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# EFFECTS OF SMOKING WITH DIFFERENT WOOD CHIPS AND BARBECUING ON SOME PROPERTIES OF SALMON FISH

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## ABSTRACT
In the present study, the effects of smoking with different wood chips and barbecuing on some properties (moisture content, pH value and lipid oxidation) of salmon fish were investigated. The smoking process was carried out by cold smoking method using five different wood chips: oak, apple, bourbon soaked oak, cherry and hickory. The lowest moisture content was determined in the samples smoked with bourbon soaked oak wood chips. Smoking and barbecuing caused an increase in the pH values and the highest pH value was determined in the samples smoked with hickory wood chips. In addition, both processes had a significant effect on TBARS value of salmon ($P$ <0.05). Wood chip types showed both antioxidant and prooxidant effects in the present study. The lowest TBARS values in smoking and barbecuing processes were determined in the samples smoked with hickory wood chips.
**Keywords:** Smoking, wood chips, barbecue, lipid oxidation, salmon

# FARKLI ODUN TALAŞLARI İLE TÜTSÜLEME VE MANGALDA PİŞİRMENİN SOMON BALIĞININ BAZI ÖZELLİKLERİ ÜZERİNE ETKİLERİ

## ÖZ
Bu çalışmada, farklı odun talaşları ile tütsüleme ve mangalda pişirmenin somon balığının bazı özellikleri (nem içeriği, pH değeri ve lipid oksidasyonu) üzerine etkileri araştırılmıştır. Tütsüleme işlemi beş farklı odun talaşı (meşe, elma, burbon, kiraz ve ceviz) kullanılarak soğuk tütsüleme yöntemiyle gerçekleştirilmiştir. En düşük nem içeriği burbon odun talaşı ile tütsülenen örneklerde belirlenmiştir. Tütsüleme ve mangalda pişirme işlemleri pH değerinde artışa neden olmuştur ve en yüksek pH değeri ceviz odun talaşı ile tütsülenen örneklerde belirlenmiştir. Ayrıca, her iki uygulama TBARS değeri üzerinde önemli ($P$ <0.05) etki göstermiştir. Odun talaşı tipleri bu çalışmada hem antioksidan hem de prooksidan etki göstermiştir. Tütsüleme ve mangalda pişirme işlemlerinde en düşük TBARS değeri ceviz odun talaşı kullanılan örneklerde belirlenmiştir.
**Anahtar kelimeler:** Tütsüleme, odun talaşı, mangal, lipid oksidasyonu, somon

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## INTRODUCTION

In recent years, there has been increased awareness of the beneficial effects of fish consumption on nutrition and health. Therefore, the demand for fresh and processed fish products in the world is increasing day by day (Guizani et al., 2014). The nutritional benefits of fish consumption are related to the use of certain vitamins and minerals, as well as the high quality protein content of the fish. In addition, fish also contain omega-3 polyunsaturated fatty acids that play an important role in human health (Sidhu, 2003). Especially fatty fishes such as salmon are noted as a good source of docosahexanoenoic acid (C22:6n-3) and eicosapentaenoic acid (C20:5n-3) (Guizani et al., 2014).

Besides its high nutritional value, fresh fish is also an easily degradable protein source due to its high water content (Slamova et al., 2017). Therefore, various methods are used to maintain and extend the shelf life of fish and other seafood (Chang et al., 1998; Guizani et al., 2014). In this context, one of the oldest methods of fish preservation is the smoking and the smoking is still widely used in fish processing. In the report published by FAO (2016), in 2014, it was reported that while 46 % (67 million tonnes) of the fish production were presented to direct human consumption, about 12% of the rest of the production for edible purposes were dried, salted or smoked. Some components with antioxidant and antimicrobial activity found in smoke increase the shelf life of fish by acting on enzymes and microorganisms. In addition, the sensory properties of the product are also improved as a result of smoking (Sunen et al., 2001; Slamova et al., 2017).

While wood chips used in smoking are generally composed of 50% cellulose, 25% hemicellulose and 25% lignin, the cellulose and hemicellulose content may vary depending on the type of wood chips. This may cause the smoke forming temperatures of the wood chips types to differ (Pöhlmann et al., 2012; Malarut and Vangnai, 2018). Therefore, in addition to factors such as smoking temperature and duration, fish type and fat content, wood chips type is also among the factors affecting the quality of smoked product (Slamova et al., 2017). Hardwoods such as beech, cherry, oak and softwoods such as pine fir are the most common types of wood chips (Stolyhwo and Sikorski, 2005).

The fish is usually cooked using different techniques, such as frying, oven, grilling or barbecuing before being consumed. However, one of the most common methods used especially in the preparation of fatty fishes is the barbecuing (Costa et al., 2009). Barbecuing is frequently used in the preparation of fatty fishes such as salmon in Turkey (Öz et al., 2010a, 2010b; Öz and Kotan, 2016).

Although there are many studies to determine the qualitative properties of smoked fish (Leroi and Joffraud, 2000; Espe et al., 2001; Espe et al., 2002; Lin et al., 2003; Martinez et al., 2007; Guizani et al. 2014; Messina et al., 2018), these studies have focused on salting conditions and smoking time and temperature. In addition, to the best of our knowledge, a study investigating the effects of smoking and barbecuing on some qualitative characteristics of salmon has not been found in the literature. Therefore, in the present study, it is aimed to determine the effects of smoking with different types of wood chips and barbecuing on moisture content, pH and TBARS values of salmon.

## MATERIAL AND METHODS

### Material

In the present study, salmon (*Salmo salar*) fishes (n=14), grown in Black Sea, were used as material. The fishes were obtained as frost from a local fish store, Erzurum. Frozen fishes were brought to the laboratory, and the fillets were prepared in the laboratory.

### Smoking

Salmon fillets were separated to seven groups and these groups were smoked with cold smoking method. Smoking process was performed by using a smoking device (Polyscience, the smoking gun PRO, ÖRKA, Turkey) in a special sealed pouch (ÖRKA, Turkey) for 3 hours at 24°C. To determine the effect of only smoking, fish fillets were not subjected to salting. Two different

control groups were used in order to determine the changes in the control group during 3-hour smoking.

**Barbecuing**
Wood charcoal was used in barbecuing process of the salmon fishes and after all flames had subsided, salmon fillets were barbecued. The surface temperature of the grill was measured by using a digital thermocouple with a surface probe (0603 1992, Testo 926, Lenzkirch, Germany) and the temperature was approximately 200 ºC.

All fillets were turned over at half of (4 min) the total cooking time (8 min). The experiment was carried out in two replications and two different salmon fillets were used for each group. After barbecuing, the fillets were cooled to room temperature. Then the skins of the fillets were removed and homogenized for analysis.

**Determination of moisture content**
The moisture contents of the salmon fillets were determined as weight loss of approximately 10 g homogenized samples after drying at 100±2 °C for 24 h (Gökalp et al., 2010).

**Determination of pH values**
To determine of pH values of the salmon fillets, 10 g sample with 100 mL distilled water were homogenized with an ultra turrax (IKA Werk T 25, Germany), then pH of the samples were measured using a pH-meter (ATI ORION 420, MA 02129, USA). The pH meter was calibrated using suitable buffer solutions (pH 4.0 and pH 7.0) (Gökalp et al., 2010).

**Determination of thiobarbituric acid reactive substances (TBARS) values**
In the determination of lipid oxidation, analysis of thiobarbituric acid reactive substances (TBARS) value was used. TBARS value was determined by the method of Kılıç and Richards (2003). In this method, 2 g samples were taken and 12 mL trichloroacetic acid (TCA) solution (7.5% TCA, 0.1% EDTA, 0.1% propyl gallate, 1-propyl gallate dissolved in 3 mL of ethanol) was added on them, they were homogenized for 15–30 s and filtered with Whatman 1 filter paper. 3 mL of the obtained filtrate was taken in a tube and 3 mL 0,02 M thiobarbituric acid (TBA) solution was added on it. These mixtures were kept in boiling water bath for 40 min, cooled under tap water for 5 min and centrifuged at 2000 g for 5 min. Afterwards, absorbance of the sample was measured at 532 nm wavelength against blind. 3 mL TBA solution was added on 3 mL TCA extract for blind and the steps for the samples were applied likewise. 1,1,3,3- tetraethoxypropane was used for the calculation of k value. TBARS values were given as mg malondialdehyde (MDA)/kg.

**Statistical analysis**
The data obtained in the present study were subjected to analysis of variance. The experiment was a completely randomized design with two replications. Duncan multi comparison test was applied to the data in order to determine the statistical differences between the values detected by using the Statistical Package for the Social Sciences 11.5 statistical software package.

## RESULTS AND DISCUSSION

**Moisture content, pH and TBARS values of salmon fishes non-smoked and smoked with different wood chips**
Moisture content, pH and TBARS values of the salmon fillets non-smoked and smoked with oak, apple, bourbon soaked oak, cherry and hickory wood chips were given in Table 1.

As can be seen from the Table 1, smoking process had a significant ($P$ <0.05) effect on moisture content and TBARS value and a very significant ($P$ <0.01) effect on pH value of the samples. The average moisture content in the non-smoked and non-stored control group samples was determined as 72.56%. The moisture content of raw salmon fillets was determined as 72.02% by Öz and Kotan (2016) and as 72.1% by Mol et al. (2008). These results are consistent with the moisture content of the raw material used in the present study. In the present study, the moisture content of the samples smoked with different wood chips varied between 66.80 and 72.93%. Moisture content was determined as 60.7% in smoked salmon samples by Mol et al. (2008), as ranged from 50.7 to 71.6% in the hot smoked

salmon by Lin et al. (2003). It is thought that the difference in moisture content of the smoked salmon is related to the variety of salmon, processed applied to the fish (salting etc.), smoking method and wood chips type. In addition, Espe et al. (2002) reported that structure of the raw material had an important effect on the chemical composition of smoked fish. In the present study, it was determined that the lowest moisture content belonged to the samples smoked with bourbon soaked oak wood chips. This could be due to the smoke generation temperatures of the wood chips used for the smoking in the present study. Indeed, it was reported that the smoke generation temperatures of wood chips varied depending on the total cellulose and hemicellulose content of the wood chips (Malarut and Vangnai, 2018).

Table 1. Moisture content, pH and TBARS values of the salmon fillets non-smoked and smoked with oak, apple, bourbon soaked oak, cherry and hickory wood chips (Mean ±SD)

| Group | n | Moisture content (%) | pH | TBARS (mg MDA/kg) |
|---|---|---|---|---|
| C-I | 2 | 72.56±0.93$^{a}$ | 6.36±0.01$^{c}$ | 0.21±0.06$^{c}$ |
| C-II | 2 | 70.87±1.14$^{a}$ | 6.37±0.03$^{c}$ | 0.40±0.11$^{ab}$ |
| S-I | 2 | 72.93±0.55$^{a}$ | 6.44±0.07$^{c}$ | 0.28±0.02$^{abc}$ |
| S-II | 2 | 70.74±0.06$^{a}$ | 6.69±0.06$^{b}$ | 0.37±0.03$^{abc}$ |
| S-III | 2 | 66.80±1.44$^{b}$ | 6.58±0.09$^{b}$ | 0.35±0.11$^{abc}$ |
| S-IV | 2 | 72.86±1.32$^{a}$ | 6.43±0.01$^{c}$ | 0.41±0.07$^{a}$ |
| S-V | 2 | 71.11±2.89$^{a}$ | 7.03±0.02$^{a}$ | 0.22±0.01$^{bc}$ |
| Sign | | * | ** | * |

C-I: control group salmon fillets non-smoked, non-stored; C-II: control group salmon fillets non-smoked, stored; S-I: salmon fillets smoked with oak smoking wood chips; S-II: salmon fillets smoked with apple smoking wood chips; S-III: salmon fillets smoked with bourbon soaked oak smoking wood chips; S-IV: salmon fillets smoked with cherry smoking wood chips; S-V: salmon fillets smoked with hickory smoking wood chips; Sign: significance; *: $P$ <0.05; **: $P$ <0.01; SD: Standard deviation

The average pH value of raw salmon fillets was determined as 6.36 (Table 1). The pH value of raw salmon fillets was determined as 6.29 by Öz and Kotan (2016) and as ranged between 6.29 and 6.73 by He et al. (2014). These results are consistent with the pH values of the raw material used in the present study. In the present study, smoking process caused an increase in pH values compared to those of the raw salmon fillets non-smoked, however, this increase was not statistically significant in the raw salmon fillets smoked with oak and cherry smoking wood chips. On the other hand, there are studies showing that smoking process caused decrease in pH values of salmon fishes (Espe et al., 2002; Messina et al., 2018). This difference is thought to result from the lack of application of salting process prior to smoking in the present study. Indeed, it was declared that ionic strength increased as a result of the combined effect of salt and smoke and this situation leads to a decrease in pH value (Leroi and Joffraud, 2000). In addition, the authors also reported that salt is 3-4 times more effective than phenols in smoke on pH decrease.

As can be seen from Table 1, TBARS value, 0.21 mg MDA/kg in raw material, varied between 0.22 and 0.41 mg MDA/kg in smoked salmon fillets depending on the type of wood chips used. It was determined that the storage of the raw salmon fillets at 24ºC for 3 h and the smoking with cherry wood chips of the salmon fillets significantly

increased TBARS values, while TBARS values of the other samples were not significantly different from each other ($P$ >0.05). Similarly, Espe et al. (2002) reported that smoked salmon samples had slightly higher TBARS values than fresh salmon fillets. On the contrary, Martinez et al. (2007) reported that TBARS values of salmon smoked with beech and oak chips were lower than those of non-smoked salmon fishes. In the present study, compared to the salmon fillets non-smoked and stored at 24ºC for 3 h, it is determined that the smoking with all of wood chips, except for the cherry smoking wood chips, caused a reduction in the TBARS values, but this decrease was not statistically significant ($P$ >0.05).

**Moisture content, pH and TBARS values of barbecued salmon fishes non-smoked and smoked with different wood chips**

Moisture contents, pH and TBARS values of the barbecued salmon fillets non-smoked and smoked with oak, apple, bourbon soaked oak, cherry and hickory wood chips were given in Table 2.

Table 2. Moisture content, pH and TBARS values of barbecued salmon fillets non-smoked and smoked with different wood chips (Mean ±SD)

| Group | n | Moisture content (%) | pH | TBARS (mg MDA/kg) |
|---|---|---|---|---|
| C-I | 2 | 65.74±0.46$^{a}$ | 6.44±0.04$^{d}$ | 0.42±0.0.02$^{a}$ |
| C-II | 2 | 66.59±0.99$^{a}$ | 6.43±0.05$^{d}$ | 0.36±0.12$^{ab}$ |
| S-I | 2 | 66.45±0.86$^{a}$ | 6.59±0.01$^{cd}$ | 0.39±0.13$^{ab}$ |
| S-II | 2 | 65.05±0.62$^{a}$ | 6.85±0.11$^{b}$ | 0.43±0.11$^{a}$ |
| S-III | 2 | 64.30±2.33$^{a}$ | 6.72±0.16$^{bc}$ | 0.27±0.02$^{ab}$ |
| S-IV | 2 | 66.81±1.20$^{a}$ | 6.60±0.01$^{cd}$ | 0.35±0.07$^{ab}$ |
| S-V | 2 | 65.71±1.20$^{a}$ | 7.12±0.01$^{a}$ | 0.17±0.01$^{b}$ |
| Sign | | ns | ** | * |

C-I: control group salmon fillets non-smoked, non-stored; C-II: control group salmon fillets non-smoked, stored; S-I: salmon fillets smoked with oak smoking wood chips; S-II: salmon fillets smoked with apple smoking wood chips; S-III: salmon fillets smoked with bourbon soaked oak smoking wood chips; S-IV: salmon fillets smoked with cherry smoking wood chips; S-V: salmon fillets smoked with hickory smoking wood chips; Sign: significance; ns: not significant; *: $P$ <0.05; **: $P$ <0.01; SD: Standard deviation

As can be seen from the Table 2, barbecuing had no significant effect on the moisture content of the samples, but had a very significant ($P$ <0.01) effect on the pH value and a significant ($P$ <0.05) effect on the TBARS value. The moisture content of the barbecued salmon fishes varied between 64.30 and 66.81%. Similarly, Öz and Kotan (2016) reported that the average moisture content of barbecued salmon fillets was 65.17%. In the present study, it was found that the significant effect of the smoking process on the moisture content of the samples disappeared with the barbecuing. This result is thought to be due to the fact that the temperature achieved during the barbecuing is more dominant than the effect of the smoking. Compared to salmon samples before barbecuing, barbecuing resulted in a decrease in the moisture content of all samples as expected. Sanchez del Pulgar et al. (2012) reported that three main processes cause water losses in meat after cooking. First, water in meat can be evaporated due to increased temperature. Second, increased temperature during cooking cause myofibrillar proteins to shrink. Due to this shrink, a parallel decrease occurs in the interfibrillar volume, which in turn leads to a

reduction in the myofibril's ability to hold water. Third, a contraction of the perimysial connective tissue seems to take place, causing a compression of the muscle fiber bundles, which in turn encourages water to be released from the meat cut.

The average pH value of the barbecued salmon fishes non-smoked was determined as 6.44 (Table 2). The pH value increased in barbecued samples smoked with different wood chips and the highest pH value was determined in the samples smoked with hickory wood chips. The pH value influences spoilage of fish because of its effect on the microorganism and enzyme activity (Ashie et al., 1996). The variation in pH value was reported to influence proteolytic activity of salmon (Hultman et al., 2004; He et al., 2014). Hultman and Rustad (2002) reported that proteolytic enzyme activity was highest at pH values close to neutrality or higher. Therefore, it is thought that fish samples smoked with hickory may be more sensitive to deterioration due to the high pH value. On the other hand, the increase in pH value of the salmon fishes non-smoked and smoked with different wood chips after barbecuing is attributed to the cleavage of bonds involving imidazole, sulfhydryl and hydroxyl groups (Girard, 1992).

The TBARS values of the barbecued samples varied between 0.17 and 0.43 mg MDA/kg and the lowest TBARS values were found in the barbecued samples smoked with hickory wood chips. In addition, TBARS values of the samples non-smoked and non-stored and the samples smoked with apple wood chips were higher than those of the samples smoked with oak, bourbon soaked oak and cherry wood chips. It is thought that these results may be due to different antioxidant activities of the wood chips. Pöhlmann et al. (2013) reported that phenolic compounds found in the wood chips at different levels play an important role in antioxidative activity of smoked products. On the other hand, the effect of meat cooking process on TBARS values of meat is still contradictive. Although it is known that many factors such as temperature, oxygen, light, catalysts etc. affect lipid oxidation in foods, cooking is more effective on the level of lipid oxidation in meat and meat products. Therefore, it is expected that lipid oxidation will increase by cooking of meat and meat products due to the fact that the iron released from myoglobin and hemoglobin that are denatured by the cooking process catalyzes the lipid oxidation (Rojas and Brewer, 2007). In addition, cooking destroys the cell structure of meat and can cause prooxidant interactions with polyunsaturated fatty acids that promote lipid oxidation (Ramirez et al., 2005). On the other hand, there are also studies in the literature showing that cooking does not affect lipid oxidation due to the reaction of the highly reactive compound measured by the TBARS test with various compounds such as proteins and amino acids present in the meat. (Serrano et al., 2007; Weber et al., 2008; Alfaia et al., 2010).

## CONCLUSION

As a result of the present research, it was determined that smoking and barbecuing had varying effects on the moisture content, pH and TBARS values of salmon fishes examined in the research. In addition, it was found that the type of wood chips used in the smoking process caused differences in the moisture content, pH and TBARS values of the salmon fishes. It was determined that the barbecuing was more effective than the smoking process on the moisture content. In addition, TBARS values, an indicator of lipid oxidation in meat and meat products, have proved that the type of wood chips used may have antioxidant or prooxidant effect. On the other hand, it is thought that the use of different types of wood chips in the smoking process should be examined for some harmful components (polycyclic aromatic hydrocarbons and heterocyclic aromatic amines) that may occur as a result of smoking and/or barbecuing.

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