Zagazig Veterinary Journal **RESEARCH ARTICLE**
Volume 44, Number 3, p. 263-272, December, 2016

DOI: 10.21608/zvjz.2016.7880

Effect of Heat Treatments on Polycyclic Aromatic Hydrocarbons Formation in Meat

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Abstract

A total of 80 samples of both beef and mutton (40, each), which were either raw or cooked by different cooking methods such as pan-frying, charcoal-grilling and charcoal-grilling with aluminum foils covers (n=10 for each of beef and mutton) besides 10 samples from raw meat of each type. The samples were collected from different restaurants at Zagazig City, Sharkia Governorate, Egypt. The samples were prepared for detection of 16 polycyclic aromatic hydrocarbons (PAHs) (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo [a] anthracene, chrysene, benzo [b] fluoranthrene, benzo [k] fluoranthene, benzo [a] pyrene, Indeno [1,2,3c-d] pyrene, Dibenzo [a,h] anthracene and Benzo [g,h,i] perylene). The recorded results showed that the total PAHs for raw, fried, charcoal grilled and foil grilled beef samples were 0.247, 1.152, 6.833 and 1.265 µg/kg respectively. Meanwhile, PAHs residual concentrations in mutton samples were 1.09, 4.606, 26.819 and 6.279 µg/kg in raw, pan-fried, charcoal-grilled and foil-grilled mutton samples respectively. We found also when meat wrapped in aluminum foil during grilling, it leads to a decrease in the total PAHs in the meat samples.

Keywords: PAHs, Pan-frying, Charcoal-grilling, Foil-grilled, Aluminum foil

Introduction

Polycyclic aromatic hydrocarbons are wide spread as environmental pollutants, which can be generated during the preparation of food [1]. PAHs are originated from many sources of environment (natural and anthropogenic), industry of food processing (such as; heating, drying, and smoking processes), materials of package and some cooking practices (such as; grilling, roasting, and frying processes) [2]. Food is the main source of exposure to PAHs for people who do not smoke, diet may cause more than 90% of total PAHs exposure of general population in different countries [3]. For mean consumers across the European countries, dietary exposure for the sum of eight carcinogenic and genotoxic PAHs (PAH8) (chrysene, benzo [a] pyrene, benzo [b] fluoranthene, benzo [k] fluoranthene, dibenzo [a,h] anthracene, benzo [g,h,i] perylene, indeno [1,2,3-c,d] pyrene and fluorene) was estimated at 1.73 mg/kg [2]. Despite the high level of PAHs is not observed in raw food as usual, the grilled food has been reported to contain PAHs at levels of 0 to 130 mg/kg [4,5]. The difference in PAHs levels in food could be attributed to the type and fat content, process of cooking (fried, grilled, roasted, boiled and smoked), temperature and cooking duration as well as fuel type used (electrical, gas, wood, and charcoal) [5].

Benzo [a] pyrene (BaP) is probably the most studied PAH. The International Agency for Research on Cancer (IARC) described BaP as probable human carcinogen in 1987 [6]. Thus, the BaP determination has been widely used in the analysis of the environment as an indicator for the PAH content [7]. Meat meals that are cooked by charcoal grilling and pan-frying are common at both home and restaurants in Egypt, also in other Arabian countries. Therefore, this study was performed to determine the effect of different cooking methods on the formation of PAHs in meat.

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Material and Methods

Samples

A total of 80 samples of both beef and mutton (40, each), which were either raw or cooked by different cooking methods (pan-frying, charcoal-grilling and charcoal-grilling with aluminum foils covers, n=10 for each beef and mutton). Samples were collected from different restaurants at Zagazig City, Sharkia Governorate, Egypt. The samples were prepared for the detection of 16 polycyclic aromatic hydrocarbons (PAHs) (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo [a] anthracene, chrysene, benzo [b] fluoranthrene, benzo [k] fluoranthene, benzo [a] pyrene, Indeno [1,2,3c-d] pyrene, Dibenzo [a,h] anthracene and Benzo [g,h,i] perylene).

The beef and mutton samples were fried in small amounts of margarine. For charcoal-grilling, beef and mutton samples were grilled over a grill fueled by charcoal at different restaurants and shops till the color became yellowish brown (well done). In addition, for charcoal grilling with aluminum foils, beef and mutton samples were wrapped by aluminum foils then grilled on a grill till the color became yellowish brown (well done).

Extraction and preparation of samples

Samples were transferred in a separate labeled aluminum foil to the Pesticide Residue Department, Central Pesticide Laboratory, Agriculture Research Center, Giza, where the extraction procedures, clean up and estimation of PAH levels by gas chromatography were conducted. Analysis of the PAHs residues was done according to Villeneuve *et al*. [8]. Twenty grams from each examined sample were grinded in a mortar with anhydrous sodium sulfate (2 g). The mixture was then squeezed with 60 mL of hexane-acetone (1-1) (v\v) mixture, filtered and the tissue was extracted twice more. Organic solvent fractions were united and filtered through filter paper with 1 g anhydrous sodium sulfate. The extract was then evaporated to about 2 mL. The extract was transferred to a round-bottom flask and 100 mL of 10% aqueous methanolic potassium hydroxide were added. The mixture was refluxed for 3 h in order to saponify the lipids. Finally, the content found in round-bottom flask was transferred to a separately funnel and cleansed with 150 mL of methanol-water (4:1) (v\v) mixture, then extracted with hexane (80 mL) to get back the non-saponified lipids.

Clean up of samples

Clean up was achieved with a silica/alumina column. Aromatic hydrocarbons were eluted with 30 ml of a mixture of hexane and dichloromethane (90:10) (v\v). The volume of the eluted fraction was reduced to 1 mL and analyzed by a gas liquid chromatography equipped with a flame ionization detector GC/FID.

Preparation of blank solution

The same volume of solvents and anhydrous sodium sulfate, that were used in the PAHs extraction of the examined samples were exposed to the same routine for the detection of any possible traces of the studied PAHs in the solvents or distilled water.

Gas chromatographic analysis

The procedure was carried out according to Moret and Conte [9]. The polycyclic aromatic hydrocarbon fraction was injected into a gas liquid chromatography equipped with a flame ionization detector GC/FID. The gas chromatograph used was Hewlett Packard GC Model 6890 equipped with a flame ionization detector (GC/FID). GC analysis was conducted on HP-608 (Agilent, Folsom, CA) fused silica capillary column (30-meter length x 0.53 millimeter internal diameter x 0.5 micrometer film thickness).

Gas chromatography operating conditions

Injector and detector temperatures were maintained at 280°C and 300°C, respectively. Initial oven temperature, 100°C for 2 min hold to 280°C at the rate of 6°C/min and was maintained at 280°C for 15 min.

Determination of the recovery percentage

The recoveries were done by adding the standard of PAHs mixture at 3 concentrations (1, 5 and 10 micrograms). The average percentages of recovery of PAHs for the examined samples at 3 levels were determined and estimated for all the tested PAHs in each sample (Figure 1).

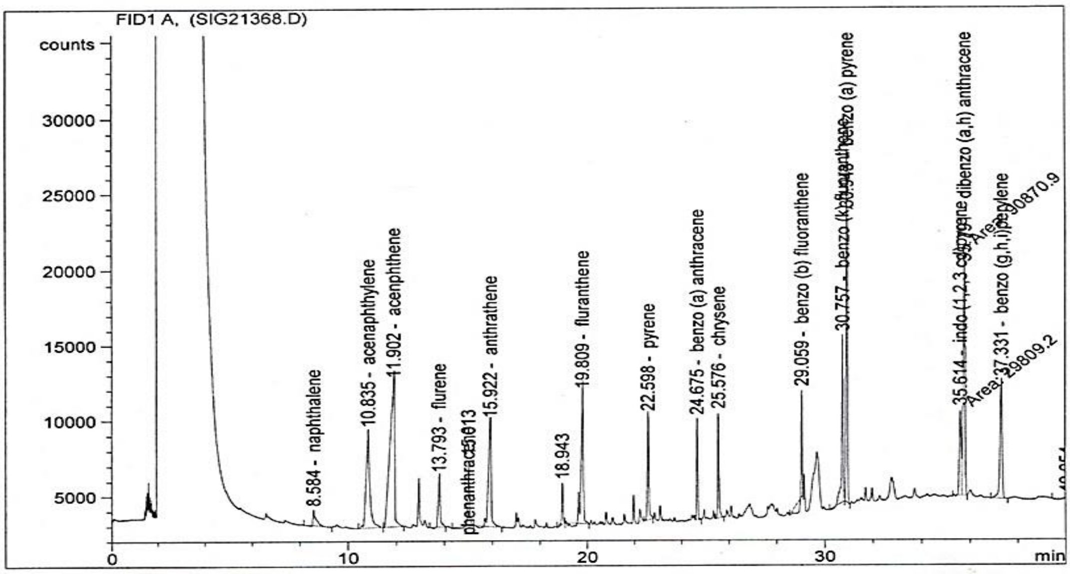

Figure 1: Exemplar for chromatogram of detected PAHs with their retention time.

Results and Discussion

The current study examined the presence of 16 PAHs compounds; namely; naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo [a] anthracene, chrysene, benzo [b] fluoranthrene, benzo [k] fluoranthene, benzo [a] pyrene, Indeno [1,2,3c-d] pyrene, Dibenzo [a,h] anthracene and Benzo [g,h,i] perylene in raw, pan-fried, charcoal-grilled and foil-grilled beef and mutton samples.

PAHs in beef

From Table (1), it is clear that the percentages of phenanthrene and anthracene in the examined samples were 10% and 10% in raw samples, 30% and 10% in pan-fried samples, 50% and 10% in charcoal-grilled samples, 10% and 10% in foil-grilled samples, respectively. Regarding to their residual concentrations, they were detected with mean values of 0.144±0.144 and 0.103±0.103 µg/kg in raw samples, 0.787±0.420 and 0.248±0.248 µg/kg in pan-fried samples, 1.501±0.508 and 0.61±0.61 µg/kg in charcoal-grilled samples and 0.571±0.572 and 0.174±0.174 µg/kg in foil-grilled samples, respectively.

Nearly similar results were obtained by Martorell *et al*. [10] who recorded the mean values of 0.16 and 0.16 µg/kg for both phenanthrene and anthracene in veal respectively. Unlikely, Mishref [11] did not detect phenanthrene in kebab samples but anthracene was recorded with a mean value of 18.2±25.04 µg/kg which is higher than the current results in charcoal grilled samples. Higher results were also obtained by Sinha *et al*. [12] and Falcó *et al* [13] who detected phenanthrene with mean values of 5.3 and 16.7 µg/kg, respectively.

Fluoranthene, pyrene, benzo [a] anthracene and benzo [b] fluoranthene compounds were detected only in charcoal grilled samples with the percentages of 10%, 10%, 30% and 10% with mean values of 0.451±0.451, 0.543±0.543, 0.545±0.280 and 0.189±0.189 µg/kg, respectively.

Higher results were obtained by Mishref [11] who detected fluoranthene and benzo [a] anthracene with mean values of 57 and 16.8 µg/kg, respectively, in kebab samples. Moreover, Hassan [14] detected fluoranthene and pyrene in charcoal grilled meat with mean values of 9.22 and 704.24 µg/kg, respectively. Additionally, Akpambagetal [15] recorded mean values of both fluoranthene and pyrene as 9.7 and 9.7 µg/kg, respectively, which were higher than the recorded results.

Regarding to benzo [a] pyrene, the most dangerous carcinogenic PAHs compound, it was detected in pan-fried, charcoal-grilled and foil-grilled meat samples with the percentages of 20%, each, with mean values of 0.117±0.085, 0.457±0.306 and 0.092±0.062 µg/kg, respectively, but was not detected in raw samples.

Table 1: Percentages of PAHs in beef and mutton meat samples exposed to different heat treatments

No.	PAHs	Beef samples%				Mutton samples%			
		Raw	Frying	grilling	Foil-grill	Raw	Frying	grilling	Foil-grill
1	Naphthalene	0%	0%	0%	0%	0%	0%	40%	20%
2	Acenaphthylene	0%	0%	0%	0%	0%	10%	20%	10%
3	Acenaphthlene	0%	0%	0%	0%	0%	0%	0%	0%
4	Fluorine	0%	0%	0%	0%	0%	20%	40%	20%
5	Phenanthrene	10%	30%	50%	10%	0%	30%	60%	30%
6	Anthracene	10%	10%	10%	10%	0%	0%	10%	0%
7	Fluoranthene	0%	0%	10%	0%	0%	0%	70%	50%
8	Pyrene	0%	0%	10%	0%	40%	50%	100%	60%
9	Benzo(a)anthracene	0%	0%	30%	0%	0%	0%	30%	0%
10	Chrysene	0%	0%	0%	0%	0%	10%	40%	20%
11	Benzo(b)fluoranthene	0%	0%	10%	0%	0%	0%	0%	0%
12	Benzo(k)fluoranthene	0%	0%	60%	30%	0%	0%	0%	0%
13	Benzo(a)pyrene	0%	20%	20%	20%	0%	10%	20%	0%
14	Indeno(1,2,3c-d)pyrene	0%	0%	0%	0%	0%	0%	10%	0%
15	Dibenzo(a,h)anthracene	0%	0%	0%	0%	30%	50%	80%	50%
16	Benzo(g,h,i)perylene	0%	0%	20%	10%	0%	10%	10%	0%

Higher results were obtained by Terzi *et al.* [16], Akpambagetal [15] and Mishref [11] who detected benzo [a] pyrene with mean values of 24.2, 2.8 and 9.2 µg/kg, respectively, in charcoal-grilled meat. However, lower results were recorded by Chung *et al.* [17], who found mean concentration of benzo [a] pyrene as 0.15 µg/kg.

The current findings concerning benzo [a] pyrene didn't exceed the MPL recommended by FAO/WHO (10 part per billion 'ppb'). Concerning benzo [k] fluoranthene and benzo [g,h,i] perylene, they could be detected in charcoal and foil grilled samples only, with the percentages of 60% and 20% in charcoal-grilled samples and 30% and 10% in foil-grilled samples, respectively. The mean values of benzo [k] fluoranthene in these samples were 1.933±0.548 and 0.172±0.089 µg/kg, while they were 0.604±0.442 and 0.256±0.256 µg/kg for Benzo [g,h,i] perylene. Lower results were obtained by Martorell *et al.* [10], who detected benzo [k] fluoranthene and benzo [g,h,i] perylene with mean values of 0.06 and 0.07 ppb respectively, also, Olatunde *et al.* [18] detected benzo [k] fluoranthene and benzo [g,h,i] perylene with mean values of 0.1 and 0.3 ppb, respectively. Both of Mishref [11] and Hassan [14] did not detect any of these two compounds in such samples.

In the current study, it is clear that none of naphthalene, acenaphthylene, acenaphthene, fluorene, chrysene, indeno [1,2,3c-d] pyrene and dibenzo [a,h] anthracene were detected in raw, pan-fried, charcoal-grilled and foil-grilled meat samples.

The total PAHs in raw, pan-fried, charcoal-grilled and foil-grilled meat samples were 0.247, 1.152, 6.833 and 1.265 µg/kg respectively (Table 2). Nearly similar results were obtained by Janoszka *et al.* [19] who recorded 2.77 µg/kg total PAHs in pan-fried beef collar, while higher results were obtained by Sinha *et al.* [12] who recorded total PAHs in pan-fried meat as 10.7 µg/kg.

Chung *et al.* [17], who reported that the total PAHs of 0.80 ppb in charcoal-grilled samples which was lower than that obtained in the current study. Higher results were obtained by Falcó *et al.* [13], Farhadian *et al.* [5], Jahurul *et al.* [20], Mishref [11] and Hassan [14], who reported that total PAHs as 13.4, 132, 66.28, 119.8 and 1170.94 µg/kg, respectively.

The differences between the obtained results in this study and the others may be attributed to the fat percentage in the meat used in this study, type of charcoal, thickness of meat and well-doneness of meat.

Table 2: Residual concentrations of PAHs in the examined raw and heat-treated beef samples (n=10)

PAHs	Raw			Fried			Charcoal-grilled			Foil-grilled		
	Min	max	Mean ± SE	min	Max	Mean ±SE	min	max	Mean ±SE	min	max	Mean SE
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenapthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	0	1.44	0.144±0.144	0	3.47	0.787±0.420	0	3.33	1.501±0.508	0	5.71	0.571±0.572
Anthracene	0	1.03	0.103±0.103	0	2.48	0.248±0.248	0	6.1	0.61±0.61	0	1.74	0.174±0.174
Fluoranthene	ND	ND	ND	ND	ND	ND	0	4.51	0.451±0.451	ND	ND	ND
Pyrene	ND	ND	ND	ND	ND	ND	0	5.43	0.543±0.543	ND	ND	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	0	2.06	0.545±0.280	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	0	1.89	0.189±0.189	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	0	4	1.933±0.548	0	0.66	0.172±0.089
Benzo(a)pyrene	ND	ND	ND	0	0.81	0.117±0.085	0	2.48	0.457±0.306	0	0.52	0.092±0.062
Indeno(1,2,3c-d)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(o,h)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	0	4.24	0.604±0.442	0	2.56	0.256±0.256
Total PAHs			**0.247**			**1.152**			**6.833**			**1.265**

Min= minimum, Max= maximum, SE= standard error, ND= not detected

Table 3: Residual concentrations of PAHs in examined raw and heat-treated mutton samples (n=10)

PAHs	Raw			Fried			Charcoal-grilled			Foil grilled		
	Min	max	Mean ± SE	Min	max	Mean ±SE	min	max	Mean ±SE	Min	max	Mean SE
Naphthalene	ND	ND	ND	ND	ND	ND	0	6.62	1.783±0.823	0	3.58	0.69±0.458
Acenaphthylene	ND	ND	ND	0	0.53	0.053±0.053	0	3.3	0.596±0.400	0	0.71	0.071±0.071
Acenapthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorine	ND	ND	ND	0	1.27	0.23±0.154	0	8.75	1.848±0.952	0	3.31	0.526±0.365
Phenanthrene	ND	ND	ND	0	1.44	0.289±0.160	0	1.46	0.662±0.189	0	0.81	0.200±0.105
Anthracene	ND	ND	ND	ND	ND	ND	0	0.49	0.049±0.049	ND	ND	ND
Fluoranthene	ND	ND	ND	ND	ND	ND	0	1.52	0.654±0.182	0	1.81	0.459±0.191
Pyrene	0	3.67	0.917±0.417	0	8.3	3.177±1.121	1.02	23.42	13.979±1.884	0	6.91	3.426±0.968
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	0	16.57	2.517±1.744	ND	ND	ND
Chrysene	ND	ND	ND	0	4.38	0.438±0.438	0	14.6	3.491±1.729	0	3	0.565±0.378
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	0	0.19	0.019±0.019	0	0.19	0.030±0.021	ND	ND	ND
Indeno(1,2,3c-d)pyrene	ND	ND	ND	ND	ND	ND	0	5.33	0.533±0.533	ND	ND	ND
Dibenzo(a,h)anthracene	0	0.9	0.173±0.098	0	1.05	0.4±0.148	0	0.98	0.503±0.099	0	0.71	0.246±0.863
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	0	1.74	0.174±0.174	0	0.96	0.096±0.096
Total PAHs			**1.09**			**4.606**			**26.819**			**6.279**

Min= minimum, Max= maximum, SE= standard error, ND= not detected

PAHs in mutton

The results in Table (3) indicated that the percentages of pyrene and dibenzo [a,h] anthracene in the examined samples were 40% and 30% in raw samples, 50% and 50% in pan-fried samples, 100% and 80% in charcoal-grilled samples and 60% and 50% in foil-grilled samples, respectively. Regarding to their residual concentrations, they were detected with mean values of 0.19±0.417 and 0.173±0.098 µg/kg in raw samples, 3.177±1.121 and 0.4±0.148 µg/kg in pan-fried samples, 13.979±1.884 and 0.503±0.099 µg/kg in charcoal-grilled samples and 3.426±0.968 and 0.246±0.863 µg/kg in foil-grilled samples, respectively.

The percentages of acenaphthylene, flourene, phenanthrene and chrysene in the current study were 10%, 20%, 30% and 10% in pan-fried samples, 20%, 40%, 60% and 40% in charcoal-grilled samples and 10%, 20%, 30% and 20% in foil-grilled samples, respectively. Their mean residual concentrations were 0.053±0.053, 0.23±0.154, 0.289±0.159 and 0.438±0.438 µg/kg in pan-fried samples, 0.596±0.4, 1.848±0.952, 0.662±0.189 and 3.491±1.729 µg/kg in charcoal-grilled samples and 0.071±0.071, 0.526±0.365, 0.2±0.105 and 0.565±0.378 µg/kg in foil-grilled samples, respectively.

Concerning benzo [a] pyrene, it was detected in fried and charcoal-grilled samples with mean values of 0.019±0.019 and 0.030±0.021 µg/kg, respectively. Higher results were obtained by Ayguns and Kabadayi, [21] and Kao et al. [22], who recorded benzo [a] pyrene levels as 43.8±1.8 and 5.8±0.5 µg/kg in grilled lamb meat and lamb steak, respectively.

Naphthalene, fluoranthene and benzo [g,h,i] perylene compounds were detected in charcoal and foil-grilled samples only, with the percentages of 40%, 70% and 10% in charcoal-grilled samples and 20%, 50% and 10% in foil-grilled samples, respectively. Their mean values were 1.783±0.823 and 0.69±0.458µg/kg for naphthalene, 0.654±0.182 and 0.459±0.191µg/kg for fluoranthene, 0.174±0.174 and 0.096±0.096 for benzo [g,h,i] perylene.

Anthracene, benzo [a] anthracene and indeno [1,2,3c-d pyrene compounds were detected only in charcoal-grilled samples in our study with the percentages of 10%, 30% and 10%, respectively. Their mean values were 0.049±0.049, 2.517±1.744 and 0.533±0.533µg/kg, respectively. In the current study, it is clear that non of acenaphthene, benzo [b] fluoranthene and benzo [k] fluoranthene could be detected in raw, fried, charcoal-grilled and foil-grilled mutton samples. It is clear from Table (3) that the total PAHs for raw, pan-fried, charcoal-grilled and foil-grilled mutton samples were 1.09, 4.606, 26.819 and 6.279 µg/kg, respectively.

For both beef and mutton

It is obvious that quantitative PAHs profile was different in pan-fried, charcoal-grilled and foil-grilled meat samples, which may be attributed to cooking temperature, cooking method and cooking time [5]. Generally, the formation mechanism of PAHs in grilled or smoked diets is unknown, it is generally considered that at least 3 possible mechanisms exist: The 1st mechanism is the organic matter pyrolysis as fat, carbohydrates and protein at temperatures higher than 200oC, and the formation of PAH mainly arise at a temperature ranges from 500 to 900oC [23]. The largest levels of PAHs may be arising from fat pyrolysis [24].

The second mechanism is due to the direct contact of the dripping arise from lipids at an extreme heat directly over a flame. This situation could produce volatile PAHs which then sticked to the food surface and the smokes rise [25]. The third mechanism is the incomplete combustion of charcoal which can generate PAHs that are brought onto the surface of the food [26].

It is obvious that the total PAHs increased after thermal treatments and this result came in harmony with WHO [4], which reported that high levels of PAHs are not usually observed in raw food. In addition, Phillips [27] mentioned that cooking processes can generate PAHs in food. It was observed that total PAHs of both beef and mutton samples is lower in fried samples than that of charcoal and foil grilled samples. On the contrary, Perelló [28] stated that the highest PAHs concentrations found after frying.

Meanwhile, Larson et al. [29] mentioned that frying didn't lead to any appreciable increase of the original trace level, and this was in agreement with this study.

Interestingly, it was found that total PAHs decreased in foil-grilled samples than charcoal-grilled one, this mean that when meat is wrapped with aluminum foil during grilling, it leads to a decrease in the total PAHs in the meat samples. These results are in agreement with Farhadian et al [30], who used aluminum foil and banana leaves to reduce total PAHs in meat samples during grilling and reported that this method is working well.

The health risk associated to the high concentration of benzo(a)pyrene, benzo(a)anthracene and chrysene in the present study was reported by Nisbet and LaGoy [31] and IARC [32], who recorded that the PAHs were proven to be animal carcinogens and in human they are suspected to be carcinogen. Therefore, many considerations should be taken before consumption of meat grilled over charcoal because large amounts of PAHs could be eaten in a single diet.

The total PAHs in beef is lower than that of mutton. This may be due to the mutton used in this study was higher in fat than beef. The percentage of fat plays an important role in PAHs formation, because barbecuing leads to melting of fat that dropped during the grilling period which provides the formation of PAHs [33].

Conclusion

In conclusion, the total PAHs increased after thermal treatments than that in raw samples. Additionally, in both beef and mutton samples, total PAHs is lower in fried samples than that of charcoal and foil-grilled samples. Total PAHs decreased in foil-grilled samples than charcoal grilled one, this means that, when meat wrapped in aluminum foil during grilling, it leads to a decrease in the total PAHs in the meat samples. Benzo [a] pyrene didn't exceed the MPL recommended by FAO/WHO (10 ppb). So, it seems that it is preferable to the consumers to wrap the charcoal grilled meat in an aluminum foil prior to grilling.

Conflict of interest

None of the authors have any conflict of interest to declare.

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الملخص العربي

تأثير طرق الطهي المختلفة علي تكوين المواد الهيدروكربونية الأروماتية متعددة الحلقات فى اللحوم

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تم تجميع ٨٠ عينة (٤٠ عينة من كل من اللحوم البقري ولحوم الضأن) مقسمة لكل منهما كالتالي: عينات اللحوم البقري (١٠ لحوم نيئة, ١٠بعد التحمير, ١٠ بعد الشواء علي الفحم, ١٠ بعد الشواء علي الفحم وملفوفة في ورق ألمونيوم), و عينات لحوم الضأن (١٠ لحوم نيئة, ١٠بعد التحمير, ١٠ بعد الشواء علي الفحم, ١٠ بعد الشواء علي الفحم وملفوفة في ورق ألمونيوم) من مطاعم مختلفة في مدينة الزقازيق, محافظة الشرقية, وتم قياس ١٦ من أهم بقايا الهيدروكربونات الأروماتية متعددة الحلقات في هذه العينات. دلت النتائج على وجود إجمالى الهيدروكربونات الأروماتية متعددة الحلقات بمتوسطات قدرها ٠,٢٤٧, ١,١٥٢, ٦,٨٣٣ و ١,٢٦٥ ميكروجرام لكل كجم من اللحوم النيئة, والمحمرة, والمشوية علي الفحم والمشوية علي الفحم والملفوفة في ورق الألمونيوم علي التوالي في عينات اللحم البقرى. أما بالنسبة لعينات لحوم الضأن دلت النتائج على تواجد إجمالى الهيدروكربونات الأروماتية متعددة الحلقات بمتوسطات قدرها ٠,٢٤٧, ١,١٥٢, ٦,٨٣٣ و ١,٢٦٥ ميكروجرام لكل كجم من اللحوم النيئة, والمحمرة, والمشوية علي الفحم والمشوية علي الفحم وملفوفة في ورق الألمونيوم علي التوالي. أوضحت النتائج ان لف اللحوم بورق الألمونيوم أدت إلي تقليل هذه المواد الخطيرة.