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Safety Assessment of the Presence of Heavy Metals and Organic Pollutants in Vended Street Foods from Selected Locations in Lagos State Nigeria

G. I. Oyet[1*] and C. B. Samuel[1]

[1]Department of Food Science and Technology, Rivers State University, Port Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration between the authors. Author GIO designed the study, wrote the protocol and wrote the first draft of the manuscript. Author CBS performed the statistical analysis and the literature searches of the study. Both authors read and approved the final manuscript.

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ABSTRACT

This study was aimed at investigating the presence of heavy metals and volatile organic pollutants in street-vended foods sourced from three selected locations in Lagos State, Nigeria, to ascertain their safety level. The study was carried out using complete randomization design and Cluster sampling technique to source vended street foods from three locations (Marina, Yaba and Apapa). The eight Food products studied were roasted (plantain, fish, yam, corn), suya meat, meat pie, egg roll and doughnuts. Lead, Cadmium, Copper, Mercury, Iron, Zinc and organic pollutants in Foods and particulate matter in Environment were examined. Heavy metals detected in vended street foods from Marina, Yaba and Apapa Lagos were; iron, copper, lead and zinc, at level ranging from 0.14 mg/kg–2.80 mg/kg, 0.08 mg/kg – 0.27 mg/kg, 0.01 mg/kg – 0.18 mg/kg, and 0.01 mg/kg – 0.04 mg/kg, respectively. Mercury and Cadmium were below detectable limit. Significantly ($P<0.05$) higher iron presence of 2.80 mg/kg and 1.99mg/kg were respectively, noticed in suya from Apapa and roasted fish also from Apapa. Significantly ($P<0.05$) higher lead (Pb) content of 0.18 mg/kg was observed in dough nut from Yaba, however, roasted plantain, roasted fish and meat pie all sourced from Yaba gave significantly ($P<0.05$) lower lead content of 0.01mg/kg. The Zinc content of roasted fish, suya and egg roll sourced from Marina, Yaba and Apapa were all significantly

**Corresponding author: Email: gogomaryo@yahoo.com;*

(P<0.05) difference, with particular respect to food type. Higher iron content of 2.80 mg/kg was noticed in suya from Apapa. Volatile organic compounds (TPH, PAHs, Phenol) were observed to be below detectable limit (<0.001 mg/kg) in all the vended street food samples. Particulate matter in air; SPM, PM_1, $PM_{2.5}$, PM_{10} and VOCs ranged from 0.34 – 0.84 mg/m^3, 0.32 – 0.56 mg/m^3, 0.32 – 0.68 mg/m^3, 0.33 – 0.79 mg/m^3 and <0.001 – 0.24 mg/m^3, respectively. PM_1 and PM_{25} from the three locations were not statistically significant (P>0.05). All the vended food samples had lead (Pb) content above the CODEX permissible limit of 0.01 mg/kg. The presence of high lead content in Vended Street food is a major source of occupational health hazards.

Keywords: Heavy metals; organic pollutants; vended street foods; Lagos State.

1. INTRODUCTION

Table-ready foods prepared and sold by street vendors and hawkers at public places for immediate consumption or consumption at a later and shortest possible time without further processing, are generally refered to as vended street foods [1,2,3]. Consumer acceptance for street-vended food is basically due to convenience and uniqueness in flavours. The role of ready-to-eat foods in maintaining the nutritional status of the population cannot be overemphasized [4]. Street food vending provides a livelihood for a large number of workers, it also assures food security and ease of food accessibility for low-income urban populations. Street food vending business requires relatively low capital, hence its popularity among the low-income urban population. Beside the perceived benefit of offering business opportunities for developing entrepreneurs, street food vending is seen to be a major public health risk. It is important to note that street-food vendors are often poor and uneducated and lack basic training and understanding of food safety, food hygiene and best practices in food handling and services. To ensure the safety of street-vended foods and to minimize the risk of food borne disease, government intervention is needed, in terms of standards and regulations, including regular training and enlightenment for street food operators, to ensure that standards for safety and best practices prevails, in line with state food safety requirement. The view that street food vending provides ready employment and some special income especially for women and the low-income urban dwellers, thus performing an important socio-economic role cannot be overemphasized [5]. Report has shown that many urban dwellers, especially the working population obtain a significant portion of their diet from street foods which enhances the street food business in major cities [4]. Exposure of street foods to various contaminants at different stages of processing and vending is common due to ignorant of food handlers and hawkers on basic food safety measures [6].

Prevalent and distribution of pollutants in the environment Is seen to increase due to increase in Industrial and commercial activities, among these are heavy metals and other serious pollutants [1]. One major source of pollution for most vended street foods is vehicular emission [7]. Food toxicity results from contamination of foods with heavy metals, its bioaccumulation and biomagnifications in the food chain [8]. Human exposure to heavy metals has increased dramatically in the last 50 years' as a result of increase in the use of heavy metals in industrial processes and production activities [4]. Heavy metals have been shown to have positive and negative roles in human life [9,10]. As reported earlier by Onianwa et al. [11]. Heavy metals composition of foods is of interest because some are essential while others are toxic in nature. For example, iron, zinc, copper, chromium, cobalt, and manganese are essential, while lead, cadmium, nickel, and mercury are toxic at certain levels. Mineral elements such as iron, zinc and copper are micro nutrients essential for biochemical reactions in the body while cadmium, lead and mercury present as major contaminants of exposed foods and may be seen as the most important problem to our environment [12]. High amount of cadmium and lead in food is associated with a number of diseases especially with cardiovascular, kidney, nervous as well as bone diseases. They have also been implicated in causing carcinogenesis, mutagenesis and teratogenesis [13]. Heavy metals such as copper, manganese, and zinc are associated with non-carcinogenic hazards such as neurologic disorders and liver disease if present in food at concentrations above their safe limit [14]. In a similar study by Itoh et al. [15] reported that consumption of rice and other foods contaminated with cadmium were associated with an increased risk of menopausal breast

cancer. Heavy metals induced toxicity is of public health concern, since food ingestion is the major pathway for human exposure to toxic substances. Therefore, there is the need to monitor their levels in frequently consumed street foods marketed in Nigerian cities.

Industrialization has posited air pollution as one of the greatest risk factors of our times [16,17]. One of the key indicators of the "better life index" in Industrialized countries is the concentration of particulate matter (PM_{10} and $PM_{2.5}$) [18]. The concentration of $PM_{2.5}$, designated by the World Health Organization as group 1 carcinogen, varies depending on the country and region [19,20,21,22].

Volatile organic compounds (VOCs) are organic chemicals that have a high vapor pressure at room temperature [14]. VOCs molecules evaporate or sublimate from the liquid or solid form of its compound and enter the surrounding air, food and surfaces, this is possible due to their high vapour pressure resulting from their low boiling point. For this study, the scope of Volatile Aromatic/Organic Compounds is limited to; total petroleum hydrocarbon (TPH), polycyclic aromatic hydrocarbons (PAHs) and Phenol. These compounds are some of the volatile organic compounds (VOCs) found in petroleum derivatives. VOCs are typically not acutely toxic, but have compounding long-term health effects. Polycyclic aromatic hydrocarbons (PAHs) are considered as potential lung cancer inducing agents [23,24]. VOCs are emitted from both natural (vegetation, specifically rural forested areas, soil microbiota and geological hydrocarbon reservoirs) and anthropogenic (transport sector, industrial solvent use, combustion processes) sources [25,26]. Traffic emission is considered the main source of VOCs in the urban areas [27].

Lagos, been the commercial nerve center of Nigeria is flagged with heavy Industrial and human activities, with consequential increase in demand for table-ready foods. Thus, need to ascertain the safety level of these ready-to-eat foods becomes of utmost necessity, in order to predict possible extents of consumer vulnerability to exposed toxic materials due to inhalation and assimilation. Three locations in Lagos State (Apapa, Yaba and Marina) were selected for this study. Apapa is a Local Government Area in Lagos, located to the west of Lagos Island. Apapa contains a number of ports and terminals operated by the Nigerian Ports Authority (NPA), including the major port of Lagos State and Lagos Port Complex, [28], Apapa been the major commercial district of Lagos is high in vehicular traffic. The Location of the study site was around clusters of Oil and Gas depots and plants, dealing on refined petroleum products.

Yaba is a suburb located on Lagos Mainland. It is home to several Federal Government Institutions ; Queen's College, the Nigerian Institute of Medical Research, the Yaba College of Technology, Igbobi College, the University of Lagos, the Federal Science and Technical College, and the Federal College of Education. Yaba is home to the major Market centre in Lagos Metropolis. Marina is a district in Lagos Island *Ìsàlẹ̀ Èkó*. It is the principal and central local government area (LGA) in Lagos State. It is part of the Lagos Division. Lagos Island plays host to the main government buildings, shops and offices and high commercial activities. This study is aimed at investigating the presence of heavy metals and volatile organic pollutants in street-vended foods commonly eaten in Lagos, Nigeria, to ascertain their safety level.

2. MATERIALS AND METHODS

2.1 Study Area

Lagos is a city State in Nigeria, located between the latitudes of 6°27'55.5192" N and longitudes 3°24'23.2128" E in the South Western Nigeria. The Study was conducted in some selected parts of Lagos State, along the following sampling clusters: Marina, Yaba and Apapa.

2.2 Methods

2.2.1 Experimental design

The study was carried out using complete randomization design. Cluster sampling technique was used to source the food samples from Marina, Yaba and Apapa, taking the three locations as clusters

2.2.2 Sample collection

Eight food samples (roasted plantain, roasted yam, roasted fish, roasted corn, suya meat, meat pie, egg roll and dough nut) each were purchased from the 3 (three) locations in Lagos (8x3) making a total of 24 food samples. The food samples were wrapped with aluminium foil paper and transported in an iced cooler to the laboratory. The choice of the samples was

carefully made to reflect the most consumed ready-to-eat street-vended foods in Lagos. The samples were stored at 4°C prior to analysis.

2.2.3 Heavy metal content

The heavy metals determined were; Iron, copper, mercury, cadmium, lead and zinc, using Atomic Absorption Spectroscopy (AAS-210 VGP, Buck Scientific), according to the methods of AOAC [29].

2.2.4 VOCs analysis in street vended food samples

Volatile Organic Compounds (total petroleum hydrocarbon, polycyclic aromatic hydrocarbon and phenol) were determined using Gas Chromatography-Mass Spectrometer (GC-MS) ASTM D5790 - 95 according to the methods of APHA [30].

2.2.5 Particulate matter in ambient air

An aerostat SPM 531 particle a met -1 aerosol mass monitor was used to measure respirable particulate and total suspended particles. Measurements from this instrument was periodically verified and calibrated using data from gravimetric instrumentation [31].

2.3 Data Analysis

All experiments and analysis were carried out in triplicates, mean and standard deviations values were calculated. Data were subjected to Analysis of Variance (ANOVA), Means were separated using Tukey's multiple comparison test, and significance accepted at $p \leq 0.05$ level. The statistical package in Minitab 16 computer program was used.

3. RESULTS AND DISCUSSION

The study was intended to examine the food safety implications of the presence of heavy metals and organic pollutants in Ready- to- eat street foods in parts of Lagos State.

3.1 Heavy Metal Content of Vended Street Foods Sourced from Three Locations in Lagos, Nigeria

Heavy metals detected in vended street foods from Marina, Yaba and Apapa Lagos were; iron, copper, lead and Zinc, at level ranging from 0.14 mg/kg – 2.80 mg/kg, 0.08 mg/kg – 0.27 mg/kg, 0.01 mg/kg–0.18 mg/kg and 0.01 mg/kg – 0.04 mg/kg, respectively. The trend of heavy metals contamination in the street food samples decreased in the following order: Fe > Cu > Pb > Zn. Iron, zinc and copper are micro nutrients and essential for biochemical reactions in the body [32], however, concentrations above their safe levels is a risk factor for non-carcinogenic hazards such as liver disease and other neurologic disorders [33]. Lead was the major contaminant of the food samples, with critical health concern. Mercury and Cadmium were observed to be below the detectable limit, this was a plus to street-vended foods sourced from Marina, Yaba and Apapa, as Cadmium is a probable human carcinogen [34]. High exposure to cadmium has been shown to cause a wide range of diseases, including, anemia, skeletal weakness, heart disease, depressed immune system response as well as liver and kidney disease [35]. Significantly ($P<0.05$) higher iron presence of 2.80mg/kg and 1.99mg/kg were respectively, noticed in suya meat from Apapa and roasted fish also from Apapa. The high Iron content may be from the source of water used in food material cleaning and processing, as the water in most part of Lagos State is high in Iron content. This is in collaboration with the study by WHO [36]. That the highest individual value (13.5 mg/l) was measured in a borehole sample from Hydrological Area 6- Lagos. These was followed by 1.86 mg/kg and 1.84 mg/kg of iron observed in egg roll and roasted yam, both from Marina Lagos. Significantly ($P<0.05$) higher lead (Pb) content of 0.18mg/kg was observed in dough nut from Yaba, however, roasted plantain, roasted fish and meat pie all sourced from Yaba gave significantly ($P<0.05$) lower lead content of 0.01 mg/kg. Lead content of 0.01 – 0.17 mg/kg seen in roasted plantain from the three locations were higher than <0.001 mg/kg reported by earlier researchers for roasted plantain from Port Harcourt [37, 38]. High Pb content of dough nut from Yaba and roasted plantain from Marina (0.17 mg/kg) is probably due to high vehicular traffic around the locations. Lead content of roasted plantain (0.17 mg/kg), dough nut (0.18 mg/kg) and meat pie (0.06 mg/kg) were lower compared to 0.31 mg/kg, 0.21 mg/kg and 0.24 mg/kg for roasted plantain, dough nut and meat pie sourced from Benin and Emunede express way, Mid- western Nigeria [39]. Emission from vehicles contributed to pollutant release to the surrounding and thus, affect the street food [40]. High exposure of Pb is associated with health damages such as anaemia, weight loss and depression [41] Lead can adversely affect kidney function, immune system, the nervous system,

reproductive and developmental systems including the cardiovascular system [37]. All the vended food samples had lead (Pb) content above the CODEX permissible limit of 0.01 mg/kg [42] except roasted plantain from Yaba, roasted Yam from Yaba and Meat Pie also sourced from Yaba. As shown in Table 1, 37.5% of the street-vended foods from Apapa and Marina had Pb content above the USEPA permissible limit of 0.05 mg/kg [14] These values were higher than the Pb values (<0.001 mg/kg) reported by Oyet et al. [37] in street-vended food samples from three locations in Port Harcourt. High concentration of Pb in foods from Apapa and Marina is probably due to high vehicular movement and Industrial activities within those locations. High concentration of Pb in the body can cause anaemia, irreversible brain damage (encephalopathy), coma and death if not treated immediately [43]. Long-term system exposure can cause damage to the kidneys and reproductive and immune system. Children are shown to absorb Pb easily making them more vulnerable than adults to Pb toxicity. A low blood lead level can affect the intellectual development or IQ of young children [44]. Pb levels in vended street foods over permissible limits are implicated in chronic lead toxicity resulting in anemia, abdominal pain and renal damage [34]. Lead is reported as an immunosuppressive agent in human and other animals. Lead, which is proven to be a serious cumulative body poison enters into the body system through air, water and food and cannot be removed by washing. The high levels of Pb in some plants due to pollutants in irrigation water, farm soil and pollution from the highways traffic had earlier been reported by Sobukola et al.,[32]. Significantly higher zinc content of 0.04mg/kg was noticed in roasted plantain, roasted fish and dough nut from Marina. The Zinc content of roasted fish, suya meat and egg roll sourced from Marina, Yaba and Apapa were all significantly (P<0.05) difference, with particular respect to food type. This is an indication that metal distribution in vended street food is affected significantly by location. Zinc is a ubiquitous metal present in the environment, Zinc is an essential trace element; the requirement for zinc changes throughout life and health effects associated with zinc deficiency are numerous. In human, acute level of zinc is associated with vomiting and gastrointestinal irritation such as; nausea, cramps and diarrhea. However, these health conditions present less when bound to food components (i.e. meat, sea foods). Zn contamination in food also impaired copper utilization [45].

Table 1. Experimental design: Locations and food samples

MARINA	YABA	APAPA
RPM	RPY	RPA
RYM	RYY	RYA
SMM	SMY	SMA
MPM	MPY	MPA
RCM	RCY	RCA
ERM	ERY	DN3
DNM	DNY	DNA
RFM	RFY	RFA

Legends: RPM = roasted plantain from Marina, RPY = roasted plantain from Yaba, RPA = roasted plantain from Apapa, RFM = roasted fish from Marina, RFY = roasted fish from Yaba, RFA= roasted fish from Apapa, RYM = roasted yam from Marina, RYY = roasted yam from Yaba, RYA = roasted yam from Apapa, SMM = suya meat from Marina, SMY = suya meat from Yaba, SMA = suya meat from Apapa, MPM = meat pie from Marina, MPY = meat pie from Yaba, MPA = meat pie from Apapa, RCM = roasted corn from Marina, RCY = roasted corn from Yaba, RCA = roasted corn from Apapa, ERM=egg roll from marina, ERY= egg roll from Yaba, ERA= egg roll from Apapa, DNM= dough nut from Marina, DNY= dough nut from Yaba, DNA= dough nut from Apapa

All the street- vended food samples examined had Zn content below the CODEX maximum limit of contaminants (MLC) of 1 mg/kg [45]. Significantly (P<0.05) higher iron content of 2.80 mg/kg was noticed in suya meat from Apapa (SMA), this value was significantly higher than 0.56 mg/kg observed in suya meat from Marina and Yaba. Iron content of the vended street foods were all within CODEX safety limit (<2.5 mg/kg). Excess iron intake may result in siderosis (deposition of iron in tissue) in liver, pancreas, adrenals, thyroid, pituitary and heart depending on the chemical form. Haemochromatosis patients suffer from liver cirrhosis, adrenal insufficiency, heart failure or diabetes [45].

3.2 Volatile Organic Compounds/ Pollutants Present in Ready-To-Eat Street Foods Sourced from Three Locations in Lagos, Nigeria

Volatile organic compounds (TPH, PAHs, Phenol) were observed to be below detectable limit (<0.001 mg/kg) in all the vended street food samples sourced from Marina, Yaba and Apapa. VOCs, though noticed in ambient air studied were not detected in vended food samples within the same locality. This observation agreed with the report of Oyet et al. [27], on ready-to-eat

street-vended foods from Port Harcourt Metropolis. Volatile organic compounds (VOCs) are organic chemicals that have a high vapor pressure at ordinary room temperature [14]. Large number of VOCs molecules evaporate or sublimate from the liquid or solid form of its compound and enter the surrounding air, food and surfaces, this is possible due to their high vapour pressure resulting from their low boiling point, such that volatile organic compounds can be converted into vapour or gas without any chemical change [27]. Volatile organic compounds are numerous, varied, and ubiquitous, they are typically not acutely toxic, but have compounding long-term health effects. Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous environmental pollutants generated primarily during the incomplete combustion of organic materials such as coal, oil, petrol, and wood. Benzo (a) pyrene, is the most carcinogenic PAH, with its maximum contaminant level (MCL) set at 0.2 ppb [14]. Total Petroleum Hydrocarbons (TPH) is a term used to describe a broad family of several hundred chemical compounds that come originally from crude oil [46]. Many of these products have characteristic gasoline, kerosene and greasy odours. Because modern society uses so many petroleum-based products (for example, gasoline, kerosene, fuel oil, mineral oil, grease, wax and asphalt), Risk of environmental pollution by these contaminants is high. Contamination caused by petroleum products will invariably contain a variety of these volatile organic pollutants. Because there are so many, it is not usually practical to measure each

Table 2. Heavy metal content of ready-to-eat street foods sourced from three locations in Lagos, Nigeria

Samples	Iron (mg/kg)	Copper (mg/kg)	Mercury (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)
RPM	0.14^{v}±0.000	0.10^{lm}±0.000	<0.001	<0.001	0.17^{b}±0.000	0.04^{a}±0.000
RPY	0.75^{n}±0.000	0.11^{k}±0.000	<0.001	<0.001	0.01^{p}±0.000	0.02^{c}±0.000
RPA	0.78^{m}±0.000	0.13^{f}±0.000	<0.001	<0.001	0.05^{j}±0.000	0.02^{c}±0.000
RFM	0.87^{l}±0.000	0.10^{n}±0.000	<0.001	<0.001	0.03^{m}±0.000	0.04^{a}±0.000
RFY	1.10^{h}±0.000	0.12^{ij}±0.000	<0.001	<0.001	0.01^{p}±0.000	0.01^{d}±0.000
RFA	1.99^{b}±0.000	0.12^{ij}±0.000	<0.001	<0.001	0.06^{i}±0.000	0.02^{h}±0.000
RYM	1.84^{d}±0.000	0.27^{a}±0.001	<0.001	<0.001	0.07^{g}±0.000	0.03^{b}±0.000
RYY	0.32^{u}±0.000	0.22^{b}±0.001	<0.001	<0.001	0.02^{n}±0.000	0.03^{b}±0.000
RYA	0.89^{k}±0.001	0.20^{c}±0.002	<0.001	<0.001	0.05^{j}±0.000	0.02^{c}±0.000
SMM	0.56^{s}±0.001	0.13^{g}±0.001	<0.001	<0.001	0.04^{l}±0.000	0.03^{b}±0.000
SMY	0.56^{s}±0.001	0.12^{h}±0.000	<0.001	<0.001	0.02^{n}±0.000	0.04^{a}±0.000
SMA	2.80^{a}±0.000	0.13^{g}±0.001	<0.001	<0.001	0.15^{c}±0.001	0.02^{c}±0.000
MPM	0.73^{o}±0.000	0.12^{h}±0.000	<0.001	<0.001	0.04^{k}±0.001	0.02^{c}±0.000
MPY	1.58^{g}±0.000	0.14^{e}±0.001	<0.001	<0.001	0.01^{p}±0.002	0.03^{b}±0.000
MPA	0.91^{i}±0.000	0.10^{c}±0.000	<0.001	<0.001	0.06^{h}±0.001	0.03^{b}±0.001
RCM	0.69^{p}±0.000	0.14^{d}±0.000	<0.001	<0.001	0.12^{d}±0.001	0.02^{c}±0.001
RCY	0.69^{p}±0.000	0.11^{k}±0.000	<0.001	<0.001	0.02^{o}±0.001	0.03^{b}±0.001
RCA	0.90^{j}±0.000	0.12^{i}±0.000	<0.001	<0.001	0.06^{i}±0.000	0.03^{b}±0.001
ERM	1.86^{c}±0.000	0.13^{e}±0.000	<0.001	<0.001	0.07^{g}±0.000	0.02^{c}±0.001
ERY	1.81^{e}±0.000	0.13^{g}±0.000	<0.001	<0.001	0.08^{e}±0.000	0.03^{b}±0.001
ERA	1.75^{f}±0.000	0.11^{j}±0.000	<0.001	<0.001	0.08^{f}±0.000	0.01^{d}±0.001
DNM	0.66^{r}±0.000	0.14^{d}±0.000	<0.001	<0.001	0.07^{g}±0.000	0.04^{a}±0.001
DNY	0.68^{q}±0.000	0.10^{m}±0.001	<0.001	<0.001	0.18^{a}±0.000	0.03^{b}±0.001
DNA	0.46^{t}±0.000	0.08^{o}±0.001	<0.001	<0.001	0.02n±0.000	0.03^{b}±0.001

Values are means ± standard deviation of triplicate samples, Mean values bearing different superscript in the same column differ significantly (P<0.05). Key: RPM = roasted plantain from Marina, RPY = roasted plantain from Yaba, RPA = roasted plantain from Apapa, RFM = roasted fish from Marina, RFY = roasted fish from Yaba, RFA= roasted fish from Apapa, RYM = roasted yam from Marina, RYY = roasted yam from Yaba, RYA = roasted yam from Apapa, SMM = suya meat from Marina, SMY = suya meat from Yaba, SMM = suya meat from Apapa, MPM = meat pie from Marina , MPY = meat pie from Yaba, MPA = meat pie from Apapa, RCM = roasted corn from Marina, RCY = roasted corn from Yaba, RCA = roasted corn from Apapa, ERM=egg roll from marina, ERY= egg roll from Yaba, ERA= egg roll from Apapa, DNM= dough nut from Marina, DNY= dough nut from Yaba, DNA= dough nut from Apapa

one individually. However, it is useful to measure the total amount of all hydrocarbons found together in a particular sample, which could be; soil, water, food or air. The amount of TPH distribution in a sample gives an indication of the level of petroleum contamination at that location [46]. Phenols are crystalline, volatile aromatic organic compounds, with molecule consisting of a phenyl group bonded to a hydroxy group [47]. Phenol and its vapours are shown to be corrosive to the eyes, skin, and the respiratory tract [48]. Its corrosive effect on skin and mucous membranes is due to a protein-degenerating effect. Phenol vapour if inhaled may cause lung disease (oedema) [48]. Phenolic substances may cause harmful effects on the heart and the central nervous system, resulting in seizures, and coma and to some extent, kidney failure [49]. Studies, have demonstrated that phenolic compounds in foods possess positive attributes such as anticarcinogenesis, antioxidant potential, antiviral activity, antimicrobial activity, and antimutagenic activity. However, other studies have shown that the same phenolic have negative attributes such as carcinogenic activity and antinutritional activity, as well as imparting negative attributes to foods [50].

3.3 Suspended Particulate Matters and Volatile Organic Content of Ambient Air from Three Locations in Lagos, Nigeria

Result for Suspended Particulate Matters and Volatile Organic content of Ambient Air from Marina, Yaba and Apapa is shown in Table 3. SPM, PM_1, $PM_{2.5}$, PM_{10} and VOCs ranged from 0.34 – 0.84 mg/m^3, 0.32 – 0.56 mg/m^3, 0.32 – 0.68 mg/m^3, 0.33 – 0.79 mg/m^3 and 0 – 0.24 mg/m^3, respectively. Differences in PM_1 and $PM_{2.5}$ from the three locations were not statistically significant (P>0.05). Suspended

Table 3. Organic compounds/pollutants

Samples	TPH (mg/kg)	PAHs (mg/kg)	Phenol (mg/kg)
RPM	<0.001	<0.001	<0.001
RPY	<0.001	<0.001	<0.001
RPA	<0.001	<0.001	<0.001
RFM	<0.001	<0.001	<0.001
RFY	<0.001	<0.001	<0.001
RFA	<0.001	<0.001	<0.001
RYM	<0.001	<0.001	<0.001
RYY	<0.001	<0.001	<0.001
RYA	<0.001	<0.001	<0.001
SMM	<0.001	<0.001	<0.001
SMY	<0.001	<0.001	<0.001
SYA	<0.001	<0.001	<0.001
MPM	<0.001	<0.001	<0.001
MPY	<0.001	<0.001	<0.001
MPA	<0.001	<0.001	<0.001
RCM	<0.001	<0.001	<0.001
RCY	<0.001	<0.001	<0.001
RCA	<0.001	<0.001	<0.001
ERM	<0.001	<0.001	<0.001
ERY	<0.001	<0.001	<0.001
ERA	<0.001	<0.001	<0.001
DNM	<0.001	<0.001	<0.001
DNY	<0.001	<0.001	<0.001
DNA	<0.001	<0.001	<0.001

Key: TPH = total petroleum hydrocarbon. PAHs = polycyclic aromatic hydrocarbons, RPM = roasted plantain from Marina, RPY = roasted plantain from Yaba, RPA = roasted plantain from Apapa, RFM = roasted fish from Marina, RFY = roasted fish from Yaba, RFA= roasted fish from Apapa, RYM = roasted yam from Marina, RYY = roasted yam from Yaba, RYA = roasted yam from Apapa, SMM = suya meat from Marina, SMY = suya meat from Yaba, SMM = suya meat from Apapa, MPM = meat pie from Marina , MPY = meat pie from Yaba, MPA = meat pie from Apapa, RCM = roasted corn from Marina, RCY = roasted corn from Yaba, RCA = roasted corn from Apapa, ERM=egg roll from marina, ERY= egg roll from Yaba, ERA= egg roll from Apapa, DNM= dough nut from Marina, DNY= dough nut from Yaba, DNA= dough nut from Apapa

Table 4. Particulate matters and volatile organic contents

Location	SPM (mg/m^3)	PM_1 (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_{10} (mg/m^3)	VOCs (mg/m^3)
Marina	0.84^{a}±0.255	0.52^{a}±0.307	0.68^{a}±0.255	0.79^{a}±0.241	0.24^{a}±0.004
Yaba	0.34^{b}±0.029	0.32^{a}±0.029	0.32^{a}±0.029	0.33^{b}±0.027	0.00^{c}±0.000
Apapa	0.59^{ab}±0.386	0.56^{a}±0.386	0.57^{a}±0.385	0.59^{ab}±0.388	0.07^{b}±0.005

Values are means ± standard deviation of triplicate samples, Mean values bearing different superscript in the same column differ significantly (P<0.05)

particulate matter (SPM) and coarse particulate matter (PM_{10}) detected at Yaba location were significantly (P<0.05) lower than those of Marina location, but not significantly difference (P>0.05) from those of Apapa location. Volatile organic compounds (VOCs) in ambient air at Yaba location was below detectable limit. VOCs in ambient air at Marina location (0.24 mg/m^3) was significantly (P<0.05) higher than 0.07 mg/m^3 detected at Yaba location. Particulate matter (PM) is the sum of all solid and liquid particles suspended in air many of which are hazardous. This complex mixture includes both organic and inorganic particles, such as dust, pollen, soot, smoke, heavy metals and liquid droplets. These particles vary greatly in size, composition, and origin. Particulate matters are widespread air pollutant that consist of a mixture of solid and liquid particles suspended in air and groundwater [51,52]. The concentration, density and distribution depend on the mass composition of the particulate matter [53]. Toxicity effect of PM on human health depends on its nature and level of spread [54]. The physical and compositional characteristics of particulate matter in ambient air is location dependent [55,56,57,58]. Sulphates, nitrates and ammonium are common chemical constituents of particulate matters [59]. Other constituents are inorganic ions such as ions of Calcium, Chlorine, Potassium, Magnesium and sodium; organic and elemental carbon; crustal material; particle-bound vapour; heavy metals such as Cadmium, Copper, Nickel, Iron and Zinc; and polycyclic aromatic hydrocarbons (PAH) [60,61,62]. It should be noted that even if concentration of Particulate matter in air is relatively low, there is a possibility that heavy metals may accumulate in street-vended foods beyond safe levels if exposure time is extended [63].

4. CONCLUSION

Lead was observed to be the major contaminant of street-vended foods from Marina, Yaba and Apapa in Lagos State, this is of critical health concern. Mercury and Cadmium were below detectable limit in food samples from all the locations, this was a plus to street-vended foods sourced from Marina, Yaba and Apapa, as Cadmium is a probable human carcinogen. All the street-vended food samples had lead (Pb) content above the CODEX permissible limit of 0.01 mg/kg, except roasted plantain from Yaba, roasted Yam from Yaba and Meat Pie also sourced from Yaba. Also, 37.5% of the street-vended foods from Apapa and Marina had Pb content above the USEPA permissible limit of 0.05 mg/kg. High concentration of Pb in ready-to-eat foods from Apapa and Marina is probably due to high vehicular movement and Industrial activities within those locations. The result showed that metal distribution in vended street food is affected significantly by location. All the street- vended food samples studied had Zn content below the CODEX maximum limit of contaminants (MLC) of 1 mg/kg. Iron content of the vended street foods were all within CODEX safety limit (<2.5 mg/kg). VOCs, though noticed in ambient air, were not detected in the vended street foods. Low particulate matter distribution in ambient air at Yaba location is probably responsible for the relatively low heavy metal content of vended street foods sourced from Yaba. Further work on the comprehensive outdoor air quality and street food quality in Lagos State to serve as a protection to public health and consumer interest is highly recommended.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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