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The Effects of Cooking Temperatures and Times on the Formation of Aromatic Amines of Meatballs Derived from Sivas Province

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ABSTRACT

In this study, nine different experimental groups were prepared by cooking meatball samples 5, for 7,5 and 10 minutes at 150, 200 and 250 ℃. Some chemical analysis including fat, protein, thiobarbituric acid contents and pH were applied to samples. The amount of Heterocyclic Aromatic Amines (HAA) of the samples treated byheat at 250 ℃ for 7,5 minutes had highest value, 0.42 ng/g. IQ (2-amino-3-metilimidazo[4,5-f]kinolin) and PhIP (2-amino-1-metil-6-fenilimidazo[4,5-b] piridin) were detected for the samples subjected to 250 ℃ heat treatment. HAA was not detected in the samples cooked at 7,5 for 10 minutes and 200 ℃, whereas MeQIx was found to be 0.17 ng/g for the samples baked for 5 minutes. Consequently, it was detected that the amount of HAA in all groups was below the 1 ng/g. which makespossible to comment chosen parameters for cooking meatballs is appropriate for formation of HAA.

Keywords: Heterocyclic aromatic amines, Meatball, Heat treatment, Time.

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Introduction

Meat and meat products are widely preferred to consume after cooking in whole world. When meat and meat products are cooked, a noticeable changes could be occured in their sensory, chemical and microbiological properties. The changes in the sensory properties of a meat product after cooking mostly defined as satisfied and aromatic by consumers.The bright red color turns into brown with the effect of heat, depending on the denaturation of the proteins, especially connective tissue/ligament proteins get brittle related to collagen denaturation.

The meat products prepared with different forms from fresh ground beef patties to meatball dough, mostly cooked as a grill called as meatballs [1]. In Turkey, the meatballs are prepared with different formulas depending on locality (İnegöl, Akçaabat, Sivas, etc.). Sivas meatball is one of most popular type that have great demand of consumer in Sivas region and also has a geographic patent.. The production of Sivas meatball comprises in three main stages as choosing raw material, preparation of dough and cooking. In order to provide the special taste and aroma of Sivas meatball , the meat should be provided from cattle or sheep meat which were grown in plateaus in the unique flora of Sivas region and fed by clover, vetch and thyme in natural environment. The meat obtained from the ribs, butt, scapula of the at least two years old calves raised in natural habitats and the meat from the butt of the sheep is used as raw material. Twenty grams of salt (NaCl) per kilogram is added and drawn in a meat grinder..The NaCl is the only ingriedient that used in the production of Sivas meatball. Prepared meatballs are cooked in the oak coal fire, flameless and with dense ember by turning them at short intervals so that both sides will be cooked or they are cooked in the oven and then served hot [2].

The consumers mostly prefer to consume meat and meat products after cooking to be certain of safety and flavor of the products. Ripened meat tastes like lactic acid due to the presence of some components such as aldehydes, amino acids, carbonyls. Increasing flavor by cooking in meat products occured by maillard reaction on the surface with the effect of heat applied to the surface of the meat and free radicals are formed at high temperatures. These free radicals have negative effects on health and they can cause unwanted taste and taste changes on the product by reacting with food components (protein, carbohydrate, fat and vitamin). Heterocyclic aromatic amines (HAA) form an is the most important groups of these compounds. HAAs are usually formed by the exposure of animal-derived products containing nitrogenous compounds such as protein and creatine to heat. Meat contains creatine and creatinine which can react with free amino acids and sugars during cooking and they form the HAAs depending on time and temperature [3]. They are present in significant amounts in heated meat and fish when the cooking temperature over 150°C [4]. In addition, HAAs can also occur in longer cooking times even at lower temperatures [5]. It has been known that HAA's are formed in very small quantities with boiling in the meat, but their formation after roasting, grilling, baking etc. has increased greatly [4].

The cooking of foodsmight be resulted in formation of HAAs in different kinds and quantities. The patterns of formations or concentrations of HAAs depend on various factors including cooking time and temperature, water activity, pH value, effect and amount of precursors required for formation (creatine/creatinine, free amino acids, sugars, peptides, proteins), fats, oil oxidation, antioxidants, amount of available inhibitor and activator components, heat and mass transfer, type of heat-treated food, cooking equipment and method [6].

HAAs can also be found in ready-to eat foods which generally cooked by using traditional frying methods. [4]. The most identified HAAs in cooked meat products are; 2-amino-3,8-dimethylimidazo [4,5-f] quinoxaline (MeIQx), 2-amino-3,4,8-trimethylimidazo [4,5f] quinoxaline (4,8-DiMeIQx) and 2-amino-1-methyl-6-phenylimidazo [4,5-b] pyridine (PhIP) [7].

In this current study, it was aimed to determine the amount HAAs that were occured during the cooking process of the Sivas Meatballs which were highly consumed by the people with pleasure.

Materials and Methods

Raw Materials

Sivas Meatballs used in the research (consist of beef and 2% (NaCl)) was obtained from a local company in Sivas province that is offered for sale in commercial and brought to the laboratory under the cold chain. Meatballs are standard size, 8 cm in diameter and 1 cm thickness.

Chemicals

Ethylenediaminetetraacetic acid disodium, trichloroacetic acid, thiobarbituric acid (TBA), diacetyl, diethyl ether, hydrochloric acid were obtained from Merck KGaA (Darmstadt, Germany). Chemicals for HAA analysis, including ethyl acetate, methanol, acetone, sodium hydroxide, hydrochloric acid, glacial acetic acid, acetonitrile, and ammonium hydroxide solution (25%) were purchased from Merck KGaA (Darmstadt, Germany). For solid phase extraction, Extrelut NT packing material (Merck, Darmstadt, Germany), Oasis MCX cartridge (Waters, Milford, Massachusetts, USA), SPE manifold (Supelco Visiprep, St. Louis, Missouri, USA), and Oasis HLB cartridge (Waters, Milford, Massachusetts, USA) were used. HAA standards were purchased from Riedel-de Haën Chemicals: IQ (CAS no:76180-96-6, 2-amino-3-methylimidazo[4,5-f]quinoline), IQx (CAS no:108354-47-8; 2-amino-3-methylimidazo[4,5-f]quinoxaline), MeIQ (CAS no:77094-11-2; 2-amino-3,4-dimethylimidazo[4,5-f]quinoline), MeIQx (CAS no:77500-04-0; 2-amino-3,8-dimethylimidazo[4,5-f]quinoxaline), 4,8-DiMeIQx (CAS no:95896-78-9; 2-amino-3,4,8-trimethylimidazo[4,5-f]quinoxaline), 7,8-DiMeIQx (CAS no:92180-79-5; 2-amino-3,7,8-trimethylimidazo[4,5-f]quinoxaline), PhIP (CAS no:105650-23-5; 2-amino-1-methyl-6-phenylimidazo[4,5-f]pyridine), harman (CAS no:486-84-0; 1-methyl-9H-pyrido[3,4-b] indole), norharman (CAS no:244-63-3; 9H-pyrido[3,4-b]indole), AαC (CAS no:26148-68-5; 2-amino-9H-pyrido[2,3-b]indole), MeAαC (CAS no: 68006-83-7; 2-amino-3-methyl-9H-pyrido[2,3-b]indole), and 4,7,8-TriMeIQx (CAS no:132898-07-8; 2-amino-3,4,7,8-tetramethylimidazo[4,5-f]quinoxaline).

Chemicals and solvents were of high-performance liquid chromatography (HPLC) or analytical grade. All solutions, except the HPLC-grade solutions, were passed through a 0.45 µm filter (Millipore, Billerica, Massachusetts, USA) before use.

Methods

Cooking process

Cooking temperature grades and times are determined as a result of preliminary studies conducted at the cooking areas commercially available for consumption (restaurants). The temperatures were setted as 150°C, 200°C and 250°C for cooking. The cooking times were specified as 5, 7.5 and 10 minutes. The oven temperature and the central temperatures of the cooked meatballs in the oven (İnoksan FKG 042) were measured by a termocouple (Datalog Termometer, RS-232 and Extech HD200) during the cooking time. In the study 9 experimental groups were composed of 3 replicates and 4 meatball samples were prepared for each group (9x3x4, total 108 meatballs).

The cooked samples were cooled at ambient temperature and then homogenized with a household mixer and stored in aluminum foil at -18°C until the proposed analyses achieved.

The determination of chemical

The protein and lipid contents were determined according to AOAC (1990) methods [8]. The lipid content was determined via the Soxhlet method and the protein content was analyzed via the Kjeldahl method. The pH of samples was measured using a digital pH meter (Hanna, Vohringen, Germany) calibrated with standard buffers of pH 4.0 and 7.0 at room temperature.

Lipid oxidation was measured by analyzing TBARS. TBARS were determined reported by AOAC (1990) [8]. TBARS values were expressed as mg of malondialdehyde mg MDA/kg of meatball.

Heterocyclic aromatic amine analysis

Extraction of heterocyclic aromatic amines

HAAs were extracted from the meatball using the method described by Murkovic [4] which is a modified method originally developed by Öz (2010) [9]. According to the method, 1 g of meatball was dissolved in 12 mL NaOH (1 M). The suspension was homogenized using a magnetic stirrer for 1 h at 500 rpm at room temperature. The alkaline solution was mixed with 13 g diatomaceous earth (Extrelut NT packaging material, Merck, Darmstadt, Germany) and then poured into empty Extrelut columns. The extractions were performed by using ethyl acetate and the eluate was passed through coupled Oasis MCX cartridges. The cartridge was washed with 2 mL of 0.1 M HCl and 2 mL MeOH. The analytes were eluted with 2 mL

MeOH-concentrated (25%) ammonia (19/1, v/v). The eluted mixtures were evaporated to dryness at 50 °C and the final extracts were dissolved in 100 µL MeOH just before measurements were taken.

HPLC analyses

HAAs were identified and quantified by HPLC (Thermo Ultimate 3000, Thermo Scientific, USA) with Diode Array Detector (DAD-3000), an auto-sampler (WPS-3000), a column oven (TCC-3000) and a pump (LPG-3400SD). Separation was carried out on a reverse phase analytical column (Acclaim™ 120 C18 3 µm (4.6 × 150 mm)) from Tosoh Bioscience GmbH (Stuttgart, Germany) at 35 °C with a mobile phase of methanol / acetonitrile / water / acetic acid (8/14/76/2, v/v/v/v) at pH 5.0 (adjusted with ammonium hydroxide 25%) as solvent A and acetonitrile as solvent B at a flow rate of 0.7 mL/min. The gradient program was: 0% B, 0–10 min; 0–23% B, 11–20 min; 23% B, 21–30 min; 0% B, 31–45 min. The injection volume was 10 µL (25% was an internal standard) from the final extract (dissolved in 100 µL of MeOH of the sample extract) as mentioned by Öz [9]. The identification of HAAs was carried out by comparing retention time and UV spectra (at 264 nm) recorded for standards and HAA standard spiked samples. Recovery rates for the different HAAs in the samples were determined by the standard addition method before extraction of the HAAs. The samples were spiked with HAA mixtures at four spiking levels (0.5, 1, 2, and 2.5 ng/g frozen meatball) by adding different volumes of a methanolic solution of the analytes [10]. The concentration of the HAAs in the samples was calculated by a standard curve running with different concentrations (0.5, 1, 2.5, 5, and 10 ng/g) of standards. Quantitative determination was performed by using an external calibration curve method. Linear regression (nanograms of compound against peak area) was performed for individual HAAs in mix stock solutions. Coefficients of the regression line (r^2) for HAA standard curves were 0.9995 for IQx, 0.9995 for IQ, 0.9995 for MeIQx, 0.9994 for MeIQ, 0.9995 for 7,8-DiMeIQx, 0.9995 for 4,8-DiMeIQx, 0.9994 for PhIP, 0.9994 for AαC and 0.9995 for MeAαC.

Statistical analysis

Statistical analyses were performed by using the Minitab 15 statistic program with ANOVA. Significant differences between two factors (GTE or MC) and two-way interactions (GTE × MC) were also analyzed based on the Duncan test (significance $P < 0.05$) using the Mstat-C statistic program.

Results and Discussion

Heat Treatment Results of Meatball Samples

Worked with three replications for each temperature-time combinations on the samples of meatballs cooked with three different combinations of temperature and time. The code number for each meatball sample, the cooking temperature, the cooking time and the internal temperature reached by the cooked meatballs are given in the following chart (Table 1).

Table 1. The code number for each meatball sample, the cooking temperature, the cooking time and the internal temperature

Code Number	Cooking Temperature (°C)	Internal Temperature (°C)	Cooking Time (min)
A	150	78.2	5
B	150	85.1	7.5
C	150	92.5	10
K	200	88.8	5
L	200	97	7.5
M	200	97.5	10
X	250	96.8	5
Y	250	98.5	7.5
Z	250	100.3	10

Chemical Analysis Results

The fat, protein, pH and TBARs results of the experimental samples are also shown in the Table 2. The average values of fat, protein, pH and TBARs of the samples withoutheat treatment were 15.8%, 32.13%, 5.3 and 0.13 MDA/kg, respectively. In experimental samples, depending on increase in temperature time the changes in the amount of fat, pH value and TBARs in the samples were not found significant($p > 0.05$). Asthe experimental samples were evaluated in terms of proteincontent, since the cooking time and temperature were increased and meatball samples were cooked for 10 minutes at 250°C due to water loss the protein concentration reached 36.19%. The statistical difference was found to be insignificant in between the samples cooked at 150°C and 200°C temperatures ($p > 0.05$).

Table 2. Chemical composition of meatball samples

Groups	Total fat (%) M±SE	Protein (%) M±SE	pH M±SE	TBARs (MDA mg/kg) M±SE
A	14.00±1.13[a]	33.51±0.71[a]	5.28±0.96[a]	0.12±0.02[a]
B	14.30±1.56[a]	32.19±1.03[a]	5.29±0.87[a]	0.14±0.05[a]
C	15.10±0.98[a]	34.15±0.86[a]	5.33±0.35[a]	0.16±0.02[a]
K	14.40±2.01[a]	35.17±0.98[a]	5.31±0.46[a]	0.19±0.06[a]
L	14.90±1.16[a]	36.11±1.11[a]	5.26±0.63[a]	0.15±0.05[a]
M	14.70±0.83[a]	35.41±0.96[a]	5.33±0.29[a]	0.14±0.02[a]
X	15.20±2.26[a]	36.10±0.76[a]	5.21±0.33[a]	0.24±0.03[a]
Y	14.90±1.93[a]	35.93±0.98[a]	5.37±0.51[a]	0.18±0.02[a]
Z	15.20±1.43[a]	36.19±1.14[a]	5.30±0.69[a]	0.19±0.05[a]

HAA content results

The recoveries obtained depended on the sample nature and the spiked concentration level. The limits of detection (LOD) and limits of quantification (LOQ) for standard solutions were calculated with a signal to noise ratio of 3 (S/N = 3) and 10 (S/N = 10), respectively. The lowest detected concentrations for each compound within the sample were: IQx = 0.004 ng/g, IQ = 0.009 ng/g, MeIQx = 0.024 ng/g, MeIQ = 0.014 ng/g, 7,8-DiMeIQx = 0.005 ng/g, 4,8-DiMeIQx = 0.008 ng/g, PhIP = 0.025 ng/g, AαC = 0.012, and MeAαC = 0.010 ng/g. The lowest quantified concentrations for each compound within the sample were: IQx = 0.013 ng/g, IQ = 0.029 ng/g, MeIQx = 0.081 ng/g, MeIQ = 0.047 ng/g, 7,8-DiMeIQx = 0.018 ng/g, 4,8-DiMeIQx = 0.025 ng/g, PhIP = 0.085 ng/g, AαC = 0.039, and MeAαC = 0.035 ng/g. Figure 1 shows an HPLC chromatogram of the mix stock solution (10 ng/g).

HAA quantities of experimental meatballs cooked at different temperatures and at different times are given in the following chart (Table 3). According to the results; 7,8-DiMeIQx, 4,8-DiMeIQx, AαC and MeAαC were not determined as numerical values at any temperature and time. Other HAAs were determined in varying amounts depending on the cooking temperature and duration.

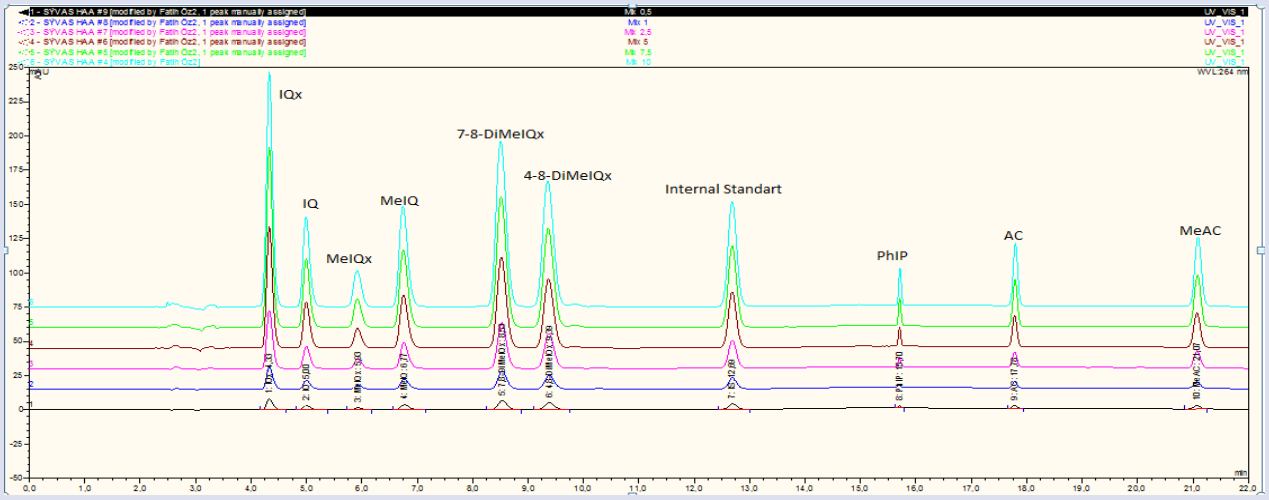

Figure 1. HAA chromatogram of standard mix 10 ng/g)

The IQx compound in the experimental samples was determined to be between 0-0.06 ng/g. The highest IQx content was determined in the meatballs cooked at 0,06 ng/g in a convection oven at 150°C for 7.5 min.Kızıl [11] has determined that the IQx content of meatballs cooked in the oven at different temperatures varied between 0-0,60 ng/g and that the highest IQx content was in the case of meatballs cooked 90 minutes at 150°C.

Table 3. The quantities of HAA (ng/g) resulting from the cooking of experimental meatball samples at different temperatures and time.

Temperature (°C)	150			200			250		
Time (min)	**5**	**7.5**	**10**	**5**	**7.5**	**10**	**5**	**7.5**	**10**
IQx	0.05	0.06	0.03	nd	nd	nd	nd	nd	nd
IQ	nd	nd	nd	nd	nd	nd	nd	0.15	0.11
MeIQx	nq	0.08	nq	0.17	nd	nd	nd	nd	nd
MeIQ	nq	nq	nd	nd	nd	nd	nq	0.05	nd
7,8-DiMeIQx	nq	nq	nq	nq	nq	nq	nq	nq	nq
4,8-DiMeIQx	nd	nq	nd	nd	nd	nd	nd	nq	nd
PhIP	nd	nd	0.18	nd	nd	nd	nd	0.22	0.17
AαC	nd	nd	nd	nd	nd	nd	nd	nd	nq
MeαAC	nd	nd	nd	nd	nd	nd	nd	nd	nq
Total HAA	0.05	0.14	0.21	0.17	-	-	-	0.42	0.28

nd: not detected (<LOD), nq: not quantities (LOD<...<LOQ).

Öz [10], they were unable to identify IQx in beef samples cooked at 200°C for 3-12 minutes with oven cooking method. Zikirov [12] determined the IQx compound between 0-0,156 ng/g in beef samples cooked in different methods. Turesky [13], they found IQx at levels of 0.2 ng/g and 0.03 ng/g in barbecued beef and roast beef steaks, respectively.

In this study, it was determined that the samples of the meatballs cooked with the convection oven contain IQ compounds in the range of nd-0,15 ng/g. The highest IQ content detected is; (0.15 ng/g) in the meatball samples cooked for 7.5 minutes at 250°C (Figure 2). When IQ contents of meatball samples are examined, at 150°C and 200°C, no IQ compound was formed, at 250°C, IQ compounds were detected in the amounts of 0,15 ng/g ve 0,11 ng/g, respectively, at 7,5 and 10 min cooked meatballs.

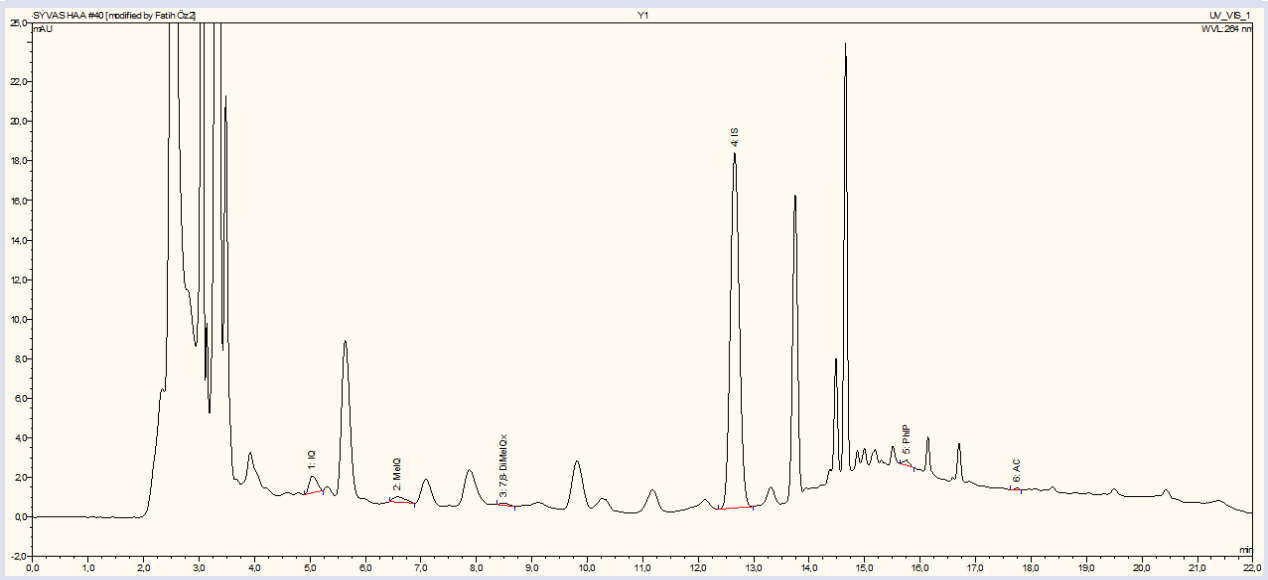

Figure 2. HPLC chromatogram of the sample baked for 7.5 min at 250°C

Kızıl [11] has found nd-1.26 ng/g IQ in the meat samples cooked at different temperatures in the oven. The highest IQ value was detected in the meatball cooked for 20 minutes at 150°C. In a study performed, in the examples cooked at 75°C and 85°C with sous-vide cooking method and with frying method (75°C internal temperature), it has been reported that IQ compound could not be determined but in the examples which were fried in a pan with internal temperature upto 95°C 0.037 ng/g IQ compound was detected [13]. In another study, in meatballs cooked at 175°C and 200°C (12 and 20 min), the IQ compound was reported as 0.7 ng/g, 1.3 ng/g, 1.7 ng/g and 4.4 ng/g, respectively [14]. Abdulkarim and Smith [15] have detected IQ up to 4.11ng/g in beef samples cooked in barbecue for 7-12 min at 200-240°C. Sinha [16] could not detect the IQ compound in beef samples cooked at different temperatures in the oven. Öz [17], in the study found 0.86 ng/g IQ in chops samples fried at 225°C but in samples at cooking temperatures of 175°C and 200°C, it was not possible to detect the IQ compound.

The contents of MeIQx of the analyzed samples were determined to be between 0-0.17 ng/g. The highest MeIQx content (0.17) was detected in the convection oven at 200°C temperature for 5 minute. 0.015 ng / g MeIQx compound was detected in samples cooked for 7.5 min at 150°C. No MeIQx compound was detected in any of the other samples. In a research done, ıt has been reported that MeIQx quantities of pork meat samples cooked in pan and in the oven are; between 0.4-4.3 ng/g in fried cooked samples and between 0-4 ng/g in the cooked in oven samples [18]. Even though HAA quantities for cooking in the oven are generally at low levels, in a study by Skog [19] they found out that the amount of MeIQx of the pork meat samples cooked in the oven was 3.2 ng/g. These values were reported to be the highest reported values for cooking in the oven. In their study Turesky [20], they found 2.7 ng/g, 4.2 ng/g and 12.3 ng/g MeIQx compounds in meatballs at which were fried at 275°C for 5, 10 and 15 minutes. Gross [21] reported that they detected a MeIQx compound of between 1.1 and 1.4 ng/g in 10 minutes of fried pork meat. Balogh [22] have found 0.5 ng/g and 0.8 ng/g at 175°C respectively and 1.5 ng/g and 4.2 ng/g MeIQx at 200°C, respectively in cooked meatball samples at 175°C and 200°C (12 and 20 min). The increase in temperature and time has led to an increase in the amount of MeIQx compound [14]. When the MeIQx results of the analyzed meatball samples were compared with the literature results, seems to be compliance provided.

In the experimental meatball samples, MeIQ was detected between nd-0.05 ng/g. The highest MeIQ amount was found as 0.05 ng/g in the meatballs cooked for 7.5 min at 250°C. In the study of Zikirov [12], MeIQ was detected between nd-0.068 ng/g in pan-fried beef

samples. Klassen [23] found that the content of MeIQ in hamburger beef samples was less than 0.1 ng/g. Abdulkarim and Smith [15] found 0.38 ng/g MeIQ compound in the grilled meats at 200 and 240°C. In their study Felton [24] found no MeIQ compound in meatball samples cooked for 12 minutes at 200°C.

When the experimental meatball samples were evaluated for 7,8-DiMeIQx and 4,8-DiMeIQx, both compounds were found, but the amount could not be determined in any sample (LOD <... LOQ). In some studies, 7,8-DiMeIQx was not found and the findings were found to be consistent with the present study[23, 25]. The 4,8-DiMeIQx compound was found in different amounts in different studies. For example, Öz [17], it could not detect 4,8-DiMeIQx in roasted chops samples (15 min) at 200°C but, found 1.77 ng/g 4,8-DiMeIQx in fried chops (15 min) at 225°C temperature. Again Öz [10] in another study they did, reported that they could not detect the 4,8-DiMeIQx compound in beef 3-12 min cooked at 200°C.

Gross [21] were unable to determine the amount of 4,8-DiMeIQx since they were below the detectable value (0.5 ppb) in the beef meatballs cooked on a grill. In another study they did, 4,8-DiMeIQx was not detected in 10 min fried beef at 250°C. However, they found 1.3 ng/g 4,8- DiMeIQx in 190°C 6 min pan fried steak.

PhIP is the most common heterocyclic aromatic amine in food and it is indicated that the formation in the food is largely depends on the cooking temperature and it occurs in excess amounts at high temperatures. In meatball samples, nd-0.22 PhIP compound was detected. The highest PhIP content was detected in samples cooked for 7.5 min at 250°C. With PhIP at 0.22 ng/g value, it is the HAA that can be detected in the highest amount among the HAAs analyzed in this study. In a study done, hamburger meatballs were cooked by using grill/ barbecue, frying pan, oven cooking method and 16.8 ng/g (grill/barbecue), 2.3 ng/g (frying pan) PhIP levels have been detected. As a reason for the formation of more PhIP in hamburger meatballs cooked using frying and grilling/barbecue methods, it has been reported that compared to cooking in the oven the same internal temperature was reached in a shorter time [23].

MeAαC and AαC compounds were not detected in any sample cooked using convection oven at different temperatures and times. MeAαC and AαC were found at the highest temperature studied but their amounts could not be determined. Öz [10] reported that MeAαC and AαC compounds could not be detected in beef samples cooked in the oven at 200°C (3-12 min), grilled (2-8 min) and fried (1.5-6 min).

As a result, it was observed that the total HAA amounts of the samples cooked in the convection oven using different temperatures and times were between 0-0.42 ng/g (Table 5). HAA was not detected at any temperature and any time for meatball samples cooked 7.5 min at 200°C, 10 min at 200°C and 5 min at 250°C. It is possible to say that sample of meatballs are safe in terms of HAA amounts according to the temperature and time they are cooked.

Table 5. The total quantities of HAA (ng/g) resulting from the cooking of experimental meatball samples at different temperatures and time

Temperatures (°C)	Time (min)	Total HAA (ng/g)
150	5	0.05
	7.5	0.14
	10	0.21
200	5	0.17
	7.5	-
	10	-
250	5	-
	7.5	0.42
	10	0.28

Based on the results of this study, it was determined that the formation of MeIQx compound increased with increasing cooking temperature. It has been observed that there are fluctuations in the amount of formation of other HAAs.

Conclusion

Heterocyclic aromatic amines are chemicals known with mutagenic and carcinogenic effects on human health and produced by the cooking process in meat products that are richin terms of protein. For this reason, the detection and prevention of HAA in meat and meat products has been the main objectives of recent studies. As a result of our study, it was determined that the application different cooking methods for cooking meatballs is suitable. Also, it was determined that the formation of MeIQx compound increased with increasing cooking temperature. It has been observed that there are fluctuations in the amount of other HAAs., This current work will be guiding for further studies researching formation of HAAs in meatballs obtained from different meat products. From this point of view, our study contributes to the literature. Morover, the reduction techniques could be developed for detection HAAs in meat products.

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Conflicts of Interest

The authors state that did not have conflict of interests.

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