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Polycyclic Aromatic Hydrocarbons Contamination in Selected Rice Grains Sold in Port Harcourt, Nigeria

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ABSTRACT

Background and Objective: Polycyclic aromatic hydrocarbons (PAHs) are common environmental pollutants and a significant group of carcinogens. Rice has been shown to contain certain PAHs, which could be a result of environmental and soil pollution, as well as manufacturing and cooking methods. The study's objective was to assess the concentration of polycyclic aromatic hydrocarbons in rice grains; both local and foreign, sold in Port Harcourt, Nigeria. **Materials and Methods:** Five samples each of local and foreign rice designated as L_{01}, L_{02}, L_{03}, L_{04} and L_{05} for the local rice samples and F_{01}, F_{02}, F_{03}, F_{04} and F_{05} for the foreign rice samples were used. For the determination of polycyclic aromatic hydrocarbon, gas chromatography with a flame ionization detector, GC-FID (HP 6890) was used. Values are expressed as Mean±Standard Deviation and ANOVA (SPSS version 21) was used to assess significant differences within groups at $p<0.05$. **Results:** The concentrations of polycyclic aromatic hydrocarbons (PAHs) in local rice showed that naphthalene concentration ($\times 10^{-2}$ µg/kg) was highest in L_{01} (1.027) and L_{02} (0.596), L_{03} had benzo[a]anthracene (0.824), L_{04} was Indeno[123-cd] pyrene (0.618) and L_{05} had anthracene (0.787) with the highest value. The concentrations ($\times 10^{-2}$ µg/kg) of PAHs with the highest concentration in the foreign rice samples are as follows; 2-methylnaphthalene in F_{01} (1.016), benzo[a]anthracene in F_{02} (0.984), F_{03} was acenaphthylene (0.81), F_{04} was fluorene (0.698), while F_{05} was naphthalene (0.825). The Σ_{16} polycyclic aromatic hydrocarbons ($\times 10^{-2}$ µg/kg) in both local and foreign rice grains was as follows: L_{05} (5.05)>F_{03} (4.782)>L_{01} (4.573)>L_{03} (4.488)>F_{04} (4.407)>L_{04} (4.018)>F_{02} (3.714)>F_{05} (3.052)>F_{01} (2.715)>L_{02} (2.328). **Conclusion:** The Σ_{16} PAHs were in no pattern, there were concentrations in both local and foreign rice samples with the least concentration in L_{02}, although they were lower than the permissible limits. This indicates long-term possible contaminations could occur and since some PAHs are carcinogenic, regulatory bodies need to monitor the level of PAHs in rice sold in Port Harcourt.

KEYWORDS

Foreign rice, local rice, polycyclic aromatic hydrocarbon, contamination, Port Harcourt

INTRODUCTION

Rice (*Oryza sativa*) along with wheat and corn are the world's principal food crops[1]. It is one of the world's most farmed crops and the world's third most consumed cereals. It is of the family Poaceae[2]. Rice is considered the most important food, with more than half of the world's population relying on it for

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around 80% of their food needs. Rice is quite simple to cultivate for both commercial and domestic usage[3]. It is an increasingly vital crop in Nigeria. It has become a staple food in many Nigerian diets since it has become more widely accepted[4].

Polycyclic aromatic hydrocarbons (PAHs) are persistent organic pollutants having two or more benzene rings that can be in the atmosphere, soil, water, sediment, vegetables, food and living organisms adipose tissues[5]. Polycyclic aromatic hydrocarbons (PAHs) are generated through the incomplete combustion of organic matter. Common sources include automobile exhaust, coal-fired power plants, domestic heating, forest fires, waste incineration, road traffic and volcanic eruptions[6].

Overexposure to PAHs can lead to various health effects such as small head circumference, low birth weight and growth retardation[6]. Others include low intelligence quotient, damaged deoxyribonucleic acid in unborn children and the disruption of endocrine systems, such as estrogen, thyroid and steroids[7].

Diet is the primary source of human exposure to PAHs, with cereals, vegetables, milk and fruits accounting for the vast bulk of dietary contribution[6,8,9]. Although PAH levels in cereals are typically modest, the enormous quantities of grains ingested make them an important source of PAHs to humans[8]. These pollutants may penetrate and accumulate in agricultural soil and crops via irrigation and atmospheric sinks, posing a direct hazard to food safety[6]. The PAHs are cancer-causing environmental pollutants that can also be found in plant vegetative structures like roots, stems and leaves[10]. Plant roots can absorb PAHs from polluted soil and transport them to other sections of the plant (bio-accumulate)[5]. In rice roots contaminated with PAHs, irrigation water is the primary cause of contamination[10]. Another contamination is the husk of rice, which plays a protective role and contains four times higher PAHs concentration compared to the grain. A research study carried out on rice grown in Japan found PAH contamination in unpolished rice (brown rice)[10]. Another study revealed metagenics and/or carcinogenic PAHs in cooked rice[2,9]. Hence this study's objective was to assess the concentration of polycyclic aromatic hydrocarbons in local and foreign rice samples sold in Port Harcourt, Nigeria.

MATERIALS AND METHODS

Study area: This research took place in the Department of Biochemistry, Rivers State University and Cendiana Medical Research Center, Alakahia, Port Harcourt, Nigeria. It started from September to October, 2024.

Sample collection: Ten rice grain samples were randomly obtained from the market in the Rumuokoro area of Port Harcourt, Nigeria. The samples were divided into five local and five foreign rice brands: denoted as L_{01}, L_{02}, L_{03}, L_{04} and L_{o5} for the local rice samples and F_{01}, F_{02}, F_{03}, F_{04} and F_{05} for the foreign rice samples. They were kept in a container until further use.

Sample extraction: Each rice sample was rinsed three times with tap water to eliminate surface pollutants and then twice with distilled water to eradicate any remaining impurities. The samples were air-dried overnight and then oven-dried at 65°C for 2 hrs, to remove moisture. After drying, the rice grains were homogenized by grinding them into a fine powder using a glass mortar and pestle. The ground samples were then kept in well-labelled airtight containers to prevent external contamination. Five grams (5 g) of the samples were measured in the laboratory apparatus.

Three distinct concentrations of mixed PAH standards (100, 500 and 1000 μg/mL) were formulated with deuterated PAHs, comprising acenaphthalene-d10, chrysene-d12, phenanthrene-d10 and perylene-d12. The deuterated PAHs serve as internal standards, allowing for the rectification of extraction losses and precise quantification of the targeted PAHs. The 5 g of the previously measured samples (in triplicate) were fortified with deuterated PAH standards to reliable recovery outcomes. This was mixed with the extraction solvent. The extraction solvent for this study was a 3:1 mixture of dichloromethane (DCM) and hexane. Then each sample was sonicated for 30 min. Following sonication, the solvent mixture containing the recovered PAHs was filtered using Whatman No. 1 filter paper. The filtrates were then concentrated with a rotary evaporator at 40°C to remove the solvent, yielding a concentrated PAH extract. The concentrated PAH extract from the rotary evaporator was re-dissolved in a 3:1 mixture of dichloromethane and hexane before being put onto an alumina column for purification. A similar solvent mixture was used as the eluent to clean the column and elute the PAHs. The use of dichloromethane and hexane ensures effective elution of non-polar PAHs from the column, while more polar compounds are retained. The eluted fraction, comprising the purified PAHs, was collected in sterile glass vials. To enhance the concentration of the PAH portion, the eluent underwent further evaporation with a rotating evaporator.

To facilitate gas chromatography (GC) injection, the purified and concentrated PAH extracts were re-dissolved in a minimal proportion of hexane and the PAHs were determined using gas chromatography with a flame ionization detector, GC-FID (HP 6890).

Chemical analysis: The concentration of PAHs was analyzed using gas chromatography with a flame ionization detector, GC-FID (HP 6890). The oven temperature was initially set to 60°C for 5 min, afterward increased to 250°C at a rate of 15°C/min, held for 14 min and then at a second rate of 10°C/min for 5 min. Nitrogen gas was used as the carrier gas at a flow rate of 1 cm^3/min and a pressure of 30 psi. The recovery experiment was initially carried out. After attaining recoveries ranging from 94.0 to 99.2%, the grain samples were removed and PAHs were quantified using the GC-FID. Following purification, the extracts were concentrated by a rotary evaporator, which reduced the solvent volume to improve PAH detection. To analyze the concentrated extracts, one microlitre (1 μL) was loaded into the gas chromatography-flame ionization detector for analysis. The flame ionization detector then identified PAHs based on their distinct retention times and response signals. Each PAH constituent produced a distinct signal, which was compared to the deuterated PAH standards for precise quantification.

Statistical analysis: Values are denoted as Mean±Standard Deviation. Using the SPSS tool (version 21), ANOVA was used to identify significant differences within the groups at $p<0.05$.

RESULTS

The concentration of PAHs in local rice grain sold in Port Harcourt, Nigeria, is shown in Table 1. The concentrations ($\times 10^{-2}$ μg/kg) of PAHs were as follows; naphthalene concentration was highest in L_{01} (1.027) and L_{02} (0.596), L_{03} had benzo[a]anthracene (0.824) as the highest concentration. Indeno[123-cd] pyrene (0.618) was highest in L_{04} while L_{05} had anthracene (0.787) with the highest value. Dibenzo[ah]anthracene (0.0027) was lowest in L_{01}, L_{02} had benzo[b]fluoranthene (0.0014) with the least value and indeno[123-cd] pyrene (0.011) had the lowest value in L_{03}. Chrysene had a low value in L_{04} (0.010) while L_{05} had pyrene (0.031) with the lowest level.

The concentration of naphthalene ($\times 10^{-2}$) was significant in the other L_{01} (1.027)>L_{02} (0.596)>L_{04} (0.355)>L_{03} (0.182)>L_{05} (0.102). Benzo[a]anthracene ($\times 10^{-2}$) was significantly as follows L_{03} (0.824)>L_{05} (0.379)>L_{02} (0.191)>L_{04} (0.026)>L_{01} (0.006) except for L_{04} and Lo1 which showed no significant difference. Dibenzo[ah]anthracene ($\times 10^{-2}$) was as follows L_{04} (0.231)>L_{05} (0.134)>L_{03} (0.085)>L_{02} (0.042)>L_{01} (0.0027) while benzo[ghi]perylene concentration ($\times 10^{-2}$ μg/kg) had L_{04} (0.504) as the highest followed by L_{05} (0.281), L_{03} (0.146), L_{01} (0.105) and L_{02} (0.0097) which was significant.

The concentration of Σ_{16}($\times 10^{-2}$ μg/kg) was as follows L_{05} (5.05)>L_{01} (4.573)>L_{03} (4.488)>L_{04} (4.018)>L_{02} (2.328). The Σ_{16} of L_{02} was significantly lower than the rest.

Table 1: Concentration of polycyclic aromatic hydrocarbons ($\times 10^{-2}$) in local rice grain sold in Port Harcourt

PAHs ($\times 10^{-2}$ μg/kg)	L_{01}	L_{02}	L_{03}	L_{04}	L_{05}
Naphthalene	1.027 ± 0.007^{a}	0.596 ± 0.01^{b}	0.182 ± 0.002^{c}	0.355 ± 0.014^{d}	0.102 ± 0.004^{e}
2-methyl naphthalene	0.216 ± 0.057^{a}	0.188 ± 0.0038^{a}	0.541 ± 0.006^{c}	0.346 ± 0.010^{d}	0.133 ± 0.012^{e}
Acenaphthylene	0.106 ± 0.000^{a}	0.481 ± 0.03^{b}	0.201 ± 0.007^{c}	0.0387 ± 0.002^{d}	0.263 ± 0.012^{e}
Fluorene	0.21 ± 0.00^{a}	0.076 ± 0.007^{a}	0.765 ± 0.009^{c}	0.021 ± 0.0017^{a}	0.615 ± 0.007^{c}
Phenanthrene	0.61 ± 0.012^{a}	0.02 ± 0.004^{b}	0.542 ± 0.017^{a}	0.243 ± 0.008^{b}	0.613 ± 0.009^{a}
Anthracene	0.472 ± 0.018^{a}	0.294 ± 0.008^{a}	0.818 ± 0.079^{c}	0.603 ± 0.007^{c}	0.787 ± 0.021^{c}
Fluoranthene	0.782 ± 0.022^{a}	0.172 ± 0.015^{bc}	0.106 ± 0.007^{bc}	0.033 ± 0.004^{b}	0.416 ± 0.016^{a}
Pyrene	0.098 ± 0.006^{a}	0.140 ± 0.002^{a}	0.036 ± 0.006^{a}	0.129 ± 0.003^{a}	0.031 ± 0.001^{a}
Benzo[a]anthracene	0.006 ± 0.0001^{a}	0.191 ± 0.0054^{b}	0.824 ± 0.005^{c}	0.026 ± 0.0013^{a}	0.379 ± 0.019^{e}
Chrysene	0.304 ± 0.002^{a}	0.0133 ± 0.0015^{b}	0.049 ± 0.0017^{b}	0.010 ± 0.001^{b}	0.263 ± 0.031^{a}
Benzo[b]fluoranthene	0.161 ± 0.0056^{a}	0.0014 ± 0.00^{b}	0.117 ± 0.008^{c}	0.277 ± 0.013^{d}	0.324 ± 0.005^{e}
Benzo[a]pyrene	0.249 ± 0.0062^{a}	0.0429 ± 0.0026^{b}	0.018 ± 0.025^{b}	0.307 ± 0.019^{a}	0.119 ± 0.008^{b}
Benzo[k]fluoranthene	0.210 ± 0.0044^{a}	0.0089 ± 0.0016^{b}	0.047 ± 0.006^{b}	0.278 ± 0.014^{ad}	0.366 ± 0.008^{de}
Indeno[123-cd]pyrene	0.0146 ± 0.0043^{a}	0.052 ± 0.0034^{b}	0.011 ± 0.002^{a}	0.618 ± 0.009^{d}	0.225 ± 0.010^{e}
Dibenzo[ah]anthracene	0.0027 ± 0.0015^{a}	0.042 ± 0.0036^{b}	0.085 ± 0.007^{c}	0.231 ± 0.008^{d}	0.134 ± 0.010^{e}
Benzo[ghi]perylene	0.105 ± 0.0028^{a}	0.0097 ± 0.0025^{b}	0.146 ± 0.005^{c}	0.504 ± 0.004^{d}	0.281 ± 0.008^{e}
Σ_{16} PAHs	4.573 ± 0.059^{a}	2.328 ± 0.034^{b}	4.488 ± 0.022^{ad}	4.018 ± 0.037^{cd}	5.05 ± 0.055^{a}
ΣLMW PAH	2.641	1.655	3.049	1.6067	2.513
ΣHMW PAH	1.9323	0.673	1.439	2.4113	2.537
ΣPAH_4	0.72	0.210	0.9027	0.62	1.165

Values are expressed as Mean±Standard Deviation (n = 3). Values with different alphabetical superscripts denote significant differences at $p<0.05$, L_{01}, L_{02}, L_{03}, L_{04} and L_{05} for the local rice samples

Table 2: Concentration of polycyclic aromatic hydrocarbons ($\times 10^{-2}$ μg/kg) in foreign rice grain sold in Port Harcourt

PAHs	F_{01}	F_{02}	F_{03}	F_{04}	F_{05}
Naphthalene	0.594 ± 0.004^{a}	0.549 ± 0.009^{a}	0.337 ± 0.007^{c}	0.188 ± 0.002^{d}	0.825 ± 0.006^{e}
2-methyl naphthalene	1.016 ± 0.006^{a}	0.545 ± 0.008^{b}	0.179 ± 0.004^{c}	0.349 ± 0.018^{d}	0.0475 ± 0.0041^{e}
Acenaphthylene	0.184 ± 0.010^{a}	0.36 ± 0.008^{b}	0.81 ± 0.008^{c}	0.028 ± 0.008^{d}	0.383 ± 0.007^{e}
Fluorene	0.257 ± 0.054^{a}	0.636 ± 0.349^{b}	0.454 ± 0.284^{c}	0.698 ± 0.189^{b}	0.354 ± 0.016^{e}
Phenanthrene	0.168 ± 0.023^{a}	0.090 ± 0.038^{b}	0.055 ± 0.047^{b}	0.325 ± 0.196^{d}	0.256 ± 0.354^{a}
Anthracene	0.154 ± 0.03^{a}	$0.231\pm0..396^{a}$	0.103 ± 0.051^{a}	0.122 ± 0.183^{a}	0.170 ± 0.299^{a}
Fluoranthene	0.149 ± 0.092^{a}	0.636 ± 0.390^{b}	0.027 ± 0.013^{a}	0.359 ± 0.052^{b}	0.10 ± 0.011^{a}
Pyrene	0.013 ± 0.009^{a}	0.062 ± 0.03^{a}	0.078 ± 0.13^{a}	0.264 ± 0.046^{d}	0.150 ± 0.027^{bc}
Benzo[a]anthracene	0.004 ± 0.0036^{a}	0.984 ± 0.042^{b}	0.267 ± 0.008^{c}	0.339 ± 0.024^{c}	0.056 ± 0.09^{ab}
Chrysene	0.017 ± 0.016^{a}	0.038 ± 0.013^{a}	0.291 ± 0.008^{c}	0.3025 ± 0.122^{c}	0.317 ± 0.002^{a}
Benzo[b]fluoranthene	0.002 ± 0.001^{a}	0.116 ± 0.004^{b}	0.269 ± 0.02^{c}	0.317 ± 0.0056^{d}	0.126 ± 0.004^{e}
Benzo[a]pyrene	0.040 ± 0.006^{a}	0.017 ± 0.002^{a}	0.287 ± 0.01^{c}	0.120 ± 0.014^{a}	0.297 ± 0.177^{c}
Benzo[k]fluoranthene	0.01 ± 0.002^{a}	0.048 ± 0.004^{a}	0.278 ± 0.006^{c}	0.362 ± 0.011^{c}	0.128 ± 0.196^{a}
Indeno[123-cd]pyrene	0.053 ± 0.006^{a}	0.013 ± 0.001^{b}	0.607 ± 0.009^{c}	0.228 ± 0.014^{d}	0.0056 ± 0.0083^{b}
Dibenzo[ah]anthracene	0.043 ± 0.002^{a}	0.082 ± 0.003^{b}	0.236 ± 0.008^{c}	0.13 ± 0.01^{d}	0.0079 ± 0.0033^{e}
Benzo[ghi]perylene	0.011 ± 0.004^{a}	0.153 ± 0.004^{b}	0.502 ± 0.011^{c}	0.275 ± 0.0057^{d}	0.1156 ± 0.0037^{e}
Σ_{16} PAHs	2.715 ± 0.055^{a}	3.714 ± 0.401^{b}	4.782 ± 0.150^{c}	4.407 ± 0.312^{c}	3.052 ± 0.423^{a}
ΣLMW PAH	2.373	2.411	1.938	1.71	2.0355
ΣHMW PAH	0.342	1.303	2.844	2.697	1.0165
ΣPAH_4	0.063	1.155	1.114	1.0785	0.5107

Values are expressed as Mean±Standard Deviation (n = 3). Values with different alphabetical superscripts denotes significant different at $p<0.05$, F_{01}, F_{02}, F_{03}, F_{04} and F_{05} for the foreign rice samples

The concentrations ($\times 10^{-2}$ μg/kg) of PAHs with the highest concentration in the foreign rice samples (Table 2) are as follows; 2-methylnaphalene concentration was highest in F_{01} (1.016), benzo[a]anthracene in F_{02} (0.984), F_{03} was acenaphthylene (0.81), F_{04} was fluorene (0.698), while F_{05} was naphthalene (0.825). The concentration of naphthalene ($\times 10^{-2}$ μg/kg) was significantly in the order: F_{o5} (0.825)>F_{01} (0.594)>F_{02} (0.549)>F_{03} (0.337)>F_{04} (0.188). Acenaphthylene ($\times 10^{-2}$ μg/kg) had F_{03} (0.81) with the highest value followed by F_{05}(0.383), F_{02} (0.36), F_{01} (0.184) and F_{04} (0.028) which was significant. There was no significant difference in anthracene within the groups. Chrysene value ($\times 10^{-2}$ μg/kg) for F_{01} (0.017), F_{02} (0.038) and F_{05} (0.0317) was significantly lower than F_{03} (0.291) and F_{04} (0.3025).

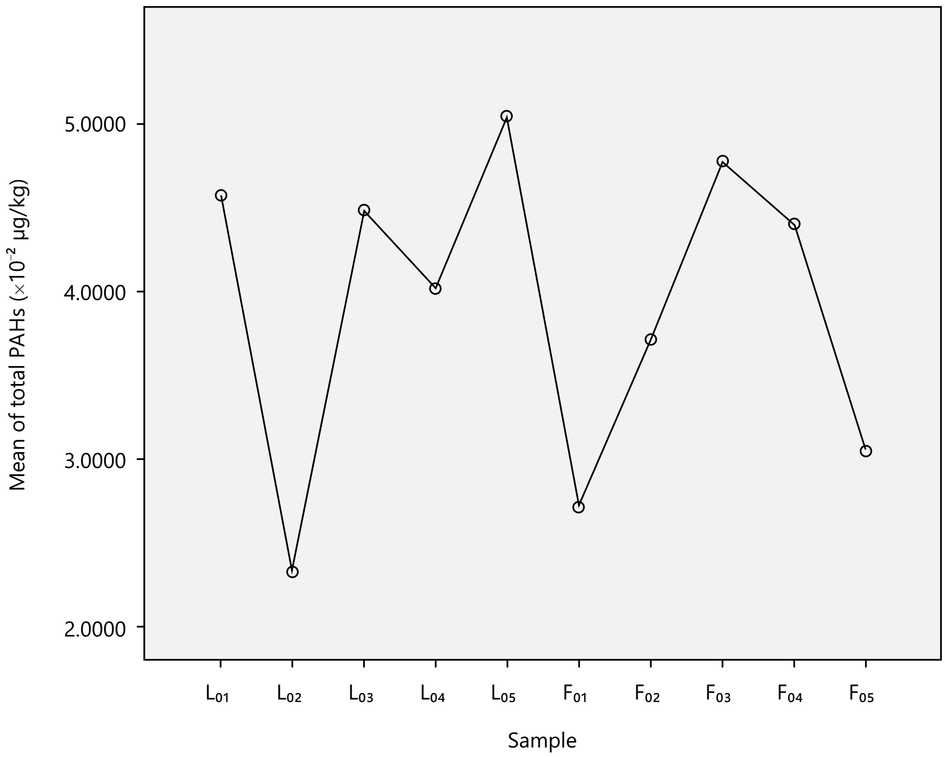

Fig. 1: Concentration of 16 polycyclic aromatic hydrocarbons found in both local and foreign rice grains sold in Port Harcourt, Nigeria

L_{01}, L_{02}, L_{03}, L_{04} and L_{05} for the local rice samples and F_{01}, F_{02}, F_{03}, F_{04} and F_{05} for the foreign rice samples

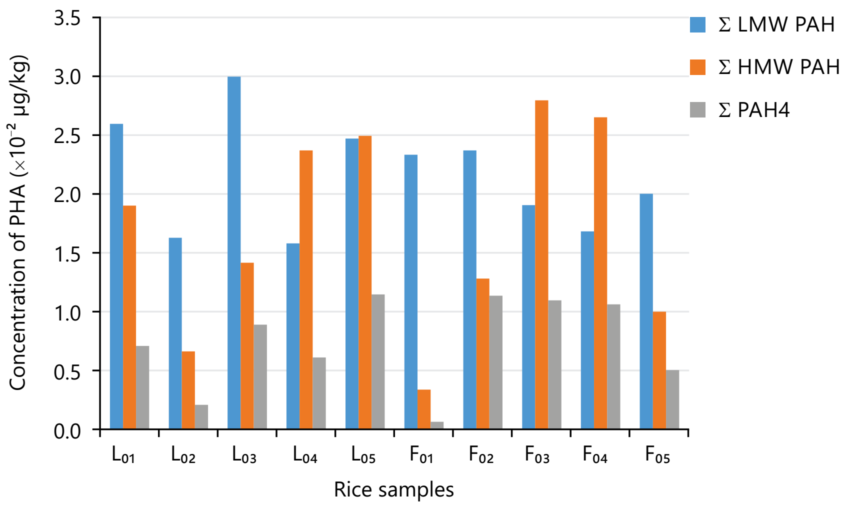

Fig. 2: Concentration of LMW PAH, HMW PAH and PAH4

L_{01}, L_{02}, L_{03}, L_{04} and L_{05} for the local rice samples and F_{01}, F_{02}, F_{03}, F_{04} and F_{05} for the foreign rice samples

Benzo[b]fluoranthene concentration ($\times10^{-2}$ µg/kg) was significantly as follows F_{04} (0.317)>F_{03} (0.209)>F_{05} (0.126)>F_{02} (0.116)>F_{01} (0.002). For dibenzo[ah]anthracene F_{03} (0.236) was higher than F_{04} (0.13), F_{02} (0.082), F_{01} (0.043) and F_{05} (0.0079), which was significant. For benzo[ghi]perylene, F_{03} (0.502) was significantly higher than F_{04} (0.275), F_{02} (0.153), F_{05} (0.1156) and F_{01} (0.011). While for 2-methylnapthalene, F_{01} (1.016)>F_{02} (0.545)>F_{04} (0.349)>F_{03} (0.179)>F_{05} (0.0475) which was significant.

The concentration of Σ_{16} PAHs ($\times10^{-2}$ µg/kg) was as follows F_{03} (4.782)>F_{04} (4.407)>F_{02} (3.714)>F_{05} (3.052)>F_{01} (2.715). The F_{01}, F_{02} and F_{05} were significantly lower than F_{03} and F_{04}.

In Fig. 1, Σ_{16} polycyclic aromatic hydrocarbons ($\times 10^{-2}$ μg/kg) was in the order: L_{05} (5.05)>F_{03} (4.782)>L_{01} (4.573)>L_{03} (4.488)>F_{04} (4.407)>L_{04} (4.018)>F_{02} (3.714)>F_{05} (3.052)>F_{01} (2.715)>L_{02} (2.328).

Figure 2 shows the concentration of LMW PAH, HMW PAH and PAH_4. The LMW PAH ($\times 10^{-2}$ μg/kg), was least in L_{04} (1.6067), L_{02} (1.655) and F_{04} (1.71) while the highest values were found in L_{03} (3.049), L_{01} (2.641), L_{05} (2.513) and F_{02} (2.411). For HMW PAH levels ($\times 10^{-2}$ μg/kg), the highest values were found in F_{03} (2.844), F_{04} (2.697), L_{05} (2.537) and L_{04} (2.4113) while the least values were seen in F_{01} (0.342) and L_{02} (0.673). The PAH_4 ($\times 10^{-2}$ μg/kg) had F_{01} (0.063), L_{02} (0.210) and L_{04} (0.62) with the least values and highest in L_{05} (1.165), F_{02} (1.155) and F_{03} (1.114).

DISCUSSION

The study evaluated the concentration of polycyclic aromatic hydrocarbons (PAHs) in selected local and foreign rice grains sold in Port Harcourt, Nigeria. The concentrations of PAHs in local rice showed that naphthalene was significant in the other L_{01}>L_{02}>L_{04}>L_{03}>L_{05}. Benzo[a]anthracene was as follows L_{03}>L_{05}>L_{02}>L_{04}>L_{01} which was significant except for L_{04} and L_{01} which showed no significant difference. For dibenzo[ah]anthracene and benzo[ghi]perylene L_{04} had the highest concentration while L_{01} and L_{02} had the lowest values respectively which was significant. The concentration of Σ_{16} for local rice had Lo_5 as the brand with the highest concentration and L_{02} with the least value. For the foreign rice grains, 2-methylnaphalene concentration was highest in F_{01}, benzo[a]anthracene in F_{02}, acenaphthylene in F_{03}, fluorene in F_{04} and naphthalene was F_{05}. The concentration of naphthalene was significantly in the order: F_{05}>F_{01}>F_{02}>F_{03}>F_{04}. Anthracene was not significantly different while chrysene value for F_{01}, F_{02} and F_{05} was significantly lower than F_{03} and F_{04}. Benzo[b]fluoranthene concentration was higher in F_{04} and lower in F_{01} which was significant. For dibenzo[ah]anthracene F_{03} was higher and F_{05} was lower which was also significant. The concentration of Σ_{16} PAHs in foreign rice grain was significantly higher in F_{03}, F_{04} and lower in F_{02}, F_{05} and F_{01}. The Σ_{16} polycyclic aromatic hydrocarbons in both local and foreign rice brands were as follows; L_{05}>F_{03}>L_{01}>L_{03}>F_{04}>L_{04}>F_{02}>F_{05}>F_{01}>L_{02}. Furthermore, LMW PAH was least in L_{04} and L_{02} and highest in L_{03}, L_{01}, L_{05} and F_{02}. For HMW PAH levels, the highest values were found in F_{03} and F_{04} while the lowest values were seen in F_{01} and L_{02}. Finally, ΣPAH_4 had F_{01}, L_{02} and L_{04} with the lowest values while the highest values were found in L_{05}, F_{02} and F_{03}.

Polycyclic aromatic hydrocarbons are harmful organic pollutants, many of which have carcinogenic and mutagenic properties that can be released into the environment through a variety of activities, including incomplete combustion of organic materials[9,11]. The PAHs can be low molecular weight (LMW) polycyclic aromatic hydrocarbons, LMW-PAHs or high-molecular-weight, (HMW) polycyclic aromatic hydrocarbons, HMW-PAHs. Polycyclic aromatic hydrocarbons (PAHs) can be classified based on the number of rings they contain. Low molecular weight (LMW) PAHs are those with up to four rings, such as naphthalene, fluorene, acenaphthylene, phenanthrene, acenaphthene and anthracene. On the other hand, high molecular weight (HMW) PAHs consist of more than four rings, including compounds like benzo[b]fluoranthene, dibenzo[a,h]anthracene, fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, indeno[1,2,3-cd]pyrene, pyrene and benzo[g,h,i]perylene[6].

Similarly, the European Commission discovered four significant PAHs (PAH4) in foods which are benzo[a]anthracene (BaA), chrysene (Chr), benzo[b] uoranthene (BbF) and benzo[a]pyrene (BaP)[12].

Polycyclic aromatic hydrocarbon intake has been assessed in several countries with rice, cereals, oils and vegetables, accounting for the majority of dietary contributions, albeit polycyclic aromatic hydrocarbon levels are frequently low in rice[2]. Dietary intake of food contaminants is determined by both the nutritional habit of the analyzed population group and the content of contaminants in the food[2]. Several studies have looked at the levels of PAH contamination in food and the impact of pollution sources[5].

From this study, local rice (three brands) contained more low molecular weight PAHs than foreign rice. This disparity could be attributed to the processing environment which increased the absorption of LMW-PAHs[13,14]. In addition, foreign rice (two brands) had more high molecular weight PAHs than local rice. The HMW-PAHs have a longer environmental persistence due to their low volatility and increased resilience to degradation[15]. The presence of HMW-PAHs in the rice samples might be frightening due to their considerable relationship with cancer through dietary intake[15]. The Σ_{16} PAHs were highest and lowest in local rice, showing no particular preference between the foreign and local rice grains. Also, the PAH4 was in no particular order between the local and foreign rice grains. These inconsistencies can be credited to potential growth surroundings, proximity to industrialized areas, packing and transportation[6]. In comparison to other research, this investigation found a lower level of Σ_{16} PAHs, than the findings of Akan *et al.*[2] and Odika *et al.*[6] but within the range of Choochuay *et al.*[5] findings. It was also lower than the EU standard of 1.0 μg/kg for cereals. Studies have estimated that consuming PAHs above the WHO/FAO threshold in rice may be linked to cancer[16], although this study seemed to be lower. The presence of PAHs in both local and foreign rice shows contamination, since rice is a staple food in Nigeria, continued exposure to even low levels of PAHs may result in accumulative health effects. Thus, it is recommended that regulatory agencies should monitor the safety of these rice whether imported or locally made. Secondly, efforts should be made to reduce PAHs contamination in rice through improved agricultural practices, manufacturing processes and cooking conditions. A limitation of this study is the small sample size.

CONCLUSION

The research on polycyclic aromatic hydrocarbons in selected rice grain sold in Port Harcourt, Nigeria showed that both local and foreign rice contain varying disparities of PAHs. The highest concentration of PHs in rice was Lo_5, followed by Fo_3, while the lowest concentration was found in Lo_2. Overall, these depict that PAHs presence can be found in nearly all the rice samples considered, whether local or foreign, although they were all lower than the permissible limits of 1.0 μg/kg.

SIGNIFICANCE STATEMENT

The increasing evidence of harmful contaminants, particularly polycyclic aromatic hydrocarbons in food, more specifically rice, is further underscored by this research. Indeed, the range of local and foreign rice PAHs contamination in Nigeria, requires the essentiality of food safety surveillance, although the concentrations were lower than the permissible limits. Thus improved safety standards are of importance.

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