THE EFFECTS OF DIFFERENT COOKING METHODS ON SOME QUALITY CRITERIA AND MINERAL COMPOSITION OF BEEF STEAKS

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ABSTRACT

Effects of different cooking methods (deep fat frying, hot plate, boiling, microwave, pan-frying with oil, pan-frying without fat or oil and oven cooking) on some quality criteria and mineral composition of steaks were investigated. Water content, pH, lipid oxidation (TBARS), color (L^*, a^*, b^* values) and mineral composition of both raw and cooked samples were determined. Cooking methods had a significant effect ($P < 0.01$) on all the parameters analyzed except for some mineral content (Fe, Mn, Ni and Pb). It was determined that pH, TBARS, L^* and b^* values of the samples increased with cooking ($P < 0.05$), while water content, a^* values and all mineral contents analyzed decreased ($P < 0.05$). Losses in the amounts of Fe, Pb, S and Zn with cooking were less than 10%, while those of other minerals ranged between 13.6 and 21.1%. The lowest dry matter and cooking loss were determined in the samples pan-fried without fat or oil ($P < 0.05$.

PRACTICAL APPLICATIONS

Cooking is a procedure usually applied immediately before consumption of meat and meat products, and meat and meat products are usually eaten cooked except for the products especially raw eaten. The cooking of meat results in better aroma and also the cooked meat is tenderer compared to raw meat. In addition, if cooked properly, meat, more attractive and delicious when served hot, is easier to digest while almost sterile. However, cooking affects the nutritional value of meat due to changes in certain components. In addition, the cooking could result in a number of harmful chemical compounds. Quality properties and nutritional values of cooked meat can be dependent on cooking method. In the present study, the changes in meat cooked by common cooking methods and the differences between cooking methods were detected.

INTRODUCTION

Cooking is a heating operation usually applied to meat and meat products immediately before consumption. It has been reported that cooking coagulates and denatures meat proteins, improves meat palatability, destroys considerable numbers of microorganisms, improves the storage life of meat products, inactivates indigenous proteolytic enzymes, prevents development of off-flavors and modifies the texture or tenderness of meat and meat products (Pearson and Tauber 1984). Therefore, cooking of meat and meat products is essential to achieve a palatable and safe product (Tornberg 2005). However, cooking can lead to undesirable modifications, such as the loss of the nutritional value of meat, mainly due to vitamin and mineral losses (Rodriguez-Estrada *et al.* 1997), and the formation of mutagenic and/or carcinogenic compounds such as heterocyclic aromatic amines and polycyclic aromatic hydrocarbons (Oz 2011; Oz and Kaya 2011a,b,c).

Meat is known as an important source of both trace elements and B vitamins, and greatly contributes to daily intakes of these micronutrients in the diet (Lombardi-Boccia *et al.* 2005). However, cooking conditions are important

factor strongly contributing to trace elements and vitamins variability in meat. The mineral (inorganic) elements or ash are normally considered synonymous and they are defined as the elements in food other than carbon that remain when a food is incinerated (oxidation of organic material) (Ockerman 1996). The main elements (Na, K, Ca, Mg, Cl, P and S) are essential for human beings in amounts >50 mg/day. Trace elements (Fe, I, F, Zn, Se, Cu, Mn, Cr, Mo, Co and Ni) are essential in amounts of <50 mg/day; their biochemical actions have been elucidated and they have very varied functions, e.g., as electrolytes, enzyme constituents and building materials, e.g., in bones and teeth. Therefore, health authorities in most countries have established recommendations for daily intake levels of essential minerals (Tomovic *et al.* 2015).

Quality properties and nutritional values of cooked meat can be dependent on cooking method. In the present study, the changes in meat cooked by seven common cooking methods (deep fat frying, hot plate, boiling, microwave, pan-frying with oil, pan-frying without fat or oil and oven) and the differences between cooking methods were detected. For this aim, water content, pH, TBARS, cooking loss, color (L^*, a^* and b^*) and mineral content (Ca, Fe, K, Mg, Mn, Na, Ni, P, Pb, S and Zn) of beef steaks were determined.

MATERIAL AND METHODS

Beef Samples and Cooking

M. *Longissimus dorsi* muscle, used to make steak, was obtained from a local slaughterhouse (Et ve Süt Kurumu Et Kombinası, Erzurum, Turkey). The muscles which were taken from carcasses ripened 24 h after slaughtering were stored at 4C and sliced for 1 cm before use. In the present study, deep fat frying, hot plate, boiling, microwave, pan-frying with oil, pan-frying without fat or oil and oven cooking methods were chosen, as representative of those most commonly employed domestically and in cuisine for beef steaks. For deep fat frying, fresh sunflower oil (2 L) was used. Whenever the temperature of oil reached 200C, the samples were fried for 4.5 min in a commercial stainless steel deep-fat fryer. For grilling, a hot plate with a stainless steel surface was heated to 200C, then the samples were fried on the hot plate. Total cooking time was 6 min (3 + 3). For boiling, a pressure cooker was used. At the end of first 5 min, the upper accumulating parts (extractive substances) on the samples were removed, then the lid of the pressure cooker was closed and the samples were boiled. Total cooking time was 20 min (5 + 15). For microwaving of the samples, a kitchen type microwave (Arçelik, Turkey) was used and cooking was done by automatically selected degrees in microwave. Total cooking time was 4.5 min. The pan-frying processes with and without oil were carried out with a Teflon-coated pan. For the pan-frying with oil, fresh sunflower oil (40 g) was used. Whenever the temperatures of the surface of the pan reached 200C, the samples were fried. Total cooking time was 4.5 min. For the oven experiment, a kitchen type oven (Arçelik, Turkey) was used. Whenever the temperature of oven reached 200C, the samples were cooked for 9 min. A detailed description of the cooking methods and conditions has been published previously (Oz 2010). Preliminary cooking trials were performed to establish the cooking temperature and cooking duration for the samples. Based on the results of these trials, the cooking conditions of the samples cooked with different cooking methods are presented in Table 1. Temperatures were measured by using a digital thermocouple (part no. 0560 9260, Testo 926, Lenzkirch, Germany) with surface probe (0603 1992, Testo 926, Lenzkirch, Germany). No salt, spice, and food additive were used in cooking procedures. Meat samples were turned over once a minute during the cooking with hot plate, pan-frying with oil, and pan-frying without fat or oil. After the cooking, the samples were cooled at room temperature. The steaks were homogenized using a kitchen blender to produce a uniform sample for analyses. Immediately after the homogenization, the analyzes were done.

TABLE 1. THE COOKING CONDITIONS OF THE SAMPLES

Cooking methods	Oil	Temperature (C)	Time (min)
Deep-fat frying	+ (2 L)	200	4.5
Hot plate	–	200	6
Boiling	–		5 + 15
Microwave	–		4.5
Pan-frying with oil	+ (40 g)	200	4.5
Pan-frying without fat or oil	–	200	4.5
Oven	–	200	9

Water Content, pH and Cooking Loss

Water content and pH values (pH meter, SCHOTT L 6880, Lab Star pH) of the samples were determined according to the methods of Gokalp *et al.* (1999). After cooking, samples were removed from the container, cooled to room temperature, blotted with a paper towel, and weighed to determine the cooking loss (Oz and Kızıl 2013). The cooking loss was expressed as a percentage of initial weight (w/w, wet basis).

TBARS Value

TBARS values of the samples were determined according to the methods of Lemon (1975). According to the method, 1 g of sample was taken from each treatment and 6 mL TCA solution was added (7.5% TCA, 0.1% EDTA, 0.1% 1-propyl

TABLE 2. THE EFFECTS OF TREATMENT, COOKING METHODS AND THE INTERACTIONS OF TREATMENT AND COOKING METHODS ON THE WATER CONTENT, pH, TBARS, COOKING LOSS AND COLOR VALUES OF THE SAMPLES

	Water content (%)	pH	TBARS (μmol MDA/kg)	Cooking loss (%)	*L**	*a**	*b**
Treatment (T)							
Raw	74.34 ± 0.27a	5.48 ± 0.03b	3.21 ± 0.69b		34.56 ± 1.13b	18.11 ± 0.76a	1.88 ± 0.88b
Cooked	60.39 ± 4.40b	5.76 ± 0.09a	4.96 ± 1.49a		47.86 ± 3.23a	9.77 ± 1.46b	11.29 ± 1.96a
Sig.	**	**	**		**	**	**
Cooking methods (CM)							
DFF	64.91 ± 10.57d	5.66 ± 0.19a	4.38 ± 1.85ab	44.64 ± 3.99b	41.32 ± 7.31ab	13.48 ± 4.87c	6.60 ± 4.88cd
HP	68.54 ± 6.25b	5.62 ± 0.16b	4.48 ± 1.82a	32.86 ± 3.87d	40.05 ± 5.84c	14.20 ± 4.09a	7.62 ± 5.91a
B	64.71 ± 10.31d	5.66 ± 0.19a	3.89 ± 1.05bc	50.20 ± 3.23a	40.74 ± 6.78bc	14.00 ± 4.30ab	5.21 ± 3.49e
M	66.26 ± 8.65c	5.63 ± 0.16ab	4.44 ± 1.46ab	38.62 ± 2.72c	41.74 ± 7.60a	14.17 ± 4.10a	6.23 ± 4.52d
PF	68.73 ± 6.13b	5.57 ± 0.14c	4.44 ± 1.73ab	33.03 ± 5.53d	41.81 ± 7.52a	13.65 ± 4.64bc	7.06 ± 5.40bc
PFF	70.23 ± 4.42a	5.58 ± 0.11c	3.62 ± 0.89cd	28.60 ± 3.68e	41.41 ± 7.50ab	13.87 ± 4.47bc	7.23 ± 5.68ab
O	68.19 ± 6.73b	5.62 ± 0.15b	3.32 ± 0.86d	35.45 ± 4.12cd	41.42 ± 7.39ab	14.21 ± 4.16a	6.14 ± 4.41d
Sig.	**	**	**	**	**	**	**
Interactions							
T × CM	**	**	**		**	**	**

DFF, deep-fat frying; HP, hot plate cooking; B, boiling; M, microwave cooking; PF, pan-frying with oil; PFF, pan-frying without fat or oil; O, oven cooking; Sig., significance; ns, not significant ($P > 0.05$). $^{**}P < 0.01$, different letters (a–e) in the same part indicate significant differences ($P < 0.05$).

gallate and 1-propyl gallate was dissolved in 3 mL ethanol). Mixture was filtered over Whatman 1 after homogenizing for 15–30 s. Then, 1 mL 0.02 M TBA solution (2.338 g/L thiobarbituric acid) was added on 1 mL filtrate. The mixture was kept in the boiling water bath for 40 min. It was cooled, and centrifuged at 2,000 rpm for 5 min. Finally absorbance was measured at 532 nm (Shimadzu, UV 160, Japan) and were expressed as μmol malonaldehyde (MDA) per kg meat.

Color Values

CIE L^* (0, darkness; 100, lightness), a^* (+, redness; −, greenness) and b^* (+, yellowness; −, blueness) values of the samples were measured using a Minolta Model tristimulus colorimeter (Minolta Chroma Meter Measuring Head CR-400, Minolta, Osaka, Japan) and this was used to objectively measure CIE Lab. L^*, a^* and b^* values which were measured on the raw meat and cooked meat surfaces at room temperature. The equipment was standardized before use with a white ceramic tile. Two samples from each group for each treatment were evaluated for color measurement and the means of the readings were determined on four locations in each sample.

Mineral Content

Macro- (P, K, Na, Ca, S and Mg), and microelements (Fe, Mn, Zn, Pb and Ni) were determined after wet digestion of dried and ground sub-samples in a H_2SO_4–Se–salisilic acid mixture. In the diluted digests, *P* was measured spectrophotometrically by the indophenol-blue method after its reaction with ascorbic acid. K, Na, Ca, Mg, Fe, Mn, Zn, Cu, Pb and Ni content analysis were determined by atomic absorption spectrometry (PerkinElmer 3690) (AOAC 1990).

Statistical Analysis

Results were analyzed with the completely randomized design procedure using the SPSS package (SPSS 2004). Statistical model included cooking methods (deep fat frying, hot plate cooking, boiling, microwave cooking, pan-frying with oil, pan-frying without fat or oil and oven cooking) and treatment (raw and cooked) as main effects and their interactions. Differences between data were tested using the Duncan's multiple range test (significance $P < 0.05$). The results of statistical analysis are shown as mean value ± standard deviation in tables.

RESULTS AND DISCUSSION

The water contents of the samples are presented in Table 2. As seen in Table 2, treatment had a very significant effect ($P < 0.01$) on the water content of the samples. While the water content of the raw beef steaks was 74.34%, cooking led to an expected decrease in the water content (60.39%). Similar results can also be seen in the literature even in different kind of meats such as beef, pork, poultry and fish (Hernandez *et al.* 1999; Tang *et al.* 2005; Liao *et al.* 2010; Oz and Celik 2015; Oz and Zikirov 2015; Oz *et al.* 2015, 2016a,b). Sanchez del Pulgar *et al.* (2012) stated that three main processes cause the water losses in cooked meat. First, water can be evaporated due to increased temperature and/or reduced pressure. Second, increased temperatures during cooking cause myofibrillar proteins to shrink, a process that

starts at 40C and becomes more intense with increased temperatures. Due to this shrinking process, a parallel decrease occurs in the interfibrillar volume, which in turn leads to a reduction in the myofibril's ability to hold water. As a consequence, part of the water retained by capillarity is lost during cooking. Finally, at temperatures between 56 and 62C, a contraction of the perimysial connective tissue seems to take place, causing a compression of the muscle fibre bundles, which in turn encourages water to be released from the meat cut.

Cooking methods had a very significant effect ($P < 0.01$) on the water content of steaks. Water contents of the cooked samples ranged between 64.71 and 70.23%. The highest water content belonged to the pan-fried without fat or oil samples that were the samples with the lowest cooking loss, while the lowest water content belonged to the boiled samples that were the samples with the highest cooking loss. In addition, the samples cooked by both deep fat frying and boiling were not statistically different each other in terms of water content ($P < 0.05$) (Table 2). On the other hand, Hernandez *et al.* (1999) declared that cooking (deep fat frying, pan frying, oven, microwave and boiling) led to a decrease in water content of pork meat and the greatest loss of water was found in boiled samples which could be explained because water is more efficient than air as a heat conductor. According to Hernandez *et al.* (1999), Guilland *et al.* reported higher losses of weight in wet cooking than in dry cooking. Moisture losses during dry cooking are due to losses by evaporation, and during wet cooking there are also losses by exudation and diffusion. It was also found that the interaction of treatment × cooking method had very important effect ($P < 0.01$) on the water content of the steaks, and the interaction graphic is given in Fig. 1a. As seen in the Fig. 1a, all cooking methods decreased the amount of water content compared to the raw samples.

pH values of the samples are presented in Table 2. Treatment had very significant effect ($P < 0.01$) on the pH values of the samples. While the pH of the raw beef steaks was 5.48, cooking led to an expected increase in the pH value (5.76). Similar results can also be seen in the literature (Kowale *et al.* 1996; Rao *et al.* 1996; Northcutt *et al.* 1998; Fletcher *et al.* 2000; Dal Bosca *et al.* 2001; Liao *et al.* 2010; Oz and Celik 2015; Oz and Zikirov 2015; Oz *et al.* 2015, 2016a,b). pH values of meat generally increases during cooking. This increase in pH value with cooking could be attributable to the cleavage of bonds involving imidazole, sulphydryl, and hydroxyl groups (Girard 1992). It was observed that cooking methods had very significant effect ($P < 0.01$) on pH values of the samples. The lowest pH value was detected in samples cooked with pan-frying both with oil and without fat or oil ($P < 0.05$), while the highest pH value belonged to the samples cooked by deep fat frying and boiling (Table 2). The interaction of treatment × cooking method had also very significant effect ($P < 0.01$) on the pH values of the samples (Fig. 1b).

TBARS values of the samples are presented in Table 2. As expected, all the cooking methods increased TBARS values, since high temperatures increase oxidation processes in meat (Dominguez *et al.* 2014). Treatment had very significant effect ($P < 0.01$) on TBARS values of the samples. While TBARS of the raw beef steaks was 3.21 μmol MDA/kg, cooking led to an increase in TBARS value (4.96 μmol MDA/kg). On the other hand, it is shown in the literature that the effect of cooking on TBARS could vary according to cooking method. In several researches, TBARS values in different animal meats increased with cooking compared to raw meat (Rao *et al.* 1996; Hernandez *et al.* 1999; Serrano *et al.* 2007; Kwon *et al.* 2008; Alfaia *et al.* 2010; Peiretti *et al.* 2012; Roldan *et al.* 2014), while some cooking methods had no similar effect on TBARS values (Serrano *et al.* 2007; Ferioli *et al.* 2008; Alfaia *et al.* 2010; Juarez *et al.* 2010; Peiretti *et al.* 2012). It is expected that cooking increases lipid oxidation in muscle (Tims and Watts 1958) and lipid oxidation may also decrease nutritional value by the formation of potentially toxic products during cooking and processing (Shahidi *et al.* 1992; Maillard *et al.* 1996). On the other hand, the compounds that are analyzed by TBARS test are very reactive, so these compounds could react with protein and amino acids of meat and they could produce different compounds, thus may have effect on the decrease of the TBARS value (Ferioli *et al.* 2008). In the present study, it was determined that cooking methods had very significant effect ($P < 0.01$) on TBARS values of the samples. The lowest TBARS value was detected in samples oven cooked, while the highest TBARS value belonged to the samples cooked by hot plate. The interaction of treatment x cooking method had also very significant effect ($P < 0.01$) on the TBARS values of the samples (Fig. 1c). Ozturk *et al.* (2014) studied the effect of wheat sprout powder incorporation on lipid oxidation and physicochemical properties of beef patties and found that wheat sprout flour could be incorporated into beef patties to improve their quality parameters and retard lipid oxidation.

Cooking of meat is very important in order to have a delicious and safe product. Cooking loss is the most important parameter in the determination of physicochemical behaviors of meat products during cooking, and it is generally related to the water and lipid binding ability of the proteins (Sayas-Barbera *et al.* 2011). Cooking caused a reduction in the weight of meat products mainly due to the water loss during cooking (Rodriguez-Estrada *et al.* 1997). However, water is not the only compound lost during the cooking process (Sanchez del Pulgar *et al.* 2012). There are various components such as myofibrillar and sarcoplasmic proteins, collagen, lipids, salt, polyphosphates and flavor compounds that are also lost together with the water (Gerber *et al.*

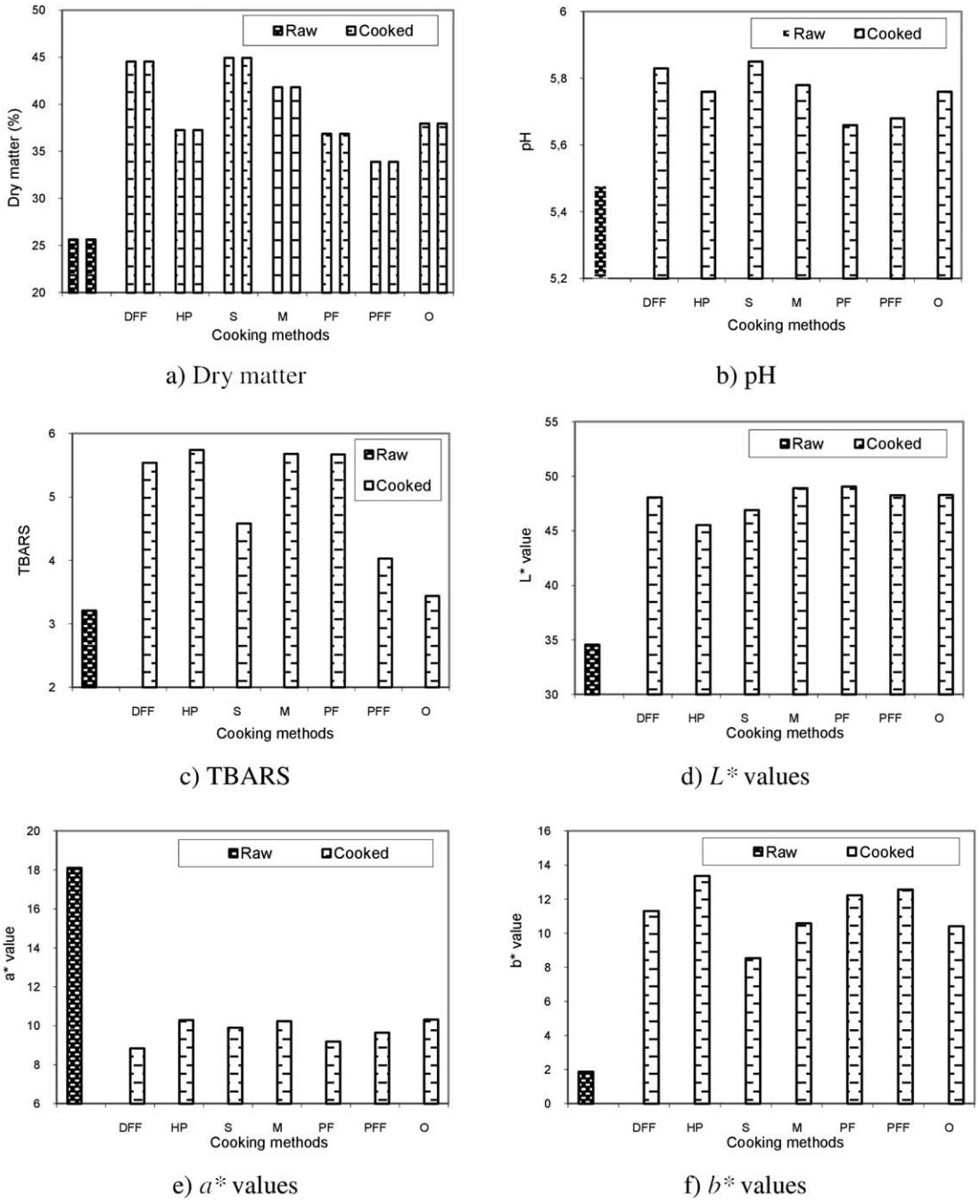


FIG. 1. THE EFFECTS OF THE INTERACTIONS OF TREATMENT AND COOKING METHODS OF (a) DRY MATTER (b) pH, (c) TBARS, (d) *L**, (e) *a** and (f) *b** VALUES

DEF, deep-fat frying; HP, hot plate cooking; B, boiling; M, microwave cooking; PF, pan-frying with oil; PFF, pan-frying without fat or oil; O, oven cooking.

2009). Cooking methods had very significant effect ($P < 0.01$) on cooking loss. In the present study, as a result of cooking with different methods, cooking losses of the beef steaks varied between 28.60 and 50.20% (Table 2). While the highest cooking loss value was detected in boiled samples, the lowest value was calculated in the samples pan-fried without fat or oil. Poltorak *et al.* (2015) studied the impact of two convection-microwave heating on cooking yield of bovine product (M. *Gluteus medius* muscle) and found that combining of convection and low-intensity microwave heating could be successfully used in catering business for beef roasting due to the shorter cooking time,

TABLE 3. THE EFFECTS OF TREATMENT, COOKING METHODS AND THE INTERACTIONS OF TREATMENT AND COOKING METHODS ON THE MINERAL CONTENTS OF THE SAMPLES (mg/100 g)

	Ca	Fe	K	Mg	Mn	Na	Ni	P	Pb	S	Zn
Treatment (T)											
Raw	1097.0 ± 71a	58.5 ± 6a	12387.5 ± 2199a	836.1 ± 86a	0.68 ± 0.2a	2007.0 ± 550a	0.76 ± 0.3a	7017.8 ± 743a	3.23 ± 0.3a	13512.3 ± 298a	372.0 ± 55a
Cooked	947.9 ± 144b	52.7 ± 7b	9982.4 ± 2345b	702.8 ± 141b	0.57 ± 0.1b	1664.9 ± 384b	0.60 ± 0.2b	6012.9 ± 1075b	2.97 ± 0.4b	13034.6 ± 1553b	340.4 ± 58b
Sign	**	**	**	**	**	**	**	**	**	**	**
Cooking methods (CM)											
DFF	926.8 ± 216e	55.4 ± 6	10988.8 ± 2518bc	756.1 ± 132c	0.57 ± 0.2	1708.9 ± 583d	0.66 ± 0.3	6126.4 ± 1298d	3.22 ± 0.4	13209.3 ± 1239cd	376.1 ± 45 a
HP	997.5 ± 130d	55.9 ± 6	10605.8 ± 2516cd	738.7 ± 125c	0.62 ± 0.1	1670 ± 76.6d	0.68 ± 0.3	6274.3 ± 985cd	3.06 ± 0.4	13051.4 ± 559d	353.1 ± 56.2ab
B	1047.9 ± 80b	57.5 ± 4	10852.5 ± 2373c	759.3 ± 104c	0.64 ± 0.1	1740.4 ± 503d	0.64 ± 0.3	6518.9 ± 779bc	3.07 ± 0.3	13480.8 ± 612bc	374.8 ± 49a
M	1018.5 ± 110cd	51.0 ± 12	9958.4 ± 3191d	687.1 ± 176d	0.59 ± 0.2	1872.0 ± 448c	0.64 ± 0.3	5954.1 ± 1292d	2.98 ± 0.6	12355.5 ± 2057e	316.8 ± 83.0b
PF	1028.5 ± 176bc	56.9 ± 6	12306.0 ± 3379a	836.1 ± 185a	0.61 ± 0.2	1821.4 ± 562c	0.62 ± 0.3	7048.3 ± 1329a	3.28 ± 0.3	14083.3 ± 1146a	381.6 ± 43a
PFF	1083.3 ± 82a	54.7 ± 6	11868.8 ± 1862a	807.4 ± 84b	0.63 ± 0.2	1951.0 ± 415b	0.84 ± 0.2	6868.0 ± 592ab	2.99 ± 0.4	13181.3 ± 579cd	347.4 ± 56ab
O	1054.9 ± 80b	58.0 ± 6	11714.4 ± 1869ab	801.7 ± 83b	0.70 ± 0.2	2087.9 ± 478a	0.67 ± 0.2	6817.4 ± 632ab	3.06 ± 0.3	13552.6 ± 280b	343.6 ± 57ab
Sig.	**	ns	**	**	ns	**	ns	**	ns	**	**
Interactions											
T × CM	**	ns	**	**	ns	**	ns	**	ns	**	**

DFF, deep-fat frying; HP, hot plate cooking; B, boiling; M, microwave cooking; PF, pan-frying; PFF, pan-frying without fat or oil; O, oven cooking; Sig., significance; ns, not significant ($P > 0.05$), **$P < 0.01$, different letters (a–e) in the same part indicate significant differences ($P < 0.05$).

reduced cooking loss of meat. Torrico *et al.* (2014) studied proximate and fatty acid compositions and sensory acceptability of Hispanic consumers towards rib-eye steaks from forage-finished steers and found that one-sided grilling and two-sided grilling did not cause significant differences in sensory liking scores.

Color is an important factor for consumer acceptance of uncooked or cooked meat and meat products. The color of meat is due to myoglobin pigment. During cooking of meats, the globin is denatured and hemoglobin is formed (Lawrie 1998; Aberle *et al.* 2001). L^*, a^* and b^* values of raw and cooked samples are presented in Table 2. Not only treatment and cooking methods but also the interaction of treatment x cooking methods (Fig. 1d–f) had very significant effect ($P < 0.01$) on the color values (L^*, a^* and b^* values) of the samples. L^* and b^* values of the samples increased with cooking, while a^* value decreased ($P < 0.05$). In the literature, numerous studies have shown that L^* value of meat decreases with dry heat cooking (Oz 2014; Oz and Zikirov 2015; Oz *et al.* 2015), while sous-vide cooking and boiling of meat caused an increase in L^* values of the samples (Oz and Zikirov 2015). In the present study, the lowest L^* value was detected in samples cooked by hot plate.

a^* value is often closely associated with the content of oxymyoglobin of meat and it is reported that high a^* values of cooked meat are adversely associated with the denaturation of myoglobin (Roldan *et al.* 2013). While a^* value of the raw beef steaks was 18.11, cooking led to a decrease in a^* value (9.77) (Table 2). It is known that decreasing in a^* values of meat after cooking is due to the pigment denaturation (Sanchez del Pulgar *et al.* 2012). When compared to cooking methods, deep fat frying, pan-frying with oil, and pan-frying without fat or oil had the three lowest a^* values.

b^* value or a yellow color intensity, which is an indicative of the yellowness value in the literature, is still unexplained. While b^* value of the raw beef steaks was 1.88, cooking led to an increase in b^* value (11.29) (Table 2). The highest b^* values of cooked samples was determined in samples cooked by hot plate.

The mineral contents of the samples are given in Table 3. Not only treatment and cooking methods (Table 3) but also the interaction of treatment and cooking methods (Fig. 2a) had very significant effect ($P < 0.01$) on the Ca content of the samples. Cooking caused a reduction in the amount of Ca. Lawrie and Ledward (2006) reported that the amount of Ca as a mineral in raw beef meat was 5.4 mg/100 g. Karakök *et al.* (2010) determined that the amount of Ca in raw beef meat was 46.50 ppm. The highest and the lowest Ca content ($P < 0.05$) were detected in the samples cooked by pan-frying without fat or oil and deep fat frying, respectively.

One of the important mineral substances that increase the importance of meat is Fe. It was determined that only treatment had very important effect ($P < 0.01$) on Fe

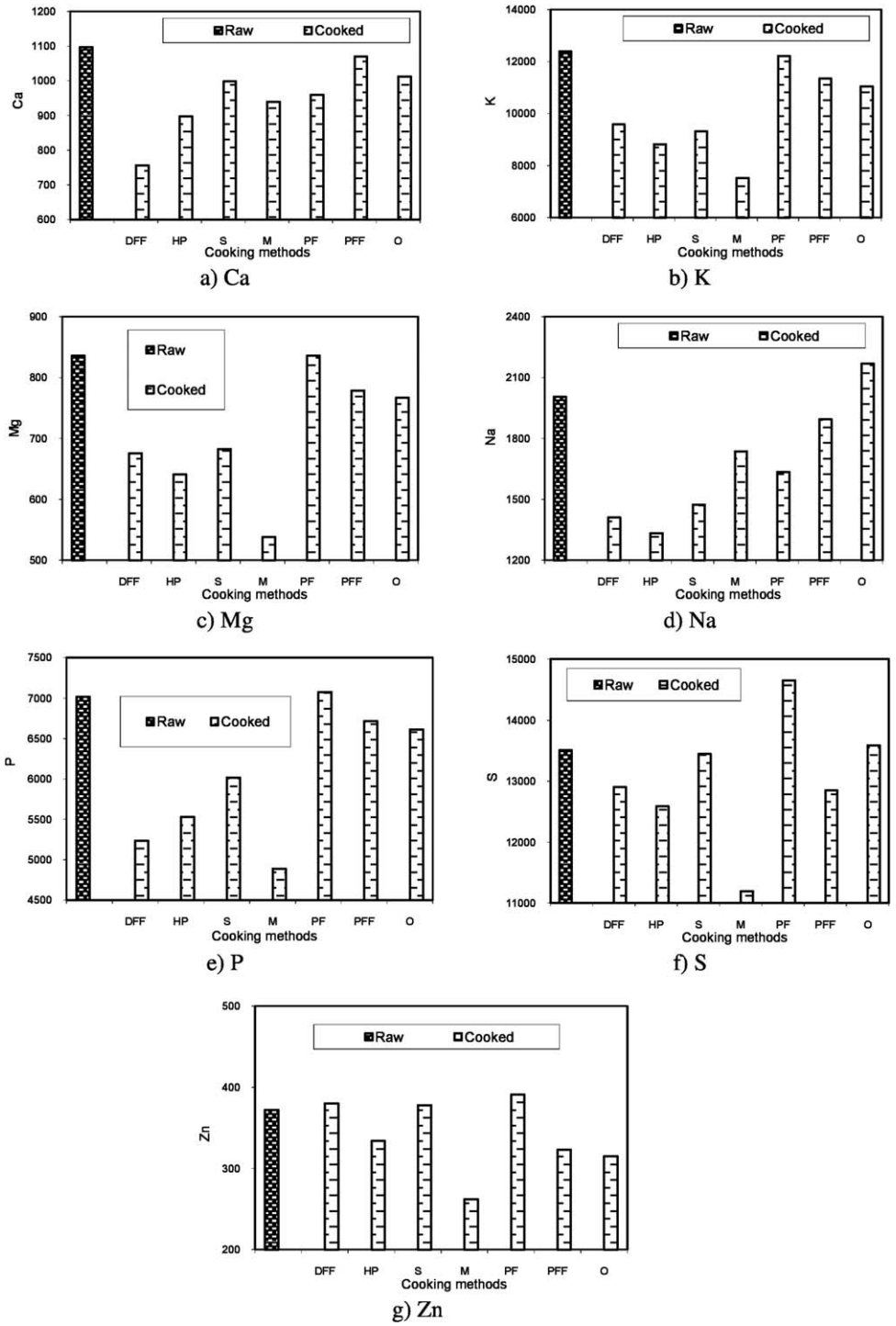


FIG. 2. THE EFFECTS OF THE INTERACTIONS OF TREATMENT AND COOKING METHODS ON THE MINERAL COMPOSITION OF BEEF CHOPS
DEF, deep-fat frying; HP, hot plate cooking; B, boiling; M, microwave cooking; PF, pan-frying with oil; PFF, pan-frying without fat or oil; O, oven cooking.

content of the samples (Table 3). Fe content decreased with cooking of the samples ($P < 0.01$) (Table 3). Fe content of the raw samples was 58.5 mg/100 g, and Fe content in all the cooking methods ranged from 51 to 58 mg/100 g. However, the change in Fe content for all cooking methods was found to be not significant ($P > 0.05$).

K content is also one of the important mineral substances that increase the importance of meat in terms of nutrition.

It was determined that treatment, cooking methods, and the interaction of treatment and cooking methods had very important effect ($P < 0.01$) on K content of the samples (Table 3). Significant reduction in K content similar to other mineral substances was observed by cooking of meat. The highest reduction in K content was seen in microwave cooking (Fig. 2b).

It was determined that treatment, cooking methods, and the interaction of treatment and cooking methods had very important effect ($P < 0.01$) on Mg content of the samples (Table 3). Mg content was also decreased with cooking. Similar to K content, the highest lost in Mg content was observed in microwaved samples (Fig. 2c). Karakök *et al.* (2010) determined that the amount of Mg in meat was 48.54 ppm.

Treatment, cooking methods and the interaction of treatment and cooking methods had very significant effect ($P < 0.01$) on Na content. Na content, which was 2,007 mg/100 g in raw meat, was determined to be 1664.9 mg/100 g in cooked meat. The reduction was 17%. The highest lost in Na content were detected in the samples cooked with deep fat frying, hot plate, and boiling. On the other hand, the highest Na content belonged to the samples cooked by oven. Lawrie and Ledward (2006) reported that the amount of Na as a mineral in raw beef meat was 69 mg/100 g, while Ockerman (1996) declared that the amount of Na in meat ranged from 0.044 to 0.168%. Also, Karakök *et al.* (2010) reported that the amount of Na of beef meat was 180.06 ppm as mean values. Sodium, if used improperly or excessive intake can be dangerous from a human health. In addition, there is a positive relationship between high sodium intake and the incidence of hypertension; hence, there is a tendency to reduce the amount of NaCl in foods (Wirth 1989).

It was determined that treatment, cooking methods, and the interaction of treatment and cooking methods had very important effect ($P < 0.01$) on P content of the samples (Table 3). P content of the samples was significantly decreased with cooking ($P < 0.01$). The highest P content was determined in the pan-fried samples, while the lowest P content was detected in the samples cooked with deep fat frying and microwave ($P < 0.05$).

Quantitatively, the lowest changed mineral substance (3.5%) according to raw meat was S. S content was 13512.3 mg/100 g in raw meat, while it was 13034.6 mg/100 g in cooked samples. Not only treatment and cooking methods but also the interaction treatment and cooking method had very significant effect ($P < 0.01$) on S content of the samples. As can be seen Fig. 2f, the highest lost in S content was observed in microwave cooking. However, S content was increased with pan-frying and oven cooking.

Only treatment had very significant effect ($P < 0.01$) on Mn, Ni and Pb contents which were detected at very small amounts in both raw and cooked meat, while cooking methods and the interaction treatment and cooking method had no significant effect ($P > 0.05$) on these mineral substances (Table 3).

It was determined that treatment, cooking methods, and the interaction of treatment and cooking methods had very important effect ($P < 0.01$) on Zn content of the samples (Table 3). Similar to other mineral substances, Zn content significantly decreased with cooking. The highest lost in Zn content was detected in microwaved meat (Fig. 2g).

Purchas *et al.* (2014) studied nutrient content of uncooked and cooked lean beef and found that Na and K decreased in concentration with cooking, while Ca, Cu, Fe, Mn, Se and Zn increased in concentration with cooking. It is suggested that divalent minerals were retained to greater extent than Na and K during cooking because of most of those measured are closely associated with proteins that are unlikely to decrease in concentration during cooking (Purchas *et al.* 2014). On the other hand, in the present study, the amounts of all of the minerals analyzed decreased with cooking (Table 3).

CONCLUSIONS

Cooking caused significant structural and compositional changes in meat. The most important of these changes are oxidation, color changes as a result of denaturation of proteins and the losses of the substances such as mineral during cooking of meat. The present study is the first report on the effects of different cooking methods on mineral matter composition, TBARS, and pH value and color properties of beef steak. The cooking methods used in this study influenced all quality parameters examined. Each cooking method has different effects on quality parameters of cooked meat. In addition, cooking caused important nutritional losses in meat. The highest mineral substance lost was observed in microwave cooking method.

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