in Yuvacık Reservoir was recorded at Y2 station in spring, likely due to high precipitation and nutrient input from the stream. Silica levels in lakes can vary due to inputs, outputs and sediment accumulation (Schelske and Stoermer, 1971). Changes in Si values at Yıvacık Reservoir are probably related to precipitation, lake mixing and stream input or discharge.

According to CCA, *Anabaena* sp.1 was related to $PO_4$-P and pH. The increase in pH at station Y1 in fall seemed to have an impact on the biovolume of *Anabaena* sp.1. Changes in the pH of the environment can affect the nutrient uptake of algae, thereby influencing their growth and species composition (Meseck et al., 2007). While increased pH does not affect the internal pH of *Anabaena* species, inhibition of photosynthesis is unlikely (Kaplan, 1981). On the contrary, Chaudhary et al. (2013) stated that there was an increase in the photosynthetic activity of *Anabaena* species as the pH increased from 7.5 to 9.5. Therefore the higher pH at Y1 in fall likely to have positively affected the photosynthetic activity of *Anabaena* sp.1. This was one of the factors that enabled the *Anabaena* sp.1 to dominate the total biovolume in fall. Cyanobacteria can assimilate phosphate and convert it into soluble organic phosphorus forms, resulting in an increase in usable phosphorus. (Mandal et al., 1999; Yandigeri et. al., 2011). With this result, it can be said that during periods when *Anabaena* sp. 1 is dominant in the biovolume, the amount of usable phosphorus increases due to pH's contribution to photosynthetic activity. Additionally, some studies on Anabaena species have stated that the increase in photosynthesis rate is related to pH (Keenan, 1973; Tsygankov et. al. 1997; Chaudhary et. al. 2013; Kumar et. al. 2015). EC and TP were associated with *Fragilaria* *crotonensis*. It has been noted that *F. crotonensis* shows a positive correlation with EC, and that it prefers alkaline waters (Zebek, 2007). Additionally, the temperature range of 10.0°C to 25.0°C is suitable for the *F. crotonensis*, and a 1°C decrease in water temperature leads to an increase in its biomass (Zebek, 2007). In fall, the increase in EC and T values at Yuvacık Reservoir, combined with suitable temperatures may have influenced the dominance of *F. crotonensis* in terms of biovolume. ***Prestauroneis crucicula*** and ***Ulnaria ulna*** were associated with silica (Si). ***Prestauroneis crucicula*** was the dominant species in total biovolume at Y1 in winter. Da Rosa et al. (2023) reported that ***P. crucicula*** was common in the winter community in lagoon lakes. Zhang et al. (2019) reported an increase in the abundance of ***U. ulna*** with higher silica concentrations in drinking water reservoirs in spring. The dominance of ***U. ulna*** in the spring at Y1 was likely due to the increased Si level. ***Melosira varians*** and ***Chlorella vulgaris*** were associated with $NO_3$-N and $SO_4$. ***Melosira varians*** showed the highest growth rate with 0.24 cells day$^{-1}$ at 28 C° at 0.0020 mg L$^{-1}$ nitrate concentration. Rukminasari (2021) stated that high nitrate concentration and temperature increase the abundance of *Melosira* sp. Probably, appropriate temperature (23.7 C°) and high $NO_3$-N (0.169 mg L$^{-1}$) concentration likely contributed to the dominance of ***M. varians*** in the summer at Y2 station. *Chlorella vulgaris* can survive at high nitrate concentrations (Jeanfils et al., 1993; Choi and Lee, 2013) but its growth and biomass may be reduced (Jeanfils et al., 1993). Additionally, Passera and Ferrari (1975) found that *Chlorella vulgaris* has a positive relationship with $SO_4$. Therefore, high $NO_3$-N (0.20 mg L$^{-1}$) and $SO_4$ (22,74 mg/L) concentration likely contributed to the dominance of *C. vulgaris* biovolume in fall and winter at Y2 station. Additionally, *F. crotonensis*, one of the dominant indicator species in the reservoir, is characteristic for mesotrophic waters, *Melosira varians* is characteristic for eutrophic waters (Van Dam et al., 1994), while Anabaena species are characteristic for eutrophic waters (Nalewajko et al., 2001). Considering the dominance of species that are indicators of mesotrophic and eutrophic waters in terms of trophic level and the relationship of these species with environmental parameters such as ortho-phosphate, total phosphorus, nitrite nitrogen and nitrate nitrogen, and the water quality in previous studies, it can be said that the trophic level of the reservoir is between mesotrophic and eutrophic.

A relationship was observed between total biovolume (TBV), diversity (DIVERS) and richness (RICH) with temperature (T) and nitrite-nitrogen ($NO_2$-N). Raimbault (1986) stated that diatoms excrete nitrite-nitrogen into the environment at certain temperatures. Additionally, nitrifying bacteria contribute minimally to decomposing nitrate and converting it into nitrite (Lomas and Lipschultz, 2006). Therefore, the dominance of Heterokontophyta members (diatoms) in terms of biovolume, species richness, and diversity was one of the reasons for the increase in the amount of $NO_2$-N released into the environment. Furthermore, Canonical Correspondence Analysis (CCA) indicated that TBV, DIVERS and RICH showed a positive relationship with Y1 and a negative relationship with Y2, with these values generally being higher at Y1. Phytoplankton tend to grow better in stagnant water. In contrast, wave movements and current effects caused by streams at inlet points hinder the persistence of phytoplankton (Akgöz et al., 2000). As a result, although $NO_3$-N values were higher in Y2, the TBV, DIVERS and RICH values of phytoplankton were not high due to the turbulent environment and current effect.

In conclusion, there were spatial and temporal fluctuations in environmental parameters, as well as spatial and temporal differences in dominant species, TBV, DIVERS and RICH at Yuvacık Reservoir. Additionally, physico-chemical parameters and indicator species should be monitored for many years to control the water quality of Yuvacık Dam Lake.

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## CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## AUTHOR CONTRIBUTIONS

Uğur GÜZEL conducted the chemical analysis, identified and counted the phytoplankton, analyzed the data, and wrote the text. Tuğba ONGUN SEVİNDİK analyzed the data and revised the manuscript. Ayşe Gül

TEKBABA conducted the chemical analysis. Rabia POLŞAK, Layla EL DRAYHI and Zehra Nur AKDEMİR conducted the field sampling. All authors have read the article and contributed to the editing in the preparation of the final version.

## ETHICAL STATEMENTS

Local Ethics Committee Approval was not obtained because experimental animals were not used in this study.

## DATA AVAILABILITY STATEMENT

Data supporting the findings of the present study are available from the corresponding author upon reasonable request.

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**Research Article** **Araştırma Makalesi**


## Evaluating Schizochytrium Supplementation on Growth Performance and Skin Colouration in Electric Yellow Cichlids (*Labidochromis caeruleus*)

## Sarı Prenses Çiklitlerinde (*Labidochromis caeruleus*) Büyüme Performansı ve Cilt Renklenmesi Üzerinde Schizochytrium Takviyesinin Değerlendirilmesi


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**Abstract:** In this study, the effects of *Schizochytrium* sp. supplementation (SCH) to feed on growth and skin coloration in electric yellow cichlid (*Labidochromis caeruleus*) were investigated. Fish (1.93 ± 0.23 g initial weight) were fed with commercial fish feed as the control group (C) and commercial fish feed supplemented with 0.5% (SCH05) and 1% (SCH1) SCH for 60 days. The SCH05 and SCH1 groups displayed the highest final weight (FW), weight gain (WG), and specific growth rate (SGR) values, with similarly favorable feed conversion ratio (FCR) levels compared to the C group ($p<0.05$). The SCH1 group exhibited statistically significant differences from the C and SCH05 groups concerning lightness (*L**) and hue values ($p<0.05$). The redness (*a**) values in the SCH05 and SCH1 groups showed a statistically significant difference compared to the C group ($p<0.05$). However, there were no statistically significant differences in the yellowness (b*) and Ch values among all groups. To conclude, the inclusion of SCH microalga as a dietary supplement markedly promoted growth performance and facilitated the attainment of marketable size in electric yellow cichlids. Additionally, although the enhancement in skin coloration resulting from the addition of 0.5% SCH to the feed did not reach a significant difference, it hints at a promising advantage that could enhance the aesthetic allure and market value of the fish.



**Keywords**
- Microalgae
- Additive
- Growth
- Ornamental fish
- Skin color



**Özet:** Bu çalışmada, sarı prenses çiklitlerinde (*Labidochromis caeruleus*) *Schizochytrium* sp. takviyesinin (SCH) büyüme ve deri renklenmesi üzerindeki etkileri araştırıldı. Balıklar (başlangıç ortalama ağırlığı 1.93 ± 0.23 g) 60 gün boyunca kontrol grubu olarak ticari balık yemi (C) ve %0.5 (SCH05) ve %1 (SCH1) SCH takviyeli ticari balık yemi ile beslendi. SCH05 ve SCH1 grupları, C grubuna kıyasla en yüksek son ağırlık (FW), ağırlık kazanımı (WG) ve spesifik büyüme oranı (SGR) değerlerini ve benzer şekilde olumlu yem değerlendirme oranı (FCR) seviyelerini gösterdi. SCH1 grubu, parlaklık (*L**) ve hue değerleri açısından C ve SCH05 gruplarından istatistiksel olarak anlamlı farklılıklar gösterdi ($p<0.05$). SCH05 ve SCH1 gruplarındaki kırmızılık (*a**) değeri, C grubuna kıyasla istatistiksel olarak anlamlı bir fark gösterdi. Ancak, tüm gruplar arasında sarılık (*b**) ve kroma (Ch) değerlerinde istatistiksel olarak anlamlı bir fark bulunamadı. Sonuç olarak, SCH mikroalginin diyet takviyesi olarak dahil edilmesi, büyüme performansını belirgin şekilde teşvik etti ve sarı prenses çiklit balığının pazarlanabilir boyuta daha hızlı ulaşmasını sağladı. Ayrıca, deri renklenmesinde istatistiksel olarak anlamlı bir artış sağlamamasına rağmen, yemlere %0.5 SCH eklenmesi balıkların estetik çekiciliğini ve piyasa değerini artırabilecek umut verici bir avantaj sunmaktadır.



**Anahtar kelimeler**
- Mikroalg
- Katkı maddesi
- Büyüme
- Süs balığı
- Deri rengi

## 1. INTRODUCTION

The aquarium sector continues to grow as keeping ornamental fish is a hobby of worldwide interest (Karadal et al., 2017; Sathyaruban et al., 2021). In recent years, significant progress has been achieved in the aquarium industry, leading to establishment of ornamental fish production as a prominent sector within aquaculture (Qaranjıkı, 2017; Mutlu, 2019). The industry encompasses the trade of approximately 5,300 freshwater and 1,802 marine fish species, with an estimated global trade value ranging from 15 to 30 billion dollars (Qaranjıkı, 2017; Yanar et al., 2019; Polat & Yağcilar, 2021). Therefore, ornamental fish production has commercial value within the aquaculture industry in developed and developing countries (Hekimoğlu, 2006). One of the most critical factors contributing to the growth of ornamental fish production is the production and marketing of the most popular species. Cichlids are among the preferred and demanded species in today's market (Yalçın, 2014). Due to their attractive colors, ***Labidochromis caeruleus***, commonly known as the electric yellow cichlid, is a highly demanded cichlid species. The electric yellow cichlid fish originates from Lake Malawi located in Africa. Renowned for tranquil disposition in aquariums, electric yellow cichlids (*Labidochromis caeruleus*) can grow up to 10-12 cm in length as adults. These cichlids are well-suited to coexist with other cichlid species in the same aquarium. The vibrant colors and peaceful nature of electric yellow cichlids have recently made it a popular aquarium fish (Cavdar et al., 2020; Yeşilayer et al., 2020).

In aquaculture, prioritizing economic efficiency and attaining optimal growth through utilizing species-specific functional feeds are major objectives. Nutrition significantly impacts fish growth, reproduction, and pigmentation (Pezeshk et al., 2019; Cavdar et al., 2020; Yeşilayer et al., 2020; Hekimoğlu & Sönmez, 2023). Furthermore, high-quality feeds are critical in sustaining fish health throughout the culture process while reducing environmental waste. These issues are pointed out not only for consumable fish culture but also for ornamental fish production (Cavdar et al., 2020). In ornamental fish production, the key determinants of growth, reproduction, and coloration predominantly hinge upon the availability of feed ingredients and additives in suitable proportions (Şahin et al., 2022). Consequently, investigations into ornamental fish diets have underscored the incorporation of natural ingredients (Yeşilayer et al., 2011) and additives (Karsli et al., 2018; Yiğit et al., 2019; Yeşilayer et al., 2020) to enhance reproductive and coloration parameters, bolster survival rates, and fortify disease resistance, thereby ensuring efficacious culture practices.

Microalgae are becoming increasingly important as a feed and supplement in aquaculture and animal feed due to their balanced nutritional content. They have the potential to replace fish meal and other traditional ingredients (Ansari et al., 2021). In recent years, studies in aquaculture have focused on incorporating microalgae as feed additives primarily to maintain the health of cultured organisms, reduce costs, and increase the quantity and quality of the products obtained or produced. Previous studies have confirmed the effectiveness of microalgae as feed supplements for cultured species such as serpae tetra (***Hyphessobrycon eques***) (Berchielli-Morais et al., 2016), guppy (***Poecilia reticulata***) (Biabani Asrami et al., 2019) and koi (*Cyprinus carpio* var. koi) (Prabhath et al., 2019).

Among the algae used for aquafeed, the microalga *Schizochytrium* sp. (SCH) is particularly noteworthy (Souza et al., 2020). This alga has a rich content of docosahexaenoic acid (DHA) (Lewis et al., 1999). Studies have shown that the inclusion of SCH in the diet has positive effects on culture parameters in Nile tilapia, ***Oreochromis niloticus*** (Sarker et al., 2016; Dos Santos et al., 2019), channel catfish, ***Ictalurus punctatus*** (Li et al., 2009) and rainbow trout, ***Oncorhynchus mykiss*** (Lyons et al., 2017). Despite the potential use as a feed additive mentioned above, to our knowledge, no studies investigating the effects of SCH on electric yellow cichlids (*L. caeruleus*) have yet been conducted. Considering the known beneficial properties of SCH, we hypothesize that its inclusion as an additive in fish feed could offer advantages to electric yellow cichlids. Moreover, such utilization could yield valuable insights into the advantageous effects of SCH. Given the economic importance of the electric yellow cichlid in the aquarium industry, along with the numerous benefits of SCH as a feed supplement, this research was conducted for the first time to evaluate the dietary effect of SCH on the growth performance and skin coloration of the electric yellow cichlid (*L. caeruleus*).

## 2. MATERIALS AND METHODS

### 2.1. Experimental design and feeding trial

The research took place at the Aquatic Organisms Experimental Unit (SUCAN) within the Faculty of Fisheries at Van Yüzüncü Yıl University, located in Van, Türkiye. A total of 135 electric yellow cichlids obtained from the Aquatic Organisms Experimental Unit, averaging 1.93 ± 0.23 g in weight, were employed for the study. The microalgae was obtained from a commercial company (Marinbio, Aydın/Turkey).

The fish were fed with control feed for two weeks for acclimatization and then distributed in the 9 glass aquariums of 100 L in triplicate. Three different groups were formed with 0 (C), 0.5% (SCH05) and 1% (SCH1) doses of SCH in the feed (Table 1). SCH powder was blended with the commercial feed via spraying, as outlined by Safari et al. (2022), and stored at the 4 ºC until use. During the 60-day study, the fish were fed near satiation with the experimental feeds twice daily, at 09:00 and 16:00. Continuous aeration of the aquariums was ensured using a central air pump (RESUN GF-250 Vortex Blower). Daily water changes of 40-50% were conducted to sustain water quality, and any uneaten food or feces were removed by siphoning to uphold a clean environment. Throughout the research, a 12:12 h (light:dark) photoperiod was maintained. Water quality parameters were assessed weekly using a multiparameter (AZ Instruments/ AZ86031), yielding the following results: temperature: 26.3 ± 0.39 °C; dissolved oxygen: 6.72 ± 0.14 mg $L^{-1}$ and pH: 8.34 ± 0.06.

### 2.2. Growth performance analysis

All fish were weighed individually at both the start and the end of the study. Weight gain (WG), feed conversion ratio (FCR), specific growth rate (SGR), and survival rate (SR) were computed using the following formulas:

WG (g/fish): Final weight (g) − Initial weight (g),
SGR (% / day): (100 × ((Ln final fish weight) – (Ln initial fish weight)/days)),

FCR: Total feed given (g)/Weight gain (g),

SR (%): (Final number of the fish/initial number of fish) × 100.

### 2.3. Color analysis

Fish skin color was assessed using a Konica Minolta CR 400 device, with six specimens per group. This involved determining the lightness value (*L**; -100, +100 white), the redness value (*a**; -100 green, +100 red), and the yellowness value (*b**; -100 blue, +100 yellow) of each group. Skin color parameters *L**, *a**, and *b** were measured from areas near the lateral line and dorsal part of the fish. Hue (H°ab) and chroma (Ch) values were derived from the *a** and *b** values. Chroma (Ch) refers to the intensity and vividness of color and is calculated using the formula $Ch = (a^{*2} + b^{*2})^{½}$. Hue, on the other hand, represents the balance between the red and yellow tones in the fillet. If a* is greater than 0, the hue angle is determined by the equation $Hab° = \tan{-1}(b^*/a^*)$. If *a** is less than 0, it is calculated using $H°ab = 180 + \tan{-1}(b^*/a^*)$ (Hunt, 1977). Regarding hue (H°ab), *a** value of 0° corresponds to a red hue, 90° to yellow, 180° to green, and 270° to blue (Hunt, 1977; Yeşilayer et al., 2020). All measurements adhered to the methods outlined by CIE (1976) and were performed using the Konica Minolta CR 400 device.

### 2.4. Statistical analysis

Data were analyzed using the SPSS 20 for Windows software package (SPSS Inc., Chicago, IL, USA). Before performing the analysis (ANOVA, Duncan test), the underlying assumptions were thoroughly examined. Skewness and kurtosis statistics were first evaluated for each group to ensure compliance with normality assumptions, and the Levene test was applied to assess the homogeneity of variances. Results were expressed as mean ± standard error. Statistical significance was determined at a threshold of $p < 0.05$.

## 3. RESULTS

### 3.1. Growth Performance

As shown in Table 2, the SCH05 and SCH1 groups demonstrated the highest FW, WG and SGR values ($p<0.05$). Similarly, the SCH05 and SCH1 groups showed the best FCR levels compared to the C group ($p<0.05$). Among the groups fed with SCH feeds, there were no statistically significant differences in SR ($p>0.05$).

**Table 1.** Composition of the commercial diet utilized in the investigation.

| Ingredient | Quantity | Ingredient | Quantity |
|---|---|---|---|
| Crude protein (%) | 47.5 | Manganese (Mg/kg) | 67 |
| Crude fat (%) | 6.5 | Zinc (Mg/kg) | 40 |
| Crude fibre (%) | 2 | Iron (Mg/kg) | 26 |
| Moisture content (%) | 6 | Vitamin D (IU/kg) | 1860 |

### 3.2. Skin coloration parameters

At the end of the 60-day feeding trial, as summarized in Table 3, the SCH1 group was found to be statistically different from the C and SCH05 groups in terms of *L** and Hue values ($p<0.05$). The *a** value in the SCH05 and SCH1 groups showed a statistically significant difference compared to the C group. There were no statistically significant variations in the *b** and Ch values among all groups.

**Table 2**. Effects of dietary *Schizochytrium* sp. on growth parameters in electric yellow cichlid.

| | C | SCH05 | SCH1 |
|---|---|---|---|
| **IW** | 1.93 ± 0.02 | 1.93 ± 0.1 | 1.93 ± 0.1 |
| **FW** | 5.24 ± 0.07$^{b}$ | 5.77 ± 0.05$^{a}$ | 5.76 ± 0.06$^{a}$ |
| **WG** | 3.30 ± 0.05$^{b}$ | 3.84 ± 0.06$^{a}$ | 3.82 ± 0.04$^{a}$ |
| **SGR** | 1.66 ± 0.00$^{b}$ | 1.83 ± 0.02$^{a}$ | 1.82 ± 0.01$^{a}$ |
| **FCR** | 2.14 ± 0.04$^{b}$ | 1.87 ± 0.03$^{a}$ | 1.86 ± 0.01$^{a}$ |
| **SR (%)** | 100 | 100 | 100 |

Data were shown as means ± SE. Different lowercase letters on each line indicate significant variations between groups ($P < 0.05$). SCH05, a diet supplemented with 0.5% *Schizochytrium* sp.; SCH1, a diet supplemented with 1% *Schizochytrium* sp; IW, initial weight; FW, final weight; WG, weight gain; SGR, specific growth rate; FCR, feed conversion ratio; SR, survival rate.

**Table 3**. Effects of dietary *Schizochytrium* sp. on skin coloration parameters in electric yellow cichlid.

| | C | SCH05 | SCH1 |
|---|---|---|---|
| ***L**** | 69.80 ± 5.01$^{a}$ | 65.40 ± 2.42$^{a}$ | 58.14 ± 1.47$^{b}$ |
| ***a**** | 2.11 ± 1.17$^{b}$ | 4.14 ± 1.02$^{a}$ | 5.87 ± 0.38$^{a}$ |
| ***b**** | 21.32 ± 2.95 | 22.58 ± 2.77 | 21.01 ± 4.96 |
| **Ch** | 21.52 ± 2.97 | 23.03 ± 2.93 | 21.91 ± 4.79 |
| **H°ab** | 84.65 ± 3.05$^{a}$ | 79.23 ± 1.05$^{a}$ | 72.61 ± 3.67$^{b}$ |

Data were shown as means ± SE. Different lowercase letters on each line indicate significant variations between groups ($P < 0.05$). SCH05, a diet supplemented with 0.5% *Schizochytrium* sp.; SCH1, a diet supplemented with 1% *Schizochytrium* sp; *L**, (+) brightness, (−) darkness; *a**, (+) redness, (−) greenness; *b**, (+) yellowness, (−) blueness; Ch, Chroma; H°ab, Hue.

## 4. DISCUSSION AND CONCLUSION

Optimizing growth performance and feed conversion ratio (FCR) in ornamental fish farming is necessary for efficient production (Hoseinifar et al., 2023). This study shows that incorporating SCH into the feed significantly improves the growth performance of electric yellow cichlids. Compared to the control (C) group, growth indices such as weight gain (WG) and specific growth rate (SGR) were positively affected in fish subjected to diets containing 0.5% and 1% SCH. Moreover, the groups receiving SCH feeds exhibited marked improvements in FCR values. The observed improvements in growth performance may be attributed to the presence of various bioactive compounds in the algae, including polysaccharides, fatty acids, pigments (especially carotenoids) and minerals. (Chen et al., 2021; Idenyi et al., 2022; Siddik et al., 2024). This might have led to increased consumption of the feeds by enhancing palatability (Xie et al., 2019; Li et al., 2023). Moreover, docosahexaenoic acid, found in high concentrations in SCH, is known to have beneficial effects on growth and development in aquatic organisms by promoting efficient nutrient absorption, enhancing metabolic efficiency, and supporting tissue growth and repair (Raghukumar, 2008; Sarker et al., 2016; Osmond et al., 2021). Additionally, bioactive compounds found in algae can improve the secretion of digestive enzymes, thereby enhancing the digestibility of feed and nutrient absorption (Abdelhamid et al., 2021). Similar to our study, Li et al. (2009) reported that supplementation with 1.0% and 1.5% SCH positively affected the growth performance of channel catfish (*Ictalurus punctatus*). In another study, the dietary inclusion of 3% SCH was reported to enhance the growth performance of golden pompano (*Trachinotus ovatus*) by increasing feed intake and feed utilization (Xie et al., 2019). Additionally, supplementation with SCH was reported to positively affect the growth performance of Nile tilapia (*O. niloticus*) (Dos Santos et al., 2019) and silver pomfret (*Pampus argenteus*) (Li et al., 2023). However, Jorge et al. (2022) found no significant variations regarding the growth performance of Nile tilapia (*O. niloticus*) fed diets SCH (3%) compared to the control group. While there is no information available on the role of SCH as a growth promoter in electric yellow cichlids (*Labidochromis caeruleus*), the impacts of different algae on the growth of electric yellow cichlids have been investigated in various studies. Similarly, to our study, Pezeshk et al. (2018) stated that added to the diet of electric yellow cichlids (*L. caeruleus*) with extracts derived from brown macroalgae (*Sargassum boveanum*), red macroalgae (*Gracilaria persica*), and green macroalgae (*Entromorpha intestinalis*) led to improved growth performance. However, some studies have stated no statistically significant variation in the growth performance of fish when algae were added to the diet as a supplement (Peyghan, 2016; Belbasi et al., 2019).

One of the most attractive features of ornamental fish is their vividly colored appearance (Kop & Durmaz, 2008; Yeşilayer et al., 2020). Hence, improving the vibrant coloration of ornamental fish stands as a crucial quality criterion in the aquarium fish industry (Sathyaruban et al., 2021). In this study, although there was no statistical difference, the yellow (+*b**) coloration increased in the SCH05 group compared to the C group. Additionally, the chroma (Ch) value, indicating color intensity and brightness, increased in the fish in the SCH05 group. However, the electric yellow cichlid is characterized by its yellow coloration, and in this study, it lost its natural coloration due to the increased redness (+*a**) when SCH was added to the feed. This phenomenon could be attributed to the elevated levels of micronutrient content in SCH, including the carotenoid astaxanthin and other bioactive compounds (Xie et al., 2019). Similarly, the addition of SCH to the diet has shown positive effects on fillet coloration in Atlantic salmon, *Salmo salar* (Katerina et al., 2020) and Nile tilapia, *O. niloticus* (Jorge et al., 2022). To date, there is no information available on the effects of SCH on skin coloration in electric yellow cichlids (*L. caeruleus*), but the effects of different algae on skin coloration in electric yellow cichlids have been investigated in various studies. Pezeshk et al. (2018) suggested that extracts obtained from *S. boveanum*, *G. persica*, and *E. intestinalis* algae could be used as feed additives to increase coloration in this species. Similarly, Peyghan (2016) reported a significant increase in skin coloration in electric yellow cichlids fed with *Sargassum angustifolium* and *Laurencia snyderia* algae. However, a study by Belbasi et al. (2019), stated no statistically significant variation in skin coloration compared to the control group in electric yellow cichlids fed with *Spirulina*-supplemented feeds.

In conclusion, the incorporation of SCH as a dietary supplement significantly enhanced the growth performance and expedited the attainment of marketable size in electric yellow cichlids (*L. caeruleus*). Moreover, although the improvement in skin coloration observed by adding 0.5% SCH to the feed was not statistically significant, it indicates a potential benefit that could be crucial for ornamental fish's aesthetic value and marketability. Considering the findings obtained; it is thought that the addition of SCH to feeds may be effective in increasing growth and pigmentation in Electric Yellow Cichlids (*Labidochromis caeruleus*), but further studies are required to prove this.

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## CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## AUTHOR CONTRIBUTIONS

Fiction: BK, DK; Literature: BK, DK; Methodology: BK, DK; Performing the experiment: BK, DK; Data analysis: BK, DK; Manuscript writing: BK, DK, Supervision: BK, DK. All authors approved the final draft.

## ETHICAL STATEMENTS

This study was conducted with the approval of Animal Experiments Local Ethics Committee of Van Yüzüncü Yıl University (protocol no: 2023/14-12).

## DATA AVAILABILITY STATEMENT

The data used in the present study are available upon request from the corresponding author. Data is not available to the public due to privacy or ethical restrictions.

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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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**Research Article** **Araştırma Makalesi**

# Ordu İlinde Yer Alan Balıkçılık Kıyı Yapıları Üzerine Bir Araştırma

## An Investigation on the Coastal Fishing Structures Located in Ordu Province

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**Özet:** Bu araştırma Ordu il sınırları içerisinde bulunan 9 adet balıkçı barınağı ve 4 adet çekek yerinin alt ve üst yapısal durumlarını belirlemek amacıyla gerçekleştirilmiştir. Çalışma sonuçlarına göre barınakların tümünde elektrik, su, fener ve ağ tamir yeri, 4'ünde buz üretim ünitesi, soğuk hava deposu ve güvenlik, 6'sında balıkçı lokali, 7'sinde ağ ve malzeme deposu ve 3'ünde idari bina bulunduğu tespit edilmiştir. Çekek yerlerinin sadece bir tanesinde elektrik, su ve ağ ve malzeme deposu bulunduğu belirlenmiştir. Kıyı yapılarının tamamında satış yeri ve ilk yardım birimi bulunmamaktadır. Ordu ilinde alt yapı ve üst yapı imkanlarının tamamıyla sağlandığı ideal bir kıyı yapısının bulunmadığı görülmüştür.

**Anahtar kelimeler**
- Balıkçılık kıyı yapıları
- Balıkçı barınakları
- Alt ve üst yapı
- Ordu

**Abstract:** This research was carried out to determine the infrastructural and superstructural conditions of 9 fishing ports and 4 boad yards located within the province of Ordu. According to the results of the study, it was determined that all of the fishing ports had electricity, water, lighthouse and net repair area, 4 had ice production unit, cold storage and security, 6 had fishermen's clubhouse, 7 had net and material storage and 3 had administrative building. It was determined that only one of the boad yards had electricity, water and net and material storage. There are no sales place and first aid unit in all of the coastal structures. It has been observed that there is no ideal coastal structure in Ordu province where infrastructure and superstructure facilities are fully provided.

**Keywords**
- Coastal structures for fisheries
- Fishing ports
- Substructure and superstructure
- Ordu

## 1.GİRİŞ

Balıkçı barınakları olarak adlandırılan balıkçılık kıyı yapıları tarım sektöründe değerlendirilmekte ve çok sayıda balıkçı teknesi veya gemi filosuna sığınak, bağlanma ve bakım-onarım olanağı sunmaktadır (Balık ve Topçu, 2013). Deniz ve tatlı su kaynaklarının etkili bir şekilde korunması ve sürdürülebilir yönetimi, sucul ekosistemlerin korunması ve balıkçılık faaliyetlerinin etkin bir şekilde yürütülmesi açısından önemli rol oynayan balıkçılık kıyı yapıları, sektörün üretim alanları olan denizlere ya da iç sulara açılan kapısı, avlanan ürünlerin karaya çıkış ve kontrol noktası, sağlıklı ürün arzının ilk halkası ve sektörün pazarlama merkezlerine açıldığı ağ-geçit olmaları nedeniyle balıkçılık için son derece önemli yapılardır (Huntigon vd., 2015). Balıkçılar için balıkçı barınakları ve çekek yerlerinin kıyılara gelişigüzel yapılması, amaç dışında kullanılması veya plansız inşa edilmesi hizmet açısından problemler yaratmakla birlikte, bu kıyı yapılarının sektör açısından üretim, değerlendirme ve pazarlama aşamalarının yürütülmesindeki rolü büyüktür (Avcı Softa, 2014; Doğan, 2005).

Ülkemizde halen geçerli olan Balıkçı Barınakları Yönetmeliği'nde barınaklar, balıkçı limanı, barınma yeri ve çekek yeri şeklinde sınıflandırılmaktadır (RG, 1996). Bu sınıflandırmada barınağın sağladığı imkân, barındırdığı gemi sayısı ve büyüklüğü gibi kriterler dikkate alınmaktadır. Karadeniz Bölgesi'nde halkın en önemli geçim kaynaklarından biri olan balıkçılık faaliyetleri gerçekleştirilirken barınak, barınma yeri ve çekek yeri şeklinde bulunan kıyı yapıları önemli rol oynadığından, balıkçılık aktivitelerinin aksamaması için bu tür kıyı yapılarının sürekli gözlenmesi ve meydana gelebilecek sorunların belirlenerek muhtemel çözümlerin irdelenmesi önem arz etmektedir.

Türkiye su ürünleri üretimi 335.003 tonu avcılık yoluyla ve 514.805 tonu yetiştiricilik yoluyla olmak üzere toplam 849.808 ton'dur. Denizlerden yapılan avcılıkta en önemli pay %73 ile Karadeniz Bölgesi'ne aittir (TÜİK, 2023). Tüm kıyılarımızda Tarım ve Orman Bakanlığı ve/veya Ulaştırma ve Altyapı Bakanlığı kayıtlarında olan balıkçılık kıyı yapıları sayısı 385 olup, envantere göre Doğu Karadeniz Bölgesi'nde 48 adet balıkçı barınağı, 63 adet çekek yeri, 5 adet barınma yeri ve 1 adet doğal barınma yeri bulunmaktadır. Batı Karadeniz Bölgesi'nde ise 33 adet balıkçı barınağı, 3 adet çekek yeri, 3 adet liman, 3 adet doğal barınma yeri ve 6 adet barınma yeri mevcuttur (Anonim, 2023).

Balıkçı liman ve barınaklarının balık boşaltma, pazarlama, satış ve muhafaza, tekne ve balıkçıların ihtiyaçlarının giderilmesi açısından yetersiz durumda olması ve altyapı yetersizlikleri balıkçılığı yapılabilir ve tercih edilen bir meslek olmaktan çıkartmaktadır (Erdem vd., 2018). Bu araştırmada Ordu ilinde bulunan balıkçı barınakları ve çekek yerlerinin alt ve üst yapısal durumlarının yeterliliği, bulunan tekne sayısı değerlendirilerek sürdürülebilir balıkçılık yönetimi açısından sağladıkları katkılar ele alınmış ve bu kıyı yapılarının etkili kullanımının öneminin ortaya çıkarılması amaçlanmıştır.

## 2.MATERYAL VE METOD

Bu çalışmada, 2023 yılında Ordu sınırlarında bulunan, Tarım ve Orman Bakanlığı envanterinde kayıtlı olarak faaliyet gösteren 9 adet balıkçı barınağı, 4 adet çekek yeri incelenmiştir (Şekil 1). Ordu ili genelinde balıkçılık kıyı yapılarının mevcut durumu, alt ve üst yapı imkanları, bulunan tekne sayılarının belirlenmesi amaçlanmıştır. Bu tesislere ait veriler su ürünleri kooperatif başkanları ve kıyı yapılarından yararlanan balıkçılarla yapılan bire bir görüşmelerden elde edilmiştir. Bunun yanı sıra Ulaştırma ve Altyapı Bakanlığı'nın balıkçılık kıyı yapıları ile ilgili hazırlamış olduğu veri tabanından da faydalanılmıştır.


**Şekil 1**. Ordu ili balıkçı barınakları ve çekek yerleri. (1.Ünye Balıkçı Barınağı, 2. Fatsa Balıkçı Barınağı, 3. Kurtuluş Mah. Çekek Yeri, 4. Bolaman Balıkçı Barınağı, 5. Yalıköy Balıkçı Barınağı, 6. Medreseönü Balıkçı Barınağı, 7. Okçulu Çekek Yeri, 8. Mersin Köyü Balıkçı Barınağı, 9. Kışlaönü Balıkçı Barınağı, 10. Kacalı Çekek Yeri, 11. Kumbaşı Balıkçı Barınağı, 12. Kirazlimanı Çekek Yeri, 13. Gülyalı Balıkçı Barınağı)

## 3.BULGULAR

Araştırmada Ordu bölgesinde küçük tonajlı teknelerin bakım, onarım işlerinin yapıldığı 9 adet barınak ve 4 adet çekek yeri incelenmiştir.

Ayrıca Ordu Büyükşehir Belediyesi tarafından işletilen ve 2014 yılından itibaren ticari faaliyet yapılmaksızın halkın kullanımına açılmış olan Ordu iskelesine ait bilgiler Tablo 1'de verilmiştir.

Çalışmada incelenen balıkçılık kıyı yapılarından 20-150 arasında tekne yararlanmaktadır. Su derinliği, ana mendirek boyu gibi temel özellikler bakımından Ünye Balıkçı Barınağı daha büyük olmakla birlikte, en fazla balıkçı teknesini barındıran barınak Kumbaşı balıkçı barınağıdır (Tablo 2).

### 3.1. Barınaklara ait bilgiler

#### 3.1.1.Gülyalı balıkçı barınağı:

Gülyalı ilçesinde bulunan bu barınak 1980-1982 yılları arasında DLH Genel Müdürlüğü (Tarım sektöründen ayrılan ödenekle) tarafından yapılmış olup, Gülyalı Belediyesi'ne devredilmiş ve halen işletimi belediye tarafından yapılmaktadır. Ana mendirek ve tali mendirek boyları 460 m-150 m, su derinliği 2-4 m, rıhtım uzunluğu ve derinliği 75 m-2 m, korunan su alanı 5,4 ha, 80 tekne kabul kapasitesine sahip olan barınaktan yararlanan balıkçı tekne sayısı da 83'tür. Barınak balıkçılığın yanı sıra turizm sektörü tarafından da kullanılmaktadır (Şekil 2).

**Tablo 1**. Ordu iskelesine ait genel bilgiler.

| Liman Hizmet Türü | Yük |
|---|---|
| Rıhtım Boyu (m) | 268 |
| Rıhtım Genişliği (m) | 10 |
| Su Derinliği (Min-Mak) (m) | 6-8 |
| Genel Kargo (ton) | 125.000 |
| Dökme Kuru Yük (ton) | 325.000 |
| Dökme Sıvı Yük (ton) | 50.000 |
| Ulaşım İmkânı | Karayolu |

**Tablo 2**. Ordu ili balıkçılık kıyı yapılarının bazı özelliklerine ait bilgiler.

| Balıkçı Barınağının Adı | Barınağın İşletmecisi | Barınan Tekne Sayısı | Su Derinliği (m) (Min-Mak) | Ana Mendirek Boyu (m) | Tali Mendirek Boyu (m) |
|---|---|---|---|---|---|
| Gülyalı Balıkçı Barınağı | Gülyalı Belediye Başkanlığı | 83 | 2-4 | 460 | 150 |
| Kumbaşı Balıkçı Barınağı-Altınordu | Kumbaşı Su Ürünleri Kooperatifi | 150 | 2-5 | 600 | 540 |
| Kışlaönü Balıkçı Barınağı-Perşembe | S.S.Perşembe Su Ürünleri Kooperatifi | 110 | 2-5 | 310 | 75 |
| Mersin Köyü Balıkçı Barınağı-Perşembe | S.S.Mersin Köyü Su Ürünleri Kooperatifi | 75 | 2-4 | 390 | 120 |
| Medreseönü Balıkçı Barınağı-Perşembe | S.S. Medreseönü Su Ürünleri Kooperatifi | 20 | 2-5 | 380 | 75 |
| Yalıköy Balıkçı Barınağı-Fatsa | S.S. Yalıköy Su Ürünleri Kooperatifi | 50 | 2-4 | 426 | 120 |
| Bolaman Balıkçı Barınağı-Fatsa | S.S. Bolaman Su ürünleri Kooperatifi | 20 | 2-4 | 400 | 180 |
| Fatsa Balıkçı Barınağı | Ordu Büyükşehir Belediyesi | 22 | 2-6 | 600 | 540 |
| Ünye Balıkçı Barınağı | S.S. Ünye Su Ürünleri Kooperatifi | 95 | 2-9 | 1475 | 500 |

| Çekek Yeri | İlçesi | Barınan Gemi Sayısı |
|---|---|---|
| Kirazlimanı Çekek Yeri | Altınordu | 15 |
| Kacalı Çekek Yeri | Perşembe | 90 |
| Okçulu Çekek Yeri | Perşembe | 38 |
| Kurtuluş Mah. Çekek Yeri | Fatsa | 20 |


**Şekil 2**. Gülyalı Balıkçı Barınağı (Google Earth).

**3.1.2.Kumbaşı balıkçı barınağı:**

Altınordu ilçesinde bulunan barınak DLH Genel Müdürlüğü (Tarım sektöründen ayrılan ödenekle) tarafından 1991-2001 yıllarında inşa edilmiştir. 2002 yılında S.S. Boztepe Kumbaşı Güzelyalı ve Kiraz Limanı Su Ürünleri Kooperatifi tarafından kiralanmış olup, Kumbaşı Su Ürünleri Kooperatifi tarafından işletmeciliği devam etmektedir. Barınaktan yararlanan tekne sayısı 150 olup, ana mendirek ve tali mendirek boyları 900 m-280 m, su derinliği 2-5 m, korunan su alanı 11 ha'dır. Rıhtım uzunluğu ve derinliği 100 m-3 m, 150 m-2 m olan barınak turizm sektörü tarafından da kullanılmaktadır (Şekil 3).

**3.1.3.Kışlaönü balıkçı barınağı:**

Perşembe ilçesinde bulunan barınak 1987-1988 yılında DLH Genel Müdürlüğü (Tarım sektöründen ayrılan ödenekle) tarafından inşa edilmiş ve Perşembe Belediyesine devredilmekle birlikte son olarak Perşembe Su Ürünleri Kooperatifi tarafından işletilmektedir. Barınaktan yararlanan balıkçı tekne sayısı da 110'dur. Ana mendirek ve tali mendirek boyları 310 m-75 m, su derinliği 2-5 m'dir. Rıhtım uzunluğu ve derinliği 70 m-4 m, 150 m-3 m, 177 m-2 m, korunan su alanı 2,7 ha'dır (Şekil 4).


**Şekil 3**. Kumbaşı Balıkçı Barınağı (Google Earth).


**Şekil 4**. Kışlaönü Balıkçı Barınağı (Google Earth).

**3.1.4.Mersin köyü balıkçı barınağı:**

Perşembe ilçesinde bulunan barınak 1975-1982 yıllarında DLH Genel Müdürlüğü (Tarım sektöründen ayrılan ödenekle) tarafından inşa edilmiş ve 1997 yılında S.S. Mersin Köyü Su Ürünleri Kooperatifine kiralanmış olup, halen kooperatif tarafından işletmeciliği devam etmektedir. Barınaktan yararlanan tekne sayısı 75 olup, ana mendirek ve tali mendirek boyları 390 m-120 m, su derinliği 2-4 m'dir. Rıhtım uzunluğu ve derinliği 50 m-3 m, 25 m-2 m, korunan su alanı 2,6 ha'dır. Barınağa ait uydu görüntüsü Şekil 5'te verilmiştir.

**3.1.5.Medreseönü balıkçı barınağı:**

Perşembe ilçesinde bulunan barınak DLH Genel Müdürlüğü (Tarım sektöründen ayrılan ödenekle) tarafından inşa edilmiş ve S.S. Medreseönü Su Ürünleri Kooperatifine kiralanmış olup, halen kooperatif tarafından işletmeciliği devam etmektedir. Barınaktan yararlanan balıkçı tekne sayısı 20, su derinliği 2-5 m'dir. Ana mendirek ve tali mendirek boyları 320 m-65 m'dir. Rıhtıma ait uzunluk ve derinlik 40 m-1 m, 65 m-4 m, korunan su alanı 2,9 ha'dır (Şekil 6).


**Şekil 5.** Mersin Köyü Balıkçı Barınağı (Google Earth)


**Şekil 6**. Medreseönü Balıkçı Barınağı (Google Earth)

**3.1.6.Yalıköy balıkçı barınağı:**

Fatsa ilçesinde bulunan barınak 1980-1986 yılları arasında DLH Genel Müdürlüğü (Tarım sektöründen ayrılan ödenekle) tarafından inşa edilmiş ve 1997 yılında S.S. Yalıköy Su Ürünleri Kooperatifince kiralanmış olup halen kooperatif tarafından işletmeciliği devam etmektedir. Barınaktan yararlanan balıkçı teknesi sayısı 50 olup, su derinliği 2-5 m'dir. Ana mendirek ve tali mendirek boyları 426 m-120 m'dir. Rıhtım uzunluğu ve derinliği 110 m-3 m, 36 m-2 m, korunan su alanı 4,3 ha'dır (Şekil 7).

**3.1.7.Bolaman balıkçı barınağı:**

Fatsa ilçesinde bulunan barınak DLH Genel Müdürlüğü (Tarım sektöründen ayrılan ödenekle) tarafından 1980-1986 yılında inşa edilmiş ve geçici devirle Bolaman Belediyesine devredilmiştir. Barınağın işletmeciliği S.S. Bolaman Su Ürünleri Kooperatifi tarafından yürütülmektedir. Ana mendirek ve tali mendirek boyları 400 m-180 m, su derinliği 2-4 m, tekne kabul kapasitesi 67, barınaktan yararlanan tekne sayısı 20'dir. Rıhtım uzunluğu 70 m-4 m, korunan su alanı 4,5 ha'dır (Şekil 8).


**Şekil 7**. Yalıköy Balıkçı Barınağı (Google Earth).

**Şekil 8**. Bolaman Balıkçı Barınağı (Google Earth).

### 3.1.8.Fatsa balıkçı barınağı:

Fatsa ilçesinde bulunan barınak DLH Genel Müdürlüğü (Tarım sektöründen ayrılan ödenekle) tarafından 1966-1969 yılında inşa edilmiş ve Fatsa Belediyesine devredilmiş olmakla birlikte Ordu Büyükşehir Belediyesi tarafından işletmeciliği devam etmektedir. Ana mendirek boyu 600 m, tali mendirek boyu 540 m, su derinliği 2-6 m, barınaktan yararlanan balıkçı teknesi sayısı 22'dir. Rıhtım uzunluğu ve derinliği 350 m-4 m, 262 m-2 m, 140 m-1.4 m, 95 m-1.2 m, korunan su alanı 5,6 ha'dır. Barınak turizm ve ulaştırma sektörü tarafından da kullanılmaktadır (Şekil 9).

### 3.1.9.Ünye balıkçı barınağı:

Ünye ilçesinde bulunan barınak 1984-1996 yıllarında DLH Genel Müdürlüğü (Tarım sektöründen ayrılan ödenekle) tarafından inşa edilmiş ve 1996 yılında S.S. Ünye Su Ürünleri Kooperatifine kiralanmış olup, halen kooperatif tarafından işletilmektedir. Barınaktan yararlanan balıkçı teknesi sayısı 95, ana mendirek ve tali mendirek boyları 1475 m-500 m, su derinliği 2-9 m dir. Rıhtım uzunluğu ve derinliği 100 m-2 m, korunan su alanı 43 ha olup turizm ve ulaştırma sektörleri tarafından da kullanılmaktadır (Şekil 10).

**Şekil 9**. Fatsa Balıkçı Barınağı (Google Earth).


**Şekil 10.** Ünye Balıkçı Barınağı (Google Earth).

**3.2.Çekek yerlerine ait bilgiler**

**3.2.1.Kirazlimanı çekek yeri:**

Altınordu ilçesinde bulunan çekek yerinden yararlanan balıkçı teknesi sayısı 15'tir. Çekek yerinin ana mendirek boyu 100 m, korunan su alanı 14 ha'dır (Şekil 11).

**3.2.2.Kacalı çekek yeri:**

Perşembe ilçesinde bulunan çekek yeri geçici devirle Perşembe Belediyesi tarafından işletilmektedir. Çekek yerinden yararlanan balıkçı teknesi sayısı 90'dır. Su derinliği 1-3 m olan çekek yerinin ana mendirek boyu 220 m, korunan su alanı 75 ha'dır (Şekil 12).


**Şekil 11.** Kirazlimanı Çekek Yeri (Google Earth).

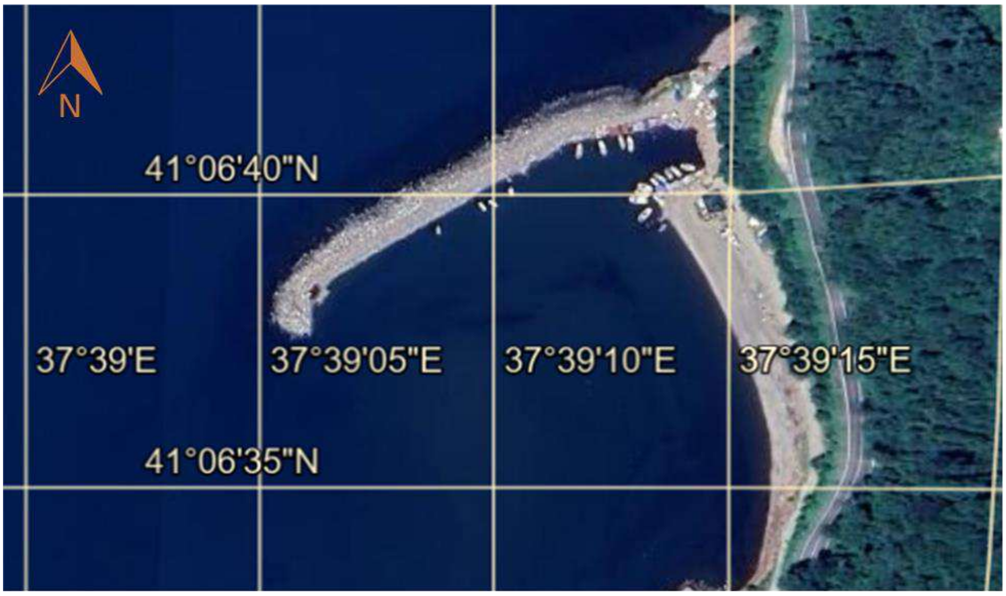

**Şekil 12.** Kacalı Çekek Yeri (Google Earth).

**3.2.3.Okçulu çekek yeri:**

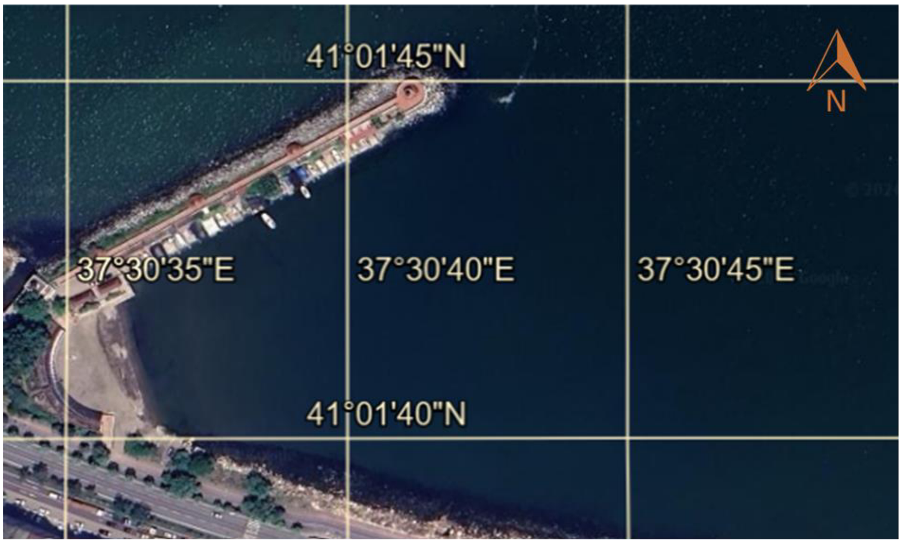
Perşembe ilçesinde bulunan çekek yerinin Ulaştırma ve Altyapı Bakanlığı'ndan Tarım Bakanlığına devri yapılmadığından kiralaması yapılmamıştır. Çekek yerinden yararlanan balıkçı teknesi sayısı 38'dir. Su derinliği 1-3 metre olan çekek yerinin ana mendirek boyu 220 metredir (Şekil 13).

**3.2.4.Kurtuluş mahallesi çekek yeri:**

Fatsa ilçesinde bulunan çekek yeri kesin devirle Fatsa Belediyesi tarafından işletilmektedir. Çekek yerinden yararlanan balıkçı teknesi sayısı 20'dir. Su derinliği 2-4 m olan çekek yerinin ana mendirek boyu 205 m, korunan su alanı 1 ha'dır (Şekil 14).




**Şekil 13.** Okçulu Çekek Yeri (Google Earth).




**Şekil 14**. Kurtuluş Mahallesi Çekek Yeri (Google Earth).

Araştırmada incelenen balıkçı barınaklarının tamamında elektrik, su ve fener bulunduğu belirlenmiştir (Tablo 3). Gülyalı, Kumbaşı, Kışlaönü, Medreseönü balıkçı barınaklarında soğuk hava deposu olduğu, balıkçı barınaklarının altısında balıkçı lokali, ikisinde idare binası, birinde kapalı depo olduğu, yedi balıkçı barınağı ve bir çekek yerinde ağ malzeme deposu olduğu saptanmıştır. Balıkçı barınaklarının tamamında ve çekek yerinde satış yeri ve ilk yardım birimi bulunmamaktadır. Kumbaşı, Kışlaönü, Fatsa ve Ünye balıkçı barınaklarında güvenlik mevcuttur (Tablo 3).

**Tablo 3.** Ordu ili balıkçı barınakları ve çekek yerinin üst yapı tesis ve birimleri

| Balıkçı Barınağının Adı | Elektrik | Su | Fener | Ağ Tamir Yeri | Buz Üretim Ünitesi | Soğuk Hava Deposu | Üst Yapı Tesisleri | Satış Yeri | İlk Yardım Birimi | Güvenlik |
|---|---|---|---|---|---|---|---|---|---|---|
| Gülyalı Balıkçı Barınağı | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Balıkçı Lokali | - | - | - |
| Kumbaşı Balıkçı Barınağı | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Balıkçı Lokali, Ağ ve Malzeme Deposu | - | - | ✓ |
| Kışlaönü Balıkçı Barınağı | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | İdare Binası, Kapalı Depo, Balıkçı Lokali, Ağ ve Malzeme Deposu | - | - | ✓ |
| Mersin Köyü Balıkçı Barınağı | ✓ | ✓ | ✓ | ✓ | - | - | Balıkçı Lokali | - | - | - |
| Medreseönü Balıkçı Barınağı | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Ağ ve Malzeme Deposu | - | - | - |
| Yalıköy Balıkçı Barınağı | ✓ | ✓ | ✓ | ✓ | - | - | Balıkçı Lokali, Ağ ve Malzeme Deposu | - | - | - |
| Bolaman Balıkçı Barınağı | ✓ | ✓ | ✓ | ✓ | - | - | Balıkçı Bürosu, Ağ ve Malzeme Deposu | - | - | - |
| Fatsa Balıkçı Barınağı | ✓ | ✓ | ✓ | ✓ | - | - | Ağ ve Malzeme Deposu, Sahil Güvenlik Binası (Ahmet Koçana Ait Tersane Balıkçılık Alanı Dışına Çıkmıştır) | - | - | ✓ |

**Tablo 3. Devamı**

| Balıkçı Barınağının Adı | Elektrik | Su | Fener | Ağ Tamir Yeri | Buz Üretim Ünitesi | Soğuk Hava Deposu | Üst Yapı Tesisleri | Satış Yeri | İlk Yardım Birimi | Güvenlik |
|---|---|---|---|---|---|---|---|---|---|---|
| Ünye Balıkçı Barınağı | ✓ | ✓ | ✓ | ✓ | - | - | İdare Binası, Ağ ve Malzeme Deposu, Balıkçılık Lokali | - | - | ✓ |
| Kirazlimanı Çekek Yeri | - | - | - | - | - | - | - | - | - | - |
| Kacalı Çekek Yeri | - | - | - | - | - | - | - | - | - | - |
| Okçulu Çekek Yeri | - | - | - | - | - | - | - | - | - | - |
| Kurtuluş Mh. Çekek Yeri | ✓ | ✓ | - | - | - | - | Ağ ve Malzeme Deposu | - | - | - |

## 4. TARTIŞMA

Çalışmada, Ordu ilinde yer alan 13 adet balıkçılık kıyı yapısına ait alt-üst yapı imkân durumları ve bu yapılardan yararlanan tekne sayıları ele alınmıştır.

Balıkçılık kıyı yapılarının mevcut durumunu belirlemek ve ihtiyaçlarını ortaya koymak amacıyla Ulaştırma ve Altyapı Bakanlığı'nca hazırlanan raporlarda, bir balıkçı limanında, büyük limanlarda ek olarak olması gereken normal yanaşma rıhtımının yanısıra yükleme boşaltma rıhtımının da bulunması gerektiği bildirilmiştir. Kıyı yapısını kullanan balıkçı teknelerinin sayısı, rıhtıma yanaşma biçimi, avlanma sıkılığı, gün içerisindeki en yoğun yükleme-boşaltma saatleri ve bağlanma koşulları gibi birtakım özelliklerin rıhtım boyunun belirlenmesinde dikkate alınması tavsiye edilmiştir (UDHB, 2011). Tokmak Kırkses ve Samsun (2020), Giresun'da yaptıkları çalışmada kıyı yapılarının büyük kısmında rıhtım bulunmakla birlikte yoğun avcılık dönemlerinde yeterli olmadığı belirtilmiştir. Trabzon'da ki kıyı yapılarından 11 balıkçı barınağı, 1 çekek yeri ve 1 barınma yerinde teknelerin yanaşması için rıhtım bulunduğu ancak avlanan balıkların karaya çıkış noktalarının balıkçı barınaklarında ki yanaşma rıhtımlarında yapıldığı belirtilmiştir (Boran & Avcı Softa, 2016). Dadaylı (2012), Zonguldak ili balıkçı barınaklarında rıhtım, çekek yeri gibi balıkçılık faaliyetleri için önemli olan ana unsurların bulunduğunu fakat bu yapıların ideal gelişimini tamamlamadıklarını belirtmiştir. Bu araştırmada incelenen kıyı yapılarından Mersin, Bolaman, Yalıköy ve Fatsa balıkçı barınaklarında rıhtım onarımına ihtiyaç duyulmakla birlikte, özellikle Yalıköy ve Bolaman balıkçı barınaklarında rıhtımın yetersiz olduğundan dolayı balıkçı teknelerinin bağlanamadığı belirlenmiştir.

Demir (2023), Van ilindeki balıkçılık kıyı yapılarının çoğunluğunda, özellikle yağışların az olduğu zamanlarda rıhtım derinliğinin 50 cm'nin altına düştüğünü; Boran ve Avcı Softa (2016), Trabzon'da yer alan balıkçı barınaklarının basen içi su derinliklerinin 1-4 m arasında değiştiğini, rıhtım boyunca su derinliği 1 m olan yerlerde büyük teknelerin yanaşamayacağını belirtmişlerdir. Mevcut çalışmada balıkçı gemilerinin rıhtımlara yanaşabilmesi açısından önemli olan su derinliği 2-9 m arasında değişmektedir.

Tokmak Kırkses ve Samsun (2020), Giresun'daki kıyı yapılarının tamamında dam bulunduğunu, balıkçıların ağ bakımlarını yapmak için teknelerini bu damların önünde bulunan çekek yerlerine aldıklarını, birçok kıyı yapısının temel sorunları arasında yer alan elektrik ve su yoksunluğu nedeniyle tekne ve ağ bakım-onarım işlemleri sırasında sorun yaşadıklarını belirtmişlerdir. Boran ve Avcı Softa (2016), ağ bakım ve onarımı için gerekli olan ağ tamir ve kurutma sahasının sadece Trabzon-Motor, Faroz ve Beşikdüzü balıkçı barınaklarında bulunduğunu bildirmişlerdir. Bu çalışmada 9 barınağın tamamında ağ tamir yeri mevcut olmakla birlikte Medreseönü, Bolaman ve Kışlaönü balıkçı barınaklarının tekne bakım ve onarım açısından yeterli olmadığı belirlenmiştir. Çekek yerlerinin hiçbirinde ağ tamir yeri olmamakla birlikte tekne bakım ve onarım açısından da yeterli olmadıkları tespit edilmiştir.

Boran ve Avcı Softa (2016), Trabzon ilinde; Tokmak Kırkses ve Samsun (2020), Giresun ilinde balıkçılık kıyı yapılarına yönelik yürüttükleri çalışmalarda balıkçılık kıyı yapılarının tamamının ilgili yönetmelik ve raporlarda belirtilen niteliklerde olmadığını, altyapı-üstyapı işlevleri bakımından yeterli şartları sağlamadıklarını bildirmişlerdir. Balık ve Topçu (2014), Ordu ilinde balıkçı barınaklarında özellikle küçük balıkçı tekneleri için çekek yerlerinin yetersiz olduğunu, elektrik ve su bulunmamasının bakım-onarım zamanlarında balıkçıların işlerini zorlaştırdığını, av aracı ve diğer ekipmanların muhafaza edilebileceği kapalı alanların bulunmadığını ifade etmişlerdir. Mevcut çalışmada da barınakların çoğunluğunda rıhtım yetersizliğinden dolayı teknelerin bağlanamadığı, elektrik ve su sorunlarının yaşandığı ve ağ ve diğer malzemelerin muhafazası için kapalı alan bulunmadığı belirlenmiştir. Çekek yerlerinin alt yapı ve üst yapı hizmet üniteleri bakımından tamamıyla yoksun olduğu sadece Kurtuluş Mahallesi çekek yerinde elektrik, su ve ağ ve malzeme deposunun bulunduğu belirlenmiştir.

Ağ kurutma sahası, idare binası, satış yeri, çok amaçlı depolar, soğuk hava deposu, şoklama ünitesi, buz üretim ünitesi, tuvalet, bakım-onarım atölyesi ve balıkçı lokali, çağdaş bir balıkçı barınağında bulunması gereken önemli ünitelerdir. Barınaklarımızda söz konusu tesislerin büyük kısmı bulunmamakta olup, halen rıhtımları tamamlanmayanlarda dikkat çekmektedir. Rıhtım bulunanlarda ise temel bağlama unsurları olan baba, halka ve usturmaça gibi olanaklar sınırlı iken, liman sahalarındaki beton kaplamalarda, aydınlatma ve güvenlik çiti gibi temel altyapılarda eksikler bulunmaktadır (Akçaoğlu vd, 2007).

## 5. SONUÇ

İncelenen kıyı yapılarının %100'ünde elektrik, su, fener, ağ tamir yeri, %44'ünde buz üretim ünitesi, %44'ünde soğuk hava deposu, %44'ünde güvenlik, %67'sinde balıkçı lokali, %78'inde ağ ve malzeme deposu ve %33'ünde idari bina bulunmakta iken tamamında satış yeri ve ilk yardım birimi bulunmamaktadır. Ayrıca Fatsa balıkçı barınağında güvenlik önlemlerinin yeterli olmamasından dolayı özellikle akşamları eğlence amaçlı kullanıldığı belirlenmiştir. 4 adet çekek yeri incelendiğinde ise sadece Kurtuluş Mahallesi Çekek yerinde elektrik, su ve ağ ve malzeme deposu bulunmaktadır.

Balıkçılık kıyı yapıları üzerine yapılan araştırmalar, deniz ve tatlı su kaynaklarının etkili bir şekilde korunması ve yönetilmesi için önemli bir referans kaynağı oluşturmaktadır. Konu ile ilgili daha önce yapılan ve mevcut çalışma sonuçları, balıkçılık kıyı yapılarının altyapı ve üstyapı potansiyeli açısından yetersiz olduğunu ve bu yapıların verimli bir şekilde kullanılamadığını göstermektedir. Bu yetersizliklerin balıkçıların çalışma koşullarını ve dolayısıyla balıkçılık sektörünün sürdürülebilirliğini olumsuz etkilediği söylenebilir. Balıkçılık faaliyetleri açısından önemli olan bu yapıların modern balıkçılığa yönelik hizmet verecek şekilde rehabilitasyonunun yapılması gerekmektedir.

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Research Article | Araştırma Makalesi

# Effect of Ultrasound Applications on Physico-Chemical, Sensory, and Microbiological Quality of Rainbow Trout (*Oncorhynchus mykiss* W.)

## Ultrason Uygulamalarının Gökkuşağı Alabalığının (*Oncorhynchus mykiss* W.) Fiziko-Kimyasal, Duyusal ve Mikrobiyolojik Kalitesi Üzerine Etkisi

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**Abstract:** Ultrasound, whose use has increased in recent years, is one of the most important food processing methods that provides to maintain food quality and increase food safety. The effect of ultrasound treatment on some quality characteristics of vacuum-packed rainbow trout (Oncorhynchus mykiss W.) fillets during cold storage was determined. Experimental groups were formed using different power and duration variables (30%W/5 min.; 30%W/15 min.; 80%W/5 min, and 80%W/15 min.). The samples were stored at 4±1ºC until physico-chemical (moisture, pH, color, and texture), sensory, and microbiological analyses were performed. The effect rates of ultrasound application on the evaluated quality characteristics differed from each other. While there was a significant difference between the groups in the decrease in moisture, increase in pH value and changes in sensory parameters, the change depending on storage was not observed within the group. The decrease in colour and texture values was prevented to a certain extent. It was observed that the effect of ultrasound applications on microbiological inactivation varied according to the type of bacteria and application conditions. The lowest increase in the number of the total mesophilic aerobic bacteria, the total psychrophilic aerobic bacteria, and the lactic acid bacteria was detected in the 80W/5 min. group, while Enterobactericeae and Pseudomonas spp. were detected in the 80 W/15 min. group. The highest inactivation was observed in Pseudomonas spp. bacteria. Our results showed that ultrasound can be an important alternative food processing method to maintain the quality characteristics and food safety of fish meat.

**Keywords**
- Cold storage
- Food quality
- Food safety
- *Oncorhyncus mykiss*
- Ultrasound

**Özet:** Son yıllarda kullanımı artan ultrason, gıda kalitesinin korunmasını ve gıda güvenliğinin artırılmasını sağlayan en önemli gıda işleme yöntemlerinden biridir. Vakum paketlenmiş gökkuşağı alabalığı (Oncorhynchus mykiss W.) filetolarının soğukta muhafazası sırasında ultrason uygulamasının bazı kalite özellikleri üzerine etkisi belirlenmiştir. Farklı güç ve süre değişkenleri (%30W/5 dk.; %30W/15 dk.; %80W/5 dk. ve %80W/15 dk.) kullanılarak deney grupları oluşturulmuş ve örnekler fiziko-kimyasal (nem, pH, renk ve tekstür), duyusal ve mikrobiyolojik analizler yapılana kadar 4±1ºC'de depolanmıştır. Ultrason uygulamasının değerlendirilen kalite özellikleri üzerindeki etki oranları birbirinden farklılık göstermiştir. Nem düzeyindeki azalma, pH değerindeki artış ve duyusal parametrelerde meydana gelen değişimler gruplar arasında önemli bulunurken ($p<0.05$), depolamaya bağlı değişim grup içinde gözlenmemiştir. Renk ve tekstür değerlerindeki azalma ise belli oranda engellenmiştir. Ultrason uygulamalarının mikrobiyolojik inaktivasyon üzerindeki etkisinin bakteri türüne ve uygulama koşullarına göre değiştiği gözlenmiştir. Toplam mezofilik aerobik bakteri, toplam psikrofilik aerobik bakteri ve laktik asit bakteri sayısında en düşük artış 80W/5 dk. grubunda tespit edilirken, Enterobacteriaceae ve Pseudomonas spp. sayısındaki en düşük artış 80W/15 dk. grubunda tespit edilmiştir. En yüksek inaktivasyon Pseudomonas spp. bakterisinde gözlenmiştir. Sonuçlarımız, ultrasonun balık etinin kalite özelliklerini ve gıda güvenliğini korumak için alternatif bir gıda işleme yöntemi olarak kullanılabileceğini göstermiştir.

**Anahtar kelimeler**
- Soğuk depolama
- Gıda kalitesi
- Gıda güvenliği
- *Oncorhyncus mykiss*
- Ultrason

## 1. INTRODUCTION

The sustainability of public health depends on reliable, healthy, balanced nutrition and quality food. Physical, chemical, sensory, and biological parameters are among the most sought-after characteristics in food safety. The most widely used food preservation m,ethod to ensure food safety is heat preservation (Raso and Barbosa-Canovas, 2003). Today, the application of "non-thermal methods" to foods has gained importance in order to eliminate the negative effects of high temperatures on the structure of food (Elez-Martinez et al., 2005). Consumers increasing demand for safe and nutritious food is expanding the different technologies used in the food industry (Türksönmez and Diler, 2021). Non-thermal methods include high hydrostatic pressure, ultrasound, pulsed electric field, pulsed light, ohmic heating, irradiation, and microwave (Karabacak, 2015). The advantages of ultrasound compared to heat treatment are that the loss of sensory and chemical properties of the food is much less, the time used is saved, and a higher percentage of enzymes and microorganisms are inactivated (Ashokkumar et al., 2008). Furthermore, in the framework of the "Green Food Processing" concept, ultrasound is used to ensure high quality and safe food (Chemat and Ashokkumar, 2017). In the literature, ultrasound-assisted salting of beef (Sanches et al., 2021), curing of meat varieties (Inguglia et al., 2018), marinating of chicken meat (Xiong et al., 2020), drying of beef (Ojha, Kerry, and Tiwari, 2017), control of microorganisms in beef and poultry meat were performed (Piñon et al., 2020). Besides, in meat products, a number of studies have focused on evaluating quality characteristics in meat emulsions (Leães et al., 2020), Italian salami (Alves et al., 2018), bacon (Pan et al., 2020), frankfurter-type sausages (Zhang et al., 2021), cooked ham (Barretto et al., 2018), and dry fermented sausage processing (Alves et al., 2020). Although there are many studies on red and white meat in the literature, studies on fish meat are more limited.

Recently, fish is considered an important protein source due to its nutritional components and the knowledge of the effects of nutrients on our health. However, lipids, proteins, and non-protein nitrogenous compounds in fish meat are exposed to post-mortem biochemical reactions. In addition, fish is one of the most perishable foods because it provides a very good environment for spoilage-causing microorganisms (Esteves et al., 2016). For this reason, the transportation of fish meat in the cold chain until it reaches the consumer or the shelf life before consumption can be ensured by cold storage. The quality changes of fish meat under cold storage conditions are directly related to food safety and should be monitored in a controlled manner. Rainbow trout (*Oncorhynchus mykiss* W.) provide a sustainable source of protein through aquaculture. The prevalence of fresh consumption necessitates the preservation of quality characteristics during cold storage and its sustainability in terms of public health. Therefore, our study consists of monitoring the changes in some quality characteristics of cold stored rainbow trout (*O. mykiss* W.) fillets exposed to ultrasound waves at different powers.

## 2. MATERIALS AND METHODS

### 2.1. Sample preparations

The material was obtained from rainbow trout reared in Sapanca Inland Fisheries Production Research and Application Unit of Istanbul University Faculty of Aquatic Sciences. 12 kg rainbow trout with an average weight (225-250 g) were filleted together with their skins under hygienic conditions. For rainbow trout fillets, the lower vacuum packing material was selected with a thickness of 150 µ and the upper vacuum packing material with a thickness of 80 µ. Fillet samples were vacuum packed using a conveyor vacuum machine (Multivac R 240, Germany). Operating conditions: 20 mbar air vacuum stop point from 1000 mbar and 0.6 seconds vacuum time. The vacuumed fillets ($n$=90) were kept at (4±1°C) for the duration of ultrasound application and analysis.

### 2.2. Ultrasound treatment

Fillet samples were placed in a 1.5 liter plastic container in the ultrasound device with probe in the presence of 1 liter of deionized water (temperature not exceeding +5 °C). The application was performed with an ultrasonic homogenizer (JY92- IIDN, China; frequency 20–25 KHz, power range 60–650 W, Ø 6 (1/4") probe), a controlled adjustable power percentage (30% W, 80% W), and a duration of 5–15 min. After the application, five different groups were formed: control, 30W/5 min, 30W/15 min, 80W/5 min, and 80W/15 min.

### 2.3. Moisture and pH measurement

Moisture content (%) was determined in an etuve (Nuve N-120) according to AOAC 950.46 (AOAC, 2005). The pH of fillet samples was measured in fish/water (1:10, w/v) homogenate using a pH-meter (Hanna HI-221) (Varlık et al., 2007).

### 2.4. Color measurement

Color measurements were performed directly on samples with a Minolta Color Reader (Minolta CR-400, Osaka, Japan). According to the Hunter $L^*$, $a^*$, and $b^*$ color scale (Hunter Associates Laboratory Inc., USA), where "$L^*$" refers to lightness (0 is black and 100 is white), "$a^*$" indicates greenness ($a^*$<0) or redness ($a^*$>0), and "$b^{**}$" measures blueness ($b^*$<0) or yellowness ($b^*$>0) of samples. As a summary measure, total color change (denoted ΔE) was used (Anonymous, 2008).

### 2.5. Texture analysis

A texture profile analysis test was performed using a texturometer (LFRA Texture Analyzer, Brookfield Engineering Labs Inc., USA) equipped with a 12.7 mm diameter stainless steel spherical probe approaching the sample at a velocity of 1 mm and clamping 5 mm into the fillet samples. Measurements (kgf, here 1 kgf = 9.806 N) were made using Texture Pro Lite v1.1 software (Brookfield Engineering Labs Inc., USA) to read values (Szczesniak, 2002).

### 2.6. Sensory analysis

The sensory evaluation panel of the samples consisted of 5 assessors who were appropriately trained on the basis of the Torry scale (color, odor, texture, and overall evaluation) (Regenstein and Regenstein, 1991). A ten-point range was used to detect sensory results (10-8, excellent; 7-5, good; and ≤4, not acceptable).

### 2.7. Microbiological analyses

On each sampling day, samples (10 g) of fillets were aseptically placed into sterile Stomacher® bags containing 90 ml of peptone water with NaCl (0.85% w/v) (Merck, Darmstadt, Germany) and homogenised for 2 min (Stomacher® 400, Seward Ltd., London, UK). Serial dilutions were prepared and total mesophilic aerobic bacteria (TMAB) and total psychrophilic aerobic bacteria (TPAB) counts were determined on Plate Count Agar (PCA) (Merck, Darmstadt, Germany) by the pour plate method, incubating TMAB, 30°C and 48 hours; TPAB, 6.5°C and 10 days (ISO 4833, 2003; ISO 17410, 2001). Lactic acid bacteria (LAB) were incubated on De Man Rogosa and Sharp (MRS) agar (Merck, Darmstadt, Germany) by double layer pour plate method at 25 °C for 5 days and LAB counts were determined (American Public Health Association, 1974). Enterobacteriaceae counts were determined on Violet Red Bile Glucose (VRBG) agar (Merck, Darmstadt, Germany) by double layer pour plate method; incubated at 37°C for 48 hours (ISO 5552, 1997). *Pseudomonas* spp. were incubated on Cephaloridine-Fusidin-Cetrimid (CFC) agar (Merck, Darmstadt, Germany) by smear plate method at 25°C for 48 hours and bacteria were counted (ISO 13720, 2000). Analyses were performed in 3 replicates and results were represented in log cfu/g.

### 2.8. Statistical analysis

The SPSS statistical software program (IBM, SPSS Statistics Version 22.00) was used for the data. Results are recorded as the mean ± standard deviation. Ultrasound-related changes in means were tested for normality of data distribution by Levene's test. Before the analyses, the percentages of the values were normalized by the arcsine transformation. Since all data met the assumptions of parametric tests, means were compared by one-way ANOVA. Homogeneity of variances it was tested by Tukey's Honest Significant Difference (Tukey HSD) ($p$<0.05) (Esteves, 2011).

## 3. RESULTS

### 3.1. Chemical changes

As the storage period progressed, the moisture values showed minimum decreases in each group. However, the decrease at the end of storage was significantly different between the experimental groups ($p$<0.05) (Table 1). The maximum decrease was determined in the 30W/5 min group (77.35±0.32- 74.46±0.45) and the minimum change was determined in the 80W/5 min group (75.45±1.71- 74.96±0.35). On the first day of the application, the highest effect of ultrasound was determined in the 80W/15 min group. At the same time, the lowest moisture value was observed in the 30W/15 min group on the 9th day (73.72±1.87).

The pH values of trout fillets changed in the direction of increasing depending on ultrasound application and storage time (Table 2). However, 30W/5 min group was the only treatment group that showed a minimum decrease (6.72±0.01-6.70±0.05) instead of an increase at the end of storage. The effect of ultrasound application was found to be different between 30W/15 min and 80W/5 min groups on the 6th day of storage and between 30W/5 min and 80W/5 min groups on the 15th day ($p$<0.05) (Table 2). However, the pH limit value for fresh fish (6.8–7.0) was not exceeded during storage

**Table 1.** Variation of moisture content percentage according to groups and storage period.

| Storage period† (days) | Power and duration of ultrasound application (%Mean± SD‡) | | | | |
|---|---|---|---|---|---|
| | Control | 30W/5 min | 30W/15 min | 80W/5 min | 80W/15 min |
| **0** | 77.42±2.43$^{ax}$ | 77.35±0.32$^{ax}$ | 76.74±1.59$^{ax}$ | 75.45±1.71$^{ax}$ | 75.01±1.49$^{ax}$ |
| **3** | 74.12±1.45$^{ax}$ | 75.45±0.59$^{abx}$ | 75.43±0.35$^{abx}$ | 74.91±0.05$^{ax}$ | 74.67±0.61$^{ax}$ |
| **6** | 74.66±0.84$^{ax}$ | 74.01±1.23$^{bx}$ | 75.12±0.49$^{abx}$ | 75.49±0.67$^{ax}$ | 75.44±0.39$^{ax}$ |
| **9** | 75.10±0.30$^{ax}$ | 74.65±0.79$^{bx}$ | 73.72±1.87$^{bx}$ | 74.33±0.34$^{ax}$ | 74.93±0.22$^{ax}$ |
| **12** | 74.03±0.56$^{ax}$ | 74.53±0.34$^{bx}$ | 75.23±0.77$^{abx}$ | 74.98±0.78$^{ax}$ | 74.67±0.18$^{ax}$ |
| **15** | 75.41±0.47$^{ax}$ | 74.46±0.45$^{bx}$ | 75.00±0.44$^{abx}$ | 74.96±0.35$^{ax}$ | 74.28±1.07$^{ax}$ |

†Ultrasound application was applied with different power (30% and 80% W) and duration (5 to 15 minutes) not exceeding 5 °C in deionized water and kept at 4±1°C during storage (0, 3, 6, 9, 12, and 15 days). ‡Means with dissimilar letters in rows (a-b) and columns (x-y) are statistically different ($p$<0.05; Tukey's HSD). The data represent the mean± SD (%) of the total 90 samples.

**Table 2.** Variation of pH value according to groups and storage period.

| Storage period† (days) | Power and duration of ultrasound applications (Mean± SD‡) | | | | |
|---|---|---|---|---|---|
| | Control | 30W/5 min | 30W/15 min | 80W/5 min | 80W/15 min |
| **0** | 6.66±0.01$^{bx}$ | 6.72±0.01$^{ax}$ | 6.78±0.10$^{ax}$ | 6.67±0.01$^{cx}$ | 6.68±0.12$^{abx}$ |
| **3** | 6.68±0.08$^{bx}$ | 6.65±0.02$^{ax}$ | 6.69±0.01$^{abx}$ | 6.73±0.03$^{bcx}$ | 6.72±0.02$^{abx}$ |
| **6** | 6.65±0.02$^{bxy}$ | 6.69±0.05$^{axy}$ | 6.62±0.02$^{by}$ | 6.75±0.04$^{bcx}$ | 6.75±0.01$^{abx}$ |
| **9** | 6.68±0.05$^{bx}$ | 6.69±0.06$^{ax}$ | 6.75±0.05$^{abx}$ | 6.67±0.03$^{cx}$ | 6.65±0.06$^{bx}$ |
| **12** | 6.79±0.10$^{abx}$ | 6.74±0.04$^{ax}$ | 6.72±0.05$^{abx}$ | 6.79±0.01$^{abx}$ | 6.74±0.01$^{abx}$ |
| **15** | 6.89±0.02$^{ax}$ | 6.70±0.05$^{ay}$ | 6.81±0.02$^{axy}$ | 6.88±0.04$^{ax}$ | 6.85±0.05$^{ax}$ |

†Ultrasound application was applied with different power (30% and 80% W) and duration (5 to 15 minutes) not exceeding 5 °C in deionized water and kept at 4±1°C during storage (0, 3, 6, 9, 12, and 15 days). ‡Means with dissimilar letters in rows (a-b) and columns (x-y) are statistically different ($p$<0.05; Tukey's HSD). The data represent the mean± SD (%) of the total 90 samples.

## 3.2. Physical changes

Although L* values of trout fillets increased in all groups, no significant difference was observed between the groups ($p$>0.05) (Table 3). However, when the changes within the groups were observed according to the storage day, a significant difference was found between the first day and the 6$^{th}$ day in the Control and 30W/5 min group, between the 3$^{rd}$ day and the 15$^{th}$ day in the 30W/15 min group, between the 3$^{rd}$ day and the 12$^{th}$ day in the 80W/min group and between the first day and the last storage day in the 80W/15 min group ($p$<0.05). 3$^{rd}$ day and 9$^{th}$ day between groups during storage except for a* values, no significant difference was observed ($p$>0.05) (Table 3). During the storage period, it was determined that there was a significant difference between day 0$^{th}$ and day 6$^{th}$ only in the 80W/5 min. group ($p$<0.05).

Contrary to this, L$^*$ and a$^*$ color parameters, yellowness (b$^*$ >0) values showed non-linear changes both between groups and during storage days (Table 3). The 30W/5 min group was observed as the group that showed differences on the 3$^{rd}$ and 9$^{th}$ days of storage. Total color change (ΔE) values of trout fillets did not differ in treatment groups or storage days ($p$>0.05).

The hardness values (N) in the texture profile decreased during storage in all treatment groups (Table 4). However, no difference was observed between the groups ($p$>0.05).The effect of ultrasound application differed in the 30W/15 min (3$^{rd}$ –15$^{th}$ day), 80W/5 min (0$^{th}$ –15$^{th}$ day) and 80W/15 min (3$^{rd}$ –12$^{th}$ day) groups on storage days ($p$<0.05). While the stickiness values decreased with storage, the stickiness value was measured as (0.02) in all groups at the end of storage. With the effect of ultrasound, the only group in which the stickiness continued to decrease without increasing in the same direction was the 30W/15 min group (Table 4). Elasticity values decreased in all groups, and the difference in storage days was observed on the 6th and 15th days. The change in elasticity values was observed between the 30W/5 min –80W/15 min and 80W/15 min –80W/5 min groups. Chewability values (kgf/mm) of trout fillets showed a 3-fold decrease between the 30W/5 min and 80W/5 min groups only on the 6th day of storage ($p$<0.05). At the end of storage, the chewability value was determined as (0.03 kgf/mm) in all groups.

**Table 3.** Variation of color parameters according to groups and storage period.

| **Storage period† (days)** | **Color parameters§** | | | | |
|---|---|---|---|---|---|
| | **Groups (Mean± SD‡)** | **L *** | **a *** | **b*** | **ΔE** |
| **0** | **Control** | 44.95±3.73$^{bx}$ | 1.52±1.08$^{ax}$ | 8.57±1.85$^{ax}$ | 0.00 |
| | **30W/5 min** | 43.98±3.53$^{cx}$ | 0.61±1.26$^{ax}$ | 7.93±2.38$^{abx}$ | 0.00 |
| | **30W/15 min** | 45.23±3.94$^{bx}$ | 0.89±1.31$^{ax}$ | 7.13±2.18$^{ax}$ | 0.00 |
| | **80W/5 min** | 46.11±3.09$^{abx}$ | 0.43±0.99$^{bx}$ | 8.91±2.63$^{ax}$ | 0.00 |
| | **80W/15 min** | 44.67±2.25$^{bx}$ | 1.13±1.89$^{ax}$ | 7.52±2.54$^{ax}$ | 0.00 |
| **3** | **Control** | 47.95±3.20$^{abx}$ | 0.28±0.78$^{ay}$ | 7.81±2.63$^{ax}$ | 3.55±2.01$^{ax}$ |
| | **30W/5 min** | 47.39±3.72$^{abx}$ | 1.49±0.84$^{axy}$ | 9.33±2.74$^{ax}$ | 3.99±1.25$^{ax}$ |
| | **30W/15 min** | 45.90±2.45$^{bx}$ | 0.96±2.08$^{axy}$ | 6.96±3.75$^{ax}$ | 2.20±0.73$^{abx}$ |
| | **80W/5 min** | 45.04±3.66$^{bx}$ | 1.35±1.16$^{abxy}$ | 9.17±2.64$^{ax}$ | 2.43±0.99$^{abx}$ |
| | **80W/15 min** | 46.45±3.62$^{abx}$ | 1.70±1.34$^{ax}$ | 7.86±2.15$^{ax}$ | 2.41±1.02$^{ax}$ |
| **6** | **Control** | 49.52±6.02$^{ax}$ | 1.27±1.23$^{ax}$ | 8.85±3.10$^{ax}$ | 4.77±2.82$^{ax}$ |
| | **30W/5 min** | 49.49±3.52$^{ax}$ | 1.21±0.96$^{ax}$ | 8.32±2.99$^{abx}$ | 3.50±0.54$^{ax}$ |
| | **30W/15 min** | 47.30±5.81$^{abx}$ | 1.85±1.44$^{ax}$ | 7.85±3.31$^{ax}$ | 4.21±1.22$^{ax}$ |
| | **80W/5 min** | 47.33±4.86$^{abx}$ | 1.97±1.90$^{ax}$ | 9.21±2.92$^{ax}$ | 2.94±1.99$^{ax}$ |
| | **80W/15 min** | 46.68±4.49$^{abx}$ | 2.30±1.29$^{ax}$ | 9.32±3.60$^{ax}$ | 2.89±0.42$^{ax}$ |
| **9** | **Control** | 47.21±1.83$^{abx}$ | 0.46±1.10$^{ay}$ | 6.61±1.37$^{ax}$ | 2.19±0.67$^{ax}$ |
| | **30W/5 min** | 45.96±2.44$^{bcx}$ | 1.57±1.46$^{axy}$ | 6.33±2.80$^{bx}$ | 4.26±0.21$^{ax}$ |
| | **30W/15 min** | 46.95±2.09$^{abx}$ | 2.08±1.77$^{ax}$ | 8.22±2.50$^{ax}$ | 5.86±2.14$^{ax}$ |
| | **80W/5 min** | 47.70±2.31$^{abx}$ | 1.44±1.53$^{abxy}$ | 8.07±1.84$^{ax}$ | 2.72±0.71$^{abx}$ |
| | **80W/15 min** | 47.48±3.35$^{abx}$ | 1.59±1.14$^{axy}$ | 8.01±1.94$^{ax}$ | 3.61±2.65$^{ax}$ |
| **12** | **Control** | 48.84±2.58$^{abx}$ | 0.84±1.32$^{ax}$ | 8.39±2.03$^{ax}$ | 2.84±1.60$^{ax}$ |
| | **30W/5 min** | 46.76±2.07$^{abcx}$ | 1.05±1.69$^{ax}$ | 6.87±2.75$^{abx}$ | 1.83±1.13$^{abx}$ |
| | **30W/15 min** | 47.33±2.71$^{abx}$ | 1.50±1.41$^{ax}$ | 7.65±2.83$^{ax}$ | 2.67±0.09$^{abx}$ |
| | **80W/5 min** | 49.16±2.70$^{ax}$ | 0.86±1.93$^{abx}$ | 8.37±2.72$^{ax}$ | 2.09±0.88$^{abx}$ |
| | **80W/15 min** | 47.06±2.66$^{abx}$ | 1.42±1.69$^{ax}$ | 7.28±2.50$^{ax}$ | 1.58±1.10$^{ax}$ |
| **15** | **Control** | 48.80±2.40$^{abx}$ | 1.39±2.37$^{ax}$ | 8.49±2.32$^{ax}$ | 1.76±0.17$^{ax}$ |
| | **30W/5 min** | 48.26±3.12$^{abx}$ | 1.71±1.71$^{ax}$ | 8.46±2.19$^{abx}$ | 3.18±1.67$^{ax}$ |
| | **30W/15 min** | 49.63±3.00$^{ax}$ | 1.06±1.17$^{ax}$ | 8.46±2.49$^{ax}$ | 3.39±2.07$^{abx}$ |
| | **80W/5 min** | 48.45±2.04$^{ax}$ | 0.99±1.60$^{abx}$ | 8.68±2.71$^{ax}$ | 2.44±0.54$^{abx}$ |
| | **80W/15 min** | 48.22±2.58$^{ax}$ | 1.89±1.58$^{ax}$ | 9.20±2.40$^{ax}$ | 2.66±1.06$^{ax}$ |

†Ultrasound application was applied with different power (30% and 80% W) and duration (5 to 15 minutes) not exceeding 5 °C in deionized water and kept at 4±1 °C during storage (0, 3, 6, 9, 12, and 15 days). ‡Means with different (a-c) letters in the same column within the same storage day are statistically different (p<0.05; Tukey's HSD). Means with different (x-y) letters in the same column for the same group are statistically different (p<0.05; Tukey's HSD). The data represent mean± SD of the total 90 samples. §L: $L^*$ indicates lightness (0 is black and 100 is white), $a^*$ indicates greenness ($a^*$< 0) or redness ($a^*$> 0), b indicates blueness ($b^*$< 0) or yellowness ($b^*$> 0) and ΔE indicates total colour change.

**Table 4.** Variation of texture parameters according to groups and storage period.

| Storage period† (days) | Groups (Mean± SD‡) | Texture parameters | | | |
|---|---|---|---|---|---|
| | | Hardness (N) | Stickiness | Elasticity | Chewability (kgf/mm) |
| 0 | Control | 5.24±1.37$^{ax}$ | 0.66±0.01$^{bx}$ | 2.04±0.43$^{ax}$ | 0.07±0.04$^{ax}$ |
| | 30W/5 min | 5.18±2.42$^{ax}$ | 0.07±0.03$^{abx}$ | 2.24±0.71$^{ax}$ | 0.10±0.08$^{ax}$ |
| | 30W/15 min | 6.23±2.61$^{abx}$ | 0.08±0.03$^{ax}$ | 2.37±0.31$^{ax}$ | 0.12±0.05$^{abx}$ |
| | 80W/5 min | 6.21±3.07$^{ax}$ | 0.08±0.04$^{ax}$ | 2.35±0.49$^{ax}$ | 0.11±0.08$^{ax}$ |
| | 80W/15 min | 4.57±1.72$^{abx}$ | 0.06±0.02$^{ax}$ | 2.03±0.63$^{ax}$ | 0.07±0.05$^{abx}$ |
| 3 | Control | 5.85±1.43$^{ax}$ | 0.08±0.03$^{bx}$ | 2.26±0.65$^{ax}$ | 0.13±0.11$^{ax}$ |
| | 30W/5 min | 4.80±2.71$^{ax}$ | 0.09±0.03$^{ax}$ | 2.29±0.42$^{ax}$ | 0.09±0.05$^{ax}$ |
| | 30W/15 min | 7.57±2.00$^{ax}$ | 0.07±0.03$^{abx}$ | 2.27±0.41$^{ax}$ | 0.13±0.10$^{ax}$ |
| | 80W/5 min | 6.14±1.76$^{ax}$ | 0.08±0.03$^{ax}$ | 2.28±0.48$^{ax}$ | 0.12±0.08$^{ax}$ |
| | 80W/15 min | 7.32±3.25$^{ax}$ | 0.07±0.01$^{ax}$ | 2.43±0.72$^{ax}$ | 0.14±0.10$^{ax}$ |
| 6 | Control | 4.43±1.00$^{ax}$ | 0.08±0.04$^{bx}$ | 2.05±0.35$^{ax}$ | 0.07±0.03$^{axy}$ |
| | 30W/5 min | 5.53±1.78$^{ax}$ | 0.07±0.03$^{abcx}$ | 2.19±0.41$^{ax}$ | 0.09±0.05$^{ax}$ |
| | 30W/15 min | 4.54±0.66$^{abx}$ | 0.06±0.02$^{abcxy}$ | 1.75±0.83$^{ax}$ | 0.06±0.02$^{abxy}$ |
| | 80W/5 min | 3.81±1.18$^{abx}$ | 0.02±0.00$^{by}$ | 0.08±0.02$^{by}$ | 0.03±0.01$^{ay}$ |
| | 80W/15 min | 4.92±0.93$^{abx}$ | 0.04±0.02$^{abxy}$ | 0.11±0.04$^{by}$ | 0.05±0.02$^{bxy}$ |
| 9 | Control | 4.91±0.82$^{ax}$ | 0.36±0.05$^{ax}$ | 0.08±0.04$^{bx}$ | 0.03±0.02$^{ax}$ |
| | 30W/5 min | 6.47±3.70$^{ax}$ | 0.02±0.01$^{cy}$ | 0.05±0.02$^{bx}$ | 0.03±0.01$^{ax}$ |
| | 30W/15 min | 4.99±1.99$^{abx}$ | 0.03±0.02$^{bcy}$ | 0.10±0.04$^{bx}$ | 0.04±0.02$^{abx}$ |
| | 80W/5 min | 6.08±1.54$^{ax}$ | 0.02±0.00$^{by}$ | 0.05±0.01$^{bx}$ | 0.03±0.01$^{ax}$ |
| | 80W/15 min | 5.23±1.29$^{abx}$ | 0.03±0.01$^{by}$ | 0.07±0.04$^{bx}$ | 0.04±0.02$^{bx}$ |
| 12 | Control | 4.40±1.08$^{ax}$ | 0.03±0.01$^{bx}$ | 0.09±0.03$^{bx}$ | 0.04±0.02$^{ax}$ |
| | 30W/5 min | 6.69±2.13$^{ax}$ | 0.03±0.02$^{bcx}$ | 0.05±0.02$^{bx}$ | 0.03±0.02$^{ax}$ |
| | 30W/15 min | 5.67±2.11$^{abx}$ | 0.03±0.01$^{bcx}$ | 0.07±0.02$^{bx}$ | 0.04±0.02$^{abx}$ |
| | 80W/5 min | 4.54±1.32$^{abx}$ | 0.03±0.01$^{bx}$ | 0.09±0.02$^{bx}$ | 0.04±0.01$^{ax}$ |
| | 80W/15 min | 3.89±0.86$^{bx}$ | 0.02±0.00$^{bx}$ | 0.08±0.01$^{bx}$ | 0.03±0.00$^{bx}$ |
| 15 | Control | 4.98±2.39$^{ax}$ | 0.02±0.01$^{bx}$ | 0.07±0.02$^{by}$ | 0.03±0.01$^{ax}$ |
| | 30W/5 min | 4.08±1.28$^{ax}$ | 0.02±0.00$^{cx}$ | 0.09±0.02$^{bxy}$ | 0.03±0.00$^{ax}$ |
| | 30W/15 min | 3.99±1.15$^{bx}$ | 0.02±0.01$^{cx}$ | 0.09±0.02$^{bxy}$ | 0.03±0.01$^{bx}$ |
| | 80W/5 min | 2.46±0.69$^{bx}$ | 0.02±0.00$^{bx}$ | 0.14±0.04$^{bx}$ | 0.03±0.01$^{ax}$ |
| | 80W/15 min | 3.87±1.78$^{bx}$ | 0.02±0.01$^{bx}$ | 0.08±0.03$^{by}$ | 0.03±0.02$^{bx}$ |

†Ultrasound application was applied with different power (30% and 80% W) and duration (5 to 15 minutes) not exceeding 5 ºC in deionized water and kept at 4±1 ºC during storage (0, 3, 6, 9, 12, and 15 days). ‡ Means with different (a-c) letters in the same column within the same storage day are statistically different ($p<0.05$; Tukey's HSD). Means with different (x-y) letters in the same column for the same group are statistically different ($p<0.05$; Tukey's HSD). The data represent mean± SD of the total 90 samples.

## 3.3. Sensory changes

While sensory parameters decreased in all groups dependent on storage, the highest values (odor, color, texture, and general evaluation) at the end of storage were determined in group 80W/15 min (Figure 1). The fastest change in odour evaluation (9.40-2.66) occurred in the control group. Odour change was observed between the control and 80W/15 min group from the 3rd day of storage ($p<0.05$).The change in the color parameter of the sensory analysis coincides with the total color change (ΔE) results of the instrumental color analysis. Initially, panelists gave close scores in terms of texture between treatment groups, but as storage progressed, the groups with higher power differed. While the parameter values of the sensory analysis decreased depending on storage, it was seen that it did not have a significant effect on the general evaluation.

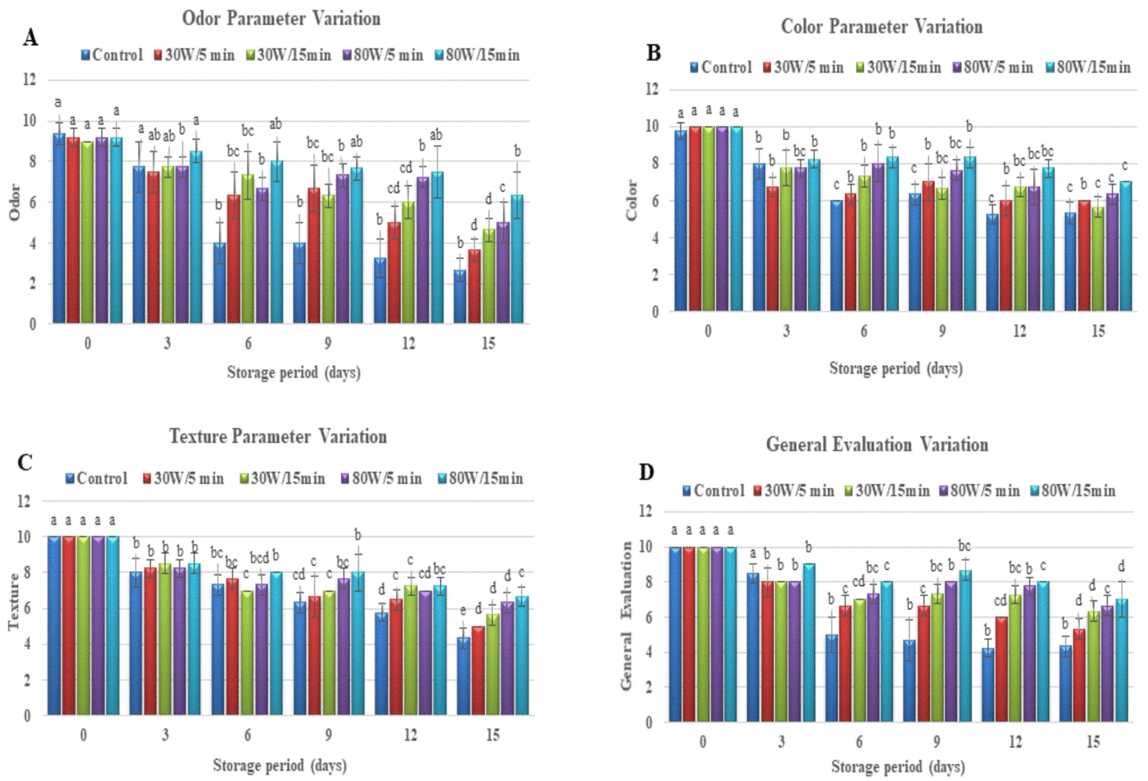


**Figure 1.** Changes in (A) odor, (B) color, (C) texture, and (D) general evaluation scores of sensory parameters according to ultrasound treatment groups during chilled storage of trout fillets. A ten-point range was used to detect sensory results (10-8, excellent; 7-5, good; and ≤4 not acceptable). The data represent the mean ± SD of a total of 90 samples. Different colored columns (groups) indicated by different letters (a-e) in the graph are significant ($p$<0.05; One-way ANOVA; Tukey's HSD).

### 3.4. Microbiological changes

The effect of ultrasound application showed an increase in TMAB counts during storage, but the acceptability limit of 7 log cfu/g was exceeded in all groups on the 9$^{th}$ day (Figure 2). The highest TMAB count was 8.34±0.12 log cfu/g in the 30W/5 min group on the 12$^{th}$ day. At the end of storage, the 80W/5 min (7.69±0.30 log cfu/g) and 80W/15 min (7.84±0.16 log cfu/g) groups showed the least change ($p$<0.05). The least effect of ultrasound application on TPAB counts in trout fillets was observed in the 30W/15 min (7.22±0.03 log cfu/g) group as of the 3$^{rd}$ day. However, it was observed that trout fillets in the 80W/5 min and 80W/15 min groups maintained their acceptability until the 9$^{th}$ day of storage (Figure 2). When the lactic acid bacteria counts were compared between the first day of the application and the 3$^{rd}$ day, a difference was found between the control group (2.03 log cfu/g), 30W/5 min (1.61 log cfu/g), 80W/5 min (1.72 log cfu/g), and 80W/15 min (1.53 log cfu/g), except for the 30W/15 min group. At the end of storage, the least increase was observed in the 80W/5 min (0.92 log cfu/g) group (Figure 2). Although the 80W/15 min group (3.80±0.05 log cfu/g), which had the lowest initial load in terms of Enterobacteriaceae, increased at the end of storage, it was still the group with the lowest load (Figure 2). *Pseudomonas* spp. counts in the samples increased during storage in all groups. The least change occurred in the 80W/15 min group (3.17±0.00 - 7.22±0.31 log cfu/g), followed by the 30W/5 min group (3.44±0.01 - 7.56±0.12 log cfu/g). At the end of storage, no difference was observed between the ultrasound treated groups.

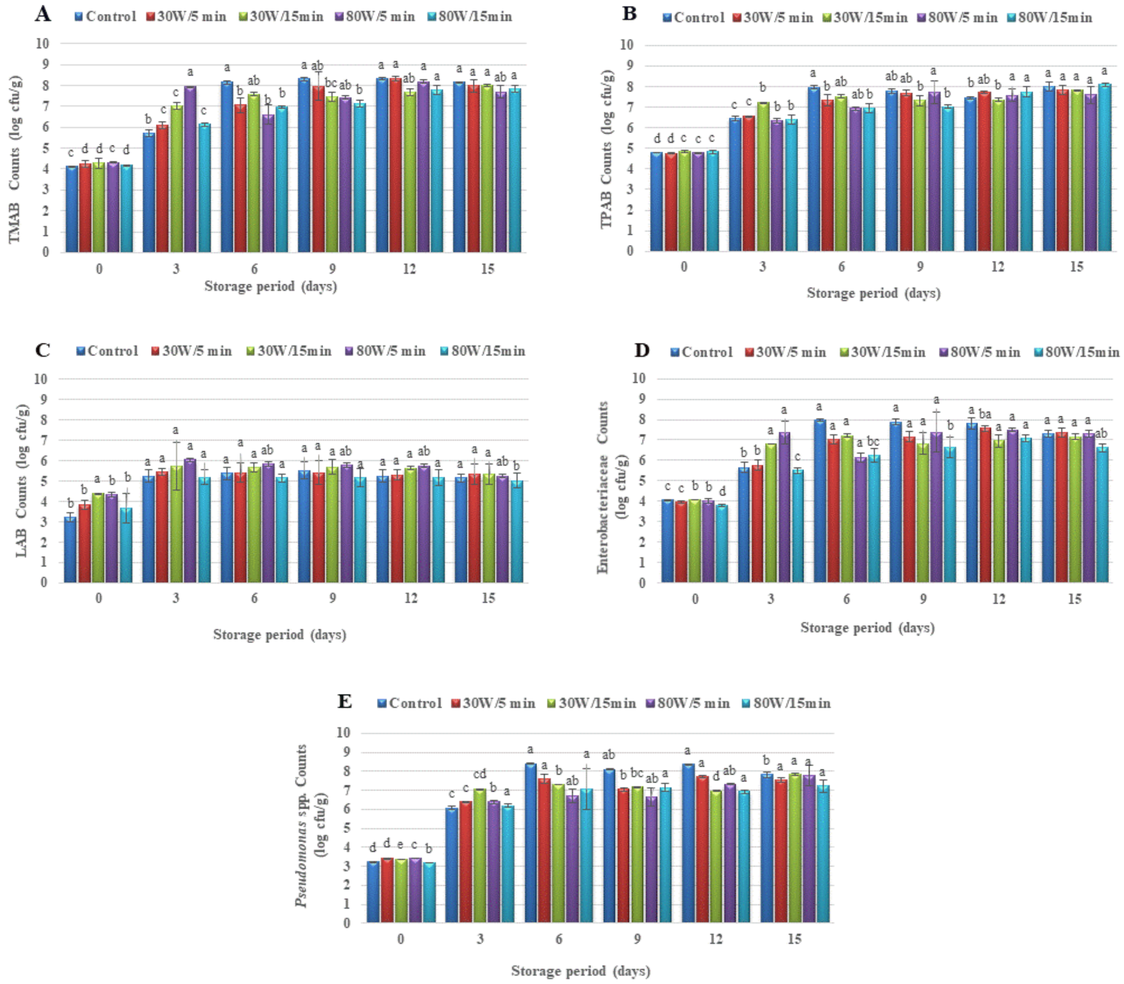


**Figure 2.**Changes in (A) Mesophilic, (B) Psychrophilic, (C) Lactic acid bacteria, (D) Enterobacteriaceae, (E) *Pseudomonas* spp. counts (log cfu/g) according to ultrasound treatment groups during chilled storage of trout fillets. The data represent the mean ± SD of a total of 90 samples. Different colored columns (groups) indicated by different letters (a-e) in the graph are significant ($p$<0.05; One-way ANOVA; Tukey's HSD).

## 4. DISCUSSION

### 4.1. Chemical changes

Although fish meat is a food with high nutritional value weak connective tissue structure in fish muscle, high enzyme activity, pH value, and water content make fish meat susceptible to spoilage (Özden and Gökoğlu, 1996). Moisture content and pH value in fish meat are the most important parameters for maintaining nutritional quality.

Recently, ultrasound has been combined with different food processing technologies and has become more widely used. Başlar, Kılıçlı and Yalınkılıç (2015) found that the drying time of salmon and trout fillets can be shortened with ultrasound assisted vacuum drying techniques. Ojha, Kerry, and Tiwari (2017) observed that the changes in water distribution in the dried beef samples were dependent on the frequency of the ultrasound effect. Grass carp (*Ctenopharyngodon idella*) samples were salted by ultrasound-treatment and then dried. It was showed that ultrasound can significantly increase the rate of water loss (Wang et al., 2018). Turhan, Sarıcaoğlu and Öz (2013) revealed that ultrasound-assisted marination accelerated moisture transport in anchovy (*Engraulis encrasicolus*) marinades. Ayvaz et al. (2019) applied ultrasound at different intensities to marinated vacuum anchovies and found that moisture content decreased depending on the intensity and storage. Moreover, the lowest moisture content in cooked ham was obtained with “0.75 salt + ultrasound” treatment (Barretto et al., 2018). Liu et al. (2023) reported that the moisture values decreased in the ultrasound application applied to ***Culter alburnus*** fillets for a fixed time (15 min.) with varying power compared to the control group and the lowest moisture value was determined at 150 W. The lowest moisture value in our study was observed in the 80W/15 min. group. It was determined that ultrasound application was effective in reducing the moisture content of vacuumed fresh trout fillets without using a different processing technology according to the application conditions and storage time. Both our and other studies confirm that ultrasound treatments support the reduction of moisture content in fish meat. It also prevented the increase of moisture content during storage and provided preserve food quality.

It was found that the pH change in two different cold-stored bovine muscles increased depending on storage time after ultrasound application (Jayasooriya et al., 2007). Our results coincide with the increase in pH in cold-stored trout fillets after ultrasound application. According to some researchers, applying ultrasound before rigor mortis can increase the initial pH of red meat (Got et al., 1999). It was observed that the short rigor period of fish meat compared to red meat slowed down the increase in pH value with ultrasound application. When the samples to which alkaline phosphate was added to increase the pH value in meat products were compared with the samples to which ultrasound was applied, the pH value was found to be higher in the ultrasound treated samples (Zhang et al., 2021). Alves et al. (2018) found that pH values varied between storage and ultrasound treatment time in Italian salami production. Similarly, the relationship between the power of ultrasound and application time was observed in our results. However, it was revealed that ultrasound treatment preserved the acceptability of trout fillets in cold storage.

**4.2. Physical changes**

Meat color is one of the most important sensory characteristics for consumers and producers. Some reports suggest that ultrasound does not affect meat color because the heat generated is insufficient to denature proteins and pigments (Sikes et al., 2014). On the contrary, in the evaluation of the effect of ultrasound (22 W/cm$^2$) on meat, it was observed that the color changed to lighter, less red, and more yellow-orange (Pohlman et al., 1997).

Ultrasound applied to fillets of different fish species without storage showed no change in all color values for mackerel (***Scomber scombrus***) and Atlantic cod (***Gadus morhua***). However, changes in yellowness, blueness, and green or red color values were observed in hake (***Merluccius merluccius***) and Atlantic salmon (***Salmo salar***) fillets (Pedros-Garrido et al. 2017). After the ultrasound treatment applied to the vacuumed ***Culter alburnus*** fillets, irregular changes were observed in L$^*$ and a$^*$ colour values according to the power, while b$^*$ colour value was observed as a decrease in all treatment groups (Liu et al., 2023). In pork products, such as Italian salami, ultrasound treatment was evaluated positively as it had no effect on both pigments and metmyoglobin (Alves et al., 2018). Jayasooriya et al. (2007) found that although there was no change in the color parameters of ***Semitendinosus*** and ***Longissimus*** muscles subjected to ultrasound at different times, all color parameters ($L^*$, $a^*$, and $b^*$) increased during storage at 5 $^o$C. In evaluation of color change in trout fillets at 4±1 $^o$C; only $L^*$ values showed an increase during storage. Among other color parameters, "$a^*$" values at the end of storage and "$b^*$" values during storage showed irregular changes. The difference in the muscle structure of red meat shows that the effect of ultrasound application on color change is observable. Our results show that there is no storage-related difference in the treatment groups, and the existing color of light colored fish meat can be preserved.

Meat quality depends on aroma, flavor, appearance, tenderness, and juiciness. Consumer behavior has shown that tenderness is the most important palatability factor in determining meat quality (Smith et al., 1991). Numerous studies have been conducted to develop methods to improve meat tenderness. Among these, ultrasound application methods have been used at various sonication times (33 seconds to 90 minutes), frequencies (15 to 130 kHz) and intensities (1.89 to 64 W/cm$^2$). Most researchers agree that ultrasound improves meat tenderness (Peña-González et al., 2017; Wang et al., 2018; Zou et al., 2018).

Vacuum packed sardine fish (*Sardina pilchardus* W.) fillets subjected to ultrasound and stored at 4 $^{\circ}$C showed a decrease in chewing value and hardness (Gündüz et al., 2019). Li et al. (2015) determined that the hardness of the tissue decreased with an increase in the duration of ultrasound applied to chicken breast meat. Changes in texture parameters of raw shrimp (***Penaeus vannamei***) were observed to vary with increasing duration of ultrasound applied a$^{\circ}$C and 50 $^{\circ}$C (Li et al., 2011). Zou et al. (2018) found that the hardness, elasticity, and chewiness values of spiced beef with ultrasound power-assisted cooking decreased with increasing power and cooking time. The ultrasound treatment of *Culter alburnus* fillets without storage with different powers (100, 150, 200, 250, 300 W) showed that the 250 W and 300 W treatment groups exhibited the highest hardness and the 250 W group exhibited the greatest gumminess and chewiness (Liu et al., 2023). In the texture profile analysis of trout fillets, it was observed that hardness, elasticity and chewability parameters increased in the 30W/15 min. group, while stickiness decreased in all treatment groups. Wang et al. (2018) determined that hardness decreased and flexibility values increased with an increase in ultrasound power applied to grass carp (*Ctenopharyngodon idella*) samples without storage. When the texture parameters (hardness, stickiness, elasticity, and chewability) of trout fillets were analyzed with storage, it was observed that although each parameter changed during the process in the groups, it decreased at the end of storage. Results of this and other studies suggest that different temperatures during ultrasound application, application time, and muscle structure have a determining effect on the shaping of the texture profile.

**4.3. Sensory changes**

Sensory analysis is considered as the main and most important method for evaluating the freshness of fishery products (Huss, 1995). In addition, sensory methods are used to monitor changes in foods during storage.

Peña-González et al. (2017) concluded that ultrasound treatment of beef significantly reduced the ripening time while maintaining the sensory characteristics of the meat. Yeung and Huang (2017) applied similar ultrasound application conditions to trout fillets and pork fillets at different power and duration, and it was determined that the samples accepted in the general evaluation section were in the treatment groups with high power and duration. Peña-González et al. (2019) stated that after 14 days of storage of beef samples treated with ultrasound, the lipid oxidation increased, the shearing force decreased, and the processed meat was more tender and juicy. Our results showed that although the scores of sensory parameters of trout fillets decreased depending on storage, it did not affect the scores of general evaluation. Ultrasound-assisted marinating of beef showed a more homogeneous distribution of mass transfer and improved meat acceptability in sensory analysis (González-González et al., 2017). Ayvaz et al. (2019) found that ultrasound application had positive effects on the color and texture characteristics of marinated anchovy (*E. encrasicolus*) and was appreciated by panelists. Ultrasound application alone supports the general acceptance of sensory parameters in the cold storage of fresh trout.

Barretto et al. (2018) emphasized that ultrasound treatment improved taste, texture, and overall acceptance of the product in the sensory analysis of low-sodium cooked ham subjected to ultrasound. Moreover, Pinton et al. (2019) indicated that ultrasound treatment could efficiently increase the scores of sensorial parameters (such as color, texture, and overall acceptance) of reduced-phosphate emulsified meat products. It was showed that ultrasound treatment has positive effects on the preservation and improvement of sensory properties. Ultrasound treatment supports the acceptability of fish meat by consumers.

**4.4. Microbiological changes**

The mechanism by which ultrasound inactivates microorganisms is explained by the heat and pressure released by acoustic cavitation, which destroys the functional components and structure of the cell and disintegrates the cell (Piyasena et al., 2003).

Caraveo et al. (2015) determined that the number of TMAB and TPAB decreased depending on the application time in the microbiological analysis of beef stored at 4 $^{\circ}$C after high-intensity ultrasound application. When the inactivation of *Listeria innocua* and mesophilic bacteria in milk by heat and ultrasonic treatment was compared, it was found that the inactivation rate was higher in ultrasonic treatment (Bermudez-Aguirre et al., 2010). Contrary to the previous studies, ultrasound application showed an increase in the number of TMAB in trout fillets, and only the 80W/15 min group was able to maintain its consumability until the 9$^{th}$ day.

Maximum reduction in bacterial groups (TMAB, TPAB and Enterobacteriaceae) was observed with ultrasound applied to fillets of different fish species and without storage, while differences were detected in the numbers of *Pseudomonas* sp. (Pedrós-Garrido et al., 2017). Chouliara et al. (2010) found a decrease of 1.0-2.1 log cfu/g in total bacteria and psychrophilic bacteria counts in ultrasound-treated raw milk, thermized milk, and pasteurized milk up to 6$^{th}$ day in cold storage. TPAB counts increased in trout fillets depending on storage, and the increase was determined to be 2.82-3.26 log cfu/g at the end of storage.

Kordowska-Wiater and Stasiak (2011) contaminated the surface of chicken wing skin with strains of gram-negative bacteria (*Salmonella enterica* subsp., *enterica* sv. *anatum, Escherichia coli, Proteus* sp., and *Pseudomonas fluorescens*) and applied ultrasound treatment in water and 1% aqueous lactic acid solution, concluding that the reduction in bacteria depended on the treatment time and type of liquid. *P. fluorescens* was found to be the most sensitive bacterium to “1% aqueous lactic acid solution + ultrasound” treatment. Herceg et al. (2012) found that gram-negative bacteria (*E. coli*) were more sensitive than gram-positive bacteria (*Staphylococcus aureus*) as a result of ultrasound application in raw milk. Different types of microorganisms have different membrane structures. For example, gram positive and gram negative bacteria do not show the same behavior towards ultrasonic waves due to their different cell and membrane structures (Piyasena et al., 2003). In our results showed that gram-negative bacteria Enterobacteriaceae and *Pseudomonas* spp. provided more microbial inactivation in trout fillets compared to other bacterial species.

It is revealed that the effect of ultrasound applications on microorganisms varies according to the material structure, processing method, bacterial species, packaging and storage status, and conditions (duration and temperature) other than the parameters of ultrasound (power, intensity, and duration). All these results provide the basis for further studies on the use of ultrasound for the processing and preservation of aquatic products.

## 5. CONCLUSION

Ultrasound waves did not affect all quality criteria for fish meat to the same extent. While changes were observed in moisture and pH values depending on storage, color and texture values remained more stable. In the sensory evaluation, it was observed that general acceptability came to the forefront in the ultrasound treated groups. It was determined that microbiological changes occurred differently according to bacterial species. In the ultrasound application groups where the power was 80% W, it was observed that the application was more effective by means of moisture, general evaluation, and Enterobacteriaceae and *Pseudomonas* spp. numbers. It was concluded that when the power and duration of ultrasound applications are optimized by repeating in different ways, it can be one of the methods that can be used to protect the safety and quality of fish meat.

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## CONFLICT OF INTEREST STATEMENT

The authors declare that there are no financial interests or personal relationships that may influence this study.

## AUTHOR CONTRIBUTIONS

Fiction: ÇO; Methodology: ÇO,AD; Conduct of the experiment: ÇO; Data analysis: ÇO, AD; Manuscript writing: ÇO; Editing: AD .All authors approved the final manuscript.

## ETHICAL APPROVAL STATEMENT

Since experimental animals were not used in this study, Local Ethics Committee Approval was not obtained.

## DECLARATION OF DATA USABILITY

The data used in this study are available on the Figshare platform with the DOI address https://doi.org/10.6084/m9.figshare.11815566.v1.

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Zhang, F., Zhao, H., & Cao, C. (2021). Application of temperature-controlled ultrasound treatment and its potential to reduce phosphate content in frankfurter-type sausages by 50%. Ultrasonics Sonochemistry, 71, 105379. https://doi.org/10.1016/j.ultsonch.2020.105379

Zou, Y., Zhang, W., Kang, D. & Zhou, G. (2018). Improvement of tenderness and water holding capacity of spiced beef by the application of ultrasound during cooking. International Journal of Food Science and Technology, 53, 828-836. https://doi.org/10.1111/ijfs.13659

# Acta Aquatica Turcica

(e-ISSN: 2651-5474)

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**PAGE SIZE**
Page should be A4 (21 cm x 29.7 cm) size.

**MARGINS**

Top: 2.5 cm Right: 2.5 cm Left: 2.5 cm Bottom: 2.5 cm Gutter: 0 cm

**TEXT FORMATING**

| | |
|---|---|
| Font | : Times New Roman |
| Font size | : 12-point |
| Alignment | : Justified |
| Indent | : 1.25 cm |
| Line spacing | : 2 |
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**TITLE PAGE**
The title page should be uploaded to the system separately from the manuscript file. The title page should contain only the following information.

***- Title***
Title should be brief and informative reflecting the study. Abbreviations and formulae usage is not recommended.

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A short (running) title with a maximum of 75 characters should be given to reflect the title.

***- Authors names***
Name and surnames of the authors should be indicated clearly. Accuracy of the names spelling should be checked before submission.

***- Institution***
Format used: University/Institution, Faculty, Department, Province-COUNTRY
Example: Isparta University of Applied Sciences, Eğirdir Fisheries Faculty, Department of Aquaculture, Isparta-TURKEY

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ORCID's of the authors should be identified. Please visit https://orcid.org to register an ORCID.

**MANUSCRIPT FORMAT**
Manuscripts in original articles, short communication, case report and reviews should be prepared in accordance with the format below*.

<table>
<tr><th>Original Article</th><th>Short Communication</th><th>Case Report</th><th>Review Article</th></tr>
<tr><td colspan="4">Title<br>Short title<br>Authors<br>Institutions<br>Corresponding author e-mail<br>ORCID’s of the authors</td></tr>
<tr><td colspan="4">Title<br>Abstract<br>Keywords</td></tr>
<tr><td colspan="4">Turkish title*<br>Turkish abstract*<br>Turkish keywords*</td></tr>
<tr><td colspan="4">1. Introduction</td></tr>
<tr><td>2. Material and Methods<br>3. Results</td><td>2. FREE CONTENT</td><td>2. Case Report</td><td>2. FREE CONTENT</td></tr>
<tr><td>4. Discussion</td><td colspan="3">3. Discussion</td></tr>
<tr><td>5. Conclusion</td><td colspan="3">4. Conclusion</td></tr>
<tr><td colspan="4">Acknowledgement<br>Funding<br>Conflict of Interest<br>Author Contributions<br>Ethical Statements<br>Data Availability Statement<br>References</td></tr>
</table>

* **Note**: Turkish title, abstract and keywords supports are provided for non-Turkish authors.

**ABSTRACT**

Abstract should concisely contain the purpose of the study, the methods used, the prominent findings, and its contribution to the literature. It should be written both in Turkish and English with a maximum of 300 words.

**KEYWORDS**

Keywords should be chosen from words that are not included in the title and reflect the study. At least 3 (three), maximum 5 (five) keywords should be specified. There should be a comma (,) between words and a dot (.) after the last word.

*Keywords:* CITES, aquaponics, production protocol, mortality, immunology.

**DECIMAL NUMBERS**

Comma “,” should be used in Turkish manuscripts and dot “.” should be used in English manuscripts.

Turkish: %10,25

English: 10.25%

**SCIENTIFIC NAMES**

The species name should be given without abbreviation (Cyprinus carpio) in the first place in the text, and then the genus name should be abbreviated (C. carpio).

**TABLES**

The table title should be positioned above the table and should be written concisely. Abbreviations used in the table should be explained below the table. The table must be in the form of a straight guide, with no special design applied. Authors are encouraged to convey the table contents to the reader in the table footer, independently of the article. Font size for footers should be 10 points. Tables should be cited in the text as Table 1, Table 2, etc. The tables should be given in the nearest place where it cited. Tables must be editable. Tables in screenshot or picture format are not accepted.

**FIGURES**
The figure title should be short and concise, centered at the bottom of the figure. Figures should have a minimum resolution of 300 DPI. Figures should be cited in the text as Figure 1, Figure 2, etc. The figures should be given in the nearest place where it cited.

**ACKNOWLEDGEMENT**
In this section, those who help to the conduct the study apart from financial support, are indicated.

Example: The authors thank Ahmet Taş (Isparta University of Applied Sciences, Turkey) for his helps during the laboratory part of the study.

**FUNDING**
In this section, institutions that provide financial support to the conduct of the study are indicated using the grant number.

Example-1: This study was supported by the Scientific Research Projects Coordination Unit of Isparta University of Applied Sciences grant 3241-E2-14.

Example-2: No financial support was received for the present study.

**CONFLICT OF INTEREST**
Conflicts of interest of the author(s), if any, are indicated in this section.

Example: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**AUTHOR CONTRIBUTIONS**
The contributions of each author to the relevant stages of the study are indicated by using each work package and the first letters of the name and surname.

Example:
Fiction: IT; Literature: KL, TN; Methodology: CT, FU; Performing the experiment: FM, CT, FU; Data analysis: FU, TA; Manuscript writing: CT, FU, Supervision: CT. All authors approved the final draft.

**ETHICAL APPROVAL STATEMENTS**
The ethics committee approvals obtained for the study are indicated with information of institute, date, and number. Manuscripts that are not declare, although they require the Local Ethics Committee Approval in studies conducted with vertebrates, and the Approval for Ethics Committee Approval of Non-Interventional Investigates in survey/interview studies will not be considered for scientific evaluation.

Example-1: Local Ethics Committee Approval was not obtained because experimental animals were not used in this study.

Example-2: This study was conducted with the approval of Animal Experiments Local Ethics Committee of Isparta University of Applied Sciences (Date: 01.07.2010, No: 21438139-147).

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In this section, data availability statement should be declared by the authors regarding the anonymous availability of the data used in the manuscript. Acta Aquatica Turcica encourages authors to share research data used.

Example-1: The data that support the findings of this study are openly available in Figshare at https://doi.org/10.6084/m9.figshare.11815566.v1

Example-2: The data used in the present study are available upon request from the corresponding author. Data is not available to the public due to privacy or ethical restrictions.

Example-3: Data supporting the findings of the present study are available from the corresponding author upon reasonable request.

Example-4: Data sharing is not applicable for the present study as no new data was created or analyzed.

Example-5: Research data is not shared.

Example-6: Data supporting the findings of the present study are available in the supplementary material to this article.

**CITATIONS**

Citations are written in the following formats, in the order of the year, separated by a semicolon (;).

- Single author

(Author, Year)

-- It is thought to be … (Küçük, 2008; Güçlü, 2018a; Güçlü, 2018b).

-- According to Küçük (2008), …

- Two authors

(Author-1 and Author-2, Year)

-- They are among the important parameters (Küçük and Güçlü; 2001; Ekici and Koca, 2021a; Ekici and Koca, 2021b).

-- According to Ekici and Koca (2021b),…

- Three or more authors

(Author-1 et al., Year)

-- It can be repeated periodically (Yiğit et al., 2006a; Yiğit et al., 2006b; Boyacı et al., 2020).

-- According to Boyacı et al. (2020),…

**REFERENCES LIST**

References should be indented 1.25 cm from the second line and should prepared according to APA version 7. Ideally, the names of all authors should be provided. Usage of "et al" in long author lists (more than 10) will also be accepted. Except for special uses, only the first letter of the title of all references should be capitalized, and all words in the names of the sources (journal, publishing house and congress) should be written with a capital letter.

***1-Journal articles***

The name of the journal (italic) without shortening, volume (italic), issue, page numbers and DOI number having an active link should be specified.

Petrauskienė, L., Utevska, O., & Utevsky, S. (2009). Can different species of medicinal leeches (Hirudo spp.) interbreed? Invertebrate Biology, 128(4), 324-331. https://doi.org/10.1111/j.1744-7410.2009.00180.x

Wagenaar, D. A., Hamilton, M. S., Huang, T., Kristan, W. B., & French, K. A. (2010). A hormone-activated central pattern generator for courtship. Current Biology, 20(6), 487-495. https://doi.org/10.1016/j.cub.2010.02.027

***2-Book***

The title of book should be written in italic, and it should be followed with Publisher information.

Nesemann, H., & Neubert, E. (1999). Annelida, Clitellata: Branchiobdellida, Acanthobdellea, Hirudinea. Spektrum Akademischer Verlag.

Sawyer, R. T. (1986). Leech biology and behavior. Oxford University Press.

***3-Book section***

The title of the chapter should be normal, the title of the book should be in italic, the editor(s), the page numbers of the section, the publisher and the DOI number (if available) having active link should be included.

Le Couteur, D., Kendig, H., Naganathan, V., & McLachlan, A. (2010). The ethics of prescribing medications to older people. In S. Koch, F. M. Gloth, & R. Nay (Eds.), Medication management in older adults (pp. 29-42). Springer. https://doi.org/10.1007/978-1-60327-457-9_3

McCormack, B., McCance, T., & Maben, J. (2013). Outcome evaluation in the development of person-centred practice. In B. McCormack, K. Manley, & A. Titchen (Eds.), Practice development in nursing and healthcare (pp. 190-211). John Wiley & Sons.

***4-Web pages / Online documents***
The title of the page should be in italic, the name of the website and the active link to the page should be specified.

International Union for Conservation of Nature. (2010). Chondrostoma nasus. https://www.iucnredlist.org/species/4789/97800985

Wikipedia. (2021). Toxicology. https://en.wikipedia.org/wiki/Toxicology

***5-Dissertations/Thesis***
The title of the dissertation/thesis should be in italic, its type (Doctoral, Master's, Specialization in Medicine) and the name of the university should be specified.

Filik, N. (2020). Inhibition effect of phenolic compounds on the environmental sensing system of Aeromonas hydrophila strains isolated from cultured fish and determination of the clonal relationship between strains by pulsed field gel electrophoresis method. [Doctoral dissertation, Isparta University of Applied Sciences].

Ozdal, A. M. (2019). Effects on growth and coloration of red pepper supplementation as pigment sources to diets of jewel cichlid (Hemichromis guttatus). [Master's thesis, Isparta University of Applied Sciences].

***6-Conference, symposium presentations***
Event date, presentation title (italic), presentation type (Oral presentation, Poster presentation), event name, city and country should be given.

Ceylan, M., Çetinkaya, O. (2017, October 4 - 6). Assessment of population structure and size of medicinal leech Hirudo verbana, inhabiting some model wetlands of Turkey [Oral Presentation]. International Symposium on Limnology and Freshwater Fisheries, Isparta, Turkey.

Snoswell, C. (2016, October 31 - November 3). Models of care for store-and-forward teledermatology in Australia [Poster presentation]. 7th International Conference on Successes and Failures in Telehealth, Auckland, New Zealand.

**NOTE:** Manuscripts that are not prepared in accordance with the journal writing rules will not be considered for scientific evaluation.

# Yazım Kuralları

**SAYFA BOYUTU**
Sayfa A4 (21 cm x 29,7 cm) formatında olmalıdır.

**KENAR BOŞLUKLARI**
Üst: 2,5 cm Sol: 2,5 cm Alt: 2,5 cm Sağ: 2,5 cm Cilt payı: 0 cm

**YAZI STİLİ**
Yazı karakteri : Times New Roman
Yazı karakteri büyüklüğü : 12 punto
Paragraf : İki yana yaslı
Paragraf girintisi : 1,25 cm
Satır aralığı : 2
Satır numarası : Metnin tümünde satır numarası atanmalıdır
Sayfa numarası : Sayfaların altına gelecek şekilde otomatik numaralanmış

**BAŞLIK SAYFASI**
Başlık sayfası, makale dosyasından ayrı olarak sisteme yüklenmelidir. Başlık sayfasında sadece aşağıdaki bilgiler yer almalıdır.

***- Başlık***
Başlık kısa, bilgilendirici ve çalışmayı net olarak yansıtmalıdır. Kısaltma ve formül kullanımı önerilmez.

***- Kısa başlık***
Başlığı yansıtacak şekilde maksimum 75 karakterde kısa bir başlık verilmelidir.

***- Yazarlar***
Yazarların ad ve soyadları kısaltılmadan açık olarak yazılmalıdır. Makale yüklenmeden önce yazar isimlerinin doğruluğu kontrol edilmelidir.

***- Kurum bilgisi***
Kullanılan düzen: Üniversite/Enstitü, Fakülte, Bölüm, İl-ÜLKE
Örnek: Isparta Uygulamalı Bilimler Üniversitesi, Eğirdir Su Ürünleri Fakültesi, Su Ürünleri Yetiştiriciliği Bölümü, Isparta-TÜRKİYE

***- Sorumlu yazar***
Makalenin tüm aşamalarından sorumlu olacak sorumlu yazar belirtilmelidir. Başlık sayfasında sorumlu yazarın iletişim bilgileri ve posta adresi verilmelidir.
*Sorumlu Yazar: Adı Soyadı, e-posta: …

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Tüm yazarların ORCID bilgileri belirtilmelidir. Lütfen ORCID tanımlaması yapmak için https://orcid.org adresini ziyaret ediniz.

**MAKALE FORMATI**
Araştırma makalesi, kısa makale, olgu sunumu ve derlemeler aşağıdaki formata uygun olarak hazırlanmalıdır.

<table>
<tr><th>Araştırma Makalesi</th><th>Kısa Makale</th><th>Olgu Sunumu</th><th>Derleme</th></tr>
<tr><td colspan="4">Başlık<br>Kısa başlık<br>Yazarlar<br>Kurum bilgileri<br>Sorumlu yazar e-posta adresi<br>ORCID bilgileri</td></tr>
<tr><td colspan="4">Başlık<br>Özet<br>Anahtar kelimeler</td></tr>
<tr><td colspan="4">Title<br>Abstract<br>Keywords</td></tr>
<tr><td colspan="4">1. Giriş</td></tr>
<tr><td rowspan="2">2. Materyal ve Metot<br>3. Bulgular<br>4. Tartışma<br>5. Sonuç</td><td>2. SERBEST İÇEREİK</td><td>2. Olgu Sunumu</td><td>2. SERBEST İÇEREİK</td></tr>
<tr><td colspan="3">3. Tartışma<br>4. Sonuç</td></tr>
<tr><td colspan="4">Teşekkür<br>Finans<br>Çıkar Çatışması Beyanı<br>Yazar Katkıları<br>Etik Onay Beyanı<br>Veri Kullanılabilirlik Beyanı<br>Kaynaklar</td></tr>
</table>

**ÖZET**

Özet, çalışmanın amacını, kullanılan metotları, öne çıkan bulguları ve literatüre katkısını öz bir şekilde içermelidir. Hem Türkçe hem de İngilizce dillerinde maksimum 300 kelime olacak şekilde yazılmalıdır.
Not: Türk olmayan yazalar için Türkçe Özet desteği sağlanmaktadır.

**ANAHTAR KELİMELER**

Anahtar kelimeler başlıkta yer almayan, çalışmayı yansıtacak kelimelerden seçilmelidir. En az 3 (üç), en çok 5 (beş) kelime belirtilmeli; kelimeler aralarında virgül (,) son kelimeden sonra ise nokta (.) gelmelidir.
Anahtar kelimeler: CITES, akuaponik, üretim protokolü, mortalite, immünoloji.

**ONDALIK GÖSTERİM**

Türkçe makalelerde “,” (virgül) İngilizce makalelerde ise “.” (nokta) olmalıdır.
Türkçe: %10,25
İngilizce: 10.25%

**LATİNCE GÖSTERİM**

Tür ismi, metinde ilk geçtiği yerde kısaltılmadan (Cyprinus carpio), sonrasında ise cinsi ismi kısaltılarak (C. carpio) verilmelidir.

**TABLOLAR**

Tablo başlığı, tablonun üstüne gelecek şekilde kısa ve öz olmalıdır. Tabloda yer alan kısaltmalar tablonun altında açıklanmalıdır. Tablo özel bir tasarım uygulanmamış, düz kılavuz şeklinde olmalıdır. İhtiyaç bulunması halinde tablo içi metinde yazı karakteri büyüklüğü 10 puntoya kadar düşürülebilir. Tablolara metin içinde Tablo 1, Tablo 2, … şeklinde atıf yapılmalıdır. Tablolar, alıntılandıkları yere en yakın yerde verilmelidir.

Tablolar düzenlenebilir olmalıdır. Ekran görüntüsü veya resim formatındaki tablolar kabul edilmemektedir.

**ŞEKİLLER**
Şekil başlığı, şeklin altına ortalanmış olarak kısa ve öz olmalıdır. Şekiller minimum 300 DPI çözünürlükte olmalıdır. Şekillere metin içinde Şekil 1, Şekil 2, … şeklinde atıf yapılmalıdır. Şekiller, alıntılandıkları yere en yakın yerde verilmelidir.

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Bu bölümde finansal destek dışında çalışmanın yürütülmesine katkı sunanlar belirtilir.

Örnek: Yazarlar çalışmanın laboratuvar bölümünde yardım eden Ahmet Taş'a (Isparta Uygulamalı Bilimler Üniversitesi, Türkiye) teşekkür etmektedir.

**FİNANS**
Bu bölümde çalışmanın yürütülmesine finansal destek sağlayan kurumlar destek numarası kullanılarak belirtilir.

Örnek-1: Bu çalışma 3241-E2-14 proje numarası ile Isparta Uygulamalı Bilimler Üniversitesi Bilimsel Araştırma Projeleri Koordinasyon Birimi tarafından desteklenmiştir.

Örnek-2: Bu çalışmanın yürütülmesinde herhangi bir finans desteği alınmamıştır.

**ÇIKAR ÇATIŞMASI BEYANI**
Bu bölümde yazarların varsa çıkar çatışmaları belirtilir.

Örnek: Yazarlar, bu çalışmayı etkileyebilecek finansal çıkarlar veya kişisel ilişkiler olmadığını beyan eder.

**YAZAR KATKILARI**
Bu bölümde isim ve soy ismin ilk harfleri kullanılarak yazarların çalışmanın ilgili aşamalarına yaptıkları katkılar belirtilir.

Örnek:
Kurgu: BT; Metodoloji: CT, FU; Deneyin gerçekleştirilmesi: FM, CT, FU; Veri analizi: FU, TA; Makale yazımı: CT, FU, Denetleme: CT. Tüm yazarlar nihai taslağı onaylamıştır.

**ETİK ONAY BEYANI**
Bu bölümde çalışmanın yürütülmesinde alınan etik kurul onayının alındığı kurum, tarih ve numarası belirtilir. Omurgalı hayvanlarla yürütülen çalışmalarda Yerel Etik Kurul Onayı, anket/mülakat çalışmalarında ise Girişimsel Olmayan Araştırmalar Etik Kurulu Onayı gerektirdiği halde beyan edilmeyen makaleler bilimsel değerlendirmeye alınmamaktadır.

Örnek-1: Bu çalışmada deney hayvanları kullanılmaması nedeniyle Yerel Etik Kurul Onayı alınmamıştır.

Örnek-2: Bu çalışma Isparta Uygulamalı Bilimler Üniversitesi Hayvan Deneyleri Yerel Etik Kurul onayı ile yürütülmüştür (Tarih: 01.07.2010, No: 21438139-147).

**VERİ KULLANILABİLİRLİK BEYANI**
Bu bölümde makalede kullanılan verilerin anonim kullanılabilirliğine ilişkin beyanda bulunulmalıdır. Acta Aquatica Turcica dergisi, yazarları araştırma verilerini paylaşmaya teşvik etmektedir.

Örnek-1: Bu çalışmada kullanılan veriler Figshare platformunda ttps://doi.org/10.6084/m9.figshare.11815566.v1 DOI adresi ile erişime açıktır.

Örnek-2: Bu çalışmada kullanılan verilere ilgili yazardan talep üzerine erişilebilir. Veriler, gizlilik veya etik kısıtlamalar nedeniyle kamuya açık değildir.

Örnek-3: Bu çalışmada kullanılan veriler makul talep üzerine ilgili yazardan temin edilebilir.

Örnek-4: Bu çalışmada yeni veri oluşturulmadığı veya analiz edilmediği için veri paylaşımı bu makale için geçerli değildir.

Örnek-5: Araştırma verileri paylaşılmaz.

Örnek-6: Bu çalışmada kullanılan veriler bu makalenin ekinde mevcuttur.

**ATIFLAR**

Atıflar yıl sırasına göre ve aralarında noktalı virgül (;) olacak şekilde aşağıdaki formatlarda yazılır:

- Tek yazar:
(Yazar, yıl)
-- … olduğu düşünülmektedir (Küçük, 2008; Güçlü, 2018a; Güçlü, 2018b).
-- Küçük (2008)'e göre …

- İki yazar:
(Yazar-1 ve Yazar-2, yıl)
-- … önemli parametreler arasında yer almaktadır (Küçük ve Güçlü; 2001; Ekici ve Koca, 2021a; Ekici ve Koca, 2021b).
-- Ekici ve Koca (2021b)'a göre …

- Üç ve daha çok yazar:
(Yazar vd., yıl)
-- … dönemsel olarak tekrarlayabilmektedir (Yiğit vd., 2006a; Yiğit vd., 2006b; Boyacı vd., 2020)
-- Boyacı vd. (2020)'e göre …

**KAYNAKLAR**

Kaynaklar APA 7. versiyona göre yazılmalıdır. Tüm yazarların isimleri verilmelidir, ancak 10. yazardan sonra "vd." kısaltması da kabul edilmektedir. Özel kullanımlar hariç olmak üzere tüm eser türlerinde eser isminin sadece ilk harfi büyük, eserin yayınlandığı veya sunulduğu dergi, yayınevi, kongre isimlerinde geçen tüm kelimeler büyük harfle başlanarak yazılmalıdır.

***1-Makale***

Dergi ismi kısaltılmadan (italik), cilt (italik), sayı, sayfa numaraları ve aktif link içerecek şekilde DOI numarasına yer verilmelidir:

Petrauskienė, L., Utevska, O., & Utevsky, S. (2009). Can different species of medicinal leeches (Hirudo spp.) interbreed? Invertebrate Biology, 128(4), 324-331. https://doi.org/10.1111/j.1744-7410.2009.00180.x

Wagenaar, D. A., Hamilton, M. S., Huang, T., Kristan, W. B., & French, K. A. (2010). A hormone-activated central pattern generator for courtship. Current Biology, 20(6), 487-495. https://doi.org/10.1016/j.cub.2010.02.027

***2-Kitap***

Kitap başlığı italik olacak şekilde ve yayın kuruluş ismi olacak şekilde verilmelidir.

Nesemann, H., & Neubert, E. (1999). Annelida, Clitellata: Branchiobdellida, Acanthobdellea, Hirudinea. Spektrum Akademischer Verlag.

Sawyer, R. T. (1986). Leech biology and behavior. Oxford University Press.

***3-Kitap bölümü***

Bölüm başlığı normal, kitap başlığı italik olacak şekilde, editör(ler), bölümün sayfa numaraları, yayıncı kuruluş ve varsa aktif link içerek şekilde DOI numarasına yer verilmelidir:

Le Couteur, D., Kendig, H., Naganathan, V., & McLachlan, A. (2010). The ethics of prescribing medications to older people. In S. Koch, F. M. Gloth, & R. Nay (Eds.), Medication management in older adults (pp. 29-42). Springer. https://doi.org/10.1007/978-1-60327-457-9_3

McCormack, B., McCance, T., & Maben, J. (2013). Outcome evaluation in the development of person-centred practice. In B. McCormack, K. Manley, & A. Titchen (Eds.), Practice development in nursing and healthcare (pp. 190-211). John Wiley & Sons.

***4-Web sitesi***

Sayfa başlığı italik, websitesinin ismi ve sayfanın aktif linki olacak şekilde verilmelidir.

International Union for Conservation of Nature. (2010). Chondrostoma nasus. https://www.iucnredlist.org/species/4789/97800985

Wikipedia. (2021). Toxicology. https://en.wikipedia.org/wiki/Toxicology

***5- Tezler***

Tez başlığı italik olacak şekilde, tez türü (Doktora, Yüksek lisans, Tıpta Uzmanlık) ve üniversite ismi belirtilmelidir.

Filik, N. (2020). Kültür balıklarından izole edilen Aeromonas hydrophila suşlarında fenolik bileşenlerin çevreyi algılama sistemi üzerine inhibisyon etkisi ve suşlar arasındaki klonal ilişkinin pulsed field jel elektroforez yöntemiyle belirlenmesi [Doktora tezi, Isparta Uygulamalı Bilimler Üniversitesi].

Özdal, A. M. (2019). Effects on growth and coloration of red pepper suplementation as pigment sources to diets of jewel cichlid (Hemichromis guttatus) [Yüksek lisans tezi, Isparta Uygulamalı Bilimler Üniversitesi].

***6- Konferans, sempozyum sunumları***

Etkinlik tarihi, sunu başlığı (italik), sunum türü (Sözlü sunum, Poster sunum), etkinlik adı, şehir ve ülke verilmelidir.

Ceylan, M., Çetinkaya, O. (2017, Ekim 4 - 6). Assessment of population structure and size of medicinal leech Hirudo verbana, inhabiting some model wetlands of Turkey [Sözlü sunum]. International Symposium on Limnology and Freshwater Fisheries, Isparta, Türkiye.

Snoswell, C. (2016, Ekim 31 - Kasım 3). Models of care for store-and-forward teledermatology in Australia [Poster sunum]. 7th International Conference on Successes and Failures in Telehealth, Auckland, Yeni Zelanda.

**NOT:** Dergi yazım kurallarına uygun olarak hazırlanmayan makaleler değerlendirmeye alınmayacaktır.