

Original Research Article

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## Estimated Daily Intake and Health Risk of Polycyclic Aromatic Hydrocarbon by Consumption of Grilled Meat and Chicken in Egypt

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### ABSTRACT

#### Keywords

PAHs; Dietary intake; Benzo(a) Pyrene; Grilled meat; Grilled chicken; Egypt.

#### Article Info

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The present study investigates the presence of polycyclic aromatic hydrocarbons in grilled meat and chicken using modified QuEChERS method. The results found that Benzo(a)Pyrene concentration in charcoal grilled chicken ranged from 0.49-7.20 $\mu$ g/kg and 2.01  $\mu$ g/kg mean concentration, while for charcoal grilled meat ranged from 2.42-4.48  $\mu$ g/kg and 0.36  $\mu$ g/kg mean concentration. The summation of 16PAHs concentrations in term of Benzo(a)Pyrene ranged from 0.03-10.65  $\mu$ g/kg and mean concentration 3.03  $\mu$ g/kg for charcoal grilled chicken, while for charcoal grilled meat from 0.10 to 6.49  $\mu$ g/kg and mean concentration 1.13  $\mu$ g/kg. The results suggested using of electric grill instead of traditional charcoal grill in order to reduce the contamination of meat and chicken with PAHs where the level of contamination reduced by 100%. The dietary intake for sum of seven carcinogenic PAHs in term of Benzo(a)Pyrene exceed than the average value by 1.6 and 2.3 times for meat and chicken respectively.

### Introduction

Polycyclic aromatic hydrocarbons (PAHs) refer to a large group of organic chemicals containing two or more fused aromatic rings made up of carbon and hydrogen atoms as a by products from the incomplete combustion of organic materials. Cooking of meat at high temperatures generate various kinds of genotoxic substances or cooking toxicants, including PAHs (Agerstad *et al.*, 2005). The main sources of PAHs in the environment

are aluminium production, coke production from coal, wood preservation, and fossil fuel combustion (traffic, domestic heating, and electricity production (Ravindra *et al.*, 2008). It has been-established that there are two major sources of PAHs formation in foods the first source is mainly due to the method of food preparation. The other major source of contamination of foodstuffs is by contact with either petroleum products or

coal tar products it would be possible to generate these naturally occurring PAHs in grilled foods (Kazerouni *et al.*, 2001).

PAHs can also form in meat cooked at high temperatures (Falcó *et al.*, 2005) and migrate through the food chain into hydrophobic compartments, and thus, accumulate in lipid components due to their lipophilic nature (Chen J and Chen S, 2005). However, according to (Richard *et al.*, 2008) significant levels of PAHs do not usually accumulate in the meat because PAHs rapidly metabolized in these species.

This accumulation could indirectly cause human exposure to PAHs through food consumption and thus might pose a human health threat (Lin D *et al.*, 2005). According to the Scientific Committee on Food (2002), PAHs showed clear evidence of mutagenicity/genotoxicity in somatic cells in experimental animals *in vivo*. They may be regarded as potentially genotoxic and carcinogenic to humans their carcinogenicity is initiated by their metabolic conversion in mammalian cells to diolepoxides that bind covalently to cellular macromolecules, including DNA, causing errors in DNA replication and mutation (Phillips DH and Grover PL, 1994).

Elbadry, (2010) Studied the effect of household cooking methods and some food additives on polycyclic aromatic hydrocarbons (PAHs) formation in chicken meat and concluded that chicken meat should be treated prior to cooking and thermal processing with food additives treatment that causing inhibition or prevention the formation of the PAHs during cooking.

The European Union suggested the analysis of the contents of 15+1 PAH compounds, which are classified as priority in food

(EFSA, 2008). These 15+1 EU priority PAH are: naphthalene, Fluorene, fluoranthene, Benz(a)Anthracene, chrysene, Pyrene, Benzo(b) fluoranthene, Benzo(k) fluoranthene, Benzo(a) Pyrene, Acenaphthene, Phenanthrene, Anthracene, Acenaphthylene, Benzo(g,h,i)Perylene, Dibenz(a,h)Anthracene and Indeno(1,2,3-cd)Pyrene. Seven PAHs been classified by the USEPA as compounds of probable human carcinogens. These are Benzo(a) Anthracene, Benzo(b)fluoranthene, Benzo(k) fluoranthene, chrysene, Benzo(a) Pyrene, Dibenz(a,h)Anthracene, and Indeno(1,2,3-cd) Pyrene(10). In September 2012, Benz(a) Anthracene, Benzo(b) fluoranthene, and chrysene were included in the assessment and recorded together with Benzo (a) Pyrene as a sum parameter (group of "PAH4"), as per Regulation (EU) number 835/2011.

The present study will monitor the extent of accumulation of PAHs in grilled meat and chicken in Giza governorate (Egypt), study how to reduce the contamination levels of PAHs in grilled meat and chicken and evaluate whether such contamination levels may pose risks to human health by calculation of the acceptable dietary intake (ADI).

## **Materials and Methods**

### **Reagents and Chemicals**

Acetone (Sigma-Aldrich, Taufkirchen, Germany, purity 99.8%), Acetonitrile (Sigma-Aldrich, Taufkirchen, Germany, purity > 99.9%), Toluene (Merck, Kenilworth, U.S.A. purity > 99.9%), Dichloromethane (CHROMASOLV, for HPLC, Sigma-Aldrich, Taufkirchen, Germany, ≥99.8%), and n-hexane (CHROMASOLV, for HPLC, Sigma-Aldrich, Taufkirchen, Germany, purity > 99.0%) were the solvents used. Agilent

(Stuttgart, Germany) QuEChERS salts and buffers were pre-packaged in anhydrous packages for EN 15662 containing 4 g magnesium sulphate (MgSO<sub>4</sub>), 1 g sodium chloride (NaCl), 1 g sodium citrate, and 0.5 g disodium citrate sesquihydrate. Silica gel (60–120 mesh, Fluka) activated at 150°C for 12 hours prior to use. A stock solution of 1000 µg/mL concentration contain 14 PAHs includes Naphthalene, Fluorene, Fluoranthene, Benz(a) Anthracene, Chrysene, Pyrene, Benzo(b) Fluoranthene, Benzo(k) Fluoranthene, Benzo(a) Pyrene, Acenaphthene, Phenanthrene, Anthracene, Acenaphthylene, and Pyrene-d10 (surrogate standard) and reference standards obtained from Sigma-Aldrich with purity > 95% were prepared, while Benzo (g,h,i) Perylene and Dibenz (a,h) Anthracene were obtained as readymade of 100 µg/mL in methylene chloride and Indeno(1,2,3-cd)Pyrene 200 µg/mL in methanol. All standard bring from Sigma-Aldrich, Taufkirchen, Germany. A working solution of 1.0 µg/mL concentration contain all 16 PAHs was prepared in toluene. Calibration mixtures with concentration 2, 10, 50, 100, and 500 ng/mL were prepared from serial dilution of the working solution in toluene where pyrene-d10 maintained at level 50 ng/mL in all calibration levels and all stored in refrigerator at 4 °C.

### **Apparatus**

PFTE or polyethylene 50mL tubes with screw cap and 15 mL tubes contain 1g magnesium sulphate were obtained for sample extraction. Centrifuge up to 4000 rpm (Heraeus Labofuge 400), Vortex, Automatic Pipettes (Hirschman Laborgerate) suitable for handling volumes of 10 µL to 100 µL and 100 µL to 1000 µL, 10 mL solvent dispenser (Hirschman Laborgerate) for Acetonitrile. The glassware washed with detergent and water then rinsed

with acetone and dried at 90°C before use. Various type of grilling equipment was use for home grilling. In present study, two commonly used two grilling methods were used, traditional disposable charcoal grill unit and electric grill unit.

Agilent 6890N series gas chromatography instrument equipped with 5975 series mass selective detector and Agilent GC Column of model J&W HP-5ms Ultra Inert with the specifications (30 m length, 0.25 mm internal diameter, and 0.25 µm film thicknesses) used for both qualitative and quantitative determination of PAHs.

### **Sampling Procedure**

#### **Monitoring Samples**

Total of 60 samples belonging to two different species (Chicken and Meat) ready to eat cooked via charcoal grill collected randomly from different regions in Giza Governorate. All samples collected during the period of November up to December 2014 to determine the concentrations of PAHs. A representative sample of about one kilogram of each was collected from the local market in Giza completely homogenized in a food mixer then stored in a freezer at -20°C. and stored freezer until analysis.

#### **Processing Samples**

Three replicates of meat and chicken grilled using the traditional disposable charcoal grills. The distance between burning coals and meat or chicken was approximately 20 cm; the temperature at the surface of the sample ranged between 120-180 °C. In addition, another three replicates of each grilled using 2000-Watt electric grill at distance of 5 cm away from meat or chicken while water is placed in the dish coated with

Teflon material under the electric coal to collect the fat and prevent the formation of smoke.

Sample preparation, sample processing and sub-sampling to obtain analytical portions should take place before visible deterioration occurs and shall ensure that samples not contaminated during sample preparation. Glassware should be rinse with high purity acetone or hexane before use to minimize the risk of contamination. (Commission regulation, 333/2007).

### **Extraction Procedure**

About 10 g of each sample was weighted in 50 mL Teflon centrifuge tube, pyrene-d10 was added which acts as surrogate standard of 50 µg/kg, and sample processed extraction using QuEChERS method as described in (Mona Khorshid *et al.*, 2015).

The validity of this method were already confirmed through our previous published research article showing the recoveries varied from 56 to 114%, limits of detection (S/N = 3) varied from 0.33 to 1.9 and limits of quantification was 2 µg/kg and showed a good linearity from 2 to 50 µg/ml with (r<sup>2</sup> 0.996 to 0.999). The measurement uncertainty expressed as expanded uncertainty and in terms of relative standard deviation (at 95% confidence level) is 12%.

### **Results and Discussion**

#### **Monitoring Results**

Table 1 summarized the results obtained from the analysis of PAHs (µg/kg) in grilled Meat collected from Giza Governorate by using traditional disposable charcoal grill unit. The results in table 1 showed that 100% of the analysed samples contaminated with Acenaphthylene (4.43-54.54 µg/kg),

Anthracene (2.48-46.5 µg/kg), Fluoranthene (3.44-56.5 µg/kg), Fluorene (3.68-102.64 µg/kg), Naphthalene (11.8-277.16 µg/kg), and Phenanthrene (12.46-237.37 µg/kg) with the mentioned concentration range. 97% contaminated with Pyrene (3.13-49.4 µg/kg), 93% contaminated with Acenaphthene (2.18-26.85 µg/kg) and Chrysene (1.07-18.86 µg/kg), 73% with Benzo(a)Anthracene (0.88-7.93µg/kg), 50% with Benzo(b) Fluoranthene (1.69-9.76 µg/kg). Only 10% with Benzo(a)Pyrene (2.42-4.48 µg/kg) and Benzo(g,h,i)Perylene (2.15-5.78 µg/kg) while Benzo(k) Fluoranthene , Dibenz(a,h) Anthracene and Indeno(1,2,3-cd)Pyrene were not detected in all meat samples. The results also showed that the range of Benzo(a)Pyrene was (2.42-4.48 µg/kg) which is lower than estimated by IARC (International Agency Research on Cancer) to contain 10.5 µg/kg and higher than that estimated to contain 0.5 µg/kg (Abou-Arab *et al.*, 2014).

It witnessed from the results that all collected grilled meat samples contaminated with 2 to 3 ring group of lower molecular weight PAHs such as Acenaphthylene, Anthracene, Fluoranthene, Fluorene, Naphthalene, and Phenanthrene that have significant acute toxicity to some organisms. A list of all PAHs quantified and their carcinogenic (IARC) classifications could be summarized in (IARC, 2010); Group 1 “carcinogenic to humans,” Group 2A “probably carcinogenic to humans,” and Group 2B “possibly carcinogenic to humans”.

Kalberlah *et al.*, (1995), calculate PAHs in term of Benzo(a)Pyrene, the toxic equivalent concentration ‘TEQ’ which is the best way to evaluation is the most popular method used to identify the toxicity of PAHs. The summation of seven PAHs (Σ7PAHs) from group 1, 2A, and 2B, and present them here

as “potentially carcinogenic PAHs” were calculated in term of Benzo(a)Pyrene. The  $\Sigma$ 7PAHs included the following PAHs: Benzo(a)Pyrene, Benz(a)Anthracene, Benzo(b) Fluoranthene, Benzo(k) Fluoranthene, Indeno(1,2,3-cd)Pyrene, Dibenz(a,h) Anthracene, Chrysene and the total 16 PAHs in term of B(a)P ( $\mu\text{g}/\text{kg}$ ).

Where toxicity equivalency concentrations (TEQs) calculated as the product of the values obtained by multiplying TEF values with concentrations of PAHs, as follows:

$$\text{TEQ} = (C_i \times \text{TEF}_i) \quad (1)$$

TEQ: Toxic equivalent concentration,  $C_i$ : Concentration of PAH<sub>i</sub>,  $\text{TEF}_i$ : Toxic Equivalency Factor

The results in tables 1 and 3, showed that grilled meat samples of ID ( 3,5 and 17 ) record the highest concentrations of Benzo(a)Pyrene ( 4.05, 4.48, 2.42  $\mu\text{g}/\text{kg}$  respectively), also the highest sum of 16 PAHs in term of Benzo(a) Pyrene (7.18, 6.44, 3.26  $\mu\text{g}/\text{kg}$  respectively), however samples of ID (3, 5 and 8 ) record the highest sum of 7 carcinogenic EU PAHs (5.98, 5.75,1.78  $\mu\text{g}/\text{kg}$  respectively), which indicate the presence of a relation between the presence of Benzo(a)Pyrene and the seven carcinogenic EU PAHs.

The results in table 2 showed that 100% of the analysed samples contain Anthracene, Fluoranthene, Fluorene, Phenanthrene and Pyrene with results range (2.5-45.9, 415-67.16, 3.28-31.95, 12.19-207.03 and 4.33-48.49  $\mu\text{g}/\text{kg}$ ) respectively, 97 % Acenaphthylene and Naphthalene (1.6-27.9, 1.29-57.88  $\mu\text{g}/\text{kg}$ ), 90 % Acenaphthene (1.3-12.43  $\mu\text{g}/\text{kg}$ ), 80 % Benzo(a)Anthracene, Chrysene (0.31-17.04,0.52-23.14  $\mu\text{g}/\text{kg}$ ),77% Benzo(b)Fluoranthene (0.44-13.02  $\mu\text{g}/\text{kg}$ ), 50% Benzo(a)Pyrene (0.49-7.2  $\mu\text{g}/\text{kg}$ ), 27% Indeno(1,2,3-cd)Pyrene

(0.82-4.25  $\mu\text{g}/\text{kg}$ ), 17% Benzo(g,h,i)Perylene ( 0.32-3.92  $\mu\text{g}/\text{kg}$ ), 13% Benzo(k)Fluoranthene ( 0.72-4.01  $\mu\text{g}/\text{kg}$ ) and only 3% of the analysed samples contain Dibenz (a,h)Anthracene (0.49-2.74  $\mu\text{g}/\text{kg}$ ).

Summation of seven PAHs ( $\Sigma$ 7PAHs) and the total 16 PAHs in term of B(a)P ( $\mu\text{g}/\text{kg}$ ). The results summarized in table 3.

From tables 2 and 3, the results showed that grilled Chicken samples of ID (8,15 and 16) was record the highest Benzo(a)Pyrene concentrations ( 7.2, 6.22, 6.48  $\mu\text{g}/\text{kg}$ , respectively), and also show the highest sum of 16 PAHs in term of Benzo(a)Pyrene (14.17, 9.96, 9.95  $\mu\text{g}/\text{kg}$ , respectively) and the highest sum of 7 carcinogenic EU PAHs (13.40, 9.11, 9.16  $\mu\text{g}/\text{kg}$  respectively) which indicate that there is a relation between the presence of Benzo(a)Pyrene and the presence of 7 carcinogenic EU PAHs and also with the sum of 16 PAHs in term of Benzo(a)Pyrene likely concluded in meat results. The level of Benzo(a)Pyrene was more than EU regulation limit 2  $\mu\text{g}/\text{kg}$  for about 10% of meat and about 57% of chicken samples.

The study indicates that the charcoal grilling has a significant effect on increasing the concentration of PAHs in grill meat and chickens samples, these findings are in agreement with that mentioned by (Phillips, 1999); where the barbecued meat total PAHs were found to be present at levels up to 164  $\mu\text{g}/\text{kg}$  with Benzo(a)Pyrene being present at levels as high as 30  $\mu\text{g}/\text{kg}$ .

### **Study the Effect of Grilling Method on the Contamination Levels of PAHs in Grilled Meat and Chicken**

In this study, three replicates of meat and chicken grilled using both traditional charcoal grill and electric grill methods then

analysed. The mean concentration of each three replicates collected and summarized in table 4.

$$\text{Reduction percentage (\%)} = 100 * (\text{Conc. found using charcoal grill} - \text{Conc. found using charcoal grill}) / \text{Conc. found using charcoal grill} \quad (2)$$

The results showed that significant reduction of PAHs contamination levels after cooking meat and chicken taken from the same raw material with electric grill where the sum of seven carcinogenic PAHs in term of B(a)P fall from 0.990 using traditional charcoal grill to 0.000 µg/kg for chicken and from 12.152 using traditional charcoal grill to 0.022 µg/kg, also the total sum of all 16 PAHs in term of B(a)P reduced from 1.600 to 0.038 µg/kg for chicken and from 13.425 to 0.048 µg/kg for meat compared to traditional charcoal grill where the reduction percentage approach to be 100% using electric grill in meat and chicken, also the level of B(a)P was reduced in chicken sample from 6.89 µg/kg to not detected after using electric grill. The results indicates the efficacy of using electric grill instead of traditional charcoal grill in meat and chicken cooking on reducing the contamination with PAHs during grilling.

### **Dietary Exposure Estimates**

The dietary exposure assessment is based on the occurrence data of PAHs concentration and consumption of the corresponding food categories. All the calculations below based on the mean concentrations of PAHs obtained from analysis of thirty samples of meat and chicken to represent the central tendency of the distribution, the use of mean concentrations would represent in the most realistic picture for long-term dietary exposure (EFSA, 2008). The assessment of dietary exposure was based on Estimated

Daily Intake (EDI) which was compared to Acceptable Daily Intake (ADI) and was expressed as a percentage (ADI%) (Joint FAO/WHO, 1997). The Acceptable Daily Intake (ADI) which is the estimated amount of a substance in food (expressed on a body-weight basis) that can be ingested daily over a lifetime without appreciable health risk to the consumer could also be used to predict the dietary intake of PAHs. The estimated dietary intake of PAHs in a given food is obtained by multiplying the residue level in the food by the amount of that food consumed. All calculations for the determination of EDI were according to international guidelines (WHO, GENEVA 2006),).

The Estimated Average Daily Intake (EADI) of PAHs can be calculated by the following equation

$$\text{EADI, expressed in } \mu\text{g/kg body weight/day} = \text{Fi} \times \text{Ri} \quad (3)$$

Fi = Food consumption of the relevant commodity (kg/day),

Ranges and sum of B(a)P,  $\Sigma 7$ PAHs (Benzo(a)Pyrene, Benz(a) Anthracene, Benzo(b)Fluoranthene, Benzo(k) Fluoranthene, Indeno(1,2,3-cd) Pyrene, Dibenz(a,h) Anthracene, Chrysene) in term of B(a)P and  $\Sigma 16$ PAHs in term of B(a)P are summarize in table 5. Chicken samples record the higher mean concentration of B(a)P,  $\Sigma 7$ PAHs and  $\Sigma 16$ PAHs in term of B(a)P when compared with meat samples. The difference is probably due to variation in fat content this is because when fat drops onto the charcoals the high temperature PAHs formed. Therefore, smoke carries the PAHs onto the surface of the chicken. The results in Table5 indicate a certain relationship between the amount of B (a)P and total amount of  $\Sigma 16$ PAHs.

**Table.1** PAHs Levels ( $\mu\text{g}/\text{kg}$ ) in Grilled Meat Collected from Giza Governorate by using Traditional Disposable Charcoal Grill Unit

Compounds	Sample ID														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Acenaphthene	N.D	7.24	26.85	3.94	13.06	6.59	9.22	14.05	8.53	3.05	7.22	12.37	4.3	10.29	3.25
Acenaphthylene	54.45	6.32	39.95	36.44	18.58	19.73	18.3	6.19	12.79	33.77	13.14	42.23	5.75	23.45	5.75
Anthracene	13.78	12.33	46.5	6.92	25.33	17.29	26.95	33.38	18.32	9.66	14.9	24.04	7.54	16.78	7.21
Benzo[a]Anthracene	1.93	3.14	12.07	1.1	7.81	2.01	4.41	7.93	2.82	1.15	1.58	3.71	0.88	5.03	1.33
Benzo[a]Pyrene	N.D	N.D	<b>4.05</b>	N.D	<b>4.48</b>	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Benzo[b]Fluoranthene	N.D	N.D	7.07	N.D	4.74	3.47	4.04	9.76	3.58	N.D	N.D	N.D	N.D	N.D	N.D
Benzo[g,h,i]Perylene	N.D	N.D	N.D	2.46	N.D	5.78	2.15	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Benzo[k]Fluoranthene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Chrysene	3.14	4.93	18.86	2.09	11.98	5.36	7.95	13.09	6.12	2.6	3.62	7.12	2.38	8.49	2.54
Dibenz[a,h]Anthracene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Fluoranthene	14.97	17.53	56.5	8.89	32.92	17.55	28.69	44.16	20	13.99	15.37	28.9	8.24	20.81	8.39
Fluorene	26.99	16.72	102.64	15.46	26.12	43.78	24	25.27	27.96	11.43	25.5	49.31	11.22	28.5	9.37
Indeno[1,2,3-cd]Pyrene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Naphthalene	119.89	112.78	277.16	76.19	200	339.53	145.85	25.98	137.55	20.61	121.47	140.55	36.29	71.98	25.69
Phenanthrene	69.01	55.84	237.37	36.82	123.67	98.06	116.87	145.38	90.97	51.43	80.65	140.48	40.84	84.13	32.67
Pyrene	9.57	14.43	N.D	8.72	24.1	16.01	21.62	49.4	15.89	12.37	12.92	23.92	7.85	14.01	8.14

Compounds	Sample ID														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Acenaphthene	5	6.21	1.58	4.41	2.45	3.87	11.03	8.85	4.01	6.3	13.65	14.44	2.18	9.27	6.42
Acenaphthylene	23.45	15.33	4.75	7.96	4.43	9.99	24.04	18.34	11.11	14.11	31.38	38.47	10.92	26.91	21.2
Anthracene	12.35	19.33	2.48	10.09	6.54	12.12	30.13	16.66	12.58	12.8	33.51	29.5	7.77	25.64	11.69
Benzo[a]Anthracene	1.64	2.3	0.68	2.06	0.88	1.72	5.94	2.65	1.7	2.2	5.82	6.21	1.94	6.43	2.48
Benzo[a]Pyrene	N.D	<b>2.42</b>	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Benzo[b]Fluoranthene	N.D	2.14	N.D	2.03	N.D	N.D	4.8	2.94	1.69	2.36	5.33	5.07	N.D	4.54	2
Benzo[g,h,i]Perylene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Benzo[k]Fluoranthene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Chrysene	3.68	4.94	1.07	3.5	1.6	2.97	10.51	3.92	3.41	3.71	12.08	10.93	3.69	8.79	4.47
Dibenz[a,h]Anthracene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Fluoranthene	16.52	21.72	3.44	13.54	8.01	13.91	32.11	16.39	13.85	14.86	40.48	32.74	9.3	27.36	13.01

<b>Fluorene</b>	17.01	11.89	3.68	12.19	6.43	13.21	24.94	28.67	18.62	19.62	33.99	43.27	8.78	23.54	21.59
<b>Indeno[1,2,3-cd]Pyrene</b>	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
<b>Naphthalene</b>	42.27	46.56	12.97	11.8	14.39	27.28	37.67	48.27	34.95	21.46	55.56	60.94	15.89	32.66	36.27
<b>Phenanthrene</b>	69.01	55.84	237.37	36.82	123.67	98.06	116.87	145.38	90.97	51.43	80.65	140.48	40.84	84.13	32.67
<b>Pyrene</b>	9.57	14.43	N.D	8.72	24.1	16.01	21.62	49.4	15.89	12.37	12.92	23.92	7.85	14.01	8.14

N.D: Not Detected,

**Table.2** PAHs Levels ( $\mu\text{g}/\text{kg}$ ) in Grilled Chicken Collected from Giza Governorate by using Traditional Disposable Charcoal Grill Unit

Compounds	Sample ID														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
<b>Acenaphthene</b>	3.25	8.41	N.D	1.55	8.1	4.82	11	10.49	7.4	3.24	12.43	2.59	5.6	5.92	8.51
<b>Acenaphthylene</b>	5.79	11.07	3.04	3.83	27.93	3.82	7.6	6.59	3.43	5.27	20.52	5.03	7.3	12.03	12.3
<b>Anthracene</b>	11.3	10.17	3.55	6.16	21.89	17.09	42.87	38.63	27.18	15.05	28.85	4.51	24.81	17.05	45.9
<b>Benzo[a]Anthracene</b>	2.48	2.63	0.72	1.13	10.51	2.66	8.91	17.04	3.38	2.21	7.32	0.31	2.16	4.91	9.86
<b>Benzo[a]pyrene</b>	0.65	0.49	N.D	N.D	4.49	2.29	3.35	<b>7.2</b>	N.D	N.D	1.95	N.D	N.D	0.87	<b>6.22</b>
<b>Benzo[b]fluoranthene</b>	2.18	2.5	N.D	1.01	8.54	4.06	6.24	13.02	3.2	2.42	5.19	0.44	N.D	4.04	7.53
<b>Benzo[g,h,i]Perylene</b>	0.58	0.88	N.D	N.D	1.37	2.31	2.43	3.92	N.D	N.D	0.74	N.D	N.D	0.32	1.46
<b>Benzo[k]fluoranthene</b>	N.D	N.D	N.D	N.D	4.01	2.9	3.58	N.D	2.53	0.72	N.D	N.D	N.D	N.D	N.D
<b>Chrysene</b>	4.45	4.39	1.05	2.2	17.52	6.06	13.69	23.14	6.2	5.43	14.68	1.03	4.05	10.28	16.49
<b>Dibenz[a,h]Anthracene</b>	0.58	N.D	N.D	N.D	1.28	N.D	N.D	2.74	N.D	N.D	N.D	N.D	N.D	N.D	0.91
<b>Fluoranthene</b>	16.61	14.34	4.71	8.71	36.08	25.31	54.87	61.47	29.49	23.17	41.66	6.52	30.59	29.55	67.18
<b>Fluorene</b>	12.88	17.79	3.67	8.35	26.54	22.61	26.72	30.24	29.93	11.06	20.17	7.65	13.89	11.74	27.95
<b>Indeno[1,2,3-cd]pyrene</b>	0.82	0.96	N.D	N.D	1.92	N.D	N.D	4.25	N.D	N.D	1.04	N.D	N.D	N.D	2.29
<b>Naphthalene</b>	23.99	57.88	12.75	15.91	46.15	53.52	35.59	26.23	6.78	18.92	33.2	18.52	11.7	22.67	5.32
<b>Phenanthrene</b>	55.28	48.89	14.09	27.83	118.78	88.56	179.44	167.49	117.62	77.46	135.99	24.82	124.69	79.68	207.03
<b>Pyrene</b>	12.24	10.06	4.33	8.18	23.2	21.68	37.65	40.87	23.28	16.92	28.56	7.08	22.75	19.1	48.49



Compounds	Sample ID														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Acenaphthene	12.43	3.43	1.3	2.14	5.16	2.64	8.95	5.9	5.97	5.34	11.2	4.27	3.7	2.66	5.95
Acenaphthylene	22.89	7.2	1.6	3.24	9.18	3.98	17.41	9.56	17.95	11.39	20.83	7.09	9.23	4.03	18.27
Anthracene	40.56	15.59	2.5	4.54	18.79	11.39	30.61	18.34	20.73	25.57	44.68	11.61	13.34	8.63	21.66
Benzo[a]Anthracene	9.14	2.09	0.43	1.04	2.44	2.15	9.77	6.44	7.33	6.52	10.21	2.02	2.27	1.99	10.2
Benzo[a]Pyrene	<b>6.48</b>	1.82	N.D	N.D	N.D	1.36	4.05	3.33	2.8	2.58	5.2	1.42	N.D	N.D	3.82
Benzo[b]Fluoranthene	7.08	1.56	0.57	1.42	2.22	2.44	7.17	5.28	6.09	5.19	8.82	2.01	2.02	2.1	6.84
Benzo[g,h,i]Perylene	1.49	0.78	N.D	N.D	N.D	N.D	1.87	1.48	N.D	1.06	1.87	N.D	N.D	N.D	N.D
Benzo[k]Fluoranthene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Chrysene	13.75	3.86	0.52	1.87	4.69	4.5	14.26	8.46	12.33	10	17.64	3.02	4.77	4.25	14.34
Dibenz[a,h]Anthracene	0.82	0.49	N.D	N.D	N.D	N.D	1.03	N.D	N.D	N.D	0.89	N.D	N.D	N.D	N.D
Fluoranthene	55.35	18.99	4.15	6.33	21	17.3	42.01	25.23	28.05	34.73	58.62	13.21	14.93	13.6	29.6
Fluorene	31.95	8.97	3.28	4.84	19.12	8.73	23.56	17.6	21.92	15.02	30.97	10.7	13.43	7.24	16.93
Indeno[1,2,3-cd]Pyrene	2.13	0.97	N.D	N.D	N.D	N.D	2.3	2.1	N.D	1.66	2.36	N.D	N.D	N.D	1.81
Naphthalene	34.15	22.64	3.9	12.68	22.54	2.64	26.47	9.47	21.06	17.1	31.8	14.54	13.78	1.29	19.97
Phenanthrene	176.66	70.94	12.19	19.9	77.33	54.88	128.34	75.96	97.3	103.9	189.02	45.72	54.28	43.51	85.56
Pyrene	37.85	13.81	7.63	7.97	18.49	13.78	28.88	18.72	18.62	21.97	40.49	10.89	15.02	10.16	20.29

**Table.3** Represent the Sum of 7 Pahs And 16 Pahs in Term Of Benzo[A] Pyrene in Grilled Chicken and Meat

Sample ID	Sum of 7 Carcinogenic EU PAHs in term of Benzo[a]Pyrene (µg/kg)		Sum of 16 PAHs in term of Benzo[a]Pyrene (µg/kg)	
	Chicken	Meat	Chicken	Meat
1	1.79	0.20	2.03	0.63
2	1.10	0.32	1.38	0.67
3	0.07	<b>5.98</b>	0.15	<b>7.18</b>
4	0.22	0.11	0.35	0.39
5	7.92	<b>5.75</b>	8.44	<b>6.44</b>
6	3.00	0.55	3.42	1.32
7	4.92	0.85	5.72	1.51
8	<b>13.40</b>	<b>1.78</b>	<b>14.17</b>	2.43
9	0.69	0.65	1.18	1.14
10	0.48	0.12	0.78	0.36
11	3.32	0.16	3.91	0.59
12	0.08	0.38	0.19	1.06
13	0.22	0.09	0.68	0.28
14	1.78	0.51	2.13	0.93
15	<b>9.11</b>	0.14	<b>9.96</b>	0.3
16	<b>9.16</b>	0.17	<b>9.95</b>	0.46
17	2.77	2.87	3.08	<b>3.26</b>
18	0.10	0.07	0.16	0.14
19	0.25	0.41	0.35	0.62
20	0.47	0.09	0.83	0.23
21	1.82	0.18	2.04	0.43
22	7.01	1.08	7.61	1.64
23	4.72	0.56	5.08	0.93
24	4.16	0.34	4.58	0.62
25	3.93	0.46	4.41	0.72
26	8.24	1.13	9.09	1.8
27	1.82	1.14	2.05	1.77
28	0.43	0.20	0.69	0.36
29	0.41	1.11	0.58	1.59
30	5.72	0.45	6.13	0.72

**Table.4** Show the Effect of Cooking Meat and Chicken with Charcoal and Electric Grill on the Level of Pahas Generated

Compounds	Meat			Chicken		
	Charcoal	Electric	Reduction %	Charcoal	Electric	Reduction %
	Mean Conc. ( µg/kg)	Mean Conc. ( µg/kg)		Mean Conc. ( µg/kg)	Mean Conc. ( µg/kg)	
Acenaphthene	16.58±20	2.42±17	85%	15.07±13	1.34±12	91%
Acenaphthylene	21.06±4	2.63±10	88%	15.02±12	1.58±10	89%
Anthracene	29.24±2	0.9±14	97%	71.81±1	0.67±9	99%
Benzo[a]Anthracene	7.02±15	N.D	100%	17.68±10	0.22±9	99%
Benzo[a]Pyrene	N.D	N.D	-----	6.89±7	N.D	100%
Benzo[b]Fluoranthene	2.84±9	N.D	100%	15.49±3	N.D	100%
Benzo[g,h,i]Perylene	N.D	N.D	-----	3.55±6	N.D	100%
Benzo[k]Fluoranthene	N.D	N.D	-----	N.D	N.D	-----
Chrysene	5±16	N.D	100%	23.42±6	0.2±9	99%
Dibenz[a,h]Anthracene	N.D	N.D	-----	1.62±3	N.D	100%
Fluoranthene	30.94±3	2.81±10	91%	105.18±10	1.55±3	99%
Fluorene	61.9±17	N.D	100%	51.83±17	N.D	100%
Indeno[1,2,3-cd]Pyrene	N.D	N.D	-----	3.02±17	N.D	100%
Naphthalene	65.49±27	9.92±24	85%	34.82±5	5.8±19	83%
Phenanthrene	101.98±5	5.96±19	94%	230.79±12	4.89±1	98%
Pyrene	18.87±5	5.23±17	72%	66.48±8	3.55±2	95%
<b>Σ7PAHs</b>	12.152	0.022	100%	0.990	0.000	99%
<b>Σ16PAHs</b>	13.425	0.048	99%	1.600	0.038	99%

N.D Not Detected, All data were expressed as means from at least two independent trails. mean number ± RSD % (Relative standard deviation of replicates)

**Table.5** PAHs Concentration ( $\mu\text{g}/\text{kg}$ ) in Term of B[a]P in Egyptian Charcoal Grilled Meat and Chicken Samples

	Grilled Meat (n=30)		Grilled Chicken (n=30)	
	Range	Mean Conc.	Range	Mean Conc.
<b>B[a]P</b>	2.42-4.48	0.36	0.49-7.20	2.01
<b><math>\Sigma</math>7PAHs in term of B[a]P</b>	0.07-5.98	0.93	0.07-13.40	3.30
<b><math>\Sigma</math>16PAHs in term of B[a]P</b>	0.14-7.18	1.35	0.15-14.17	3.70

**Table.6** Estimated Daily Intake in Term Benzo[a]Pyrene ( $\text{ng}/\text{kg}$  body per weight per day)

	Grilled Meat		Grilled Chicken	
	Maximum	Mean	Maximum	Mean
<b>B[a]P</b>	2.46	0.20	3.28	0.89
<b><math>\Sigma</math>7PAHs in term of B[a]P</b>	3.29	0.52	6.11	1.50
<b><math>\Sigma</math>16PAHs in term of B[a]P</b>	3.95	0.74	6.46	1.69

The results in table 6 showed that the maximum and mean Estimated Daily Intake in term of Benzo(a)Pyrene ( $\text{ng}/\text{kg}$  body weight per day) for both meat and chicken by Egyptian Adult. Food consumption rates selected based on the consumption data issued by WHO (20) which is relatively within the same range of the Egyptian food balance sheet issued by economic affairs sector, ministry of agriculture (EFBS, 2008).

According to JECFA (WHO, GENEVA 2006), the estimated exposure limit for Benzo(a)Pyrene was  $4.0 \text{ ng}/\text{kg}$  body weight per day and the maximum limit was  $10 \text{ ng}/\text{kg}$  body weight per day (estimates for Benzo(a)Pyrene as a marker for polycyclic aromatic hydrocarbons PAHs).

The results showed that, the mean Estimated Daily intake Benzo(a)Pyrene for adults of  $70 \text{ kg}$  average weight was  $0.2 \text{ ng}/\text{kg}$  body weight per day (5% of Estimated exposure limit by JECFA) and the maximum reaching was  $2.46 \text{ ng}/\text{kg}$  body weight per day (24% of the estimated maximum limit) for grilled meat. While for chicken the mean Estimated Daily intake Benzo(a)Pyrene was  $0.89 \text{ ng}/$

$\text{kg}$  body weight per (22.2% of estimated exposure limit by JECFA) and  $3.28 \text{ ng}/\text{kg}$  body weight per day (32% of the estimated maximum limit).

However for  $\Sigma$ 7PAHs in term of B(a)P, Estimated exposure limit in term of B(a)P was  $6.38 \text{ ng}/\text{kg}$  body weight per day for meat (160% of Estimated exposure limit by JECFA) and  $9.27 \text{ ng}/\text{kg}$  body weight per day for meat (232% of Estimated exposure limit by JECFA) for chicken.

The mean intake values obtained in this study were lower compared to estimates for EU countries; however, the results show that, for sum of seven carcinogenic PAHs in term of B(a)P, the intake may be significant and exceed than the average value by 1.6 and 2.3 times meat and chicken respectively.

The present study showed the efficient role of traditional charcoal grill on contamination of the investigated foodstuffs by different levels of individuals PAHs where, grilled chicken record the higher Benzo(a)Pyrene concentration compared with grilled meat due to the fact that pyrolysis of fat that drops

in chicken was greater than meat samples. Also cooking via traditional charcoal grill produce high level of individuals PAHs of both meat and chicken while electric grill is much lower level of PAHs were detected.

The mean intake values obtained in this study were lower compared to estimates for EU countries; however, the results show that, for sum of seven carcinogenic PAHs in term of B(a)P, the intake may be significant and exceed than the average value by 1.6 and 2.3 times meat and chicken respectively

These results proved that it is recommended to use electric grill instead of traditional charcoal grill in order to reduce the contamination of meat and chicken where the level of contamination reached to 100% for both EU 7 carcinogenic PAHs and total 16 PAHs in term of B(a)P.

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