

Polycyclic Aromatic Hydrocarbons (PAHs) in Charcoal Grilled Meat (Kebab) and Kofta and the Effect of Marinating on their Existence

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Abstract

Sixty samples of non-marinated and marinated charcoal grilled meat (Kebab) and Kofta (30, each) were analyzed for the existence of 11 polycyclic aromatic hydrocarbons (PAHs) including Naphthalene, Acenaphthylene, Acenaphthene, Fluorine, Phenanthrene, Anthracene, Fluranthene, Chrysene, Benzo(a)pyrene, Benzo(a)anthracene and Benzo(g,h,i)perylene by using Gas Chromatography equipped with a flame ionization detector GC/FID. The obtained results declared that Anthracene, Fluranthene, Chrysene, Benzo(a)anthracene and Benzo(a)pyrene were detected in 40%, 20%, 100%, 60% and 40% of the examined non-marinated charcoal grilled Kebab with a mean concentration values of 18.2 ± 11.2 , 57 ± 28.59 , 18.6 ± 1.69 , 16.8 ± 7.0 and 9.2 ± 5.67 $\mu\text{g}/\text{kg}$, respectively. Benzo(a)anthracene and Benzo(a)pyrene were only found in 100% and 40% in the examined non-marinated charcoal grilled Kofta with a mean concentration values of 33.2 ± 4 and 26 ± 16 $\mu\text{g}/\text{kg}$, respectively. The total concentration values of the existed PAHs in the examined non-marinated charcoal grilled Kebab and Kofta were 119.8 ± 54.15 and 59.2 ± 16.9 $\mu\text{g}/\text{kg}$, respectively. It was observed that meat marinating for four hours before its charcoal grilling had a high effect on the existence of PAHs where the total concentration values of PAHs in marinated Kebab and Kofta were reduced to 57.93 ± 2.77 and 30.2 ± 5.89 $\mu\text{g}/\text{kg}$ with reduction percentages of 51.6% and 49%, respectively. In addition, some types of existed PAHs in non-marinated meat were undetected (100% reduction) after marinating and charcoal grilling such as Fluranthene and Benzo(a)pyrene. Thus indicating that marinating of meat prepared for charcoal grilling will greatly reduce the most hazardous carcinogenic PAHs compound such as Benzo(a)pyrene (BaP) resulting in more safe charcoal grilled meat for human consumption.

Keywords: Polycyclic Aromatic Hydrocarbons (PAHs), Meat, Marinating, Grilling

Introduction

Polycyclic aromatic hydrocarbons (PAHs) are a group of hydrophobic compounds consisting of two or more fused aromatic rings [1]. PAHs containing four fused rings, such as Benzo(a)anthracene and Chrysene are weakly carcinogenic compounds.

In addition, PAHs containing five or more rings such as Dibenz(a,h)anthracene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Benzo(b,k)fluoranthene and Benzo(g,h,i)perylene are considered potentially genotoxic and carcinogenic to humans and thus they are

among the organic pollutants of public health concern [1].

PAHs are ubiquitous environmental pollutants and they can be generated during the preparation of food [2]. They originate from environmental sources (natural and anthropogenic), industrial food processing (such as heating, drying, and smoking), packaging materials and certain cooking practices (grilling, roasting and frying) [3].

The main source of exposure to PAHs for non-smokers and non-occupationally-exposed adults is food. Diet contributes more than 90%

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of total PAHs exposures of the general population in various countries [4]. The average consumption across the European countries and the 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 as 1.73 mg/day [5].

The variation in PAHs levels in food is mainly due to the type and fat content of the food, cooking process (frying, grilling, roasting, boiling and smoking), temperature and duration of cooking, type of fuel used (electrical, gas, wood, and charcoal), proximity and direct contact with the heat source [6].

Meat dishes prepared by charcoal grilling are increasingly popular both at home and in restaurants in Egypt as well as in other Arabian countries. Therefore, this study aimed to monitor PAHs in these food products and using a marinade treatment prior to charcoal grilling as a trial to obtain the most preferable methods which prevent or reduce the PAHs formation during meat processing.

Material and Methods

Samples

Thirty samples of non-marinated, charcoal grilled Kebab and Kofta (15, each) were collected from different restaurants in Mansoura city, Dakhlia Governorate, Egypt. In addition, thirty samples of charcoal grilled Kebab and Kofta (15, each) were collected for marinating process. The samples were prepared for the detection of 11 PAHs residues (Naphthalene, Acenaphthylene, Acenaphthene, Fluorine, Phenanthrene, Anthracene, Fluranthene, Chrysene, Benzo(a)pyrene, Benzo(a)Anthracene and also Benzo(g,h,i)perylene).

Preparation of the samples

Marinated samples were examined according to El Badry [7] and Farhadian *et al.* [8]. In brief: all marinade ingredients (yoghurt,

salt, turmeric, mustard, curry powder, cardamom, vinegar and onion) were obtained from local markets in Mansoura city. The marinade (for 1 kg of meat) composed of 30 g yoghurt, 2 g salt, 2 g turmeric, 1 g dry mustard, 4 g curry powder, 1 g ground cardamom, 5 mL lemon juice, 5 mL white vinegar, 1/2 onion (cut in half and broken up into layers), 4 small tomatoes (halved), one lemon (cut in wedges) and parsley.

All marinade ingredients were mixed in a blender and kept in the refrigerator (4°C) until used (at a maximum duration of 4 h). They were then added to the beef samples, well mixed and left for at least 4 h at 4°C. The marinating meat samples were grilled on a grill fueled by charcoal until the color turned yellowish brown (well done). Each sample was then transferred in a separate labelled aluminium foil to the Pesticide Residues Department, Central Pesticide Lab, Agriculture Research Center, Giza, Egypt.

Analysis of the samples

The non-marinated and marinated charcoal grilled meat (Kebab) and Kofta were prepared, extracted and cleaned up according to the method recommended by Villeneuve *et al.* [9]. Such prepared samples were analyzed for the existence and level of PAHs according to Moret and Conte [10] using Gas Chromatography (Hewlett Packard GC Model 6890) equipped with a flame ionization detector GC/FID. The GC analysis was conducted on a HP-608 (Agilent, Folsom, CA) fused silica capillary column (30 m length x 0.53 mm internal diameter (i.d) x 0.5 µm film thickness). The obtained data were statistically analyzed according to Petric and Waston [11].

Results and Discussion

The results in Tables (1 and 2) declared that Anthracene, Fluranthene, Chrysene, Benzo(a)anthracene and Benzo(a)pyrene were detected in 40%, 20%, 100%, 60% and 40% of the examined non marinated charcoal grilled Kebab samples with a mean concentration values of 18.2 ± 11.2 , 57 ± 28.59 , 18.6 ± 1.69 , 16.8 ± 7.0 and 9.2 ± 5.67 µg/kg, respectively.

Benzo(a)anthracene and Benzo(a)pyrene were only found in 100% and 40% of the examined non-marinated charcoal grilled Kofta samples

with mean concentration values of 33.2 ± 4 and $26 \pm 16 \mu\text{g/kg}$, respectively.

Table 1: The percentage of detected PAHs residues in charcoal grilled non-marinated and marinated samples of Kebab and Kofta (N=15, each)

Existed PAHs	Non-marinated		Marinated	
	Kebab	Kofta	Kebab	Kofta
Naphthalene	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	20%
Acenaphthene	ND	ND	ND	ND
Fluorine	ND	ND	ND	20%
Phenanthrene	ND	ND	ND	ND
Anthracene	40%	ND	60%	ND
Fluranthene	20%	ND	ND	ND
Chrysene	100%	ND	100%	ND
Benzo(a)anthracene	60%	100%	60%	80%
Benzo(a)pyrene	40%	40%	ND	ND
Benzo(ghi)perylene	ND	ND	ND	ND

ND: Non Detectable

The total concentration values of the existed PAHs in the examined non-marinated charcoal grilled Kebab and Kofta were 119.8 ± 54.15 and $59.2 \pm 16.9 \mu\text{g/kg}$, respectively. Such finding coincide with previously reported studies [12-16]. Regarding the mean concentration values of the total PAHs, the obtained results are lower than those reported

previously [6,17], while they were higher than $8 \mu\text{g/kg}$ [18]; $1 \mu\text{g/kg}$ [19]; $0.8 \mu\text{g/kg}$ [20] and $66 \mu\text{g/kg}$ [21] obtained in other studies. Such variations are expected and could be attributed to the cooking method, cooking time and cooking temperature, also, it could be due to measurement techniques and the used device sensitivity.

Table 2: Concentrations ($\mu\text{g/kg}$) of detected PAHs residues in charcoal grilled non-marinated samples of Kebab and Kofta (N =15, each)

Compounds	Kebab			Kofta		
	Min.	Max.	Mean \pm SE	Min.	Max.	Mean \pm SE
Anthracene	ND	49	18.2 \pm 11.2	ND	ND	ND
Fluranthene	ND	285	57 \pm 28.59	ND	ND	ND
Chrysene	15	25	18.6 \pm 1.69	ND	ND	ND
Benzo(a)anthracene	ND	33	16.8 \pm 7.0	21	45	33.2 \pm 4
Benzo(a)pyrene	ND	25	9.2 \pm 5.67	ND	70	26 \pm 16
Total PAHs	59	336	119.8 \pm 54.15	21	101	59.2 \pm 16.9

ND: Non Detectable

Only Anthracene, Chrysene and Benzo(a)anthracene were found in 60%, 100% and 60% of the examined marinated charcoal grilled Kebab with mean concentration values of 25.27 ± 6 , 13.5 ± 1.75 and 19.2 ± 5.14 $\mu\text{g}/\text{kg}$, respectively (Tables 1 and 3). Meanwhile, Acenaphthylene, Fluorine and Benzo(a)anthracene were detected in 20%, 20% and 80% of the examined marinated charcoal

grilled Kofta with a mean concentration values of 3 ± 1.69 , 6.3 ± 3.38 and 20.87 ± 3.46 $\mu\text{g}/\text{kg}$, respectively (Tables 1 and 3). The total concentration values of the existed PAHs in the examined marinated charcoal grilled Kebab and Kofta were 57.93 ± 2.77 and 30.2 ± 5.89 $\mu\text{g}/\text{kg}$ respectively (Tables 1 and 3). These findings are nearly in agreement with those recorded previously [7,8,22].

Table 3: Concentrations ($\mu\text{g}/\text{kg}$) of detected PAHs residues in charcoal grilled marinated samples Kebab and Kofta (N=15, each)

Compounds	Kebab			Kofta		
	Min.	Max.	Mean \pm SE	Min.	Max.	Mean \pm SE
Anthracene	ND	56	25.27 \pm 6	ND	ND	ND
Chrysene	4	26	13.5 \pm 1.75	ND	ND	ND
Benzo(a)anthracene	ND	57	19.2 \pm 5.14	ND	45	20.87 \pm 3.46
Acenaphthylene	ND	ND	ND	ND	19	3 \pm 1.69
Fluorine	ND	ND	ND	ND	35	6.3 \pm 3.38
Total PAHs	39	82	57.93 \pm 2.77	ND	74	30.2 \pm 5.89

ND: Non Detectable

From the results illustrated in Figures (1 and 2) it is found that marinating of meat for four hours before its charcoal grilling had a high reduction effect on the existence of PAHs in well done meat. Also, the total concentration values of the existed PAHs in the examined non-marinated charcoal grilled Kebab and Kofta were 119.8 ± 54.15 and 59.2 ± 16.9 $\mu\text{g}/\text{kg}$ and they were reduced to 57.93 ± 2.77 and 30.2 ± 5.89 $\mu\text{g}/\text{kg}$ with reduction percentages of 51.6% and 49%, respectively. In addition, some types of the existed PAHs in non-marinated meat disappeared completely (100% reduction) after marinating and charcoal grilling such as Fluranthene, Benzo(a)pyrene. Such finding substantiate what has been reported in previous studies [7,8,22,23].

By comparison of the obtained results with the recommended maximum level for the most hazardous carcinogenic PAHs compound

Benzo(a)pyrene (BaP) (5 $\mu\text{g}/\text{kg}$ in smoked meat products) reported by the European Commission [24], it was found that 40% of the non-marinated charcoal grilled Kebab samples with a range between 21 and 25 $\mu\text{g}/\text{kg}$ exceeded the recommended maximum level but they were totally reduced in marinated Kebab samples. In addition, 40% of the non-marinated charcoal grilled Kofta samples with a range between 60 and 70 $\mu\text{g}/\text{kg}$ exceeded the recommended maximum level and they were totally reduced in marinated Kofta samples. Such finding indicated that treatment of meat prepared for charcoal grilling by marinating will greatly reduce the hazardous carcinogenic PAHs compounds such as Benzo(a)pyrene (BaP) which will make the charcoal grilled meat safe for human consumption. This is in agreement with what has been mentioned previously [7,8,22].

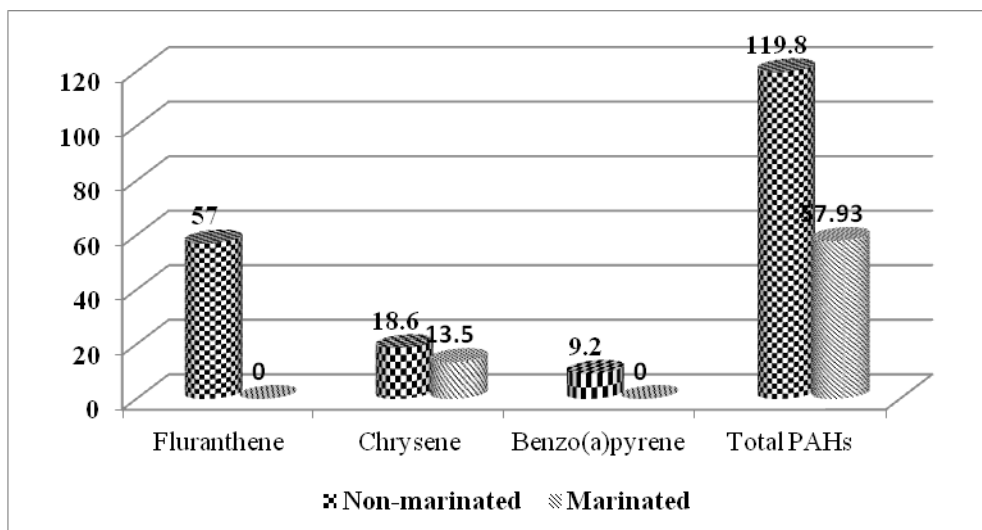


Figure 1: Effect of marinating on PAHs concentrations ($\mu\text{g}/\text{kg}$) in the examined samples of charcoal grilled Kebab.

The reduction effect of marinating on PAHs formation could be due to the presence of spices which have antioxidant activity [8]. At longer residence times and higher temperatures, initial pyrolysis products of Maillard reaction can undergo additional reactions to form PAHs [25]. Onion and garlic

contain a lot of organic sulfur compounds that prevent the Maillard reactions [23,26]. Moreover, they have been reported to act as inhibitors to the formation of some carcinogen compounds such as heterocyclic aromatic amines (HCA) [27].

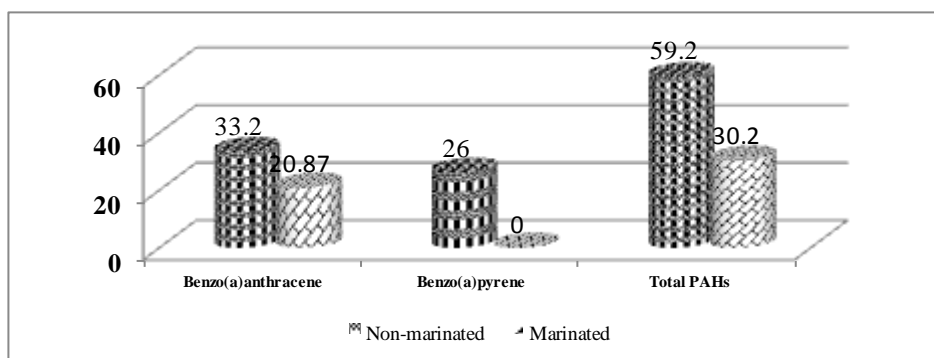


Figure 2: Effect of marinating on PAHs concentrations ($\mu\text{g}/\text{kg}$) in the examined samples of charcoal grilled Kofta.

The health risk associated with the high concentration of Benzo(a)anthracene, Benzo(a)pyrene and Chrysene was reported in previous studies in which PAHs were proven to be animal carcinogens and in humans they are suspected to cause cancer [1,28]. Therefore, special attention must be given for charcoal grilled Kebab and Kofta intakes,

because high amounts of PAHS can be taken in a single meal.

Conclusion

It is recommended that meat should be marinated prior grilling to minimize the hazards of PAHs on human health.

Conflict of interest

The authors declare no conflict of interest.

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الملخص العربي

الهيدروكربونات الأروماتية متعددة الحلقات في اللحوم المشوية على الفحم (الكباب) والكفتة وتأثير التتبيل على تواجدها

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الهيدروكربونات الأروماتية متعددة الحلقات هي مركبات كيميائية تنتج من الاحتراق غير الكامل للفحم وهي تتواجد في بعض أنواع الأغذية وقد تتسبب في أضرار متنوعة على صحة المستهلك. أجريت هذه الدراسة لمعرفة مدى تواجد بقايا (١١) من أهم الهيدروكربونات الأروماتية متعددة الحلقات في الكباب والكفتة المشوية على الفحم (٣٠ من كل نوع منها) (١٥) عينه قبل التتبيل ومثلها بعد التتبيل) ثم الشى على الفحم كمحاولة لدراسة تأثير التتبيل على مستوى الهيدروكربونات الأروماتية متعددة الحلقات. أكدت النتائج على أن متوسط تواجد إجمالي الهيدروكربونات الأروماتية متعددة الحلقات كانت ١١٩,٨ ، ٥٩,٢ ميكروجرام لكل كجم من الكباب والكفتة المشوية على الفحم الغير متبلة على الترتيب ، وانخفضت هذه المتوسطات بشكل ملحوظ الى ٥٧,٩٣ ، ٣٠,٢ ميكروجرام لكل كجم من الكباب والكفتة المشوية على الفحم المتبلة على الترتيب. مما سبق يتبين لنا التأثير الإيجابى للتتبيل على تقليل الهيدروكربونات الأروماتية متعددة الحلقات. من بين كل أنواع الهيدروكربونات الأروماتية متعددة الحلقات لم يحدد الإتحاد الأوروبى الحد الأقصى المسموح به فى الأغذية إلا لمركب واحد وهو بنزو(إيه)بيرين وذلك لانه المركب الأكثر خطورة على الصحة العامة ويعد مؤشرا لمخاطر الإصابة بالسرطان ، وجد مركب بنزو(إيه)بيرين بمستويات أعلى من المسموح بها فى ٤٠% من كلا من عينات اللحوم المشوية على الفحم الغير متبلة وعينات الكفتة المشوية على الفحم الغير متبلة وقد تم تقليل هذه النسبة كليا بعد التتبيل ، مما أفاد أن تتبيل اللحوم المعدة للشى على الفحم سوف يؤدي الي تقليل كثير من خطر الهيدروكربونات الأروماتية متعددة الحلقات المسرطنة مثل البنزو(إيه)بيرين وعليه الحصول على لحوم مشوية أكثر أماناً للإستهلاك الأدمي.