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Research Article **Araştırma Makalesi**

Monitoring of Quality Parameters in Vacuum-Packed Sea Bass (*Dicentrarchus labrax*) During Refrigerated Storage at (0-4°C) and Evaluation of Electronic Nose Effectiveness

Buzdolabında (0-4°C) Depolama Sırasında Vakumla Paketlenmiş Levrek (*Dicentrarchus labrax*) Kalite Parametrelerinin İzlenmesi ve Elektronik Burun Etkinliğinin Değerlendirilmesi

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Abstract: The effectiveness of electronic nose (e-nose) on vacuum packed, gutted and descaled sea bass (*Dicentrarchus labrax*) was investigated during 18 days in refrigeration (0-4°C). Microbiological (total aerobic mesophilic bacteria, psychrophilic bacteria and aerobic bacteria counts) chemical (TVB-N, TMA, TBARS) and sensory quality were also determined in this study. Total aerobic mesophilic and psychrophilic bacteria counts increased during the storage period of vacuum packed and gutted European sea bass . Total aerobic mesophilic bacteria and psychrophilic bacteria exceeded the shelf life limit (7 log cfu/g) on day 18. Upon the completion of the 18th day of the storage period; TVB-N, TBARS, TMA-N values were determined as 22.42±2.87 mg/100 g, 0.37±0.12 µmol/100g, 4.12±0.41 mg/100 g, respectively. The sensory score was determined as 14.43±0.14 on the 18th days of storage. The findings of this study reveal that the microbiological data of the vacuum-packed sea bass stored at 4°C indicate that the shelf life was 15 days of the storage period. In the electronic nose measurements, the sensor results on days 1st, 4th, 6th and 8th days, which are assumed to continue the freshness of the fish, gave close values, while the 8th day distributions were more scattered than the others, and this was accepted as an indication that odour changes had begun. The values for the 11th, 13th and 15th days of storage were close to each other and sometimes gave the same distribution. The results demonstrate that electronic nose technology is a potential tool for monitoring fish freshness and can be used in conjunction with traditional sensory analyses.

Keywords
- *Dicentrarchus labrax*
- Fish quality
- Vacuum-pack
- E-nose

Özet: Elektronik burun (e-burun) kullanımının, 18 günlük depolama (0-4°C) süresince vakumlu paketlenmiş, temizlenmiş ve pulları alınmış levrek (*Dicentrarchus labrax*) üzerinde etkinliği incelenmiştir. Bu çalışmada, mikrobiyolojik (toplam aerobik mezofilik bakteri, psikrofilik bakteri ve aerobik bakteri sayısı), kimyasal (TVB-N, TMA, TBARS) ve duyusal kalite de belirlendi. Toplam aerobik mezofilik ve psikrofilik bakteri sayıları, vakumlu paketlenmiş ve içi temizlenmiş levreklerin depolanması sırasında arttı. Toplam aerobik mezofilik bakteriler, psikrofilik bakterilerin sayısı 18. günde raf ömrü sınırını (7 log cfu/g) aşmıştır. Depolama sürecinin 18. gününün tamamlanmasının ardından; TVB-N, TBARS, TMA-N değerleri sırasıyla 22,42±2,87 mg/100 g, 0,37±0,12 µmol/100g, 4,12±0,41 mg/100 g olarak belirlenmiştir. Duyusal puan, depolamanın 18. gününde 14.43±0.14 olarak belirlendi. Bu çalışmanın bulguları, 4°C'de saklanan vakumlu ambalajlı levreklerin mikrobiyolojik verilerinin, raf ömrünün saklama süresinin 15. günü olduğunu göstermektedir. Elektronik burun ölçümlerinde, balığın tazeliğinin devam ettiği varsayılan 1., 4., 6. ve 8. günlerdeki sensör sonuçları birbirine yakın değerler verirken, 8.

Anahtar kelimeler
- *Dicentrarchus labrax*
- Balık kalitesi
- Vakum paket
- E-burun

gün dağılımları diğerlerine göre daha dağınık olup, bu durum koku değişikliklerinin başladığının bir göstergesi olarak kabul edilmiştir. Depolamanın 11., 13. ve 15. günlerine ait değerler birbirine yakın olup bazen aynı dağılımı vermiştir. Sonuçlar, elektronik burun teknolojisinin balık tazeliğini izleme açısından potansiyel bir araç olduğunu ve geleneksel duyusal analizlerle birlikte kullanılabileceğini göstermektedir.

1. INTRODUCTION

Türkiye is a leading producer and exporter of sea bass, achieving a remarkable production of 61,281,828 tonnes in 2024, emphasizing its significant role in the national economy. In Türkiye, sea bass is typically preserved freshly chilled, or the freezing technology is used as another preservation method. According to 2023 data, the evaluation indicates 44,454,815 tonnes of fresh products, 9,989,632 tonnes of fresh fillets, 9,760,879 tonnes of frozen fillets, and 4,687,265 tonnes of frozen products (Kızıltan 2024).

To preserve the freshness of seafood for longer, there are several technical and traditional ways, with vacuum packing being the most prevalent packaging technique. Protection against oxidation and microbial degradation is ensured by using specialised hoover machines to reduce air contact with the product. Vacuum packing is a cost-effective technique that significantly lowers oxygen levels, hence inhibits microbial proliferation and lipid oxidation. Studies indicate that seafood items kept using vacuum packaging have lower bacterial counts than those preserved using air or conventional packaging techniques (Nguyen et al., 2023). This technique also protects the food from moisture loss, reducing the deterioration of freshness in terms of texture and flavour caused by storage. Another benefit of vacuum packing is the maintenance of the biological integrity of fish (Ghaly et al., 2010). Various quality indicators are assessed to determine the length of time that fish can be kept in the refrigerator (Phuhongsung et al., 2017). The sensory attributes of fish, especially odour, are essential factors influencing consumer acceptability and marketability. Scents are volatile chemical substances detected by olfactory receptors and sent to the brain via nerves to be recognised. Olfaction involves the complex interplay of biological, psychological, and social elements. Technological gadgets have been engineered to replicate human sensory perception. In order to facilitate the detection and categorisation of certain chemical elements, electronic noses, also known as e-noses, are designed to work in a manner that is analogous to the human olfactory system. They facilitate the identification and examination of diverse odours and volatile organic chemicals. In contrast to human olfactory receptors, the olfactory region of the brain is linked to a network of sensors and a sophisticated pattern recognition system (Şahin, 2008). Electronic noses often use metal oxide semiconductor sensors that display varying electrical resistances when exposed to certain gases, therefore offering insights about the amounts of these gases (Gardner & Bartlett, 1999; İncegül et al., 2022). The interest in using electronic noses (e-noses) for the fast and non-destructive identification of volatile compounds, indicative of fish freshness deterioration and rotting, is growing daily. This method has shown its efficacy, and has enabled its use for many fish species and storage circumstances (Wu et al., 2022). The sensors in the electronic nose demonstrate selectivity due to molecular variations and lead to alterations in physical parameters such as conductivity or current through sensor reactions, which generate numerical data and identify changes in specific volatile compounds linked to microbial activities during fish spoilage in storage. They facilitate the identification of spoilt fish (İncegül et al., 2022). Research indicates that metal oxide semiconductor (MOS) sensors are very proficient at identifying both fresh and spoilt fish owing to their sensitivity and selectivity for various odour compounds (Al-Hooti et al., 2024). Furthermore, the use of chemometric techniques such as principal component analysis (PCA) augments the analytical proficiency of electronic noses. PCA facilitates the assessment of fish freshness levels using the intricate data generated by sensor arrays (Wilson et al., 2013). The absence of deformation in fish caused by e-noses makes them appropriate for extensive industrial applications. Traditional techniques of assessing fish quality are time-consuming, labour-intensive, and result in deformation of the fish. Conversely, electronic noses have the potential for rapid and secure application across several

phases of the supply chain, from processing to sale (Madhubhashini et al., 2023). The sensitivity and specificity of electronic noses may be affected by ambient conditions. Variations in temperature, humidity, and background odours, contingent upon storage circumstances, may profoundly affect the efficacy of electronic noses, resulting in erroneous quality evaluations (Phuhongsung et al., 2017). The intricate composition of fish odours complicates the correct differentiation between fresh and spoilt seafood (Wilson et al., 2013). While electronic noses are designed to replicate human olfactory reactions, they do not possess the nuanced sensory acuity of trained panellists, and hinder their ability to discern minute variations in scent and flavour, particularly in intricate food matrices such as fish (Gliszczyńska-Świgło & Chmielewski, 2016). A further drawback of electronic noses is their need for frequent calibration and maintenance because of exposure to diverse components (Zaukuu et al., 2019). This may hinder small-scale fish processing facilities from adapting to this technology, particularly in commercial settings where regular quality monitoring is crucial, since it might elevate operating costs and complexity (Grassi et al., 2019). The analysis of complicated data produced by the electronic nose necessitates sophisticated chemometric procedures, which may hinder users lacking competence in data processing and might result in misunderstanding of the findings (Li et al., 2019).

This research examines the efficacy of an electronic nose in assessing the quality alterations that transpire during the refrigeration of vacuum-packed and processed sea bass (*Dicentrarchus labrax*), from storage to consumption. This is of great importance given the substantial economic implications that sea bass presents for the aquaculture industry in Turkey.

2. MATERIAL AND METHODS

2.1. Fish sample

European sea bass (*D. labrax*), comprising 40 individuals with a mean weight of 308.68±18.77 g and a mean total length of 27.84±1.42 cm, were obtained from a local seafood processing plant in Izmir, Türkiye. Fresh sea bass were gutted and descaled before being transported to the laboratory on ice. Sea bass that had been caught the previous day were used in this process. They were then vacuum packed by a vacuum packaging machine (MG42, Abant Machine, Türkiye) and stored in the refrigerator at 0-4°C. Quality changes were determined by chemical, microbiological, and sensory analyses, as well as electronic-nose analyses at the beginning of storage and on the specified days during storage.

2.2. Chemical analysis

Total volatile basic nitrogen (TVB-N; mg/100 g fish) and trimethylamine (TMA; mg/100 g fish) were analysed utilizing the methodology established by Malle & Poumeyrol (1989). 100 g of sea bass meat were extracted using 200 millilitres of 7.5% trichloroacetic acid (Carlo Erba, 76-03-9) and then filtered into a 250 millilitre conical flask. The filtrate (25 ml) was placed into a distillation tube, and six millilitres of a 10% sodium hydroxide solution (Carlo Erba, 1310-73-2) was added. The distillation tube was placed in the Gerhardt Kjeldahl Vapodest 45 distillation apparatus. Seventy five milliliters of water was added to the apparatus. A conical flask with a capacity of 250 millilitres was positioned at the distillate terminus of the apparatus. Prior to the procedure, ten millilitres of the indicator solution were incorporated. The indicator solution included a 4% boric acid (Carlo Erba, 10043-35-3) solution, formulated by including 0.7 ml of methyl red in a 0.1% alcohol solution and 1 ml of bromocresol green in a 0.1% alcohol solution. At the end of the distillation process, the sample (50 ml) was collected in the conical flask. The collected sample was titrated with a solution of sulphuric acid (0.025 N) (Carlo Erba, 7664-93-9). The data obtained from titration was used in the following calculation to calculate TVB-N value.

14 g/mol x consumption rate x 0,025x300 = TVB-N mg/ 100 g fish flesh

For the analysis of trimethylamine (TMA), 25 ml of the filtrate and 6 ml of 10% NaOH as well as 20 ml of formaldehyde (35%) were put into the same distillation tube. All procedures mentioned above for TVB-N are also applied for the determination of Trimethylamine. The measurements were made in triplicate.

Thiobarbituric acid reactive substances (TBARS) levels (μmoles malondialdehyde/100 g tissue) was conducted using a modified version of the technique established by Lemon (1975). Approximately 10 g of sea bass meat was combined with 7.5 ml of 0.1% (w/v) propyl gallate (Sigma-Aldrich, 121-79-9) and EDTA (Carlo Erba, 6381-92-6). After homogenisation

in an Eberbach blending jar for 10 seconds, 15 ml of 7.5% (w/v) trichloroacetic acid (TCA) solution was added. Propyl gallate and EDTA reduced homogenisation-induced lipid oxidation. Coarse filter paper (Q8, Fisher Scientific) was used for homogenisation. Five millilitres of filtrate were combined with five millilitres of TBA reagent (Merck, 504-17-6) in a securely closed tube. The tubes were subjected to heating in a water bath at 100°C for 40 minutes. After cooling to ambient temperature, the contents were clarified once more using the same kind of filter paper. The absorbance was measured at 530 nm relative to a blank sample. TBARS readings were derived using a standard curve with ranges of (0.00-0.06) for total malondialdehyde and (0.00-1.0) for absorbance. The calibration curve was constructed using 1,1,3,3-tetraethoxypropane (TEP) (Sigma-Aldrich, 122-31-6) and quantified in µmole malondialdehyde per 100 g of mince.

2.3. Microbiological analysis

For all microbiological assays 100 g of the material was extracted into 90 ml of peptone water (0.1%) (Difco, 0118-17-0) . Further dilutions in decimal form were prepared from 10-1. Plate Count Agar (Difco, 0479-17) was used to count total viable count (TVC) and psychrophilic bacteria according to the pour plate technique described by ICMSF (1983). Inoculation plates were incubated at 30°C for 24-48 hours for total live mesophilic counts and at 5°C for 72 hours for psychrophilic counts. For five days at 25°C, anaerobic bacteria were enumerated utilising pour plate methods on plate count agar (Debevere & Boskou, 1996).

2.4. Electronic nose measurements

The present study utilised the electronic nose which was developed by the Materials Institute of the TÜBİTAK Marmara Research Centre (Figure 1). The electronic nose is configured with a total of fourteen quartz crystal microbalance sensors. The development of these sensors was undertaken by the Marmara Research Centre Materials Institute. The system, as elucidated by Erdem (2016), has been integrated with the desiccator, thereby enabling a more efficient and expedited sample procedure. The unit of measurement employed to record the outcomes of the electronic nose was Hertz (Hz). Principal component analysis (PCA) was incorporated into the program utilised for data analysis.

Figure 1. Electronic nose system.

2.5. Sensory assessment

The adapted Tasmanian Food Research Unit (TFRU) approach was employed to assess the sensory quality of sea bass. Five panellists evaluated sensory qualities (appearance, colour, hardness, stench) of fish samples employing the TFRU test developed by Alasalvar et al. (2001). A sensory evaluation, named the TFRU test, assigns an overall score for sensory qualities as follows: “0” denotes fresh quality, “1” signifies neutral, “2” indicates fishy, and “3” represents spoilt. The individual attribute ratings were

aggregated to get a comprehensive sensory score. The sensory technique assigned a score of zero (or near zero) to extremely fresh fish, but progressively higher scores were recorded as the fish decayed. Due to the removal of internal organs and gills, odour characteristics were excluded.

Three different packages were taken for sensory, microbial, chemical and electronic-nose analysis and all measurements were made in triplicate.

2.6. Statistical analysis

Chemical quality control, microbiological and sensory analyses were performed for the findings. Statistical analysis was accomplished utilizing SPSS for Windows 20 statistical package program. Results are given as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) was implemented to the data where Tukey and Duncan tests were made for multiple comparisons. The relationship between storage-related parameters was respected significant when ($P \leq 0.05$).

3. RESULTS

3.1. Results of chemical analysis

The TVB-N parameter is predominantly made up of ammonia, in addition to primary, secondary, and tertiary amines at various concentrations. Microorganisms are responsible for the production of amines, such as trimethylamine (TMA) and dimethylamine (DMA), during the process of decomposing fish muscle and nitrogenous compounds that do not contain protein. As a method of determining whether the integrity of muscle tissue has been compromised, this is widely used (Souza et al., 2010). In newly caught fish, the concentration of TVB-N is normally between 5 and 20 mg TVB-N/100g, but values of 30–35 mg TVB-N/100 g meat are widely debated to be the threshold of acceptableness for fish stored and cooled in ice (Iacumin et al., 2022). In the specific instance of sea bass, there is just one author who has defined restrictions associated with TVBN. Consequently, Kyrana & Lougovois (2002) determined that a value limit of 25 mg should be applied to this species. In our study the TVB-N value was ascertained as 19,81±1,07 at the prologue of storage and reached the 22.42 mg TVB-N/100 g fish flesh on day 18 ($p \geq 0,05$) (Table 1).

Following the breakdown of trimethylamine N-oxide (TMAO) by means of bacterial degradation and enzymatic activity, trimethylamine nitrogen (TMA-N) has become a well-established biomarker for determining the quality of fish (Huidobro et al. 2001). In our study TMA-N value was determined as 2.03±0.32 mg/100 g at the beginning of the storage and reached 4.12 ±0.41 mg/100 g fish flesh at the end of the 18-day storage period ($p \leq 0.05$), which is still below the value of 5 mg N/100 g (Table 1).

Table 1. Results of Chemical Analysis.

Days of storage	TVB-N	TMA	TBARS
D1	19,81±1,07^{ab}	2,03±0,32^{a}	0,16±0,01^{a}
D4	19,04±1,15^{ab}	2,55±0,32^{a}	0,37±0,21^{a}
D6	17,55±1,24^{a}	2,87±0,43^{ab}	0,29±0,08^{a}
D8	17,36±0,52^{a}	1,89±0,21^{a}	0,30±0,03^{a}
D11	18,15±1,03^{ab}	2,45±0,64^{a}	0,24±0,05^{a}
D13	20,54±1,64^{ab}	2,31±0,21^{a}	0,34±0,19^{a}
D15	20,3±1,59^{ab}	3,78±0,72^{b}	0,29±0,14^{a}
D18	22,42±2,87^{b}	4,12±0,41^{b}	0,37±0,12^{a}

Identical letters in the same column for each parameter signify no substantial variation ($p \geq 0.05$).

Thiobarbituric acid-reactive substances (TBARS) are widely used as indicators of lipid oxidation and can lead to off-flavors, discoloration, and nutritional degradation in fish based on the estimation of malondialdehyde (MDA), which is formed by hydroperoxides and a critical factor affecting the quality and shelf life of seafood products. (Moretti et al., 2016). Table 1 shows TBARS value during the storage period. The TBARS value was determined as 0.16±0.01 µmol/100g at the beginning of the storage and reached 0.37±0.12 µmol/100g on day 18 ($p \geq 0,05$).

3.2. Results of microbiological analysis

Vacuum packaging effectively reduces oxygen, which is responsible for food spoilage due to microbial growth and oxidative deterioration, and effectively extends the shelf life of products. The initial total viable counts, and counts of psychrophilic bacteria and anaerobic bacteria in vacuum-packed sea bass stored at 4°C were determined to be 3.50±0.82, 3.70±0.70. 2.42±0.32 log cfu/g on day zero., These values increased to 7.11±0.22, 7.05±0.05, 6.05±0.05 on day 18, respectively (Table 2). Figure 2 shows the linear forecast trendline for microbial analysis. According to the TVC and

psychrophilic bacteria results, the sea bass counts exceeded 7 log cfu/g on day 18, which is the maximum eligibility level for marine and freshwater fish . The anaerobic bacteria count was determined as 6.05 log cfu/g at the end of the storage.

Table 2. Results of microbiological Analysis.

Days of storage	Total viable count (log cfu/g)	Psychrophilic bacteria count (log cfu/g)	Anaerobic bacteria count (log cfu/g)
D1	3,50±0,82^{a}	3,70±0,70^{a}	2,42±0,32^{a}
D4	4,15±1,03^{a}	4,26±0,20^{ab}	1,64±0,66^{a}
D6	4,82±0,14^{ab}	4,93±0,11^{ac}	2,51±0,37^{ab}
D8	5,51±0,31^{ab}	5,85±0,72^{cd}	3,81±0,55^{c}
D11	5,15±1,02^{ab}	5,48±0,68^{bc}	3,88±0,32^{c}
D13	6,11±0,50^{ab}	6,21±0,42^{cd}	3,72±0,71^{bc}
D15	6,85±0,11^{b}	6,84±0,11^{d}	5,86±0,07^{d}
D18	7,11±0,22^{b}	7,05±0,05^{d}	6,05±0,05^{d}

Identical letters in the same column for each parameter signify no substantial variation (p≥0.05).

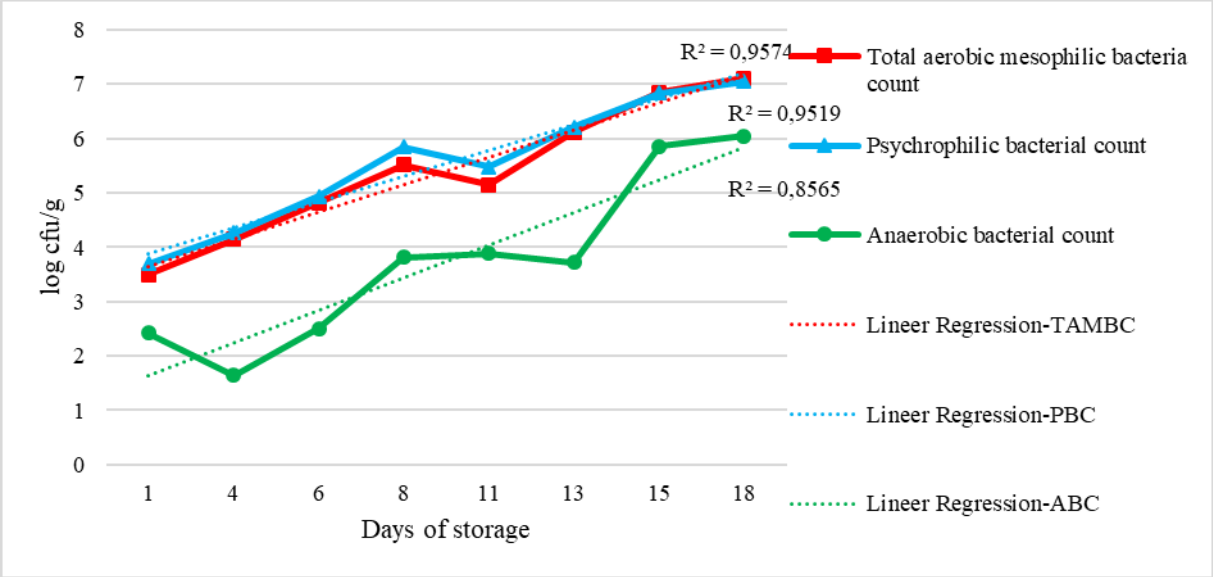

Figure 2. Microbial analyses and linear forecast trendline.

3.3. Results of Electronic nose (E-Nose) analysis

Figure 3 shows the data distribution for all the analysis days. The results for day 8 are more widely dispersed than those for the other days. The distributions for the thirteenth day are positioned in 3 regions on the graph. The data for day 11 is concentrated in an area between the other analysis days. The data for day 15 are located in a separate area compared to the other data. The data for day 18 is densely concentrated in the same region.

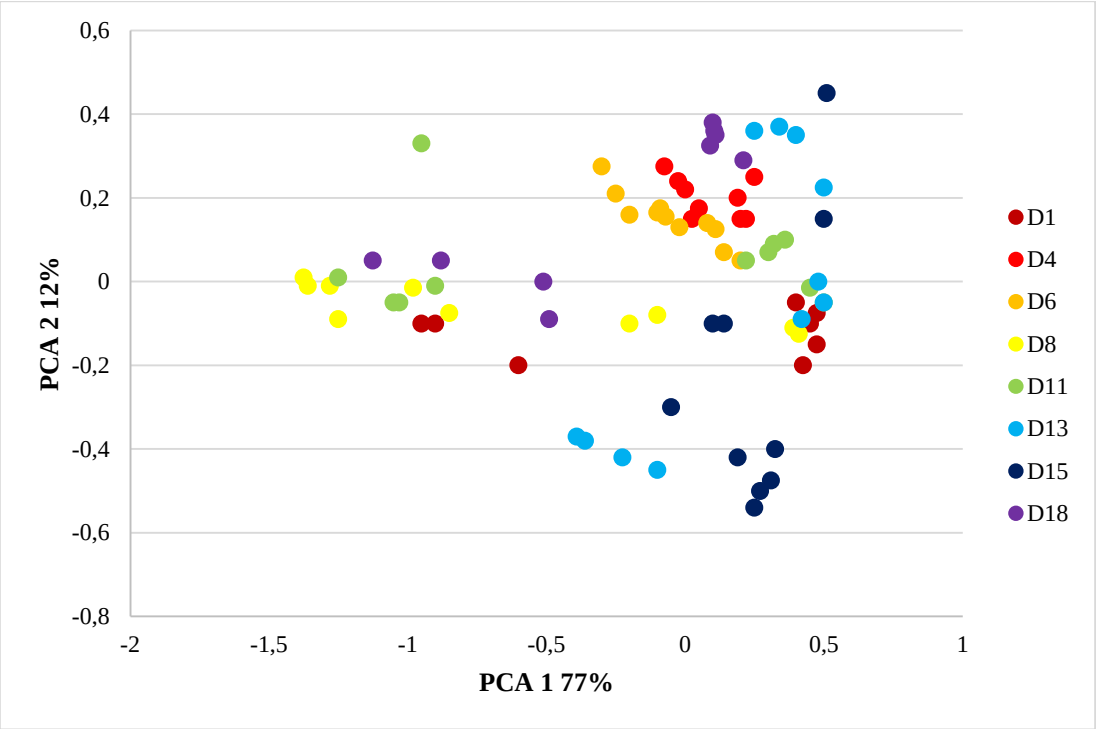

Figure 3. PCA plot of Electronic nose measurements.

Figure 4 shows the electronic nose data distributions for the 1st, 4th, 6th and 8th analysis days. As in Figure 3, the graphs for the 1st, 4th and 6th days are located close to each other in Figure 4, almost intertwined.

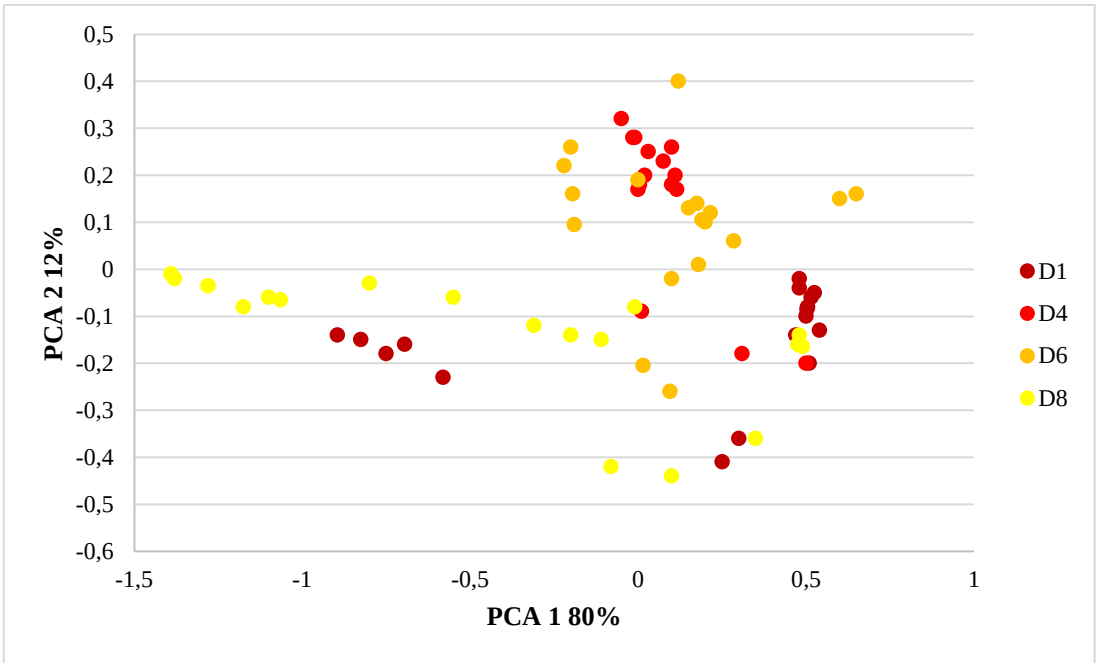

Figure 4. Electronic nose chart on the 1st, 4th, 6th and 8th days of analysis.

Figure 5 shows the electronic nose data distributions for the days 11th, 13th, 15th and 18th of the analysis. Similar to Figure 2, the results for the 13th day of analysis are located in three regions.. The distributions for the 11th day of analysis are located in two different locations in the graph.

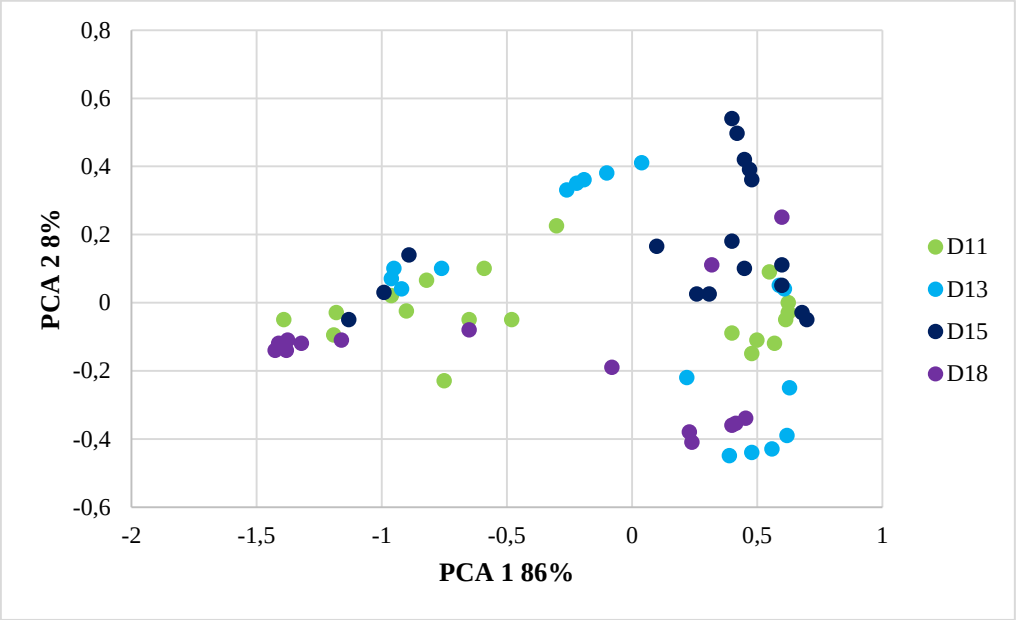

Figure 5. Electronic nose chart on the 11th, 13th, 15th and 18th days of analysis.

The sensor results showed that the values for days 11, 13 and 15 were close to each other and sometimes gave the same values. The sensor results for day 18 differed from other measurements, with the collection area located far from the others in Figure 5. Although the distributions on the 18th day appear scattered in the graph, they are located in a narrow area away from others.

The graphs of the frequency Hz values of the sensors number 1 in Figure 6, number 5 in Figure 7 and number 13 in Figure 8 are given.

Figure 4 shows the frequency Hz values of sensor number 1. is given in. The measurements on days 1st, 4th and 6th days are between the frequency Hz values of 9982680 and 9982670 and are very close to each other. The analysis on the 8th day is at a frequency Hz value of 9982664. The measurements on days 11th, 13th and 15th are between the frequency Hz values of 9982640 and 9982650 and are also very close to each other. The analysis on the 18th day is at a frequency Hz value of 9982632.

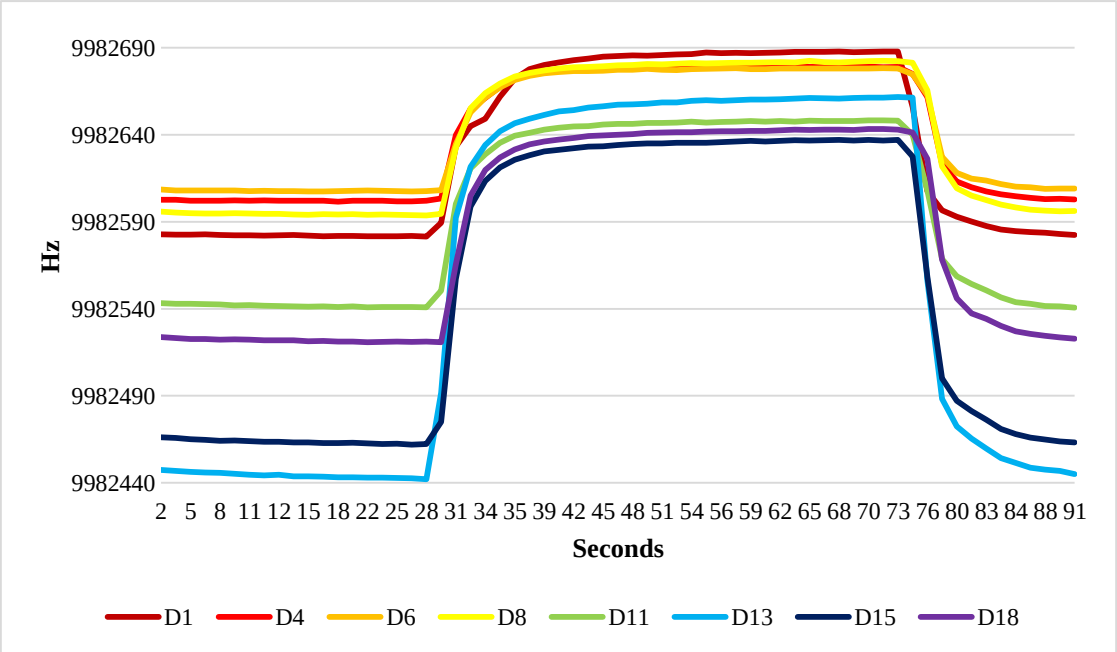

Figure 6. Measurement data of sensor number 1.

Figure 7 shows the frequency Hz values for sensor number 5.. The values for the 1st and 4th days of analysis are at a frequency of 9982358 Hz. The measurement on the 6th day is at a frequency of 9982315 Hz, and the measurement on the 8th day is at a frequency of 9982334 Hz. The measurements on days 11th, 13th and 15th were detected between the frequency values of 9982220 and 9982230 Hz, while the measurement on day 18th was detected at frequency of 9982159 Hz.

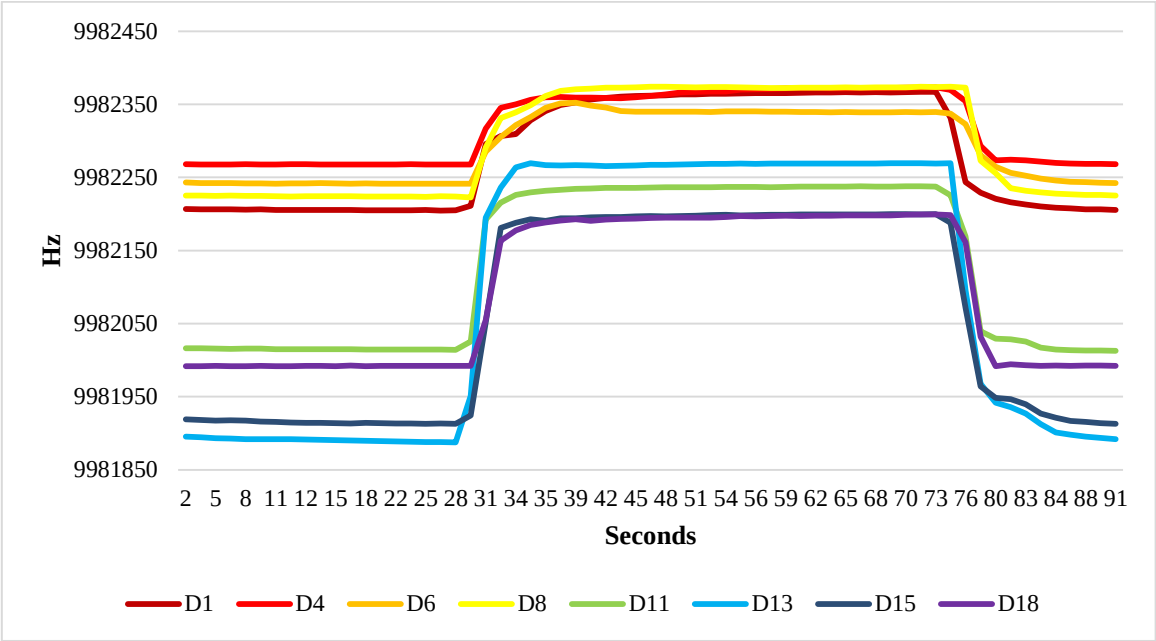

Figure 7. Measurement data of sensor number 5.

Figure 8 shows the frequency Hz values for sensor number 13. The 1st day of measurement was determined as 9982110 frequency Hz. The measurements on the 4th, 6th and 8th days were between 9982095 and 9982100 frequency Hz, and the measurements of the 11th, 13th and 15th days between 9982075 and 9982080 frequency Hz. The measurement on the 18th day was 9982068 frequency Hz.

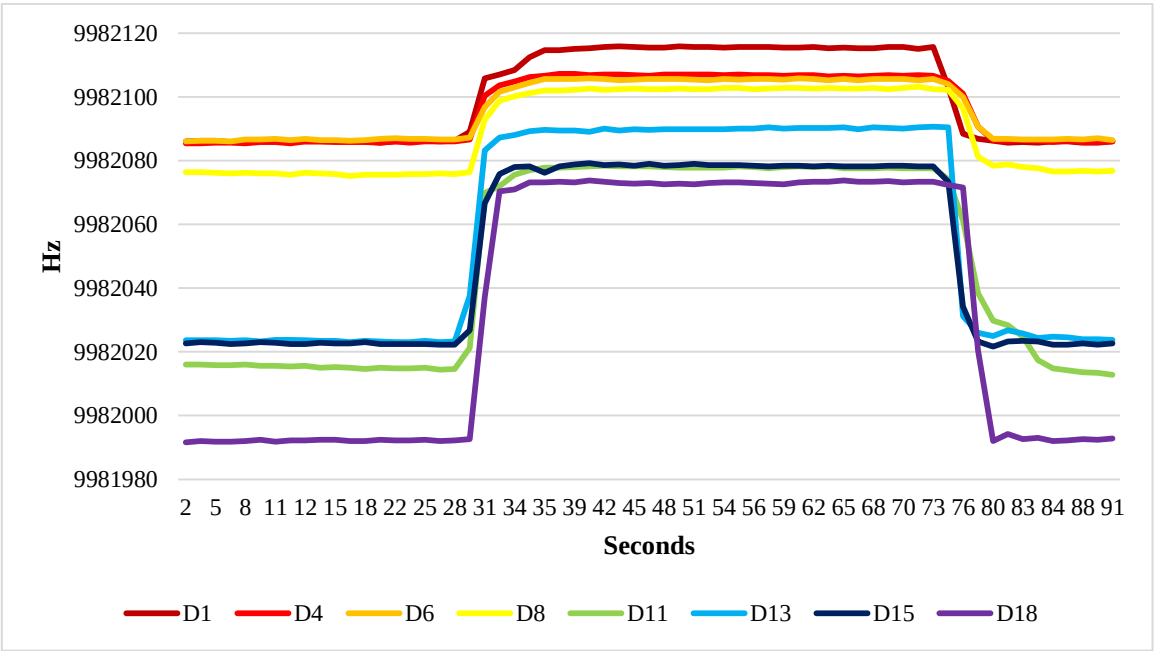

Figure 8. Measurement data of sensor number 13.

There are differences between the analysis times of the electronic nose results. The electronic nose measurements on days 1, 4, 6 and 8, when the fish was assumed to be fresh, were similar, while the distributions on day 8 were more scattered than the others, indicating that changes in the odour had begun. The sensor results showed that the values for the 11th, 13th and 15th days of storage were close to each other and sometimes identical. However, on the 18th day of storage analyses , a different appearance was detected in the sensor results compared to the other measurements. In Figure 5, it was determined that the collection area was farther than the others.

3.4. Results of sensory analysis

The sensory analysis findings are shown in Figure 9, which can be found here. When the quality of sea bass was evaluated using sensory analysis, it was found that there was a continuous rise that was connected with the length of time that the fish was stored. As a consequence of the sea bass being gutted and having their gills removed, the sensory analysis was unable to identify any fragrance characteristics. At the beginning of the first day, the first sensory analysis scores were recorded as 5.96±2.30. On the eleventh day, a statistically significant change was detected, which resulted in a score of 11.16±0.32. When compared to the measurement that was taken on day 11th of storage, the measurement that was obtained on day 18th of storage was 14.43±0.14, indicating that there was no substantial adjustment. The panel members consider a score close to 20 to be insufficient. A score of 0 indicates that the fish is totally fresh, while a score of 38 indicates that it has completely gone bad.

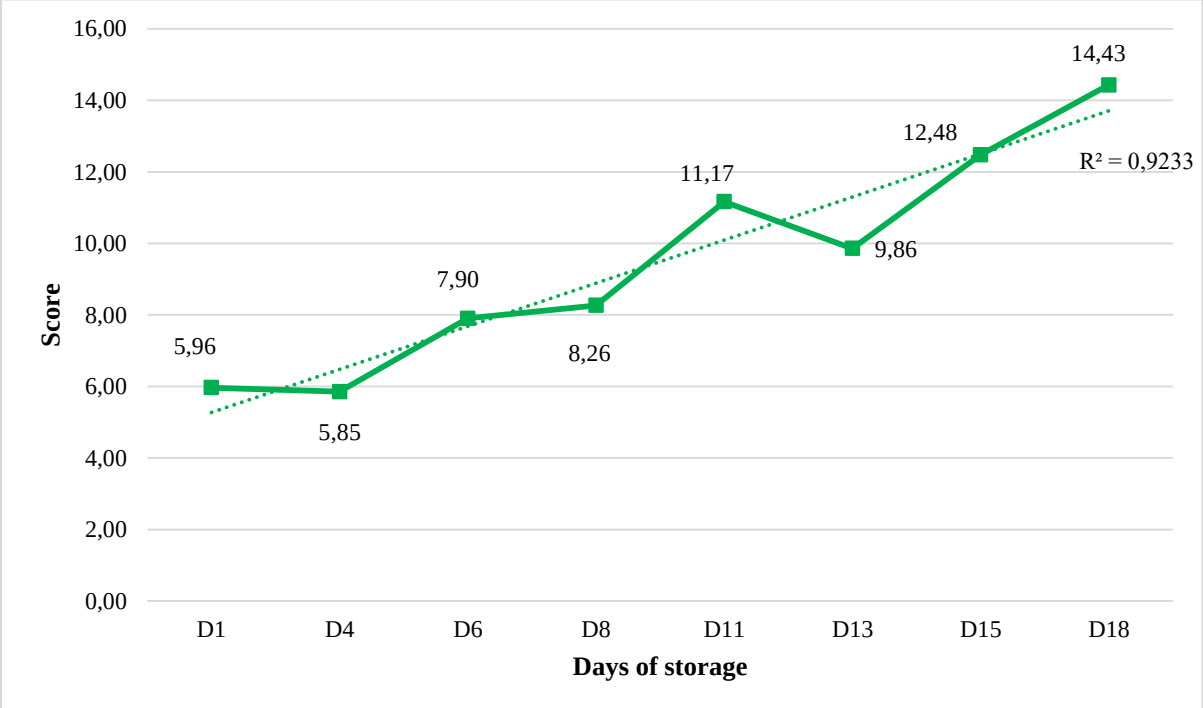

Figure 9. Scores of sensory analyses.

4. DISCUSSION

Studies have shown that acceptable levels of TVB-N can be maintained in vacuum-packed sea bass during cold storage at 4°C, as minimising oxygen exposure slows down the growth of spoilage bacteria and production of TVB-N (Hsiao & Chang, 2016). An examination of the levels of TVB-N in European sea bass fillets that had been cold-stored was carried out by Kritikos et al. (2020). The findings of this inquiry revealed that the TVB-N value ended up reaching 26.8 mg N/100 g by the 16-day storage period. The study by Castro et al. (2006) concentrated on determining the maximum allowable levels of TVBN in sea bass as part of their examination of the changes that take place in sea bass during its permissible shelf life. Throughout the entirety of the study, the readings of TVBN remained consistently similar and showed no indications of an increase. The delay in the progress of TVBN exceeded the standard preservation duration for fish on ice, which is twenty days, resulting in the

fish not being preserved. According to Kyrana & Lougovois (2002), the decreased levels of TVBN can be linked to comparatively low pH values as well as the specific characteristics of the microbial flora that were identified during their study. Çakli et. al., (2006) investigated differences in the chemical quality of gutted sea bass during ice storage. They reported that the TVB-N value was 19.46 mg/100g fish flesh on day 7, reaching 49.66 mg/100g fish flesh on day 14. These TVB-N results are not similar when compared with our results. The TVBN level has been demonstrated to be an inadequate measure of fish freshness, as indicated by the findings of Kyrana and Lougovois (2002), and supported by Castro et al. (2006). It has been understood that both groups have similar study findings and claims. Iacumin et.al., (2022) studied the quality of vacuum-packed sea bass stored at 6°C and declared that the TVB-N value reached the 35.2 mg N/100 g. TVB-N's value can be changed by a multitude of factors, including initial fish quality, storage temperature, packaging methods, and the application of preservatives or coatings.

TMA is present at low levels in newly captured fish, and increases during storage time,depending on species, temperature, and hygiene. The results of Gram & Huss (1996) indicate that TMAO may be converted to TMA by endogenous bacteria at the beginning of the process, after which gram-negative bacteria become active. As a consequence of this, the increased levels of TMA are generally considered to be an indication that the fish has gone bad. According to Kyrana & Lougovois (2002), there was a progressive increase in the amount of TMA found in European sea bass. Çaklı et al. (2006) investigated the quality of gutted sea bass while it was being stored in ice. They discovered that TMA-N levels reached 8.71±0.06 mg/100 g by the end of the 14-day storage period. However, values between 5 and 10 mg per 100 g are considered to be the acceptable threshold for the majority of marine fish species (Connel, 1995). Fresh fish normally have TMA-N levels that range from 2-4 mg per 100 g, whereas levels between 5 and 10 mg per 100 g are considered to be acceptable. According to Fuentes-Amaya et al. (2015), while *S. putrefaciens* is known to make eTMA, other organisms that cause spoilage, such as *Pseudomonas spp*. do not make TMA. It is also likely that the existence of *Pseudomonas spp*. might hinder the spread of *S. putrefaciens*, which would result in a decrease in the densities of 8-9 log10 cfu/g that are required for the synthesis of TMA (Gram & Huss 1996).

The permissible limit for TBARS is defined as less than 2 mg MDA/kg of sample; any readings higher than this level are considered to indicate spoilage (Senapati, et.al., 2017). It was determined by Çaklı et al. (2006) that the TBA value was recorded at 1.42 ± 0.05 mg malonaldehyde/kg on the 18th day of the storage. This was the result of their examination of the quality changes in sea bass that had been gutted and kept on ice. In our research, we determined a value of 0.27 mg/kg malonaldehyde, which is very low compared to the acceptable limit.

The TVC increases in parallel with storage duration (Lan et al., 2024). Parlapani et al. (2015) reported that the TVC of gutted sea bass stored at 2°C in air and in a modified atmosphere was initially approximately 3 log cfu/g, reaching 7.5 and 7 log cfu/g on the 9th and 13th days, respectively. Paleologos et al. (2004) notified that the TVC of whole, gutted and filleted sea bass stored on ice was 3.5, 4.2 and 5.2 log cfu/g on the first day of storage, respectively. However, this value exceeded the acceptable limit on the 11th day of storage for ungutted sea bass, on the 9th day for gutted sea bass, and on the 7th day for fillet samples. The level of microbial load at the beginning of storage in this study is complementary to our research. Lan et al. (2024) reported that the TVC of sea bass (*Lateolabrax japonicus*) fillets in vacuum packaging after being immersed in distilled water for 10 min was 2.73 log cfu/g on the initial day, indicating that the fish was fresh. On the 10th day of storage, the TVC was determined as 7.08 log cfu/g, exceeding the spoilage limit (7 log cfu/g). Lan et al. (2022) stated that the initial TVC of sea bass fillets immersed in deionized water, vacuum packaged and stored in cold storage was below 3 log cfu/g, but they reported that the TVC reached an unacceptable limit on the 12th day of storage. It can be said that sea bass that is gutted, vacuum packed and stored in cold conditions has better storage quality than fillet sea bass. Carracossa et al. (2014) investigated microbial growth in ice-stored sea bass (*D. labrax*) using predictive modeling. They observed that the TVC in muscle tissue was 1.89 log cfu/g on day 0, and they stated that the TVC number exceeded 7 log cfu/g on the 10th day of storage.

Lan et al. (2022) noted that the initial psychrophilic bacteria count of sea bass fillets immersed in deionized water, vacuum-packaged and stored in cold storage was between 2 and 3 log cfu/g, indicating a similar increase with the TVC. Carracossa et al. (2014) investigated predictive models for bacterial growth in *D. labrax* stored on ice and reported that the psychrophilic bacteria count was 1.07 log cfu/g on the initial day of storage and reached 7 log cfu/g on the 14th day of storage. Results of this study are similar to our study. In our study, the psychrophilic bacterial count approached 7 log cfu/g on the 15th day of storage and exceeded this level by the 18th day. Debevere & Boskou (1996) reported that the anaerobic bacterial count in packaged cod fillets did not heighten in the first 3 days of storage, but did increase from the 4th day onwards, reaching the same levels as the TVC by the 7th day of storage.

The shelf life of seafood is influenced by storage conditions, including ambient temperature and the atmosphere to which it is exposed, the level of microbial contamination at the time of removal from the water, handling processes and other environmental factors that may trigger the development of microorganisms that cause spoilage (Parlapani et al., 2015).

An investigation into the efficacy of an electronic nose for determining the freshness of anchovies was carried out by Amari et al. (2007). The researchers used a device that was fitted with a 12-sensor array to carry out their investigation. For the purpose of determining whether the electronic nose is capable of distinguishing between various phases of freshness, the researchers utilised principal component analysis (PCA) and linear discriminant analysis (LDA). The findings revealed that the amounts of volatile chemicals which are responsible for the odour of fish that are associated with rotting, increase with the length of time that the fish is stored, 4, 6, and 9 days. When it comes to a particular linear discriminant, sensors that display loading parameters that are close to zero indicate that they make a limited contribution to the overall response of the array. On the other hand, sensors that exhibit elevated values indicate that they have considerable discriminative capabilities. It has been demonstrated through findings that a reduction in the rate of spoilage is associated with a discount in the conductance of the sensor's responsiveness. Madhubhashini et al. (2023) indicated that while e-noses are praised for their rapid assessment capabilities, they may not provide a comprehensive assessment of fish quality. Factors such as texture, nutrient content, and microbial load are critical to determining overall quality but cannot be directly measured by e-noses.

In a study conducted by Çaklı et al. (2006), the sensory quality of gutted and whole sea bass was examined during the process of ice storage. The researchers observed that the freshness of the sea bass was pronounced from day 1 to day 7. It gradually faded to a bland and somewhat fresh state by day 7, and eventually became undesirable by day 14. The shelf life of ungutted sea bass (*D. labrax*) was noticed to be ten days, as reported by Poli et al. (2001), but the shelf life of gutted and headed sea bass (*Lateolabrax japonicus*) was found to be nineteen days, reported by Chang et al. (1998). According to the results of the mentioned examination, the findings were comparable to those of our research.

5. CONCLUSION

On the basis of findings of the microbiological analysis, the conclusions of the present research show that the shelf-life of vacuum-packed gutted sea bass that is kept at 4°C is fifteen days. During the whole period of cold storage at 4°C, vacuum-packed sea bass displayed levels of TVB-N, TMA-O, and TBARS that were adequate. Electronic noses may not be able to completely replace conventional sensory assessment techniques when it comes to assessing quality features that are essential for client acceptability, despite the fact that they give preliminary assessments. The use of electronic nose technology may be more suitable as a supplement to conventional analytical methods, taking into consideration the limits that are now in place. It is possible that the exploration of alternative preservation methods will result in an improvement in the quality and safety of seafood that has been vacuum-packed and kept in the refrigerator.

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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: ÖAE; Literature: ÖAE, ŞTY; Methodology: ÖAE, ŞTY, ABY; Performing the experiment: ÖAE, ŞTY, ABY; Data analysis: ÖAE, ŞTY, ABY; Manuscript writing: ÖAE, ŞTY, ABY; Supervision: ŞÇ. All authors approved the final draft.

ETHICAL STATEMENTS

Local Ethics Committee Approval was not obtained because experimental animals were harvested before purchase in the present study.

DATA AVAILABILITY STATEMENT

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

REFERENCES

Alasalvar, C., Taylor, K. D. A., Öksüz, A., Garthwaite, T., Alexis, M. N., & Grigorakis, K. (2001). Freshness assessment of cultured sea bream (*Sparus aurata*) by chemical, physical and sensory methods. *Food chemistry, 72*(1), 33-40.

Al-Hooti, H. S., Al-Bulushi, I. M., Al-Attabi, Z. H., Rahman, M. S., Al-Subhi, L. K., & Al-Habsi, N. A. (2024). Efficiency of electronic nose in detecting the microbial spoilage of fresh sardines (*Sardinella longiceps*). *Foods, 13*(3), 428.

Amari, K., Díaz-Vivancos, P., Pallás, V., Sánchez-Pina, M. A., & Hernández, J. A. (2007). Oxidative stress induction by *Prunus necrotic* ringspot virus infection in apricot seeds. *Physiologia Plantarum, 131*(2), 302-310.

Çakli, S., Kilinc, B., Cadun, A., Dincer, T., & Tolasa, S. (2007). Quality differences of whole ungutted sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) while stored in ice. *Food Control*, 18(5), 391-397.

Carrascosa, C., Millán, R., Saavedra, P., Jaber, J.R., Montenegro, T., Raposo, A., Esteban Pérez, E. & Sanjuán, E. (2014). Predictive models for bacterial growth in sea bass (*Dicentrarchus labrax*) stored in ice. *International Journal of Food Science and Technology*, 49, 354–363.

Castro, P., Penedo Padrón, J. C., Caballero Cansino, M. J., Sanjuán Velázquez, E., & Millán De Larriva, R. (2006). Total volatile base nitrogen and its use to assess freshness in European sea bass stored in ice. *Food Control, 17*(4), 245–248.

Chang, K. L. B., Chang, J., Shiau, C.-Y., & Pan, B. S. (1998). Biochemical, microbiological, and sensory changes of sea bass (*Lateolabrax japonicus*) under partial freezing and refrigerated storage. *Journal of Agricultural and Food Chemistry, 46*(2), 682-686.

Connell, J. J. (1995). Control of fish quality (4th ed.). London, UK: Fishing News (Books) Limited.

Debevere, J., & Boskou, G. (1996). Effect of modified atmosphere packaging on the TVB/TMA-producing microflora of cod fillets. *International Journal of Food Microbiology, 31*(1-3), 221-229.

Erdem, Ö. A. (2016). Quality monitoring using electronic nose and machine vision on some cultured fish species at refrigerator storage (PhD. Thesis in Turkish). Ege University Graduate School of Natural and Applied Sciences, Türkiye.

Fuentes-Amaya, L. F., Munyard, S., Fernandez-Piquer, J., & Howieson, J. (2016). Sensory, microbiological and chemical changes in vacuum-packaged blue spotted emperor (*Lethrinus sp*), saddletail snapper (*Lutjanus malabaricus*), crimson snapper (*Lutjanus erythropterus*), barramundi (*Lates calcarifer*), and Atlantic salmon (*Salmo salar*) fillets stored at 4°C. *Food Science & Nutrition, 4*(3), 479–489.

Gardner, J. W., & Bartlett, P. N. (1999). Odour sensors. In J. W. Gardner & P. N. Bartlett (Eds.), *Electronic Noses: Principles and Applications* (pp.67-116). Oxford University Press.

Ghaly, A. E., Dave, D., Budge, S. M., & Brooks, M. S. (2010). Fish spoilage mechanisms and preservation techniques: review. *American Journal of Applied Sciences, 7*(7), 859-877.

Gliszczyńska-Świgło, A., & Chmielewski, J. (2017). Electronic nose as a tool for monitoring the authenticity of food. A review. *Food Analytical Methods, 10*, 1800-1816.

Gram, L., & Huss, H. H. (1996). Microbiological spoilage of fish and fish products. *International Journal of Food Microbiology*, 33(1), 121-137.

Grassi, S., Benedetti, S., Opizzio, M., Nardo, E. d., & Buratti, S. (2019). Meat and fish freshness assessment by a portable and simplified electronic nose system (Mastersense). *Sensors, 19*(14), 3225.

Houicher, A., Küley, E., Bendeddouche, B., & Özoğul, F. (2013). Effect of *Mentha spicata* L. and *Artemisia campestris* extracts on the shelf life and quality of vacuum-packed refrigerated sardine (*Sardina pilchardus*) fillets. *Journal of Food Protection, 76*(10), 1719-1725.

Hsiao, H., & Chang, J. (2016). Developing a microbial time-temperature indicator to monitor total volatile basic nitrogen change in chilled vacuum-packed grouper fillets. *Journal of Food Processing and Preservation, 41*(5), e13158.

Huidobro, A., Mendes, R., & Nunes, M. (2001). Slaughtering of gilthead seabream (*Sparus aurata*) in liquid ice: influence on fish quality. *European Food Research and Technology, 213*, 267-272.

Iacumin, L., Jayasinghe, A. S., Pellegrini, M., & Comi, G. (2022). Evaluation of different techniques, including modified atmosphere, under vacuum packaging, washing, and *Latilactobacillus sakei* as a bioprotective agent, to increase the shelf-life of fresh gutted sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus aurata*) stored at 6 ± 2 °C. *Biology, 11*(2), 217.

ICMSF, (1983). Métodos recomendados para el análisis microbiológico en alimentos, In: Microorganismos de los alimentos, I. Técnicas de análisis microbiológicos, 2da, Ed. Acribia, Zaragoza, Espanã, 105-280pp.

Incegül, Y., Ozkan, G., Incegül, A., & Taşdelen, K. (2022). Use of electronic nose metal oxide semiconductor sensors in food analysis. Akademik Gıda, 20(4), 454-473. (in Turkish)

Kızıltan, S. (2024). Turkish seafood: a rising star in the global market. 52nd WEFTA Annual Meeting, Cesme, Izmir, Turkiye, 14-18 October 2024.

Kritikos, A., Aska, I., Ekonomou, S. I., Mallouchos, A., Parlapani, F. F., Haroutounian, S. A., & Boziaris, I. S. (2020). Volatilome of chill-stored European sea bass (*Dicentrarchus labrax*) fillets and Atlantic salmon (*Salmo salar*) slices under modified atmosphere packaging. *Molecules, 25*(8), 1981.

Kyrana, V. R., & Lougovois, V. P. (2002). Sensory, chemical and microbiological assessment of farm-raised European sea bass (*Dicentrarchus labrax*) stored in melting ice. *International Journal of Food Science and Technology, 37*, 319–328.

Lan, W., Shao, Z., Lang, A., Xie, J. (2024). Effects of slightly acidic electrolyzed water combined with ε-polylysine-chitooligosaccharide Maillard reaction products treatment on the quality of vacuum packaged sea bass (*Lateolabrax japonicus*). *International Journal of Biological Macromolecules*, 260, 129554.

Lan, W., Zhao, Y., Liu, J., Xie, J. (2022). Effects of Chitosan-Grafted-Phenolic Acid Coating on Quality and Microbiota Composition of Vacuum-Packaged Sea Bass (*Lateolabrax japonicus*) Fillets during Chilled Storage. *Journal of Food Protection*, 85, 5, 803–814.

Lemon, D.W. (1975). An improved TBA test for rancidity. In New Series Circular, no 51; Oceans Canada, Halifax Laboratory: Halifax, Noca Scotia.

Li, P., Ren, Z., Shao, K., Tan, H., & Niu, Z. (2019). Research on distinguishing fish meal quality using different characteristic parameters based on electronic nose technology. *Sensors, 19*(9), 2146.

Madhubhashini, M. N., Liyanage, C. P., Alahakoon, A. U., & Liyanage, R. P. (2023). Current applications and future trends of artificial senses in fish freshness determination: A review. *Journal of Food Science, 89*(1), 33-50.

Malle, P., & Poumeyrol, M. (1989). A new chemical criterion for the quality control of fish: trimethylamine/total volatile basic nitrogen (%). *Journal of Food Protection, 52*(6), 419-423.

Mediterranean Sea bass (*Dicentrarchus labrax*). *Food Microbiology*, 21, 549–557.

Moretti, V., Vasconi, M., Caprino, F., & Bellagamba, F. (2016). Fatty acid profiles and volatile compounds formation during processing and ripening of a traditional salted dry fish product. *Journal of Food Processing and Preservation, 41*(5), e13133.

Nguyen, M. V., Karnue, S., & Kakooza, D. (2023). Effect of packaging method and storage temperature on the sensory quality and lipid stability of fresh snakehead fish (*Channa striata*) fillets. *Food Science and Technology, 43*, e116222.

Paleologos, E.K., Savvaidis, I.N., Kontominas, M.G. (2004). Biogenic amines formation and its relation to microbiological and sensory attributes in ice-stored whole, gutted and filleted

Parlapani, F.F., Serkos A. Haroutounian, S.A., Nychas, G-J. E., Boziaris, I.S. (2015). Microbiological spoilage and volatiles production of gutted European sea bass stored under air and commercial modified atmosphere package at 2 °C. *Food Microbiology*, 50, 44-53.

Phuhongsung, P., Zhang, M., Bhandari, B., & Gao, Z. (2017). Effect of vacuum storage on the freshness of grass carp (*Ctenopharyngodon idella*) fillet based on normal and electronic sensory measurement. *Journal of Food Processing and Preservation*, *42*(2), e13418.

Poli, B. M., Parisi, G., Zampacavallo, G., Iurzan, F., Mecatti, M., Lupi, P., & Franci, O. (2001). Quality outline of European sea bass (*Dicentrarchus labrax*) reared in Italy: Shelf life, edible yield, nutritional and dietetic traits. *Aquaculture, 202*(3), 303–315.

Şahin, M.E. (2008). Determination of microorganisms by means of electronic nose and principle component analysis (MSc Thesis in Turkish). Dumlupınar University Graduate School of Natural and Applied Sciences, Türkiye.

Senapati, S. R., Kumar, G. P., Singh, C. B., Xavier, K. M., Chouksey, M. K., Nayak, B. B., & Balange, A. K. (2017). Melanosis and quality attributes of chill stored farm raised whiteleg shrimp (*Litopenaeus vannamei*). *Journal of Applied and Natural Science, 9*(1), 626-631.

Souza, B. W., Cerqueira, M. A., Ruiz, H. A., Martins, J. T., Casariego, A., Teixeira, J. A., & Vicente, A. A. (2010). Effect of chitosan-based coatings on the shelf life of salmon (Salmo salar). *Journal of Agricultural and Food Chemistry, 58*(21), 11456-11462.

Wilson, A. D., Oberle, C. S., & Oberle, D. F. (2013). Detection of off-flavor in catfish using a conducting polymer electronic-nose technology. *Sensors, 13*(12), 15968-15984.

Wu, K., Debliquy, M., & Zhang, C. (2022). Metal-oxide-semiconductor resistive gas sensors for fish freshness detection. *Comprehensive Reviews in Food Science and Food Safety*, *22*(2), 913-945.

Zaukuu, J. Z., Bázár, G., Gillay, Z., & Kovács, Z. (2019). Emerging trends of advanced sensor based instruments for meat, poultry and fish quality- a review. *Critical Reviews in Food Science and Nutrition*, *60*(20), 3443-3460.