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Polycyclic Aromatic Hydrocarbons (PAHs) in Edible Oil: Temperature Effect on Recovery from Base Hydrolysis Product and Health Risk Factor

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Abstract This study investigates the concentration levels of selected priority PAHs; Phenanthrene (Phe), benzo[a] pyrene (BaP) and benzo[k] fluoranthene (BkF) in three brands of refined edible seed oils (30 samples). The samples were hydrolyzed in methanolic potassium hydroxide, and the PAH extracted in n-hexane according to standard methods. The PAH extracts were cleaned using solid phase extraction (SPE), and then separated and quantified using a GC-FID (Schimadzu-2010 *plus*). Results showed that the concentrations of PAHs detected in the different edible seed oils varied. The mean concentration of the PAHs in edible oil derived from a blend of sunflower and soya bean seeds (S-blend) were the least and ranged; BaP, 1.95±0.15μg/kg and BkF, 2.12±0.30μg/kg. The mean concentration of BaP and BkF in edible oil SA_1ranged, 2.13±0.45μg/kg and 1.90±0.42μg/kg, respectively, and 1.71±0.35μg/kg and 4.46±0.41μg/kg, respectively in extract obtained from SA_2. Edible oil sample SA_2 had the highest concentration of BkF 4.46 μg/kg, while SA_1 had the highest concentration of BaP 2.13 μg/kg. The recovery of the evaluated PAH fractions obtained from low temperature hydrolysis product were the highest compared to those obtained at higher temperatures. The effect of temperature on the recovery of PAHs from alkaline hydrolysis products, and the potential consequences of dietary exposure were also discussed.

Keywords Polycyclic aromatic hydrocarbons(PAHs), Edible oil, Hydrolyzed, Extracts, Exposure, Consumption

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are complex mixtures consisting of hundreds of compounds which may differ in composition depending on how they are generated [1]. Polycyclic aromatic hydrocarbonsare formed within food substance matrices or added to the food substances, especially those subjected to heat/thermal treatment during their preparation [1, 2]. The nature and type of PAH emission added to food substances is dependent on several factors such as food preparation methode.g. drying, heating, boiling, char boiling, baking, grilling, roasting, smoking, etc.[3]. Other factors may include fat content of the food, fuel type e.g. natural gas, wood fire, coal tar, crude oil, coke or asphalt, oxygen level, processing temperature, the distance of food from heat source, duration of cooking[4-8] etc.

According to Bartle [9], air deficient combustion (pyrolysis) of organic matter at temperatures between 500°C and 900°C favours the formation of PAHs, especially at temperatures above 700°C. At such high temperatures, organic compounds decompose to form free radicals which recombine to form stable polycyclic aromatic compounds (pyro-synthesis) [10]. While combustion emissions are from combustible organic matter such as proteins and carbohydrates, the emission of complex PAHs matrices have been reported to arise from pyrolysis of fats and lipids [6, 9].

Both natural and industrial oil seed drying processes (air drying, smoke drying, seed roasting etc.) add PAHs to seeds. Although substantial amount of PAHs areadded to edible oils by atmospheric deposition in environments where air is laddened with PAHs [1, 2, 11], their levels are largely exacerbated during production process, i.e. from seed drying to the refining of seed extracts. Hence the occurrence and presence of PAHs in edible oils and fats, and in different food substances containing oils and fats, and or prepared using PAH contaminated oil. Howard et al. [12] reported that "the concentration of BaP (a PAH biomarker) in edible oils ranged between 0.4 – 1.5 μg/kg" [13]. Grimmer and Hildebrandt [14] reported higher PAH concentrations reaching 4.10μg/kg in palm kernel oil; 10.6 μg/kg in sunflower oil, and43.7 μg/kg in crude coconut oil. Edible oils such as corn oil, grape seed oil, groundnut oil, olive oil,

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palm oil, pumpkin seed oil, rapeseed oil, rice bran oil, soybean oil and sunflower seed oil were reported to be PAH contaminated to varying extent in the order of a few μg/kg [15-18]. Speer et al. [15] and Teixeira et al. [19] however reported that the levels of PAHsin edible oils may be reduced by deodorization and charcoal treatment, as well as bleaching during the process of production refining.

Low molecular weight PAH compounds are volatile, while the high molecular weight members are less volatile and chemically inert. The chemical inertness of the compound forms the basis of their matrix and environmental persistence, and consequent bio-accumulative tendency. In the process of oil use for food processing such as frying, the levels of PAHs increase as a result of the generation of PAHs vis-à-vis aromatization and de-hydrocyclization of mono-unsaturated hydrocarbons present in the edible seed/vegetable oils. This may lead to the contamination of food processed using such oils.

The occurrence of polycyclic aromatic hydrocarbons (PAHs) in many food substances represents serious risk to human and environmental health and safety. Exposure of humans to elevated levels of PAHs through food may result in deleterious toxic effects. Animal studies revealed that PAHs are probably carcinogenic and mutagenic. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) [20], and the European Food Safety Authority Food Chain Contaminants panel ((EFSA-CONTAM Panel) concluded that 15 PAHs namely:benzo[a] anthracene, benzo[b] fluoranthene, benzo[j] fluoranthene, benzo[k] fluoranthene, benzo[g,h,i] perylene, benzo[a] pyrene, chrysene, cyclopenta[c,d] pyrene, dibenz[a,h] anthracene, dibenzo[a,e] pyrene, dibenzo[a,h] pyrene, dibenzo [a,i] pyrene, dibenzo[a,l] pyrene, indeno[1,2,3-cd] pyrene, and 5-methylchrysene may be regarded as potentially genotoxic and carcinogenic to humans.

The association of PAHs with cholesterol, oil and fat have been reported to affect the recovery of PAH from matrices containing them [21]. Alkaline hydrolysis (saponification) of matrices containing lipids, oils and fats, prior to solvent extraction procedures has been described [22-25]. However effective recovery from such matrices depends on several factors such as the temperature under which the hydrolysis is conducted, and the concentration and characteristics of the alkaline solution used in hydrolysis. The base alkaline characteristics have been examined and reported. Based on many of the reports, 2 *M* methanolic KOH (9:1v/v) was reported to be very sufficient for hydrolysis of matrices containing oil and fat [26, 27]. However information concerning temperature effect on the recovery of PAHs from matrices containing oil and fat is scarce.

In this study, the concentration levels of three of the EFSA listed four probable carcinogenic biomarker polycyclic aromatic hydrocarbons (PAH-4) consisting of phenanthrene, benzo[a] pyrene and benzo[k] fluoranthene, and the effect of temperature on the recovery of PAHs from edible oilswere investigated in some commercially available edible seed oils, sold off counters in shops around Cape Town. This is in order to ascertain the risk of exposure associated with the use and consumption of such readily available edible oils.

2. Experimental

2.1. Sample Collection

Three brands of edible seed oils were randomly purchased over the counter in shops around Cape Town. Cape Town, the administrative seat of Western Cape consists of a cosmopolitan population. A large percentage of the population depend on groceries consisting of partially or fully prepared foods from shops, outdoor catering services in eateries, and homemade foods for their daily diets. Edible seed/vegetable oil however is one major ingredient bought and used in food preparation such as frying, and for which human can be at risk of exposure if it contains elevated levels of PAHs.

2.2. Sample Preparation

2.2.1. Alkaline Hydrolysis of Oil Samples

About 5 g each of the edible oil samples were separately measured into different pre-cleaned beakers. Each of the samples was mixed with 2 g anhydrous Na_2SO_4 to remove any traces of water present. Thereafter, the oil samples were hydrolyzed in 100 mL 2 *M* methanolic KOH (9:1v/v) [23, 24]. The resulting mixtures were placed on a horizontal shaker at 1500 rpm for 30 min, after which they were refluxed in a water bath at 25℃ for 32 hr. The procedure was repeated at temperatures of 100℃, 150℃ and 200℃ respectively.

2.2.2. Extraction of PAHs (Liquid–Liquid Extraction)

The hydrolyzed samples were allowed to cool to room temperature. This was followed by liquid-liquid extraction of the PAH into a 1:4 mixture of DCM and n-hexane in 4-cycles of 25, 20, 15, 10 mL, using pre-cleaned separating funnels. The combined extracts obtained were concentrated by drying each sample under nitrogen stream and each reconstituted in 3 mL 1:4 mixture of DCM and n-hexane.

2.2.3. Sample Clean up

The PAH extracts in n- hexane were subjected to cleaning using solid phase extraction (SPE) column containing neutral/basic/acidic/neutral silica as described by Olatunji et al. [28]. Prior to sample loading, each SPE column was activated by running the following solvent through in a sequence of 15 mL of DCM, 20 mL n-hexane, 15 mL 1:4 mixture of DCM and n-hexane at a rate of 1 mL/min. The 1:4 mixtures of DCM and n-hexane was allowed to drop just to the level of the solid phase column, after which the extracts were loaded on each column and eluted at the rate of 1 mL/min. Each of the SPE cleanup columns were drained with 20 mL n-hexane after elution in order to recover residues of PAHs from the SPE columns. The combined eluates were transferred into separate pre-cleaned test tubes

and centrifuged at 2000 rpm for 30 min. The clear liquid were decanted into clean beakers and subsequently dried under nitrogen stream. The dried clean extracts were each reconstituted in 1 mL n-hexane for GC analysis.

2.3. Analysis

2.3.1. Standard Preparation

Stock solutions of phenanthrene(Phe) (100 mg/L), benzo [a] pyrene (BaP) (100 mg/L) and benzo [k] fluoranthene (BkF) (100 mg/L) were prepared by dissolving 0.01 g of neat crystals of each of the standards (Sigma-Aldrich) in10 mL mixture of dichloromethane (DCM) and n-hexane (1:4). Working solutions of the calibration standards in the range 50 – 200μg/L were prepared from the stock solution, for instrument calibration and method validation.

2.3.2. Analyte Recovery

The accuracy of the liquid-liquid extraction procedure used for the recovery of PAH from edible oil was determined by analyzing the extracts obtained from the different oil after spiking each sample with the standards of the target PAH fraction at five different concentration levels namely, 10, 20, 30, 40 and 50μg/kg. Each spiked level was analyzed in triplicate.

2.3.3. Limit of Detection and Limit of Quantification

The limit of detection (LOD) which is the least quantity of an analyte that can be distinguishedbyan instrument, was defined by the quantity, 3 multiples of the standard deviation (SD) of the concentration of blank (blank signal) measured in 10 replicates, within 95% confidence limit [29]. The limit of quantitation (LOQ) is the least or minimum concentration that gives rise to signal that is at least ten times the adjacent noise signal [29].

The LOD for the analytes Phe, B[a] P, and B[k] F were 0.1, 0.1, 0.4 μg/kg respectively. The coefficient of correlation (R^2) of the calibration curves for instrument response (peak area) to gradient increase in the concentration of the calibration standards for each of the analyte PAH fraction were 0.9947, 0.99985 and 0.9984 for Phe, B[a] P and B [k] F, respectively. The recovery of the PAH fractions spiked in the different edible oils at 10, 20, 30, 40 and 50 μg/kg were ranged 78.52 – 86.69%, 84.92 – 93.05%, 90.75 – 95. 26%, 89.58 – 92.19%, and 85.72 – 96.14%, respectively, with mean recoveries of 83.46%, 89.90%, 91.08%, 90.26%, and 92.65%, respectively.

2.4. Detection

The PAH fractions in the n-hexane extracts carried in high purity helium gas mobile phase, were separated using a thermal gradient ramping programme for the elution in a ZB-5MS column [Agilent (30 m x 0.25 mm i.d. x 0.25 µm film thickness)] of a Schimadzu 2010 (*Plus*) Gas Chromatograph coupled with Flame Ionization Detector (GC-FID). The column temperature was programmed at 80℃ initially, and held for 4 mins. This was ramped at 8℃ /mins to 170℃ held for 10 mins, and thereafter at 8℃ min^{-1} to 250℃ and held for 10 minutes. The temperature was further ramped at a rate of 10℃ min^{-1} to 300℃ and held for 10 minutes. The temperature of the injection port/transfer line was set at 280 ℃ (isothermal), while detector temperature was set at a temperature of 320℃ (isothermal). The response factor of each PAH fraction to the individual internal standard was measured and calculated at least three times at the beginning, in between and at the end of each batch of GC injection (10 samples).

3. Results and Discussion

3.1. Effect of Temperature on Recovery of Polycyclic aromatic Hydrocarbon from Base Hydrolyzed Edible Oil

The edible oil samples were subjected to hydrolysis at different temperatures before the liquid-liquid extraction procedure. The concentration levels of Phe, BaP and BkF detected in the extracts recovered from all three edible oils after hydrolysis in methanolic KOH at different temperature are presented in Figures 1, 2 and 3.

The recovery of PAH fractions Phe, BaP and BkF in sunflower seed oil sample SA_1 were highest at hydrolysis temperature of 25℃. The mean concentration of the Phe, BaP and BkF were: 1.87, 1.90 and 2.13μg/kg, respectively (Figure 1). The detectable concentration decreased with increase in temperature. The mean concentration of Phe, BaPand BkFat temperatures of 100, 150 and 200℃ were 1.11, 0.92, 1.05 μg/kg; 0.66, 0.87, 1.04μg/kg and 0.45, 0.92, 0.91 μg/kg, respectively (Figure 1). There were significant differences ($p>0.05$) between the concentration of the PAH fractions detected in extracts recovered from hydrolyzate at 25℃ and those recovered from extracts from hydrolyzates at temperatures of 100, 150 and 200℃. However the difference in the concentrations of the fractions recovered from hydrolyzates obtained at 100, 150 and 200℃ were not significant ($p<0.05$), except for Phe in extracts recovered from hydrolyzate obtained at 100 and 150℃. The low PAHs concentrations detected in the high temperature shydrolysis extracts, may not be unconnected to the volatilization of the examined PAH fractions, as a result of high temperature hydrolysis. This implies that, the recoveries of PAHs in oils and other fatty foods, treated by alkaline hydrolysis or saponification at high reflux temperatures prior to liquid-liquid extraction may be low.

The recovery of PAHs in hydrolyzate extracts of sunflower seed oil SA_2 followed the same pattern, with the 25℃ extracts having the highest concentrations of Phe, BaP and BkF; 1.45, 4.47 and 1.71 μg/kg, respectively (Figure 2). There were significant decrease ($p>0.05$) in the extractible concentrations of Phe, BaP and BkF with increase in hydrolysis temperature, except for Phe at 150℃ and 200℃. The concentration of Phe, BaP and BkF at 100, 150 and

200℃ were: 0.96, 2.22, 1.19μg/kg; 0.44, 1.18, 0.82 μg/kg and 0.28, 0.68, 0.59 μg/kg respectively (Figure 2).

In the sunflower and soya bean blended seed oil (S-blend), the concentration of Phe, BaP and BkF were highest in methanolic KOH hydrolyzate extracts at 25 ℃ with concentrations 1.27, 2.12, and 1.95μg/kg, respectively (Figure 3). The difference in the concentrations of BkF in extracts recovered from hydrolyzate at 25℃, 100℃ and 150℃ (1,91, 1.93, and 1.80 μg/kg respectively) were not significantly different ($p<0.05$), while BkF in 200 ℃ hydrolyzate (1.45 μg/kg) was the lowest, and significantly different ($p>0.05$) from the others. The concentration of Phe and B[a] P in extracts recovered from KOH hydrolyzates at 25℃, 100℃, 150℃ and 200℃ (1.27, 2.10 μg/kg; 0.95, 1.79μg/kg; 0.82, 1.56 μg/kg and 0.61, 0.84 μg/kg, respectively(Figure 3)) were significantly different from one and other, except for Phe in hydrolyzate extracts obtained at 100℃ and 150℃ which were not significantly different from each other.

Results showed that the recovery of the evaluated PAHs fractions were highest at low temperature (25℃) with BkF showing the highest recovery of 4.47±0.41μg/kg in the sunflower seed oil SA_2. The low PAHs recovery observed with increased temperatures may be due to the low vapour pressure of the investigated fractions, which result in volatilization.

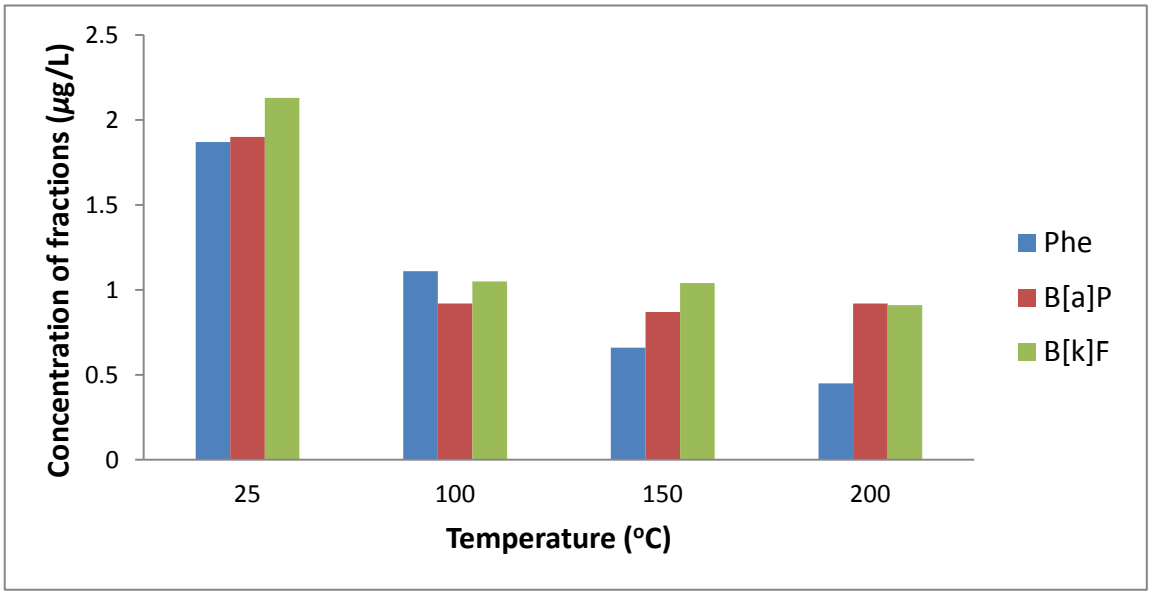

Figure 1. Concentration of the evaluated PAH fractions in extracts recovered from edible in pure sunflower seed oil (SA_1) hydrolyzate at different temperature

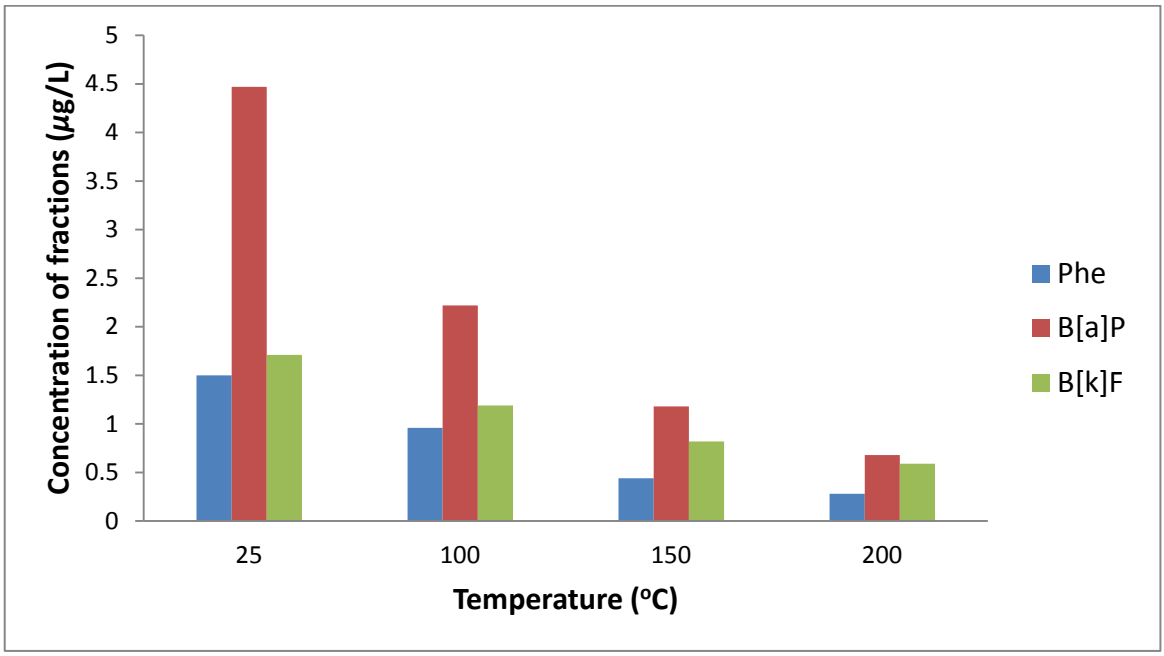

Figure 2. Concentration of the evaluated PAH fractions in extracts recovered from edible pure sunflower seed oil (SA_2) hydrolyzate at different temperature

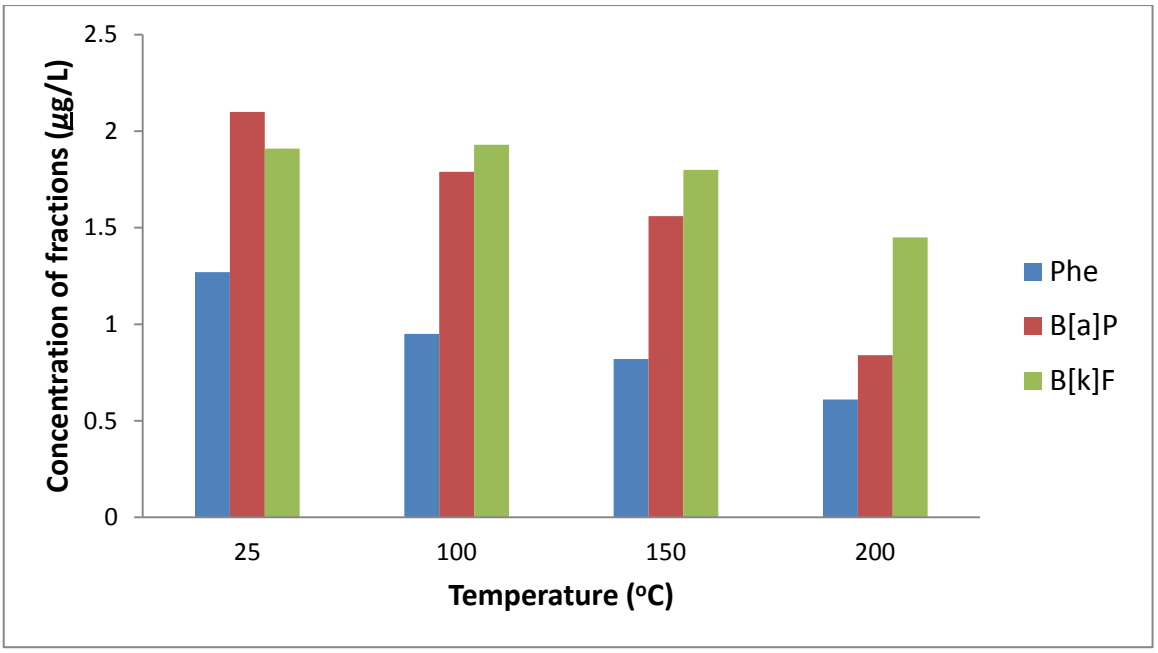

Figure 3. Concentration of the evaluated PAH fractions in extracts recovered from edible blended sunflower and soya bean seed (S-blended) oilhydrolyzate at different temperature

3.2. Concentrations of Polycyclic Aromatic Hydrocarbons in Hydrolysis Extract from Edible Oils

The results of the separation and detection of phenanthene (Phe), benzo[a] pyrene (BaP), and benzo[k] fluoranthene (BkF)in all the brands of the edible oil samples are presented in Table 1.

Table 1. Concentration levels (μg/kg) of some PAHs fraction in selected branded edible vegetable oil

		Phenanthrene µg/kg	Benzo[a]pyrene µg/kg	Benzo[k]fluoranthene µg/kg
Pure sunflower seed oil (SA1)				
N = 10	Min	0.42	0.85	0.80
	Max	1.97	2.45	2.20
	Mean ±Std. Dev.	1.87±0.19	2.13±0.45	1.90±0.42
Sunflower seed oil (SA2)				
N = 10	Min	0.28	0.49	0.56
	Max	1.51	1.96	4.76
	Mean ±Std. Dev.	1.45±0.03	1.71±0.35	4.47±0.41
Blended sunflower and bean seed oil (S-blend)				
N = 10	Min	0.60	1.44	0.73
	Max	1.32	2.04	2.32
	Mean ±Std. Dev.	1.27±0.07	1.95±0.15	2.12±0.30

Min – minimum concentration value; Max – maximum concentration value; Std. Dev. – standard deviation

The concentrations of the polycyclic aromatic hydrocarbon fractions; Phe, BaP, and BkF detected in the extracts recovered from the edible oil samples were variable. Also in the two brands of sunflower seed oils (SA_1 and SA_2), the levels of Phe, BaP and BkF were variable. The concentrations ranged: Phe0.42 – 1.97 μg/kg and 0.28 – 1.51μg/kg; BaP, 0.85 – 2.45 μg/kg and 0.49 – 1.96μg/kg; and BkF, 0.80 – 2.20μg/kg and 0.56 – 4.76 μg/kg, respectively. Edible oil sample SA_2 had the highest concentration of BkF (4.76μg/kg), while SA_1 had the highest

concentration of BaP (2.45μg/kg) and Phe (1.97 μg/kg). A WHO [30] report revealed BkF as one of the most available and frequently occurring PAHs in food substances.

Contrary to the expected contributive addition effect of seed blending in blended seeds oil (S-blend), the levels of the investigated PAHs were the least among the different edible oils studied with Phe, 0.60 – 1.32μg/kg; BaP, 1.44 – 2.04μg/kg and BkF, 0.73 – 2.32μg/kg. The mean concentrations of PAH fractions, Phe (1.27±0.07μg/kg) was observed to be the least in the sunflower and soya bean seeds blend (S-blend) edible oil samples, while the sunflower seed oil SA_1 had the highest mean concentration of 1.87±0.19μg/kg for Phe. The sum total of the mean concentrations of all the measured fractions ($\sum_3$PAH) were: S-blend, 5.34 μg/kg, SA_1, 5.90 μg/kg and SA_2, 7.74 μg/kg. Thus the blended seed oils were the least PAH contaminated oil among the evaluated brands of edible oils, while pure sunflower seed oils SA_2 were the most contaminated. The reason for this may probably be as a result of the variability in the efficiency of the process of refining, which include deodorization and bleaching of raw seed oil extracts, known to greatly reduce PAH levels in edible oils [12, 17, 19, 31]. For instance, refined sunflower oil, soy oil and extra virgin oil examined in Portugal were of low level PAHs contamination. This indicates that, many refined branded edible oils and fats, commercially available as food or raw material for food preparation contains PAHs at different concentrations. Consequently the direct consumption and or indirect consumption of products containing oil and fats as ingredient, present a risk of human exposure to PAHs. For instance margarine was noted to be a major dietary source of PAHs [18].

The concentration of B[a]P observed in this study is consistent with the findings of Dennis et al. [16] who reported higher and more variable amounts in vegetable oils with B[a]P reaching a mean level of 1.29 μg/kg, and low BaP, (0.06 μg/kg) levels in retail fish and animal derived oils and fats such as butter. A survey conducted by the Food Safety Authority of Ireland showed that the sum of 15 PAH ($\sum_{15}$PAH) content in refined oils ranged between 1.38 – 8.0 μg/kg fresh weights, with many of the examined oils showing below 5 μg/kg EFSA recommended concentration levels, except for grape seed oil (8.0 μg/kg) [32].

This implies that the process of refining is not effective in removing PAHs, thus there must be an effective measure that can eliminate or greatly minimize PAHs during processing [33]. Also the use and re-use of edible oils for certain purposes such as frying may however be of concern since the levels of PAHs may increase during this process. The International Union of Food and Technology (IUFoST) in 2011, recommended that control measure must be in place to limit PAHs production and to screen out foods known or found to be significantly contaminated.

3.3. Dietary Levels of Polycyclic Aromatic Hydrocarbons

Study results revealed that the edible oils contain different concentration levels of the selected fractions between Phe, 1.27±0.07 μg/kg in S-blend oilsto BkF, 4.47±0.41 μg/kg in SA_2 oils. The amount detected may not be unconnected to the seed types and the methods used in the production of the edible oils [12, 13, 31]. Although the extraction of edible oils from raw materials, especially those from seeds exposed to atmospheric deposition, and to a lesser extent uptake, exacerbates PAHs levels, the use of different solvents also contaminate the oils [12, 13, 31, 34, 35]. For instance Kolarovic and Traitler [36] reported that, a total PAH concentration of 10.3 μg/kg for grape seed, 22.9 μg/kg for rape seed, 25.2 μg/kg for sunflower seed, 178 μg/kg soy bean and 615 μg/kg and 107 μg/kg for peanut oil can be expected.

A threshold limit of 2.00 μg/kg was set for BaP in oils and fats intended for direct human consumption or use as an ingredient in food (excluding cocoa butter and coconut oil); and 10.00 μg/kg for the sum of four PAHs (benzo[a] pyrene, benzo[a] anthracene, benzo[b] fluoranthene and chrysene) [1]. In Spain a limit of 2.00 *n*g/g was set for some PAH compounds in olive residue oils [37, 38]. The German Society for Fat Science recommended 25.00 *n*g/g limits for total PAHs and 5 *n*g/g for the heavy PAH fraction in oils and fats [15].

In this study over 90% of the samples contain lower than 2.00 μg/kg BaP, while all the samples contain less 10.00 μg/kg sum of the PAH4. The CONTAM panel of the European Food and Safety Agency (EFSA) using the Margin of Exposure (MOE) approach, concluded that the concern for average estimated dietary exposure to PAH in edible oil is low, although high level consumers with MOEs of nearly 10,000 is of potential health concern. Thus there is no cause for concern about the direct human dietary exposure to PAHs in the examined edible oils.

3.4. Toxicity, Human Response and Regulation

Organism response to different endogenous PAH fractions are intrinsic, depending on individual physiological and hormone codes, and these are regulated by homeostatic mechanism. For instance, it was reported that humans shows dose-dependent variations in toxic effects of multiple chemical exposures, thus human toxicological response to PAH compounds contamination may be very variable. According to WHO [39], it is not possible to assume a threshold mechanism, thus provisional tolerable weekly intake (PTWI) cannot be established. Animal studies revealed that the lipophilic character of PAHs enhances their bile salt facilitated absorption from the lungs, gut and skin of mammals into gastrointestinal tracts, when present as solutes in various dietary lipids and fats [30, 40, 41].

3.5. Regulation and Control

Different brand of commercially available refined edible oil may contain PAHs in varying amount. The use and re-use of edible oils for purposes such as frying may however be of concern since the levels of PAHs may increase during this

process [42]. Thus, there is need for regular monitoring of commercially available edible oils, particularly those in-use by food business operators, with a view to ensure lower dietary exposure levels via compliance to regulation, in order to promote public health. Also enforcement agencies and other stakeholders including food business operators (FBOs) should have control measures in place, and must be proactive in implementing risk management and safety measures.

Regulatory limits for PAHs in foods and water have been set in some countries (Nollet and Toldra [43]. For instance, the European Union laid down a regulation establishing maximum levels for benzo [a] pyrene and for the sum of 4 PAHs (benzo [a] pyrene, chrysene, benzo [a] anthracene and benzo[b] fluoranthene) in a variety of foodstuff. Maximum levels range from 1.0 μg/kg to 6.0 μg/kg, for benzo[a] pyrene and 1.0 μg/kg to 35.0 μg/kg for the sum of the PAHs ($\sum_i$PAH) [44]. Furthermore, the Codex Committee on Food Additives and Contaminants (CCFAC) in 2006, agreed to elaborate a proposed draft Code of Practice for the reduction of contamination of food with PAHs from direct drying and smoking processes [39].

4. Conclusions

The recoveries of PAHs from low temperature alkaline hydrolysis product of the edible oils were higher than in high temperatures alkaline hydrolysis products, and this may be as a result of the volatilization of PAH at higher temperature. Results from this study also showed that, refined edible oils are contaminated by PAHs to variable extent, although the observed concentration levels were mostly within the acceptable guideline concentration levels in food recommended by EFSA. The levels of PAH detected in the investigated edible oils available on shelf, and for use as food, food ingredient, food additive or used in food preparation may provide baseline information on the health hazards associated with dietary exposure to these PAH sources. In order to ensure low public exposure and risk to human health and environmental safety; agencies and departments concerned with food control and health must ensure adequate censoring and monitoring of such products in order to ensure compliance to food regulation.

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