DETERMINATION OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) IN COMMERCIAL BREADS IN MALAYSIA AND HEALTH RISK ASSESSMENT

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ABSTRACT

Certain polycyclic aromatic hydrocarbons (PAHs) are listed as potentially carcinogenic to humans by the International Agency of Research on Cancer (IARC). In this study, the concentration of 4 polycyclic aromatic hydrocarbons (PAHs) namely fluorine, chrysene, benzo[a]pyrene, and pyrene in 3 commercial bread samples from 3 different types of bread were examined. The analysis was performed by high-performance liquid chromatography with fluorescent detector (HPLC-FLD) after Soxhlet extraction and clean-up of the extract. The concentration of several PAHs was detected in 18 out of 27 samples. In general, the mean of PAHs concentration was found on pyrene (2.38 µg/kg) followed by B[a]P (1.47 µg/kg), chrysene (1.31 µg/kg), and fluorine (1.31 µg/kg). The mean concentration in 3 out of 6 samples indicate the B[a]P reading more than 1 µg/kg and not complied with the European Union standard for bread. There is a significant difference in PAHs concentration between the bread types in all of the PAHs. Meanwhile, only fluorine is significant compared to chrysene, B[a]P, and pyrene between the brands. The health risk assessment of PAHs was carried out using the chronic daily intake (CDI), hazard quotient (HQ), and lifetime cancer risk (LCR). The calculation revealed that HQ values were less than 1.0. However, the calculation of the LCR has indicated the relatively high level of B[a]P with above 10^{-6} for men, women, and children. This high level indicates that there is a high probability of cancer risk from the consumption of bread. Thus, the routine monitoring for the PAHs concentration in the commercial breads should be implemented.

Keywords: Polycyclic aromatic hydrocarbons, commercial breads, health risk assessment

1.0 INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are organic molecules that contain two or more fused aromatic rings made up of carbon and hydrogen atoms. They are solids and have high melting and boiling points (Mahgoub, 2019). PAHs are produced and emitted during incomplete combustion or pyrolysis of organic matters such as waste or food during manufacturing processes, fuel combustion, and other human activities. Various PAHs have toxicological, mutagenic, and/or carcinogenic properties (Hussein et al., 2016). According to the United States Environmental Protection Agency (USEPA), there are 16 PAHs listed as primary pollutants including naphthalene, acenaphthylene, acenaphthene, phenanthrene, fluorene, fluoranthene, anthracene, pyrene, benz[a]anthracene, benzo[b]fluoranthene benzo[k]fluoranthene, chrysene, benzo[a]pyrene, benzo[ghi]perylene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene (Lawal, 2017). From animal studies, these PAHs are reasonably expected to be human carcinogens based on ample proof of carcinogenicity.

PAHs can accumulate in food either from the ecosystem or during food processing. The factors affecting the accumulation of PAHs in foods include food preparations such as cooking, grilling methods, grilling temperature, smoking procedure, smoking degree, baking, frying, roasting, and fat content (Norrani, 2014). According to the Scientific Committee on Food (2002), the instability of PAHs influenced transportation to the environment. These factors determine the longevity and ability of PAHs to bioaccumulate in the food chain. Furthermore, PAHs are lipophilic and have a very low aqueous solubility. PAHs accumulate in the fatty layer of plants and animals. However, PAHs may not appear to accumulate in plant tissues with a high-water content and a minimal transition from soil to root vegetables. (Eugenio et. al., 2018). Several studies have confirmed that food and cereals are one of the main leading causes of human exposure to PAHs (Rozentale et al., 2017). Although bread consumption has declined in recent years, it continues to be the diet of many cultures (Millar et al., 2019). Bread is an important food for human nutrition. Thus, bread could also lead to the largest intake of PAHs by humans owing to its high consumption rate. In addition, a study conducted by Ciecierska & Obiedziński in 2013 reported that the contamination of PAHs in bread could contribute to the contamination of the raw material of the bakery, in particular flour, and the baking process. The baking temperature on the bread can manipulate the concentration of PAHs as nature itself can be produced during incomplete combustion. PAHs also can bioaccumulate in soil that is used to plant the main ingredient of making bread which is grain.

Food authorities from different countries worldwide have recommended different maximum residue limits of PAHs. A maximum of 3-5 ppb has been suggested in Spain, Italy, and Canada. The recommended limits for the sum of heavy PAHs in Germany are 5 ppb and 1 ppb for benzo[a]pyrene (B[a]P) (Yoo et. al., 2014). Previous studies by Tran-Lam et al. (2018) revealed that the most carcinogenic PAHs are benzo[a]pyrene (B[a]P). In 2008, as the scientific opinion endorsed by the European Food Safety Authority concluded, benzo[a]pyrene was not an acceptable marker and was not a reasonable indicator of concentrations of other carcinogenic PAHs in food. Therefore, the sum of 4 PAHs (benzo[a]anthracene, chrysene, benzo[b]fluoranthene, and benzo[a]pyrene) has been proposed as a more appropriate indicator of PAHs in food (Polachova et al., 2020).

In this study, the PAHs in commercial breads in Malaysia were investigated. In addition, their potential carcinogenic effects on human beings on bread consumption in Malaysia is evaluated using human health risk assessment.

2.0 METHODOLOGY

2.1 Sampling Design & Collection

Three (3) types of commercial bread were selected as the target sample based on the frequency of consumption. White bread, whole grain bread, and wholemeal bread from three (3) different brands of similar sizes (about 500g) were purchased in the supermarket. The whole loaves were analyzed to determine the level of PAHs contamination. For the analysis, nine (9) samples of each substance were used (three samples, each from three separate batches). After selection, all samples were covered with aluminum foil to prevent photodegradation and transported to the lab. Each sample was individually cut into small pieces and homogenized. Then, three subsamples (50g) from each type of bread were taken for analysis. After mixing, the samples were placed in amber glass bottles with Teflon-lined caps at -20°C waited for analysis.

2.2 Analytical Procedure

2.2.1 Sample Preparation for PAHs Determination

For extraction procedures, the method was conducted according to Tawfic et al. (2000). While the method described by Ciecierska and Obiedziński (2013) was used for clean-up procedures. Bread subsamples of 50 g each with 200 mL of n-hexane in Soxhlet were extracted for 10 h. Then, the extract was then concentrated at 2 mL using a rotary evaporator. Using 100 mL of aqueous methanolic KOH (30 g of KOH dissolved in 30 mL of purified water and 270 mL of methanol), the concentrated extract was transferred to a round bottom flask and saponified to remove possible fat matter and the mixture was refluxed again for 2 h. Using 100 mL of aqueous methanol KOH (30 g of KOH dissolved in 30 mL of distilled water and 270 mL of methanol), the concentrated extract was transferred to a round bottom flask and saponified to eliminate possible fat and the mixture was refluxed for 2 h. The aqueous film in the beaker was filtered out and extracted again with 100 mL of n-hexane. Aqueous layers were removed when organic layers were combined and evaporated using a rotary evaporator, and residues were quantitatively transferred to the top of the glass column, ready for clean-up.

For the PAHs isolation step, further cleaning was performed using SPE Silica cartridges. The SPE cartridge sorbent was first filled with 5 mL of cyclohexane and the extracts were loaded into the cartridges. The analytes of interest were then extracted from the cyclohexane column (3 x 3 mL). The fraction obtained was then evaporated under a nitrogen stream at 40 °C, dissolved in 50 μL of cyclohexane, and transferred to the autosampler vial for further PAH analysis by HPLC-FLD.

2.2.2 *Preparation of Standard Solution*

Decon solution was used to soak all glassware and sample containers for 1 day followed by rinsing with distilled water. Then, the glassware and sample containers were dried for 1 day before used. For standards and solutions extracted from samples, different glassware and syringes were used to avoid contamination. The solvents are of HPLC grade, and water is purified. The standard solution containing 4 PAHs: fluorene, pyrene, benzo[a]pyrene, chrysene, obtained from Merck and was stored at 4ºC. For spiking solutions and calibration standards, a serial dilution of stock standards (1000µg/L) was prepared. Five calibration points have been prepared: 10, 50, 100, 500, 1000µg/L.

2.2.3 *Preparation of Calibration Curve*

The linearity of the method used for PAH analysis was assessed by constructing the calibration curve for the chromatographic area obtained versus the PAH concentration of 0.01-1.0 µg/L for individual PAH. The correlation coefficient for most PAHs is appropriate as it is above 0.998. The calibration characteristics of the 4 PAHs are shown in Table 2.1.

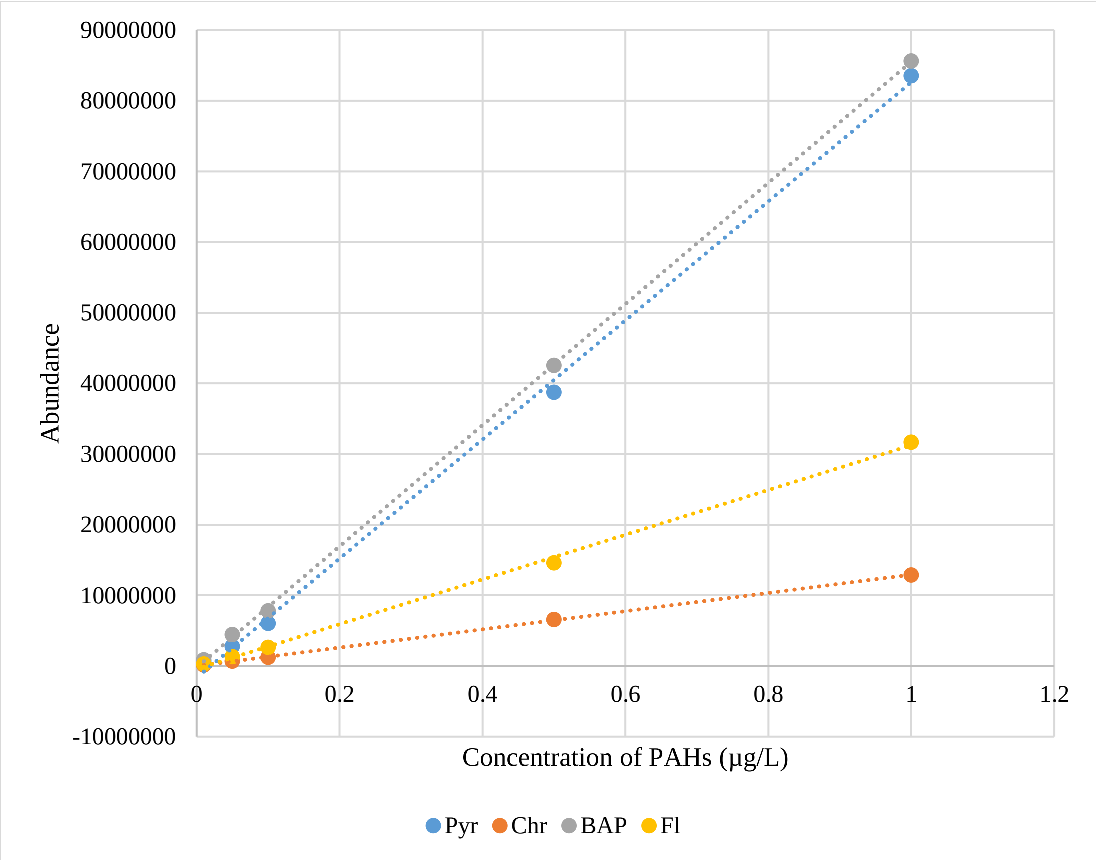


Figure 2.1 Calibration curve of the 4 PAHs

Table 2.1: Calibration characteristics of the 4 PAHs

No	**PAHs**	**Method linearity range (µg/L)**	**Calibration curve**	**Correl. coeff. (r^2)**
1	Fl	0.01-1.0	y=3E=07x-411652	0.9985
2	Chr	0.01-1.0	y=1E+07x+15458	0.9999
3	Pyr	0.01-1.0	y=8E=07x-2E+06	0.9987
4	B[a]P	0.01-1.0	y=9E+07x-218425	0.9999

2.2.4 HPLC Analysis

The HPLC-FLD determination was conducted using the Shimadzu fluorescent HPLC and consisted of the liquid chromatography LC-20A pump A, the RF-20A detector A, the SIL-20A autosampler, and the LabSolution 2.1 computer software. The isothermal temperature of the column was 30°C. The time of injection was 1µl/min. A gradient system was used with a flow rate of 1 ml/min and 80:20 (A) acetonitrile/water and (B) acetonitrile for the mobile phase. The column was returned to initial conditions after 30 min of analysis and stabilized for 20 min. The following wavelength programs (Ex/Em) and retention time used for the determination of PAHs by fluorescence detector (FLD) were listed in Table 2.2.

Table 2.2 Wavelength programs and retention time of the 4 PAHs

PAHs	Excitation	Emission	Retention Time (min)
Fluorine	224	320	9.681
Chrysene	238	398	10.875
Pyrene	238	398	11.546
B[a]P	268	398	17.353

2.2.5 Estimation of Health Risk Assessment

Health risk assessment recommendations endorsed by the US EPA as defined by Abdul-Gafaru (2017), were used to evaluate the carcinogenic risk of exposure to PAHs in bread.

The chronic daily intake (CDI) was calculated to determine the exposure rate of PAH in bread from Eq.1

$$CDI = \frac{C(PEC) \times CR \times EFD}{BW \times AT}$$

(1)

Where CDI= chronic daily intake; C (PEC) = the concentration of PAH in bread (mg/kg); CR = the consumption rate (114g/day); EF = the exposure frequency (365 day/year); ED = the exposure duration (year) (for children: ED = 7; for men: ED = 43; for women ED = 43) for non-cancer risk and 70 years for lifetime cancer risk assessment, BW is body weight (kg) (for children: BW = 32.3; for men: BW = 66.59; for women: BW = 58.44) (Azmi et.al., 2009; Yang et.al., 2017) and AT = duration over which the dose is averaged (for non-cancer risk: AT = 70 years / 365 days/year; for cancer risk: AT = ED x 365 days/year). The rate of bread consumption used to calculate the dose was determined in the bread consumption survey conducted by the Malaysian Adult Nutrition Survey (MANS).

The hazard quotient was calculated by dividing the estimated dosage (CDI) by the Reference Dose (RfD). The RfD was adapted by USEPA-IRIS for each PAH of fluorine ($6x10^{-2}$), B[a]P ($3x10^{-4}$), and pyrene ($3x10^{-2}$). The ratio between the possible exposure to a substance and the degree to which no adverse effects are predicted was assessed in compliance with Eq.2

$$HQ = CDI \times RfD$$

(2)

The lifetime cancer risk was calculated by multiplying the approximate dose (CDI) by the Cancer Slope Factor (CSF) of 1 per mg/kg-day for B[a]P ingestion, which adapted from USEPA-IRIS (2017). B[a]P is used as a marker for the conversion of the carcinogen potency of each PAH to determine the carcinogenic health risk of PAH. Lifetime cancer risk (LCR) was assessed according to Eq.3

$$LCR = (CSF)(CDI) \tag{3}$$

3.0 RESULTS AND DISCUSSIONS

3.1 Comparison of the Overall Concentration of 4 PAHs in Commercial Breads

Table 3.1 shows the overall concentration of 4 PAHs detected in the commercial bread. The highest level of PAHs was detected in pyrene with the maximum level was 12.18 µg/kg and a mean of 2.38 µg/kg. While the lowest level was detected in chrysene with a maximum level of 4.43 µg/kg and a mean of 1.31 µg/kg. This is also supported in a study that no sample shows the concentration of chrysene in commercial toasted bread samples (Rey-Salgueiro, 2008). However, this is contrary to the study reported by Rozentale et. al., (2017), among four individual PAHs conducted in the research, chrysene has always been the most abundant PAH with an average content of 0.254 µg/kg.

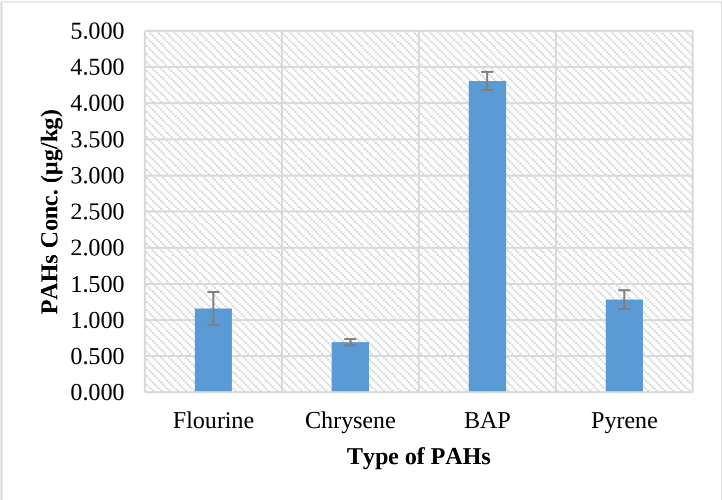
Table 3.1 Overall concentration of 4 PAHs (μg/kg)

PAHs	**Min**	**Max**	**Mean ± SD**
Fluorine	0.00	8.22	1.31 ± 2.70
Chrysene	0.00	4.43	1.31 ± 1.34
Benzo[a]Pyrene	0.00	6.95	1.47 ± 2.66
Pyrene	0.00	12.18	2.38± 3.41

3.2 Comparison of PAHs Concentration Between White, Wholemeal and Wholegrain Breads

Based on Figure 3.1, shows the average PAHs concentration in white, wholemeal, and wholegrain bread for 4 PAHs: fluorine, chrysene, B[a]P, and pyrene. In white bread, the highest concentration is B[a]P with 4.307 μg/kg which is quadruple times the other PAHs concentration. The lowest concentration is fluorine with 0.692 μg/kg. Some studies also showed the higher B[a]P level in white bread, which is reported to be in the range of 2.83 – 16.54 μg/kg in 8 samples out of 18 samples (Al-Rashdan et. al., 2010). However, in the study conducted by Rey-Salgueiro et. al., 2008, B[a]P was detected in low levels for some of the few samples they analyzed in the range of 0.13-0.23 μg/kg. In wholemeal bread, chrysene has been recorded the highest concentration of 2.234 μg/kg on 6 samples of the 9 samples. While the lowest concentration of PAH was found in B[a]P with 0.053 μg/kg. The chrysene level is also stated to be between 0.7 and 4.19 μg/kg, which is considered to be high (Al-Rashdan et. al., 2010). In wholegrain bread, the level of pyrene is recognized highest at 5.703 μg/kg wholegrain bread. However, B[a]P was detected as the lowest contamination with 0.056 µg/kg. The presence of pyrene was observed with 2.19 µg/kg for brown wheat bread, respectively (Al-Rashdan et. al., 2010). In fact, in the study conducted by Ciercierska and Obiedzinski (2013), relatively high levels of pyrene were observed in the majority of cases based on raw materials from the bakery chain, in the grain, flour, and bran groups obtained by grinding the grain into flour. To sum up, wholegrain bread contributes to the highest concentration of 4 PAHs followed by white bread and wholegrain bread. This is contrary to the study conducted by Heng, (2014), wholemeal bread products could be more PAHs contamination compared to white bread products.

A



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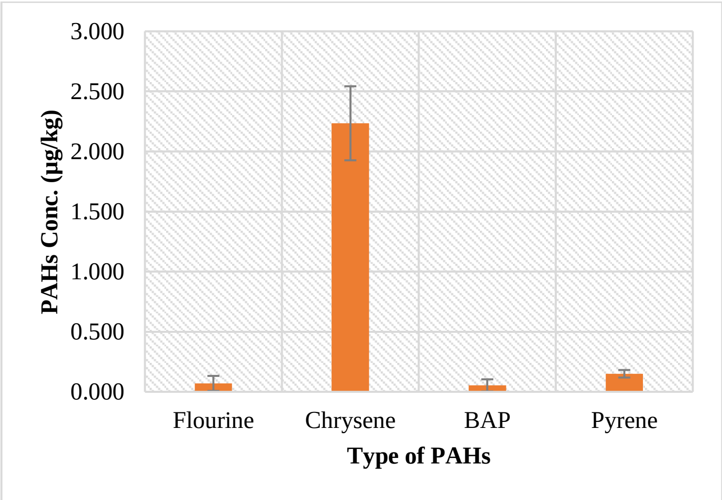

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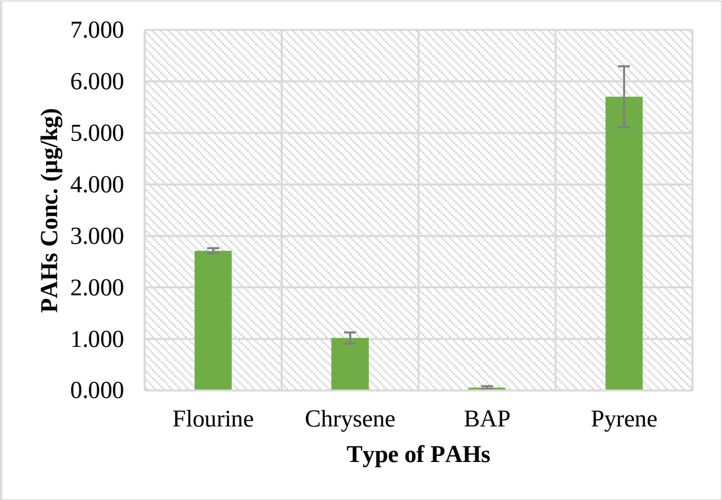

Figure 3.1 Average PAHs concentration at different types of bread (A) white bread, (B) wholemeal bread, and (C) wholegrain bread.

Table 3.2 shows the mean and standard deviation, and the p-value for the types of bread by using one-way ANOVA. There was a significant different in all of the PAHs concentration with *p*-value <0.05. The reading as determined by one-way ANOVA are Fl ($F(2,6) = 126.792$, $p = 0.000$), Chr ($F(2,21) = 6.850$, $p = 0.005$), B[a]P ($F(2,20) = 19.068$, $p = 0.000$) and Pyr ($F(2,20) = 86.486$, $p = 0.000$).

Table 3.2: One-way ANOVA for types of bread

PAHs	White bread	Wholemeal bread	Wholegrain bread	p-value
Fluorine	1.159 ± 0.229	0.070 ± 0.062	2.713 ± 0.049	0.000
Chrysene	0.692 ± 0.044	2.234 ± 0.308	1.018 ± 0.108	0.005
BAP	4.307 ± 0.125	0.053 ± 0.051	0.056 ± 0.028	0.000
Pyrene	1.281 ± 0.128	0.150 ± 0.031	5.703 ± 0.591	0.000

3.3 Comparison of PAHs Concentration Between Brand A, Brand B, and Brand C

Figure 3.2 shows the concentration of PAHs in different brands. In our investigation, bread supplied by Brand C is detected highest with fluorine (2.713 µg/kg) followed by Brand B with 1.159 µg/kg and Brand A (0.070 µg/kg). Similarly, in the study conducted by Al-Rashdan et.al. (2010), fluorine is shown in several studies to be one of the most abundant PAHs in bread. In 15 of the 18 samples, the concentration of fluorine was detected in the range of 0.51-22.9 ng/g. Chrysene was identified as the highest in Brand A with (2.082 µg/kg). The lowest level of PAHs was identified in Brand C (0.557 µg/kg). Contrary to chrysene levels found in 5 samples of 18 samples with a range of 0.12 – 4.19 ng/g in bread and flour samples reported by Al-Rashdan et.al., 2010 which is lesser than the result obtained. Besides, there are least studies that conduct the level of chrysene singularly as this PAH is known to trigger cancer when combining with other PAHs. In another research, B[a]A/(B[a]A + Chr) ratios varied from 0.12 to 0.39 and an average value of 0.27 for the bread baked with various baking fuels (Orecchio and Papuzza, 2009). Carcinogenic PAHs expressed as B[a]P were found higher in Brand B (2.233 µg/kg) followed by Brand A (2.071 µg/kg). While the lowest level was found in Brand C with 0.112 µg/kg. From the study made by Heng, (2014), the results of B[a]P were found between the obtained previous results with the ranges of $7.09 \pm 0.48 – 18.24 \pm 9.71$ ng/g. In a study performed by Eslamizad et.al., (2016), B[a]P was not found in up to 26 industrial bread samples (Senan bread), yet 2 out of 3 Sangak bread samples were polluted at the levels of 2.73 and 3.19 (ng/g of wet weight). According to the permissible limit or European Commission, the regulatory control level for B[a]P (1 µg/kg wet weight) in processed cereal-based foods and baby foods for babies and young children indicates that the concentration of B[a]P in Brand B and Brand A is greater than the permissible limit. For pyrene, the highest concentration level was detected in Brand B (3.772 µg/kg) compare with Brand C (2.032 µg/kg) and Brand A (1.330 µg/kg). These results are higher same as the study conducted by Ahmed et. al., (2000) which is an average of 25.7, 13, 16.2, 0.00 µg/kg were found in the residues of pyrene in bread by using different types of baking method. To conclude, Brand B contains the highest level of 4 PAHs concentration compared to Brand A and Brand C.

Figure 3.2 Average PAHs concentration at different Brands

Table 3.3 shows the reading of mean and standard deviation, and the p-value for the bread brands by using one-way ANOVA. The only significant difference was found in fluorine with a *p*-value <0.05 compared to the other PAHs. There was a significant difference between fluorine in brands of bread as determined by one-way ANOVA ($F(2,6) = 126.792$, $p = 0.000$). There was no significant difference between chrysene, benzo[a]pyrene, and pyrene for brands with a *p*-value equal to 0.242, 0.114, and 0.728, respectively.

Table 3.3: One-way ANOVA for brands

PAHs	Brand A	Brand B	Brand C	p-value
Fluorine	0.070 ± 0.121	1.159 ± 2.007	2.713 ± 4.700	0.000
Chrysene	2.082 ± 1.787	1.306 ± 1.385	0.557 ± 0.827	0.242
BAP	2.071 ± 3.504	2.233 ± 3.756	0.112 ± 0.105	0.114
Pyrene	1.330 ± 1.055	3.772 ± 6.356	2.032 ± 1.865	0.728

Higher pollutants could be due to PAH generation in commercial bread, PAH contamination in raw materials (at source), or during thermal processing (Rey-Salgueiro, 2008). According to our knowledge, there are just a few publications on PAH contamination in commercial bread (Rey-Salguiero, 2008; Al-Rashdan, 2010; Abdul-Ghafaru, 2017). Previously, the maximum limits for PAHs in baked, packed bread and breakfast cereals had not been defined, although the consumption rate has steadily increased. According to the European Union (EU), 1 μg/kg for infant food and dietary food is equivalent to the total of four EU PAH markers (PPAH4; PAH4; i.e. CHR, B[a]A, B[a]P, and B[b]F (Kacmaz, 2019).

3.4 Health Risk Assessment of PAHs Exposure from Consumption of Bread

According to EFSA opinion (2008), the MOE (Margin of Exposure) analysis is a novel approach to risk assessment for genotoxic and carcinogenic PAHs. The MOE was calculated by dividing the estimated toxicity (BMDL – benchmark dose lower confidence limit) from animal studies by the estimated food consumption. In addition, the findings of the average dietary exposure to PAHs and the analysis of the margin of exposure (MOE) interpret that bread products are of little importance for public health. However, the concentration of PAHs in these food products should be regularly monitored because of the carcinogenic effects and the growing rate of intake of these foods in most countries (Ciecierska and Obiedzinski, 2013).

According to the USEPA, the risk level considered appropriate or inconsequential is one in a million probability of additional human cancer over a lifespan of 70 years (LCR = 10-6) for cancer risk and hazard quotients below 1.0 for non-cancer risk, since this contrasts favorably with risk levels from other 'usual' human activities such as X-rays, fishing, etc. However, the levels selected are not regulatory levels and are given to help assess the relative value of various contaminants in terms of their ability to cause adverse health effects (USEPA, 2016).

3.4.1 Chronic Daily Intakes (CDI) and Hazard Quotient (HQ)

The reference doses (RfD) are shown according to USEPA-IRIS (1987, 1990, 2017) for fluorine, pyrene, and B[a]P. However, there is no reference dose (RfD) assessed for chrysene. Therefore, the results included the reading of CDI and HQ for Fl, B[a]P, and Pyr only.

The chronic daily intake (CDI) from the exposure assessment using equation (1) was used for the carcinogenic risk assessment. Hazard quotient is done to evaluate the non-cancer risk of the bread. The result of Table 3.4 shows the health risk caused by PAHs in bread against men, women, and children. The result shows that the hazard quotient in fluorine, benzo[a]pyrene, and chrysene are below 1.0. The highest HQ was detected in pyrene with 1.22E-04. Whereas, the lowest HQ was detected in B[a]P with 8.60E-07. Thus, there is no risk for the majority of the population to get cancer health effects over a daily consumption of bread.

Table 3.4 Chronic daily intake (CDI) and Hazard Quotient (HQ) for men, women, and children

PAHs	**Men**		**Women**		**Children**	
	CDI	**HQ**	**CDI**	**HQ**	**CDI**	**HQ**
Fl	2.24E-03	1.35E-04	2.56E-03	1.53E-04	4.62E-03	2.77E-04
B[a]P	2.52E-03	7.55E-07	2.87E-03	8.60E-07	5.19E-03	1.56E-06
Pyr	4.07E-03	1.22E-04	4.64E-03	1.39E-04	8.40E-03	2.52E-04

3.4.2 Lifetime Cancer Risk (LCR)

B[a]P is the utmost regulated PAH compound by legislation, where the cancer slope factor has also been used to calculate the PAH concentration in foodstuffs as an indicator. This risk is expressed in Table 3.5 for lifetime cancer risk (LCR). It was apparent that all of the lifetime cancer risks for benzo[a]pyrene for men, women, and children is above 10-6 mg/kg/day, implying a cancer risk that could result from ingestion of the contaminated bread.

European Union legislation (EUL) allows for a maximum permissible concentration of benzo[a]pyrene in the range of 1-10 μg/kg/kg for various food products. In Africa, the chronic daily intake for PAH exposure is 2.52E-10 at 5%, 1.87E-09 at 50%, and 2.06E-07 at 95% in the year 2017 (Abdul-Ghafaru, 2017) whereas dietary exposure to B[a]P in Tehran and Shiraz by bread consumption in Iran was 170.6 ng/day and 168.7 ng/day, respectively (Eslamizad et. al., 2016). In the Al-Rashdan (2010) report, the daily consumption of B[a]P dependent on 300 g of bread per day was found to be lower in the 0.85 to 4.69 μg/day/person range compared to Orrechio and Papuzza 2009 and Ahmed et. Al., ranging from 0.33 to 8.1μg/day/person for bread samples using different baking processes.

Table 3.5 Lifetime Cancer Risk (LCR) for Men, Women, and Children

	Men	**Women**	**Children**
Benzo[a]Pyrene	1.5459E-03	1.7615E-03	5.1882E-04

4.0 CONCLUSION AND RECOMMENDATION

There have been no publications on the determination of PAHs in different types of bread baked from white, wholemeal, and wholegrain on various commercial bread products in Malaysia to the best of our knowledge. The developed method was used in 27 samples of commercial bread to determine the concentration of PAHs. The values obtained in this analysis was higher in wholegrain bread compared to white and wholemeal bread. Results of the present study indicate that there is a significant difference in the 4 PAHs concentration between the bread types. However, only fluorine shows a significant difference compared to the other PAHs for the brands of bread. Therefore, it can be concluded that the raw materials are the biggest contributor to the concentration of PAHs in bread compared to the brands.

Taking into consideration the obtained values on the hazard quotient and lifetime cancer risk for the bread consumption to PAHs, it may be inferred that the bread understudy constitutes a low concern for consumer's health. However, because the rate of bread intake is high, more study on the content of PAHs in these products is also required to routinely monitor dietary exposure to these compounds. To sum up, the current study had fulfilled the information gap of PAHs contamination through dietary exposure of commercial breads in Malaysia.

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