Arch Lebensmittelhyg 66,
141–148 (2015)
DOI 10.2376/0003-925X-66-141

ISSN 0003-925X

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Effects of different processing techniques on the carpet shell (*Ruditapes decussatus* Linnaeus, 1758)

Auswirkung unterschiedlicher Verarbeitungstechniken auf die Qualitätsmerkmale von Teppichmuscheln (Ruditapes decussatus, Linnaeus, 1758)

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Summary

In this study, the effects of different processing techniques on the food quality of carpet shells (*Ruditapes decussatus,* Linnaeus, 1758) were Investigated. Carpet shells were smoked, smoked-marinated, and marinated, and stored for 7 months at 2±1 °C. During the 210-day storage period, total volatile basic nitrogen, trimethylamine nitrogen, thiobarbituric acid, total mesophilic and psychrophilic aerobic bacteria counts, yeast-mold counts, and lactic acid bacteria counts for each group did not exceed acceptable limits, and coliform bacteria, *E. coli, Staphylococcus aureus, Salmonella* spp., or *Listeria* spp. were not detected. However, sensory scores for texture, appearance, odor, and flavor decreased gradually over time. Based on the results of our sensory, chemical, and microbiological analysis, smoked, smoked-marinated, and marinated carpet shells can be safely consumed within 120, 150, and 180 days, respectively.

Keywords: Carpet shell, smoking, marination, shelf life, *Ruditapes decussatus*

Zusammenfassung

In dieser Studie wurden die Effekte unterschiedlicher Verarbeitungstechniken auf die Lebensmittelqualität von Teppichmuscheln (*Ruditapes decussatus,* Linnaeus, 1758) untersucht. Die Teppichmuscheln wurden entweder geräuchert, geräuchert und mariniert oder mariniert und anschließend für 7 Monate bei 2 ± 1 °C gelagert. Während der 210tägigen Lagerungsdauer wurden bei den verschiedenen Parametern (flüchtige Basenstickstoffe, Trimethylamin-Stickstoff, Thiobarbitursäure, aerobe mesophile und psychrophile Gesamtkeimzahl, Schimmelpilze und Hefen und Milchsäurebakterien) keine Grenzwertüberschreitungen festgestellt. Ferner wurden keine coliformen Bakterien, *E. coli, Staphylococcus aureus, Salmonella* spp. oder *Listeria* spp. nachgewiesen. Jedoch verschlechterten sich im Laufe der Zeit die sensorischen Eigenschaften in Bezug auf Textur, Erscheinungsbild, Geruch und Geschmack. Basierend auf den Ergebnissen der sensorischen, chemischen und mikrobiologischen Untersuchungen lässt sich festhalten, dass die geräucherten Teppichmuscheln innerhalb von 120 Tagen, die geräuchert-marinierten Teppichmuscheln innerhalb von 150 Tagen und die marinierten Teppichmuscheln innerhalb von 180 Tagen verzehrt werden sollten.

Schlüsselwörter: Teppichmuschel, Räuchern, Marinieren, Haltbarkeit, *Ruditapes decussatus*

Journal of Food Safety and Food Quality 66, Heft 5 (2015), Seiten 125–156

Introduction

Seafoods have high nutritional value. They are rich in protein, vitamins, and unsaturated fatty acids, and they contain almost all of the amino acids found in nature (Bilgin, 2003). Countries that promote balanced diets are investing in the future by looking for new food-industry technologies that can enhance current protein sources and produce products that will satisfy consumers' tastes (Aslan, 1999). Currently, smoking and marination are two common commercial processing techniques used for seafoods.

Smoked products are processed by exposing the product to smoke from wood and wood chips, which extends product shelf life (Erkan, 2004) through dehydration and the antibacterial and antioxidant effects of the smoke (Goulas and Kontominas, 2005). Other components such as formaldehyde, carboxylic acid, and phenols also provide a specific aroma and color to the fish (Goulas and Kontominas, 2005).

Marination is an ancient preservation method that increases the shelf life of products through a combination of acetic acid and salt, which inhibits the action of bacteria and enzymes. Today, marinated foodstuffs may be processed with acid, salt, vegetable fat, and sometimes flavorings (TGK, 2000). Marinated products may be packed in sauce or brine, or they may be heat treated (Meyer, 1965). They are considered a fast food in that they are usually consumed without cooking (Gram and Huss, 1996).

Carpet shell (*Ruditapes decussates,* Linnaeus, 1758) belongs to the family Veneridae and lives buried in sandy and muddy ground. It has become an important commercial product in demand by some countries, is exported as fresh or chilled by Turkey (Çelik, 2004). Though Portugal is currently the largest carpet shell producer, France and Spain are also significant producers. In Turkey, carpet shells are collected from the Black Sea and the Aegean coast and are marketed to West European countries. The total world production of carpet shells was 3,798 tons in 2000 and grew to 4,103 tons in 2012 (FAO, 2012). Developing new processing techniques that extend shelf life will allow exporters to expand their markets.

The aim of this study was to determine the effects of different processing techniques (smoking, smoking and marinating, and marinating) on quality criteria and shelf life of carpet shells stored at 2 ± 1 °C.

Material and Methods

Live carpet shells *(R. decussatus)* were obtained from a private company operating on the Aegean Sea in Edremit (Balikesir Province, Turkey). A total of 100 kg of carpet shells were used (mean size ± : length = 4.36 ± 0.38 cm; thikness = 2.31 ± 0.23 cm; width = 3.13 ± 0.27 cm; weight = 20.86 ± 5.86 g). Carpet shells were placed into hot water (85 °C) until the shells opened (~5 min). After separating the meat from the shell (BC), 21.22 kg of meat were pretreated for 15–20 min in a 10% salt solution and then divided into three treatment groups: smoked carpet shell (SC), smoked-marinated carpet shell (SMC), and marinated carpet shell (MC). All groups were packaged.

The smoking process was performed in three stages (predrying: 30 min at 30 °C; smoking: 60 min at 60 °C; cooking: 30 min at 90 °C) in a mechanical smoking oven. After smoking, 7 kg (SC group) were vacuum packed (125 g per package) and 7 kg were marinated.

The marination process was the same for both smoked and unsmoked carpet shell meat. The meat was marinated (1:1.5 meat/marinade) in a solution of 3 % acetic acid (Merck, Rahway, NJ, USA) and 6 % salt (Billur, İzmir, Turkey) for 20 hours at 2 ± 1 °C. Smoked-marinated samples (SMC group) were vacuum packed (125 g meat per package). The nonsmoked marinated meat (7 kg; MC group) was packed in sunflower oil in transparent plastic containers (250 mL; 125 g meat per box). All groups were stored at 2 ± 1 °C in a laboratory refrigerator (Atasoy, Trabzon, Turkey) that can be adjusted to 0–5 °C. Analyses were performed on fresh, boiled, and treated carpet shells. During storage, treated and packaged carpet shells were tested monthly; three new randomly chosen packages from each treatment group were tested each month. Results of testing days 120, 150, and 180 are reported.

Chemical analysis

Dry matter, crude ash, crude protein, and crude fat content of the samples were determined using the methods described by Norwitz (1970). Total volatile basic nitrogen (TVB-N) was determined according to the Lücke-Geidel method (İnal, 1992; Varlık et al., 1993). Thiobarbituric acid (TBA) was determined according to the method of Tarladgis (1960). Trimethylamine nitrogen (TMA-N) was determined according to Dyer's (1959) method (AOAC, 1990). The pH was measured as described by Curran et al., 1980, using a HI 3220 pH meter (Hanna Instruments, Woonsocket, RI, USA). Water activity (a_w; 0.100–1.000 ± 0.003) was measured with the AquaLab 4TE (Decagon Devices, Inc., Pullman, WA, USA) device (ISO, 2004). Salt and acid content of the samples were determined according to Varlık et al. (1993) and Karl (1994), respectively.

Color analysis

The homogenized samples for color analysis were measured using the CR-14 Color Reader (Konica Minolta, Japan). The Y*, x*, y* values were determined according to CIE color table values.

Microbiological analysis

All chemicals for microbiological analysis were obtained from Merck (Rahway, NJ, USA), unless otherwise noted. Microbial counts were duplicated and expressed as log CFU/g (FDA, 1998; Halkman, 2005; Harrigan and Mccance, 1976; Pal and Marshall, 2009).

For each analysis, a 10 g sample was aseptically placed into a sterile stomacher bag containing 90 mL of sterile dilution and homogenized using a stomacher (Interscience). Serial dilutions were prepared to 10^{-6} g/mL: physiological saline (85 %) was used for total viable bacteria, yeast-molds, lactic acid bacteria, total coliform, and *Escherichia coli* counts; maximum recovery diluent was used for *Staphylococcus aureus* counts; buffered peptone water was used for *Salmonella* counts; and listeria enrichment was used for *Listeria* counts.

Total viable counts of mesophilic and psychrophilic microorganisms were obtained using plate count agar incubated at 37 °C for 48 h and at 4 °C for 8 days, respectively (Halkman, 2005). Yeast-mold counts were taken after incubation on potato dextrose agar at 37 °C for 48 h. Lactic acid bacteria were counted using de Man-Rogosa-Sharpe (MRS) agar incubated at 30 °C for 3–5 days (Dalgaard and Jorgensen, 1999). Violet red bile agar was used for total coliform and *E. coli:* plates were first incubated at

37 °C for 48 h, after which, suspect *E. coli* colonies from each plate were incubated at 44.5 °C for 24 h in tubes containing tryptone water and then tested for indole with Kovac's reagent (Halkman, 2005).

Staphylococcus aureus counts were determined using Baird-Parker agar; plates were incubated at 37 °C for 24–48 h and suspect colonies were confirmed biochemically (FDA, 1998). *Salmonella* spp. were incubated at 35 °C for 24 h in buffered peptone water, and then enriched in tetrathionate broth, incubated at 35 °C for 24 h. The selective enrichment cultures were seeded onto xylose lysine deoxycholate agar plates and at incubated 35 °C for 24 h. Typical *Salmonella* spp. colonies were confirmed with biochemical tests (FDA, 1998; Pal and Marshall, 2009).

For *Listeria* spp. count, cultures were first enriched in Listeria enrichment broth then incubated at 30 °C for 4 h. Listeria selective enrichment supplement (0.5 mL) was added into cultures, which were then incubated at 30 °C for 48 h. Finally, the cultures were seeded onto PALCAM agar plates and incubated at 35 °C for 48 h. Typical *Listeria* spp. colonies were confirmed with biochemical tests (FDA, 1998).

Sensory analysis

Sensory evaluations were conducted by five experienced panelists, according to the method described by Schormüller (1968) and modified by Varlık et al. (1993) for processing techniques specific to carpet shells. The samples were assessed on odor, taste, appearance, and texture characteristics using a 9-point descriptive scale. A score of 7–9 indicated "very good" quality, 5.1–6.9 was "good" quality, 4.0–5.0 met "the limit of acceptability," and 1–3.9 was "spoiled".

Statistical analysis

Analysis of variance (ANOVA) was used to compare results within groups and among groups. A Tukey test (P <0.05) was used to compare means when significant differences were found through ANOVA. Statistical analyses were carried out using JMP 5.0.1 (SAS Institute, Inc., Cary, NC, USA) (Sümbüloğlu and Sümbüloğlu, 2000). Graphs were plotted with SigmaPlot 12.0 (Systat Software Inc., San Jose, CA, USA).

Results and Discussion

After separation from the shells, meat yield was 21.22 %. The dry matter content of fresh carpet shell meat was 18.41 %. After boiling, smoking, and marinating processes, this value increased to 19.51 % in BC, 24.3 % in SC, 23.35 % in SMC, and 23.59% in MC on Day 0 (Fig. 1a.). These findings are similar to those of other researchers. Çelik (2004) found that dry matter of fresh and marinated clam *(Tapes decussatus)* was 18.17 % and 23.43 %, respectively. Cakli et al. (2004) reported that dry matter content of raw clam *(Ruditapes decussates)* varied between 11.84–16.01 % during an 8-month period. In another study, dry matter content was 25.55 % in fresh clam *(R. decussatus)* and 27.05 % in marinated clam (Cakli et al., 2005).

The crude ash content of fresh carpet shell was 3.16 % and that value increased to 6.17 % in SC, 5.96 % in SMC, and 5.28 % in MC on Day 0 after the smoking and marinating processes. These increases were in proportion to the amount of salt used in marinating and the amount of water lost during smoking. Except for Day 180, there were no significant differences in crude ash content between the SC and SMC groups during the storage period. However, crude ash content in these groups was significantly different from that of the MC group (P <0.05) on all testing days except Day 0, 15 and 30 (Fig. 1b.). Turan et al. (2007) stated that crude ash content of raw, boiled, smoked Mediterranean mussels was 0.95 %, 0.77 %, and 6.22 %, respectively. Whereas, Çelik (2004) found crude ash content was 1.50 % in raw clams, which decreased to 1.37 % after marinating.

The changes in crude fat content during storage were greatest in the MC group and least in the SMC group. The crude fat content of fresh carpet shell (0.34 %) increased after the smoking and marinating processes (Fig. 1c.). The crude fat content of SC, SMC, and MC on Day 1 were 0.53 %, 0.54 %, 0.42 %, respectively; the crude fat content increased after Day 15 for the MC group due to the addition of sunflower oil. By the end of the storage period, the MC group's crude fat content (Day 210 = 2.45 %) was significantly higher (P <0.05) than that of the other groups. Turan et al. (2008) reported the crude fat content of Mediterranean mussels was 1.14 % in fresh mussels, 2.11 % in boiled mussels, and 10.04 % in smoked mussels. In fresh clams, crude fat content (1.80 %) increased to 2.33 % on Day 1 after marination (Cakli et al., 2005).

Finally, the crude protein content of fresh carpet shells (10.54 %) increased based on treatment. By Day 210, crude protein content (SC = 13.84 %; SMC = 12.68 %; MC = 13.53 %) was significantly different (P <0.05) between groups (Fig. 1d.). Similarly, protein content was reported as 10.76 % in fresh clams (Çelik, 2004) and 10.8 % in fresh Mediterranean mussels (Goulas, 2008).

Fresh carpet shell samples contained 0.97 % salt, and all groups were pretreated in 10 % brine. After smoking, the salt content of the SC group was 3.6 % (Fig. 2a.). The salt content of the SMC and MC groups on Day 0 was 5.30 % and 5.08 %, respectively. Similarly increases, Cakli et al. (2005) found that the salt content of marinated clams was 1.24 % on Day 1, 1.28 % on Day 10, 2.49 % at Month 2, and 2.30 % at Month 6.

Acid content was 0.15 % in fresh carpet shells. After maturation, acid content reached 2.11 % in the SMC group and 2.64 % in the MC group on the Day 0 (Fig. 2b.). Acid content continued to increase in both groups during storage, reaching 2.69 % in the SMC group and 3.41 % in the MC group at the end of the storage, which was significantly different (P <0.05). Dalgıç and Erkoyuncu (2003) reported that acid content varied over time in both smoked mussel marinades (2.70–2.99 %) and nonsmoked mussel marinades (3.12–3.66 %). Other studies found that acid values were 0.68 % in marinated clams (Çelik, 2004), 0.47–0.92 % in marinated clams during a 6-month storage period (Cakli et al., 2005) and 0.31–0.71 % in marinated warty venus during a 76-day storage period (Kilinc et al., 2008).

Figure 3a shows the total volatile basic nitrogen (TVB-N) values for all groups. The TVB-N initially decreased after boiling (fresh: 5.63 mg/100 g; boiled: 5.28 mg/100 g) then increased during storage. TVB-N values of SC, SMC and MC groups were found as 28.86 mg/100 g, 11.26 mg/100 g and 19.01 mg/100 g on Day 210, respectively. Despite these increases, no group's TVB-N exceeded the 35 mg/100g acceptable limit. Similar results were found in smoked-marinated (4.15 mg/100g) and nonsmoked-marinated (11.90 mg/100 g) (Dalgıç and Erkoyuncu, 2003). Kilinc et al. (2008) reported a TVB-N of 13.72 mg/100 g in fresh mussels *(Venus verrucosa);* this value decreased to

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7.53 mg/100 g after marinating and reached 14.9 mg/100 g at the end of a 76-day storage period.

Seafood meats are exposed to lipid oxidation, which produces thiobarbituric acid (TBA), at higher rates than other meats due to their high unsaturated fat content (Ramanathan and Das, 1992; Olgunoğlu, 2007). In this study, TBA values of fresh carpet shells was found 0.94 mg malonaldehit(MA)/kg, and this value decreased to 0.75 mg MA/kg after boiling (Fig. 3b.). No significant differences were found between SC and SMC groups during the storage period (P >0.05). Indeed, evaluators judged their TBA quality as "very good" after 210 days of storage. It is likely that oxidation in these groups was prevented by the relatively low fat content of carpet shells and the vacuum packaging. In contrast to the SC and SMC groups, the MC group had a TBA of 2.32 mg MA/kg on Day 0 after maturation, and this increased to 6.4 mg MA/kg, with the addition of fat during packaging. Cakli et al. (2005) reported that TBA values were 2.64 mg MA/kg in fresh clams, 2.61 mg MA/kg on Day 1 after maturation, and 4.43 mg MA/kg at the end of storage. Kilinc et al. (2008) reported TBA values for marinated warty venus as 3.99 mg MA/kg on the first day and 4.42 mg MA/kg at the end of the storage period.

Trimethylamine nitrogen (TMA-N), which is responsible for osmoregulation, varies depending on species, size, age, season, and environment (Huss, 1995; Koutsoumanis and Nychas, 1999). In our study, TMA-N values of were as follows: fresh = 0.72 mg/100 g; boiled = 0.61 mg/100 g; and Day 0: SC = 0.75 mg/100 g; SMC = 0.92 mg/100 g; and MC = 0.97 mg/100 g. On Day 210, there were significant differences (P <0.05) between groups: MC was highest (3.55 mg/100 g), SMC was lower (2.84 mg/100 g), and SC was the lowest (2.49 mg/100 g). However, TMA-N values did not exceed food-industry limits in any group (Fig. 3c.). TMA-N values of fresh Mediterranean mussel were reported as 1.13 mg/100 g (Turan et al., 2007) and 1.82 mg/100 g (Goulas et al., 2005). Kaba and Erkoyuncu (2005) stated that TMA-N values of differently processed mussels were 1.58 mg/100 g (fresh), 0.81 mg/100 g (boiled, Day 0), 5.85 mg/100 g (raw, Month 9), and 3.95 mg/100 g (boiled, Month 9).

A pH of 4–4.5 effectively prevents bacterial decomposition of marinated products (Varlık et al., 2004). The pH values of groups in this study are shown in Figure 3d. The pH of fresh carpet shells (6.68) decreased to 5.20 after smoking (Day 0). Significant pH changes did not occur in the SC group during the storage period (P >0.05). At the

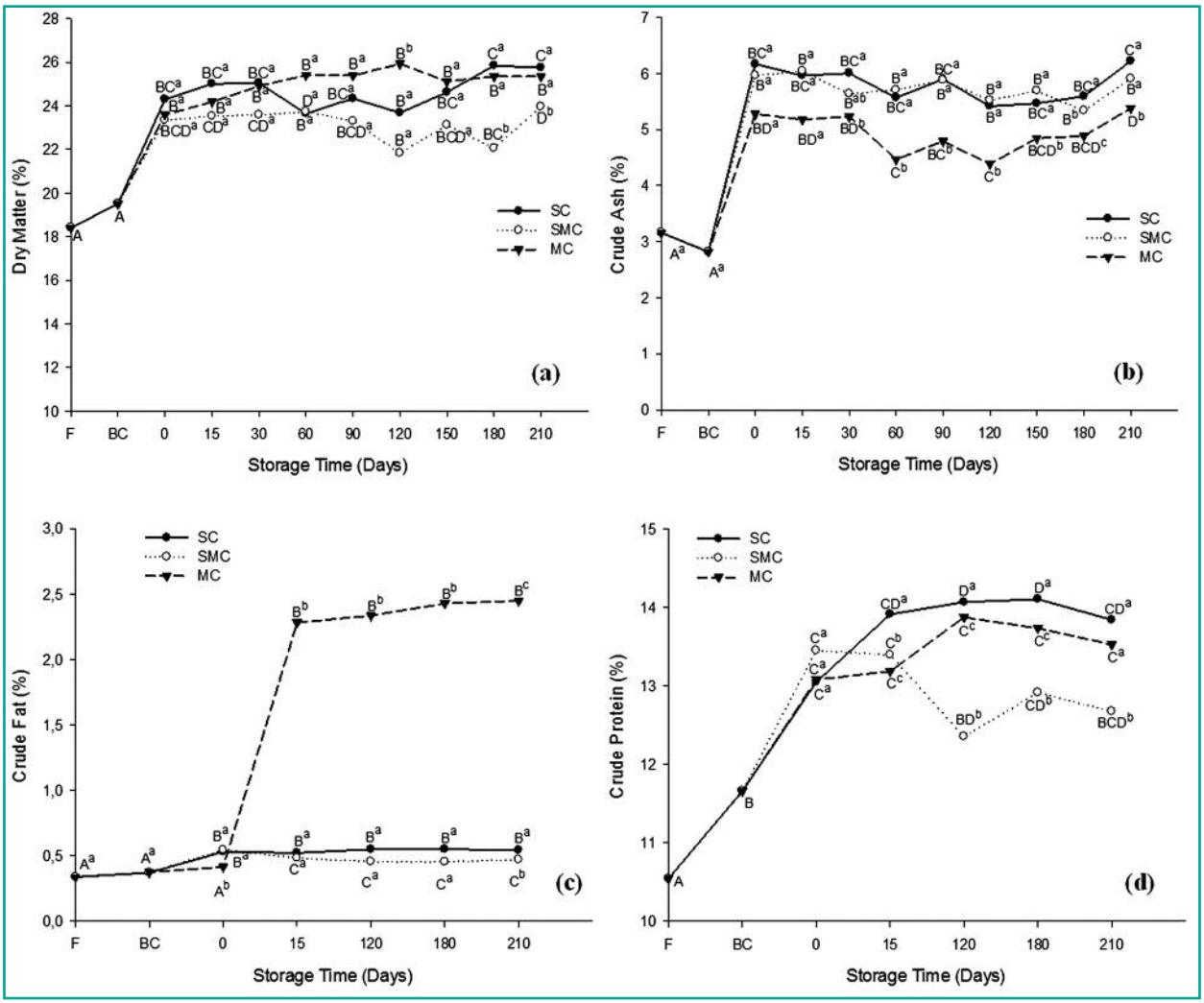

FIGURE 1: *Biochemical contents of smoked and marinated carpet shell during the storage. F, fresh; BC, boiled carpet shell; SC, smoked carpet shell; SMC, smoked marinated carpet shell; MC, marinated carpet shell. The different letters (A,B,C…) shows statistical differences were detected within the same group in the different storage day (P<0.05). The different letters (a,b,c) shows statistical differences were detected among groups in the same storage day (P<0.05).*

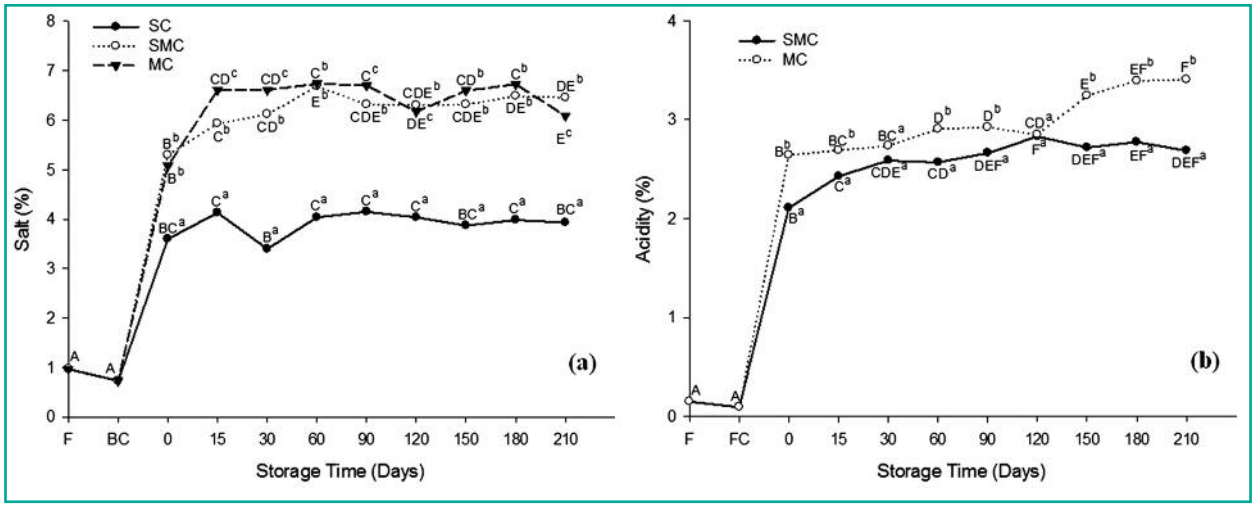

FIGURE 2: *Salt and acidity contents of smoked and marinated carpet shell during the storage. F, fresh; BC, boiled carpet shell; SC, smoked carpet shell; SMC, smoked marinated carpet shell; MC, marinated carpet shell. The different letters (A,B,C…) shows statistical differences were detected within the same group in the different storage day (P<0.05). The different letters (a,b,c) shows statistical differences were detected among groups in the same storage day (P<0.05).*

beginning of storage (Day 0), pH values of SMC and MC were 4.16 and 3.82, respectively, and were found statistically different (P <0.05). Cakli et al. (2005) reported that the pH of marinated clams decreased to 3.73 (Day 1) and changed between 3.73–4.47 during the storage period. Kilinc et al. (2008) found that the pH of marinated warty venus increased from 3.99 to 4.42 during a 76-day storage period. Similar results were found in Mediterranean

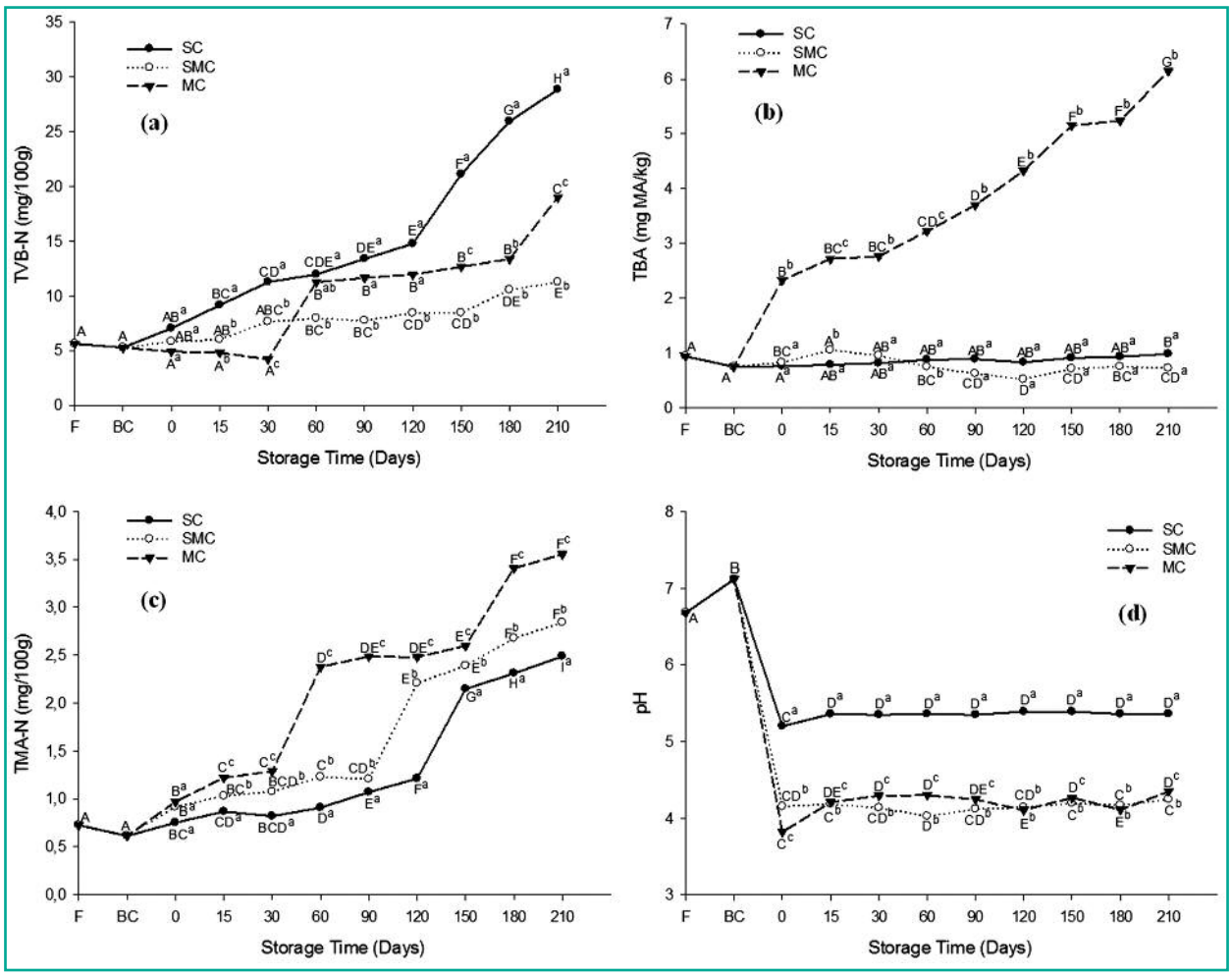

FIGURE 3: *Chemical contents of smoked and marinated carpet shell during the storage. F, fresh; BC, boiled carpet shell; SC, smoked carpet shell; SMC, smoked marinated carpet shell; MC, marinated carpet shell. The different letters (A,B,C...) shows statistical differences were detected within the same group in the different storage day (P<0.05). The different letters (a,b,c) shows statistical differences were detected among groups in the same storage day (P<0.05).*

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mussels; the pH of 6.45 in fresh mussels increased to 7.38 after boiling and then decreased to 4.51 following smoking (Turan et al., 2008).

Salting and smoking are effective preservation methods because they reduce the amount of water in food products and thereby minimize microbial growth. Fernandez-Salguero and Llinarcs (1985) reported that water activity (a_w) values of smoked, canned, and marinated Spanish fish products were 0.935–0.993, 0.968–0.974, and 0.976, respectively. Catteneo and Cantoni (1987) stated that vacuum-packed smoked trout should have a value higher than 0.94 (Kılıç, 2005). In this study, the a_w values of vacuum-packed groups were less than 0.97, which prevents the survival (toxin production) of *Clostrodium botulinum* (FDA, 2001). The a_w value of carpet shells decreased from 0.981 (fresh) to 0.964 boiled. Following the smoking and marinating processes, Day 0 a_w values were 0.959 (SC), 0.967 (SMC), and 0.987 (MC; Fig. 4a.). These values decreased in all groups during the storage period (Day 210 a_w values: SC = 0.947, SMC = 0.958, and MC = 0.952; P >0.05).

The color of a substance may be objectively measured using a color space in which "Y*" indicates brightness, "x*" indicates redness, and "y*" indicates greenness. On Day 210, the color dimensions of the groups ranged from 8.35 to 15.40 (Y*), from 0.365 to 0.406 (x*), and from 0.376 to 0.384 (y*). The Y* values for SC and SMC groups were low due to the smoking process. In contrast, the Y* value of the MC group was higher due to marination and the addition of sunflower oil (Fig. 4b.). On Day 210, the x* values for each group was 0.397 (SC), 0.406 (SMC), and 0.365 (MC), and the MC group was significantly different (P <0.05) from the other groups (Fig. 4c.). The values of y* increased from 0.350 (fresh) to 0.383 (boiled) and showed fluctuations during the storage period; however, y* values were 0.384 (SC), 0.382 (SMC), and 0.376 (MC) at the end of the storage period (Fig. 4d.). The irregular color results for carpet shell meat may be due to the multiple color pigments in its structure. However, because no other studies have measured color in seafood using Y*, x*, y* criteria, the cause of our irregular results is unknown.

Total aerobic mesophilic bacteria (TAMB) count was 2.36 log CFU/g for fresh samples. After boiling, TAMB count decreased to below 1.47 log CFU/g. Microbiological activities were further restricted by the effects of marinating and smoking. Storage temperature (2 ± 1 °C) and vacuum packaging of SC and SMC groups also provided a restricting effect. Consequently, significant microbial growths did not occur in any groups (P >0.05). Just, the MC group increased after the Day 90 and TAMB count was found 1.75 log CFU/g on Day 150, 2.39 log CFU/g on Day 180 and 2.62 log CFU/g on Day 210. Similarly, total aerobic psychrophilic bacteria (TAPB), yeast-molds, and lactic acid bacteria counts were all <1.47 log CFU/g during the storage

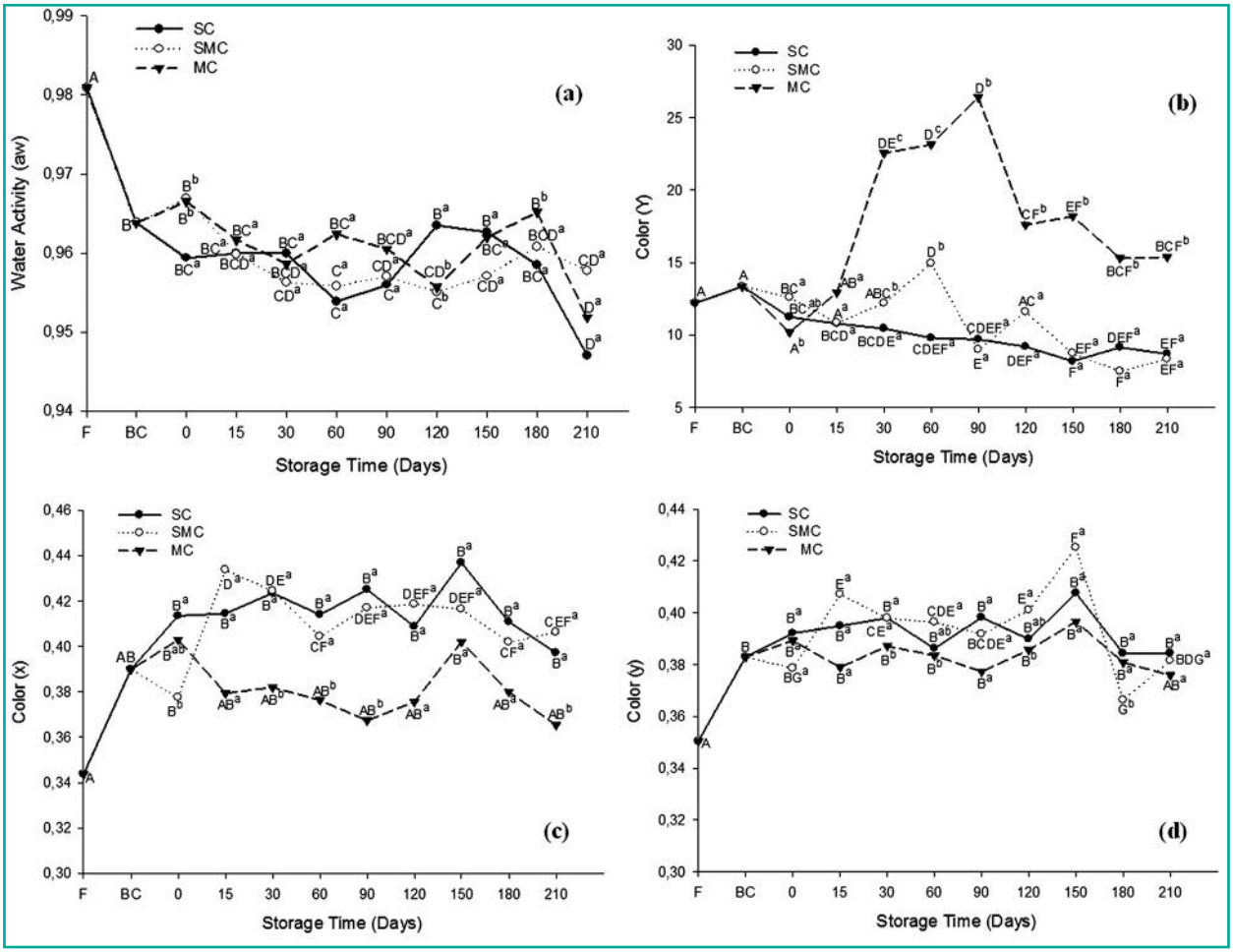

FIGURE 4: *Water activity and color values of smoked and marinated carpet shell during the storage. F, fresh; BC, boiled carpet shell; SC, smoked carpet shell; SMC, smoked marinated carpet shell; MC, marinated carpet shell. The different letters (A,B,C...) shows statistical differences were detected within the same group in the different storage day (P<0.05). The different letters (a,b) shows statistical differences were detected among groups in the same storage day (P<0.05).*

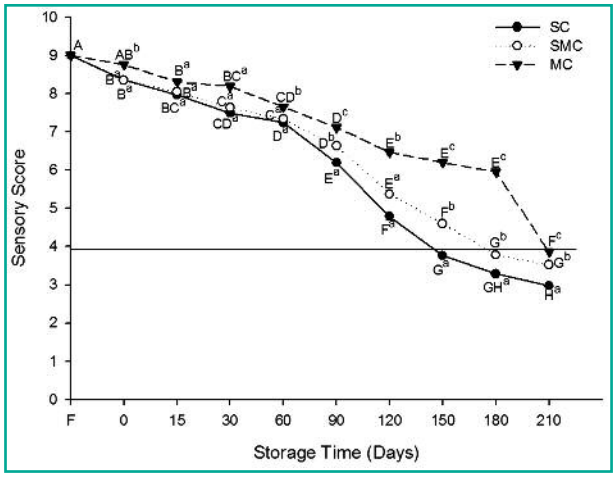

FIGURE 5: *Average Sensory Scores of smoked and marinated carpet shell during the storage. F, fresh; BC, boiled carpet shell; SC, smoked carpet shell; SMC, smoked marinated carpet shell; MC, marinated carpet shell. The different letters (A,B,C...) shows statistical differences were detected within the same group in the different storage day (P<0.05). The different letters (a,b,c) shows statistical differences were detected among groups in the same storage day (P<0.05).*

period. Though total coliform bacteria, *E. coli, Staphylococcus aureus, Salmonella* spp., and *Listeria* spp. analyses for all groups were carried out during the storage period, none were detected during the study period. Patir and Duman (2006) stated that bacteria count in smoked fish was significantly less than that in fresh fish, and the amount of decrease depended on the type of processing. According Aksu et al. (1997), high acid and salt concentrations have inhibiting effects on microorganisms. Ozogul et al. (2008) did not detect *E. coli,* coliform, *Salmonella,* and *Staphylococcus aureus* in mixed marinated seafood salad, and the total viable bacteria count remained low (3 log CFU/g) after 3 months of storage.

Sensory analysis is one of the most commonly used methods in the evaluation of food deterioration. In our study, panelists evaluated product groups on appearance, texture, odor, and flavor criteria (see Fig. 5. for full results). The scores of all groups decreased significantly during the storage period (P <0.05). Panelists reported that the MC group was the most liked, and the SC group was the least liked. Indeed, sensory scores (appearance, texture, odor, and flavor) for the SC group were scored as "spoiled" (1–3.9) earlier than the SMC and MC groups. SC, SMC and MC groups fell below limit value (3.9) on Day 150 (3.76), 180 (3.78) and 210 (3.86), respectively. However, in Cakli and colleagues' (2005) study, marinated clams did not fall below sensory analysis limits during a 6-month storage period. Kilinc et al. (2008) stated that marinated warty venus did not fall below the limits for taste, texture, appearance, and odor during a shorter 76-day storage period. In contrast, Dalgıç and Erkoyuncu (2003) reported that smoked marinated and nonsmoked marinated mussels stored at 5 °C fell below acceptable limits at Month 4 and Month 3, respectively.

Conclusion

In this study, marination, without smoking, was the most suitable method for carpet shell processing. Smoked and smoked-marinated products are viable alternatives, but our results show that they have a shorter shelf life. According to our sensory, chemical, and microbiological analyses, smoked carpet shells can be safely consumed within 120 days, and smoked-marinated carpet shells must be eaten within 150 days, but marinated carpet shells may last an extra month (180 days). Today, the marketability of a wide variety of preserved fishery products depends on the development of fast-food technology. Based on our results, we recommend that producers consider offering marinated carpet shells to consumers, perhaps as a fast food that can be combined with salads and pastas.

Acknowledgments

This study was supported by the Scientific Research Fund of Recep Tayyip Erdogan University (RTEUBAP) with project number 2012.103.03.1. We would like to thank their financial and technical support.

Conflict of interest

The authors declare that there are no conflicts of interest.

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