International Journal of
Agriculture, Environment and Food Sciences

JAEFS e-ISSN : 2618-5946 DOI: 10.31015/jaefs.2021.1.6 www.jaefs.com

Research Article Int J Agric Environ Food Sci 5 (1):42-50 (2021)

Combination effect of hot smoking and vacuum packaging on quality parameters of refrigerated thornback ray (*Raja clavata* Linnaeus, 1758)

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Abstract

In this study, hot smoking process was applied to thornback ray (*Raja clavata*), which is a non-target catch, and the product obtained was vacuum packaged and then stored at refrigerated conditions (4±1 °C) for 120 days. The nutritional, chemical, microbiological, and sensory changes in the products were examined every 15 days. After the hot smoking process applied to thornback rays, significant changes were observed in the nutritional composition of the products (P<0.05). Total volatile basic nitrogen (TVB-N), trimethylamine nitrogen (TMA-N), and thiobarbituric acid (TBA) values of smoked thornback rays increased during storage, and these values were determined between 23.11-98.06 mg/100 g, 2.48-7.33 mg/100 g, and 0.1-0.3 mg malondialdehyde/kg, respectively. It was determined that the total aerobic mesophilic bacteria (TAMB) count detected in the fresh sample decreased in smoked products due to the smoking process and the value was found below the detectable limit value (1.47 log CFU/g) during storage. As a result of the sensory evaluation, it was determined that the texture, odor, and flavor criteria of the smoked thornback rays were below the consumable limit value on the 120th day. According to the results, it was determined that the thornback ray vacuum packaged by hot smoking can be consumed safely for 105 days at 4±1 °C. This study shows that discarded thornback rays, which are a high protein food, can be transformed into high value-added products by applying different processing methods such as smoking and so can be evaluated as human food.

Keywords: Thornback ray, Vacuum packing, Hot smoking, Cold storage, Shelf life

Introduction

Due to the rapid increase in the world population and the changing ecological balance, the importance of limited food sources is increasing constantly. This situation causes nutritional problems, which is the most important element of human life, and people demand different foods. Aquatic animal resources are of vital importance in this respect. Efforts are being made to maximize opportunities to exploit the existing potential of seafood around the world. The importance of animal origin proteins in the healthy nutrition of living creatures is increasing day by day. Seafood are a high-value food group thanks to their protein, fat, mineral, and vitamin content (Çağlak and Karsli, 2013). However, seafood are among the foods that spoil very quickly due to their biological structure. In this respect, it is important to keep it under suitable conditions after hunting and to increase the variety with different processing methods (Ayas et al., 2005).

The consumption of seafood in Turkey is generally listed as fresh, frozen, and other processing techniques (salting, canning, smoking, and marinade). While many of the smoked products are consumed as a delicious taste in various parts of the world, there is no great demand for these products in Turkey (İzci

Cite this article as:
Karsli, B., Caglak, E. (2021). Combination effect of hot smoking and vacuum packaging on quality parameters of refrigerated thornback ray (Raja clavata Linnaeus, 1758). J. Agric. Environ. Food Sci., 5(1), 42-50
DOI: https://dx.doi.org/10.31015/jaefs.2021.1.6
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Received: 11 November 2020 **Accepted:** 30 December 2020 **Published Online:** 20 February 2021
Year: 2021 **Volume:** 5 **Issue:** 1 (March) **Pages:** 42-50
Available online at : http://www.jaefs.com - http://dergipark.gov.tr/jaefs

and Ertan, 2004; Duman and Patır, 2007). Smoked products are products whose durability is increased by reducing the amount of moisture, especially by using wood shavings, and by processing with antioxidant and antimicrobial effects of smoke compounds such as formaldehyde, carboxylic acid, and phenols. Besides, thanks to the smoking process, products are given sensory properties such as special flavors and color (Gökoğlu, 2002; Erkan, 2004). Hot smoking is usually applied at temperatures of 80-100 °C and it is in the forefront of give the products a smoke aroma during cooking (Gülyavuz and Ünlüsayın, 1999). Chemical, microbiological, and sensory changes occur during the storage of smoked products, and these changes depend on the fish species, fat ratio, pre-smoking processes, smoking method, smoking time, smoking temperature, and smoke content. Also, the storage conditions and packaging processes affect maintaining the quality of smoked products (Erkan, 2004). Duyar et al. (2008) reported that the shelf life of Atlantic bonito increased thanks to hot smoking and vacuum packaging.

When the meat structure of thornback ray is examined, it has the potential to be considered as a food source in terms of having rich protein and fatty acid content like other seafood (Turan et al., 2007). There is no commercial hunting on thornback ray in Turkey and it is generally obtained as a discarded product. While the thornback ray, which is not consumed in Turkey, can be considered as an export product in the Aegean region, however, it is not subjected to any evaluation process in the Black Sea region. In this respect, it is economically important to transform this species, which has valuable nutritional components, into high value-added products by applying different processing methods.

In this study, it was aimed to determine the combined effect of hot smoking and vacuum packaging on some quality changes of thornback ray under refrigerator conditions (+4±1 °C) and to create an economic value for discarded this species with different consumption methods.

Materials and Methods

Fish Material

Thornback ray caught as discarded products were obtained from a fishing boat registered in Rize province, Turkey. 40 thornback rays in total were iced immediately after hunting and brought to Recep Tayyip Erdogan University Fish Processing Technology laboratory in a styrofoam box. Following the thornback ray cleaning procedure, the wing parts of the thornback ray were cut and separated. Then, the skins of the cut wings were peeled off and the meat portions were obtained.

Smoking Process

The smoking process was performed using a mechanical smokehouse with an electronic thermostat (0-300 °C) and humidity control according to the method of Çağlak et al. (2015). Rough sawdust obtained from beech wood was used for the smoking process. First, the products were kept in 10% salt solution at +4 °C for 90 minutes and then filtered for 15 minutes to remove the excess water from the products. Afterward, the filtered products were taken to the incense grids and the smoking process was carried out at 30 °C for 30 minutes (pre-drying), at 60 °C for 60 minutes (smoking), and at 90 °C for 30 minutes (cooking) (Figure 1). The products obtained after the smoking process were cooled, vacuum packed, and stored at +4±1 °C. During storage, analyses were carried out every 15 days with 3 randomly selected packages.

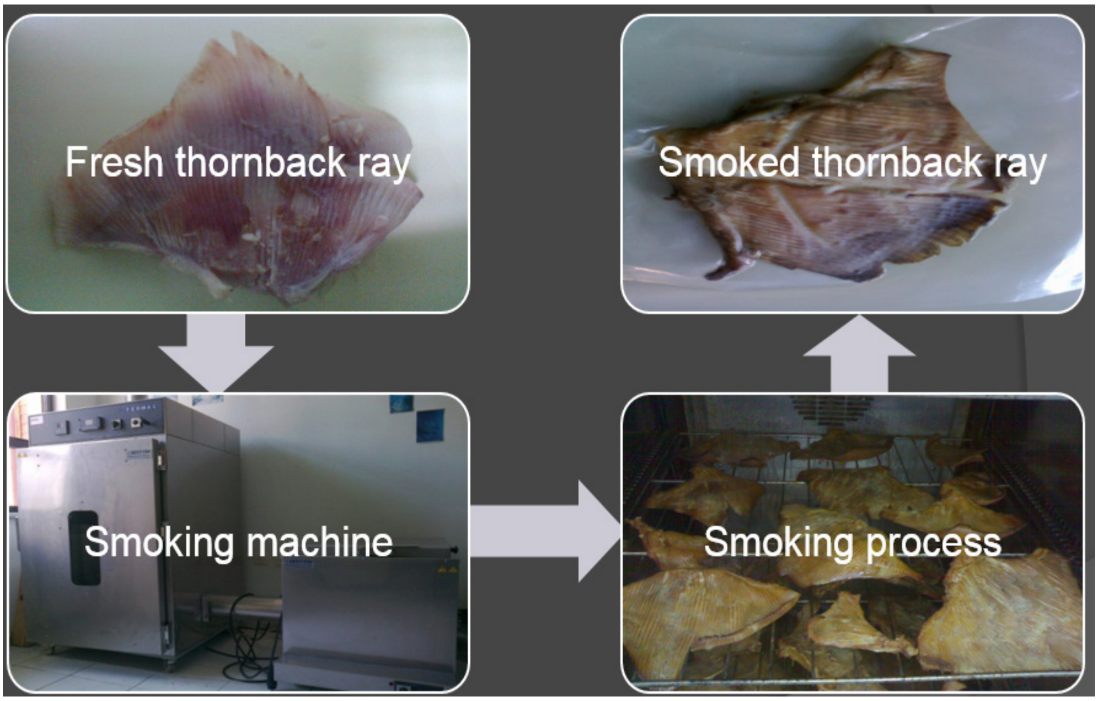

Figure 1. The scheme of product development

Analyses

Meat yield was determined by the ratio of the weight of edible parts to the total fish weight and it was expressed as a percentage (%). The moisture (%), crude ash (%), crude fat (%), and crude protein (%) analyses were performed according to the method of Norwitz (1970). Total volatile basic nitrogen (TVB-N) analysis was carried out according to the Lücke-Geidel method (İnal, 1992; Varlık et al., 1993), trimethylamine nitrogen (TMA-N) analysis was performed according to the method proposed by Dyer (1949) (AOAC, 1990), thiobarbituric acid (TBA) analysis was performed according to Tarladgis et al. (1960) method and pH measurement was conducted according to Curran, et al. (1980).

To determine the microbiological load of the samples, 25 grams of samples were homogenized in sterile physiological saline solution (PSS) of 0.85% and all serial diluting was carried out using PSS. Then, 0.1 ml of the appropriate dilutions were inoculated onto petri dishes. The inoculation process carried out as 48 hours at 37 °C using Plate Count Agar for total aerobic mesophilic bacteria (TAMB) count, 48 hours at 37 °C using Violet Red Bile Agar for total coliform bacteria count, and 3-5 days at 30 °C using Potato Dextrose Agar for the yeast-mold count (Harrigan and McCance, 1976; Halkman, 2005). At the end of the incubation, the results were expressed as log CFU/g.

For sensory analysis, the sensory evaluation form was created by modifying the method reported by Kurtcan and Gonul (1987), Altuğ and Elmacı (2005), and Özer et al. (2012). The products were evaluated by a panelist group of 7 people, considering this form. According to the sensory evaluation form, the appearance, texture, flavor, and odor values of the products were determined using the 10-point hedonic scale (1-2= dislike strongly, 3-4= dislike moderately, 5-6= neutral, 7-8= like moderately, 9-10= like strongly).

Statistical Analysis

All the tests were done in triplicate. Data analyses were performed by one-way ANOVA (analysis of variance) using the JMP software program 5.0.1 (SAS Institute Inc, Cary, NC, USA). Comparison of means was performed using a least significant difference (LSD) method at P<0.05 (Sümbüloğlu and Sümbüloğlu, 2000).

Results and Discussions

In the present study, a total of 25135 g of thornback rays were used and the weight of the remaining wing parts after cleaning was determined to be 8762.04 g. The meat yield of fresh thornback rays before the smoking process was calculated as 34.86%. After the smoking process, the weight of the thornback ray wings was determined to be 5502.35 g (37.2% of total raw wing weight). Meat yield in fish may vary depending on fish species, gender, age, size, breeding period, nutritional status, stomach contents, and geographic region. In the present study, the meat yield of thornback ray was 62.8%. Similarly, Yılmaz and Akpınar (2003) reported that the meat yield of common guitarfish (*Rhinobatos rhinobatos*) was 65%.

The moisture, crude protein, crude fat, and crude ash values (%) of fresh thornback ray were determined as 77.12%, 20.24%, 0.85%, and 1.03%, respectively. Changes were observed in the biochemical composition of smoked thornback rays depending on pre-smoking procedures and temperature applications during smoking process. After the smoking process, the moisture, crude protein, crude fat, and crude ash values of smoked thornback rays were found to be 74.33%, 25.23%, 1.17%, and 2.17%, respectively (Figure 2). The changes in the moisture, crude ash, crude fat, and crude protein of smoked thornback rays during storage are shown in Figure 2. Depending on the smoking process, the initial decrease in the moisture values stabilized after the 15th day of storage. During refrigerated storage, the minimum and maximum moisture values of smoked thornback rays were found to be 68.37% and 74.33%, respectively. There was no statistically significant difference among storage days in terms of moisture values (P>0.05), however, the fresh thornback ray with the highest moisture content differed statistically from smoked products (P<0.05). Due to brine treatment applied to the samples before the smoking process, an increase in ash content of smoked samples was observed, and these values varied between 1.59% and 2.40% during the storage period. The crude ash content of fresh sample was statistically lower than smoked products determined during storage (P<0.05). There is an inverse relationship between fat and moisture ratios. A proportional increase in crude fat values was observed as a result of the loss of moisture due to the temperature process applied in the smoking process. The lowest and highest crude fat value during refrigerated storage was found to be 1.17% on day 1 and 2.54% on day 120, respectively. When examining the changes in crude values during storage, it was determined that the fresh product was different from those on other storage days except day 1 (P<0.05). Also, statistically significant differences were found in the crude fat values of smoked products depending on the storage period (P<0.05). The crude protein value detected in fresh thornback rays increased by 19.78% on day 1 after the smoking process. It was determined that the protein value, which was 25.23% on the 1st day of storage, reached the highest value with 30.64% on the 45th day and this value was found to be 27.64% at the end of the storage period (120th day). The amount of protein detected on the 45th day of storage statistically differed from fresh and 1st day values (P<0.05). This proportional increase in the amount of protein after the smoking process is thought to be due to a decrease in moisture loss due to the heat applied in the smoking process.

In general, the biochemical composition of seafood consists of 66-84% water, 15-24% protein, 0.1-22% fat, 0.8-2% mineral substances, and very small amounts of carbohydrates (Jeyasanta and Patterson, 2013; Matsumoto, 1979). In this study, the moisture, crude protein, crude fat, and crude ash values (%) of fresh thornback ray were within these reported values. The biochemical composition of seafood varies from species to species, as well as among individuals of the same species, depending on age, sex, season, and hunting area. (Huss, 1988; Borgstrom, 1961). Ayas et al. (2019) reported that the fat levels in the muscle tissue of the four ray species (*Dasyatis pastinaca*, *Raja radula*, *Raja clavata,* and *Torpedo* *marmorata*) were between 0.71-1.90%. They also determined that the fat levels of *R. clavata* were between 0.95-1.38%. Özer et al. (2012) investigated the changes in microbiological, physicochemical, and sensorial quality of vacuum-packed sausage from thornback ray and they reported that moisture, protein, fat, and ash content of thornback ray at the beginning and after the smoking process was 75.08-66.34%, 21.57-22.35%, 0.43%-2.40% and 1.47-3.73%, respectively. Colakoglu et al. (2011) stated that the moisture, protein, fat, and ash values of thornback rays were 76.51%, 18.58%, 3.39%, and 1.1% in fresh and 61.36%, 30.62%, 4.41%, and 2.65% in smoked products, respectively. Turan et al. (2007) reported that the moisture, crude protein, crude ash, and crude fat values of thornback rays were 77.47%, 20.02%, 1.38%, and 0.51%, respectively. In another study, it was reported that the moisture, crude protein, crude fat, and crude ash values of common guitarfish changed between 75.83-79.88%, 16.63-22.63%, 0.2-0.7%, and 1-1.65%, respectively (Yılmaz and Akpınar, 2003). Pastoriza and Sampedro (1994) reported that the protein, fat, ash, and moisture values of *R. clavata* wing meats were 16.87%, 0.8%, 1.1%, and 78.9%, respectively. It was determined that the moisture, crude fat, crude protein, and crude ash values determined in the present study were compatible with the nutritional content obtained from other studies.

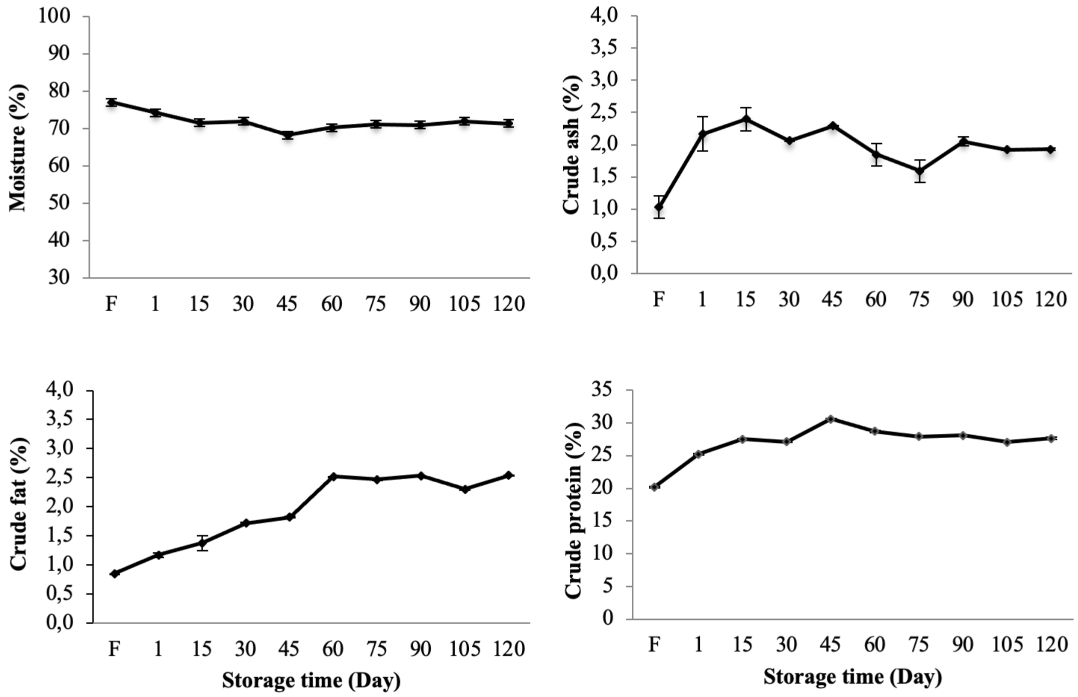

Figure 2. Changes in the biochemical composition of hot smoked thornback ray during storage (F: Fresh).

The change in the pH, TVB-N, TMA-N, and TBA values of the smoked thornback ray during the storage period is shown in Figure 3. In this study, pH was measured as 6.74 in fresh samples. Then this value decreased after the smoking process due to acidic compounds and it is determined to be 5.51 at the end of the 120 days storage period. While a difference was observed between the pH values of the fresh and smoked thornback ray ($P<0.05$), no significant difference was observed among the pH value of the smoked products depending on the storage time ($P>0.05$). It has been stated that the pH value for fresh fish is 6-6.5 and the consumable limit value is 6.8-7 (Connell, 1980; Varlık et al., 1993). Mugica et al. (2008) stated that the initial pH value (6.5) of *Raja clavata* stored in ice increased to 9 levels on the 10th day of storage. Pastoriza and Sampedro (1994) reported that the pH value of *R. clavata* wing muscle, which was initially determined as 6.24, reached 9 at the end of the 15-day ice storage period. In another study, pH values of frozen common guitarfish during the 6-month storage were between 6.5-6.82 (Yılmaz and Akpınar, 2003). Turan and Sönmez (2007) found that the pH values of surimi made from thornback ray fluctuated between 6.9 and 7.4 during storage. Özer et al. (2012) determined that the pH value of the thornback ray was 6.41 at the beginning and 6.18 after the smoking process. They also reported that the pH dropped to 5.8 levels on the 49th-56th days of storage, while it was between 6.1 and 6.4 on other storage days. Compared to the pH data of fresh thornback ray, the data of the present study were similar to the results of Mugica et al. (2008) and Yılmaz and Akpınar (2003), while the findings found by Pastoriza and Sampedro (1994) and Özer et al. (2012) were found to be higher than the data of this study. In the present study, the decreases in the pH values of the thornback ray after the smoking process compared to the fresh sample were also similar to the data reported by Özer et al. (2012).

Thornback ray, which is included in the cartilage fish group, has a higher proportion of urea and nitrogen compounds than other seafood due to their biological structure. In this respect, the TVB-N limit value for cartilage fish is stated as 50-100 mg/100 g (Varlık et al., 1993; Uyttendaele et al., 2018). The TVB-N content of smoked products varies according to fresh product quality, product packaging type, brine density applied before smoking, storage conditions, and the type of product processed (Bilgin et al., 2007). In this study, the TVB-N value of fresh thornback ray was determined to be 23.11 mg/100 g, however, it reached 98.06 mg/100 g on day 90 (Figure 3). These values determined in fresh and on the 90th day was statistically different compared to other storage days (P<0.05). Although fluctuations were observed in the TVB-N value of smoked thornback rays during storage, it generally tended to increase. Considering the TVB-N limit value of 100 mg/100 g, it was observed that the TVB-N value of smoked thornback ray approached the limit value on the 90th day (98.06 mg/100 g). Turan and Sönmez (2007) stated that the TVB-N value of fresh thornback ray is 15.4 mg/100 g. Özer et al. (2012) reported that the initial TVB-N value of sausages obtained from thornback ray increased from 28.7 mg/100 g to 31.5 mg/100 g after the smoking process. In the same study, they also reported that the TVB-N value of thornback ray sausages stored at +4 °C increased to 50 mg/100 g on the 14th day, decreased to 25 mg/100 g on the 21st day, and then again increased to 43 mg/100 g at the end of the storage period. Yılmaz and Akpınar (2003) reported that the TVB-N values of frozen common guitarfish during the 6-month storage period were between 19.87 mg/100 g and 48.62 mg/100 g. The high TVB-N value detected in thornback ray in this study was similar to other literature studies. Similarly, it was determined in other studies that TVB-N values of rays did not exceed the limit value of 100 mg/100 g reported for TVB-N. It is thought that this increase in the TVB-N value of the smoked products is caused by the water loss of the products as a result of the smoking process and the proteolytic activities that continue in the fish during salting and smoking (Günlü, 2007).

The lipids in seafood are more exposed to oxidation than other meats due to their high unsaturation. Depending on the oxidation, fatty acids and peroxides are formed first, and then the oxidation of peroxides creates aldehydes and ketones that cause unpleasant odor and rancidity. Thiobarbituric acid (TBA) value is used to determine the rancidity of lipids (Ramanathan and Das, 1992; Soyer, 1999). It was reported that TBA should be lower than 3 mg malonaldehyde (MA)/kg in very good material, 3-5 mg MA/kg in a good product, and the consumable threshold value is 7–8 mg MA/kg (Schormuller, 1968). TBA value, which is indicative of lipid oxidation, was in the range of 0.1 and 0.3 mg MA/kg during 120 days of refrigerated storage (Figure 3). The TBA value of the fresh sample was statistically different from the values of the smoked products obtained during storage (P<0.05). Considering the changes between storage days, it was determined that the TBA value on the 105th and 120th days of storage was statistically different from the other storage days (P<0.05). The low levels of TBA during storage are thought to be due to the low fat content of the thornback ray used in this study, the antioxidant properties of the smoke compounds, and the oxidation inhibiting effect of the vacuum packaging application. Aberoumand and Baesi (2020) reported that vacuum packaging treatment had significant effects on delaying lipid oxidation. Turan and Sönmez (2007) reported that the maximum TBA value of frozen surimi thornback ray stored for 6 months was 1.24 mg MA/kg. Özer et al. (2012) reported that the TBA value of vacuum-packed sausage from thornback ray increased regularly during 56 days of storage and it did not exceed 2.5 mg MA/kg at the end of the storage period. As seen in other studies, the increase in the TBA values of the rays during the storage in the present study was limited and the TBA value did not even reach 3 mg MA/kg, which is a very good material value.

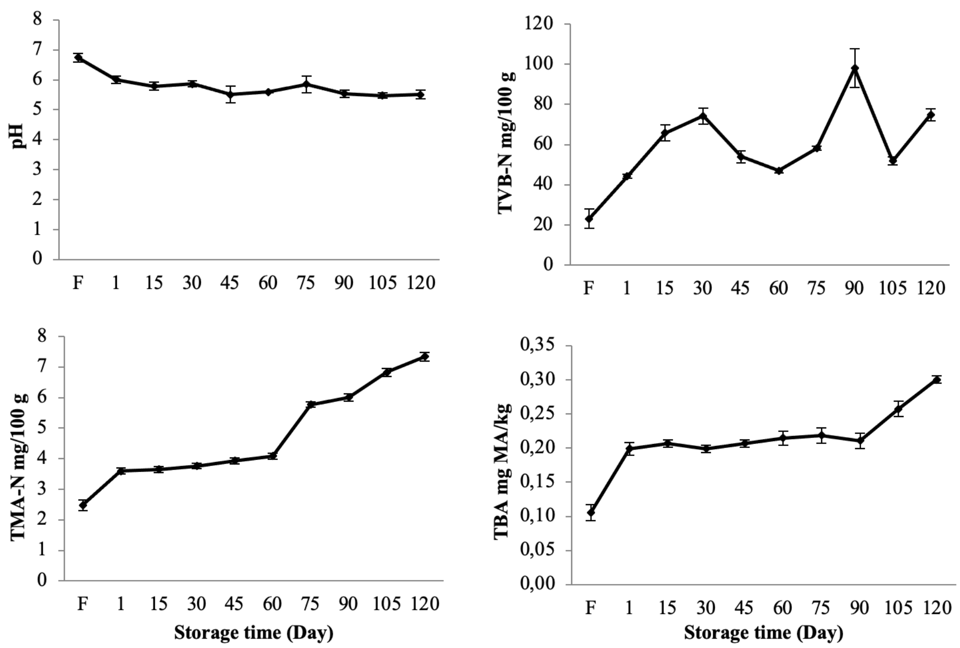

Figure 3. Changes in pH, TVB-N, TMA-N, and TBA values of hot smoked thornback ray during storage (F: Fresh).

TMA-N is degraded by the reduction of trimethylamine oxide (TMAO) by bacteria and mostly forms the breakdown products of proteins. TMAO is a quaternary ammonium compound responsible for osmoregulation in marine fish and its amount in fish may vary depending on the fish species, size, age, seasons, and environmental conditions (Huss, 1995; Koutsomanis and Nychas, 1999). It has been recommended that the TMA-N value should be between 1 and 8 mg/100 g in quality seafood for human consumption (Varlık et al., 1993). In another study, the TMA-N value was reported to be good up to 4 mg /100 g and marketable up to 4-10 mg/100 g (Nickerson and Sinskey, 1972). In the present study, the amount of TMA-N in the fresh thornback ray was found to be 2.48 mg/100 g. The differences observed in TMA-N values among storage days (except for the 1st and 15th days of storage) were found to be statistically significant ($P<0.05$). The TMA-N value of smoked products increased regularly during storage period and reached 7.33 mg/100 g on the 120th day (Figure 3). At the end of the storage period, it was determined that smoked thornback ray preserved their marketable feature according to the limit values reported in terms of TMA-N values. Similarly, Turan and Sönmez (2007) reported that the TMA-N value of fresh thornback ray is 2.08 mg/100 g. Özer et al. (2012) stated that the initial TMA-N value of 0.4 mg/100 g in vacuum-packed sausage from thornback ray increased to 2.8 mg/100 g at the end of the storage period (56 days). This increase in TMA-N was in agreement with the result of the present study, but they found a lower TMA-N value than the present study data at the end of the storage period. This difference is thought to be due to the different initial TMA-N content. In addition, Goulas and Kontominos (2005) reported that the TMA-N value of vacuum-packed smoked chub mackerel increased during 30 day storage periods at 2 °C, however, TMA-N values of salted and smoked products were at very low levels (2.28-3.64 mg/100 g) at the end of the storage.

The maximum microbiological limit value in seafood for consumption has been reported as 6-7 log CFU/g for total aerobic bacteria and 2.0 log CFU/g for total coliform (ICMSF, 1986). Coliform bacteria are not found in fish caught from clean waters, but these bacteria can be found in fish meat as an indicator of contamination in further processing (Patır and İnanlı, 2005). In this study, TAMB, total coliform, and yeast-mold analyses were carried out during the study period. The TAMB count in fresh thornback ray was found to be 2.64 log CFU/g and the value fell below detectable the limit value of 1.47 log CFU/g after the smoking process. Total coliform and yeast-mold values were determined as <1.47 log CFU/g in fresh and smoked products during refrigerated storage. Also, it was determined that TAMB, total coliform, and yeast-mold values did not change during 120 days of storage and these values were below 1.47 log CFU/g. Therefore, data on TAMB counts were not shown in Figure. The reason for this decrease may be the killing or preventing the growth of bacteria with the effect of the temperature and smoke components used in the smoking process. Vyncke (1978) reported that the initial total bacteria of thornback ray treated with sodium tripolyphosphate and citric acid kept under ice increased from 5.8 log CFU/g to 9 log CFU/g at the end of the storage period. In a study, the total bacterial count of *R. clavata* wing muscle was reported as 3 log CFU/g at the beginning and 6.6 log CFU/g at the end of 15 days storage (Pastoriza and Sampedro, 1994). Özer et al. (2012) found that the TAMB count of vacuum-packed sausage from thornback ray increased from 4.09 log CFU/g (initial value) to 7.69 log CFU/g at the end of 56 days storage. They also reported that the total coliform and yeast-mold counts were not detected in samples during storage. The TAMB count in fresh thornback ray determined in the present study was similar to the results reported by Pastoriza and Sampedro (1994). Also, the results of total coliform and yeast-mold count reported by Özer et al. (2012) were consistent with the result of the present study. However, it is seen that the number of TAMB detected in this study is lower than the other study data. Microorganism load in fish is affected by many internal and external factors such as fish species, fishing location, fishing season, and procedures applied (Hussain and Uddin, 1997). In addition, packaging conditions that reduce the amount of oxygen present in the package, such as vacuum package, can inhibited the growth of aerobic spoilage bacteria and extend the shelf life of the product (Jaberi et al., 2019). In this respect, the differences observed in the studies are thought to arise due to these factors.

The results of the sensory analysis performed by using the appearance, texture, flavor, and odor criteria of the thornback ray are shown in Figure 4. Sensory evaluation is one of the most important criteria used in determining the quality of seafood. If a product is sensually undesirable, it cannot be consumed even if it is of good quality in terms of other quality criteria (Dokuzlu, 1997; Özden et al., 2001). Criteria such as appearance, odor, flavor, and texture considered in the sensory analysis are evaluated with human senses. Therefore, considering these sensory criteria in studies on food is of great importance for the consumer in food quality control. In this study, a 10-point hedonic scale was used for the sensory evaluation of the products, and products below 5 points were considered to be inconsumable. At the beginning, the smoked samples were appreciated by the panelist and received a higher score. Then, the sensory scores of the smoked thornback ray evaluated by the panelists showed a linear decrease depending on the storage time. According to the sensory evaluation, it was determined that smoked thornback rays maintained their sensory quality for 105 days, while texture, flavor, and odor criteria of the products were below the consumable limit values (5) on the 120th day of storage. It was determined that the changes in appearance, texture, flavor, and odor criteria, which decreased depending on the storage period, were statistically significant ($P<0.05$). Özer et al. (2012) reported that the average sensory acceptability of vacuum-packed sausage from thornback ray was 5.98 out of 10. Turan and Sönmez (2007) stated that the sensory scores of surimi thornback rays were at moderate and acceptable levels at the end of the 6-month storage period. Yılmaz and Akpınar (2003) reported that the sensory scores (appearance, smell, chewiness, aroma, moistness and overall palatability) of frozen common guitarfish, which were evaluated over 10 points, were 6.0-

7.1 in vacuum products and 5.7-6.4 in non-vacuum products at the end of 6 months storage. Comparing the data of this research with other studies, it has been observed that although the sensory qualities of different products obtained from rays changed depending on the processes performed, they preserve their organoleptic properties for a long time.

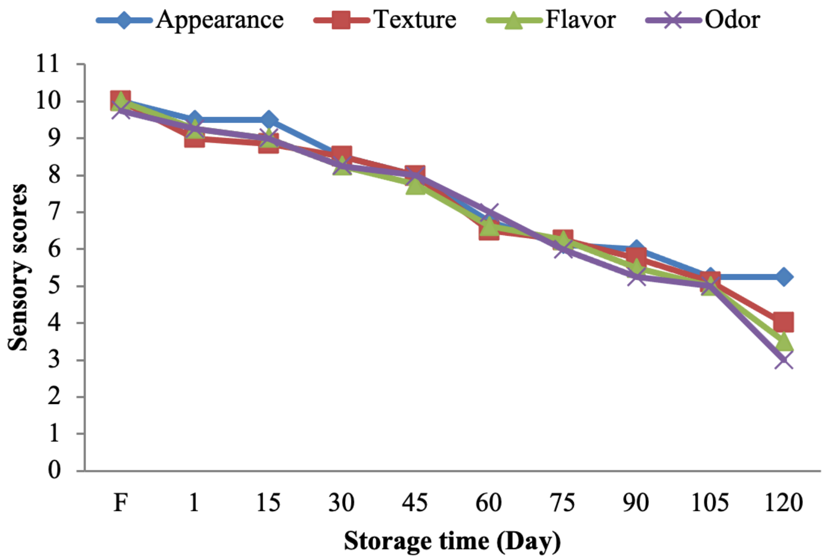

Figure 4. Changes in the sensory scores of hot smoked thornback ray during the storage period (F: Fresh)

Conclusion

In this study, nutritional, chemical, microbiological, and sensory changes of hot smoked thornback ray stored at +4±1 °C for 120 days were examined. According to the results, the chemical quality criteria such as TVB-N, TBA, and TMA-N of smoked thornback rays were within the consumable limit values during the storage period. The smoked thornback ray maintained their sensory quality for 105 days and remained within the consumable limit values. However, the sensorial scores of smoked thornback rays were below the consumable values at the end of the 120 day storage. It is thought that the extension of the shelf life and the improvement of the quality criteria of samples during the storage period is due to the combined effect of hot smoking and vacuum packaging. When it was examined nutritionally, it was observed that thornback ray has high protein content such as anchovy, bonito, horse mackerel, sea bass, sardine fish which are generally consumed. Smoked thornback ray was also sensually appreciated by panelists. According to these results, the evaluation of discard products such as thornback ray used in this study by applying different processing methods such as smoking, marination, and canning will be of great importance in meeting the increasing food demand due to the increasing world population. Thus these applications can contribute to both waste management and the economy.

Compliance with Ethical Standards

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Not applicable.

Funding

No financial support was received for this study.

Data availability

Not applicable.

Consent for publication

Not applicable.

References

Aberoumand, A. and Baesi, F. (2020). Effects of vacuum packaging in freezer on oxidative spoilage indexes of *fish Lethrinus atkinsoni*. Food Science &Nutrition, 8(8), 4145-4150. Doi: https://doi.org/10.1002/fsn3.1704

Altuğ, T. and Elmacı, Y. (2005). Duyusal değerlendirme Teknikleri. Sidas Medya Ltd. Şti., İzmir. ISBN: 978-9944-5660-8-7 (in Turkish).

AOAC. (1990). Official methods of analysts, 15th ed. Arlington, VA: Association of Official Analytical Chemists.

Ayas, D., Ekingen, G. and Çelik, M. (2005). Seyhan Baraj The Seasonal differences in nutrient composition of the fillets of common carp (*Cyprinus carpio* L. 1758) caught from Seyhan dam lake and chemical organoleptic changings of these fillets following hot smoking. Journal of Eğirdir Fisheries Faculty of Süleyman Demirel University, 1(1), 12-20.

Ayas, D., Eliuz, E.A.E, Peri, F. and Bakan, M. (2019). Determination of usage potential of some Mediterranean rays in fish oil production. Marine Science and

Technology Bulletin, 8(1), 13-22. Doi: https://doi.org/10.33714/masteb.480957

Bilgin, Ş., Ertan, Ö.O., and İzci, L. (2007). Investigation on changes in the chemical composition of hot smoked Salmo trutta macrostigma, Dumeril 1858, stored different temperatures. Journal of FisheriesSciences.com, 1(2), 68-70.

Borgstrom, G. (1961). Fish as Food, Volume I: Production, Biochemistry, and Microbiology, Academic Press Inc., London. ISBN: 978-0-12-395569-2.

Colakoglu, F.A., Ormanci, H.B. and Cakir, F. (2011). Effect of marination and smoking on lipid and fatty acid composition of thornback ray (*Raja clavata*) and spiny dogfish (*Squalis acanthias*). European Food Research and Technology, 232, 1069-1075. Doi: https://doi.org/10.1007/s00217-011-1477-x

Connell, J.J. (1980). Control of Fish Quality. 2nd Ed., Fishing News Books Ltd., Surrey, England. ISBN: 978-0852381052.

Curran, C.A., Nicoladies, L., Poulter, R.G., and Pors, J. (1980). Spoilage of fish from Hong Kong at different storage temperatures. Tropical Science, 22, 367-382.

Çağlak, E. and Karslı, B. (2013). Seasonal meat yield and chemical composition of zander (*Sander lucioperca* Linnaeus,1758) in Beyşehir Lake. Eğirdir Su Ürünleri Fakültesi Dergisi, 9(1), 1-8

Çağlak, E., Karslı, B. and Koral, S. (2015). Effects of different processing techniques on the carpet shell (*Ruditapes decussatus* Linnaeus, 1758). Journal of Food Safety and Food Quality, 66(5), 141-148. Doi: https://doi.org/10.2376/0003-925X-66-141

Dokuzlu, C. (1997). Marinat hamsi üretimi sırasında kullanılan asit-tuz oranlarının ürünün mikrobiyolojik ve organoleptik kalitesi üzerine etkileri ve raf ömrünün belirlenmesi. Pendik Veteriner ve Mikrobiyoloji Dergisi, 28(1), 81-90 (in Turkish).

Duman, M. and Patır, B. (2007). Tütsülenmiş aynalı sazan (*Cyprinus carpio* L.) filetolarının bazı kimyasal ve duyusal özelliklerinin belirlenmesi. Fırat Üniversitesi, Fen ve Mühendislik Bilimleri Dergisi, 19(4), 463-472 (in Turkish).

Duyar, H.A., Erdem, M.E., Samsun, S. and Kalayci, F. (2008). The effect of the different woods on hot-smoking vacuum packed Atlantic bonito (*Sarda sarda*) stored at 4 °C. Journal of Animal and Veterinary Advances, 7(9), 1117-1122.

Dyer, W.J. (1949). Bacterial reduction of sodium nitrite and formation of trimethylamine. Journal of the Fisheries Research Board of Canada, 7, 576-579. Doi: https://doi.org/10.1139/f47-037

Erkan, N. (2004). Dumanlama Teknolojisi, Su Ürünleri İşleme Teknolojisi. Su ürünleri İşleme Teknolojisi. Ed: Varlık, C. İstanbul Üniversitesi, yayın No: 4465, 234-273, İstanbul. ISBN: 975-404-715-4 (in Turkish).

Goulas, A.E. and Kontominos, M.G. (2005). Effect of salting and smoking method on the keeping quality of chub mackerel (*Scomber japonicus*): biochemical and sensory attributes. Food Chemistry, 93(3), 511–520. Doi: https://doi.org/10.1016/j.foodchem.2004.09.040

Gökoğlu, N. (2002). Su Ürünleri İşleme Teknolojisi, Su Vakfı Yayınları, İstanbul, 157p. (in Turkish).

Gülyavuz, H. and Ünlüsayın, M. (1999). Su Ürünleri İşleme Teknolojisi. Şahin Matbaası, Ankara. ISBN: 975-96897-0-7 (in Turkish).

Günlü, A. (2007). Determination of shelf-life and changes of some nutrient components after smoking proces of cultured sea bass (*Dicentrarchus labrax* L. 1758). Journal of Natural and Applied Sciences, Isparta, Turkey.

Halkman, A. (2005). Merck gıda mikrobiyoloji uygulamaları. Başak Matbaacılık Limited Şti., Ankara. ISBN: 9750037308 (in Turkish).

Harrigan, W.F. and McCance, M.E. (1976). Laboratory Methods in Food and Dairy Microbiology. Academic Press Incorporated, London. ISBN: 012326040X.

Huss, H.H. (1995). Quality and quality changes in fresh fish. FAO Fisheries Technical Paper, Rome.

Huss, H.H. (1988). Fresh fish: quality and quality changes. Food and Agriculture Organization (FAO) of the United Nations, Rome.

Hussain, M.M. and Uddin, M.H. (1997). Quality control and marketing of fish and fish products: Needs for infrastructure and legal support. National workshop on fisheries resources development and management in Bangladesh. Bay of Bengal Programme, Madras, India, pp. 231-272.

ICMSF (1986). Microorganisms in foods 2: sampling for microbiological analysis: principles and specific applications. 2nd Edn. International Commission on Microbiological Specifications for Foods. Blackwell Scientific, Oxford.

İnal, T. (1992). Besin hijyeni. Hayvansal gıdaların sağlık kontrolü. Final Ofset, Genişletilmiş 2. Baskı, İstanbul. (in Turkish).

İzci, L. and Ertan, Ö.O. (2004). Changes in meat yield and food component of smoked tench (*Tinca tinca* L., 1758). Turkish Journal of Veterinary and Animal Sciences, 28, 1037-1041.

Jaberi, R., Kaban, G. and Kaya, M. (2019). Effects of vacuum and high-oxygen modified atmosphere packaging on physico-chemical and microbiological properties of minced water buffalo meat. Asian-Australasian Journal of Animal Sciences, 32(3), 421-429. Doi: https://doi.org/10.5713/ajas.18.0391

Jeyasanta, K.I., Patterson, J. (2013). Total lipid, phospholipid and cholesterol contents of six commercially important fishes of Tuticorin, south east coast of India. Sky Journal of Food Science, 2(6), 47-53

Koutsomanis, K., Nychas, G.J.E. (1999). Mediterranean boque (*Boops boops*) stored aerobically at 0, 3, 7 and 10 °C. Applied and Environmental Microbiology, 65, 698–706. Doi: https://doi.org/10.1128/AEM.65.2.698-706.1999.

Kurtcan, Ü. and Gönül, M. (1987). Gıdaların duyusal değerlendirilmesinde puanlama metodu. Ege Üniversitesi Mühendislik Fakültesi Dergisi, 5, 137-146. (in Turkish).

Matsumoto, J.J. (1979). Denaturation of fish muscle proteins during frozen storage. Advances in Chemistry, pp. 205–224. American Chemical Society: Washington, DC. Doi: https://pubs.acs.org/doi/abs/10.1021/ba-1979-0180.ch010

Mugica, B., Barros-Velazquez, J., Miranda, J.M. and Aubourg, S.P. (2008). Evaluation of a slurry ice system for the commercialization of ray (*Raja clavata*): Effects on spoilage mechanisms directly affecting quality loss and shelf-life. LWT-Food Science and Technology, 41, 974-981. Doi: https://doi.org/10.1016/j.lwt.2007.06.017

Nickerson, J.T. and Sinskey, A.J. (1972). Microbiology of Foods and Food Processing. American Elsevier Publishing Company Inc., New York. ISBN: 978-0444001245.

Norwitz, W. (1970). Drained weight determination of frozen glazed fish and other marine products. AOAC Official Method.

Özden, Ö., Metin, S., Baygar, T. and Erkan, N. (2001). Vakum Paketlenmiş marine balıkların kalitesinin belirlenmesinde yağ asitleri ve aminoasit bileşimindeki değişimlerin incelenmesi. Proje Sonuç Raporu, Tübitak, Proje No: VHAG-1713/ADP.

Özer, E., Ünlüsayın, M. and Erdilal, R. (2012). Microbiological, physicochemical and sensorial quality of vacuum-packed sausage from thornback ray (*Raja clavata* L., 1758) at chilled storage. Journal of Agroalimentary Processes and Technologies, 18(1), 1-7.

Pastoriza, L. and Sampedro, G. (1994). Influence of ice storage on ray (*Raja clavata*) wing muscle. Journal of the Science of Food and Agriculture, 64, 9-18. Doi: https://doi.org/10.1002/jsfa.2740640103

Patır, B. and İnanlı, G.A. (2005). Microbiological Quality and TMA-N levels of fresh horse Mackerel (Trachurus mediterraneus, S. 1868) marketed in Elazığ. Fırat University Journal of Engineering Science, 17, 360-369.

Ramanathan, L. and Das, N.P. (1992). Studies on the control of lipid oxidation in ground fish by some polyphenolic naturel products. Journal of Agricultural Food Chemistry, 40, 17-21. Doi: https://doi.org/10.1021/jf00013a004

Schormuller, J. (1968). Handbook of food chemistry (Band III/2). Springer-Verlag, Berlin, Heidelberg.

Soyer, A. (1999). Balıkta lipit oksidasyonunda rol oynayan hücresel faktörler. Gıda Teknolojisi, 4(3), 58-64 (in Turkish).

Sümbüloğlu, K. and Sümbüloğlu, V. (2000). Biyoistatistik, Hatiboğlu Yayınları No: 53, 9. Baskı, Ankara. (in Turkish).

Tarladgis, B.G., Watts, B.M., Younathan, M.T. and Dugan, L. (1960). Distillation method for the determination of manolaldehyde in rancid foods. Journal of the American Oil Chemists Society, 37, 44–48. Doi: https://doi.org/10.1007/BF02630824

Turan, H. and Sönmez, G. (2007). Changes in the quality of surimi made from thornback ray (*Raja clavata*, L. 1758) during frozen storage. International Journal of Food Sciences and Nutrition, 58(7), 557-566. Doi: https://doi.org/10.1080/09637480701343762

Turan, H., Sönmez, G. and Kaya, Y. (2007). Fatty acid profile and proximate composition of the thornback ray (*Raja clavata*, L. 1758) from the Sinop coast in the Black Sea. Journal of FisheriesSciences.com, 1(2), 97-103. Doi: https://doi.org/10.3153/jfscom.2007012

Uyttendaele, M., De Loy-Hendrickx, A., Vermeulen, A., Jackxsens, L., Debevere, J. and Devlieghere, F. (2018). Microbiological guidelines: Support for interpretation of microbiological test result of foods. Die Keure Publishing, Brugge, Belgium. ISBN: 978-2874035036.

Varlık, C., Uğur, M., Gökoğlu, N. and Gün, H. (1993). Su ürünlerinde kalite kontrol ilke ve yöntemleri. Gıda Teknolojisi Derneği Yayın No:17, İstanbul, 174p. (in Turkish).

Vyncke, W. (1978). Influence of sodium tripolyphosphate and citric acid on the shelf life of thornback ray (*Raja clavata* L.). Zeitschrift für Lebensmittel Untersuchung und Forschung, 166, 284-286. Doi: https://doi.org/10.1007/BF01127654

Yılmaz, A.B. and Akpınar, D. (2003). Determination of Proximate Composition and Quality Changes in the Common Guitarfish (Rhinobatos rhinobatos L., 1758) during Cold Storage. Turkish Journal of Veterinary Animal Sciences, 27, 207-212.