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Research Article

Microbiological Quality and Potential Exposure to Aflatoxins from Consumption of Street-Vended Snacks in Lagos

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Abstract

Background and Objective: Snacks may be contaminated with various kinds of bacteria species and this is common with street vended foods. This study was carried out to determine the microbiological quality and potential exposure to aflatoxins from consumption of selected street-vended snacks in the Lagos metropolis. **Materials and Methods:** Twenty samples each of groundnut, *kuli-kuli* (groundnut cake), popcorn and chin-chin, making eighty samples, were collected from five areas in Lagos: Surulere, Oshodi, Iyana-Ipaja, Ojota and Festac. The samples were evaluated for bacteria load, fungi (yeast/mold) load and aflatoxins using standard methods. The data were analyzed statistically using Statistical Package for Social Sciences (SPSS) version 20. **Results:** Bacteria and fungi loads were lower than the regulatory limit. The level of total aflatoxin was highest (37.75 μg kg^{-1}) in *kuli-kuli*, followed by groundnut (21.24 μg kg^{-1}), chin-chin (3.88 μg kg^{-1}) and lowest in popcorn (0.45 μg kg^{-1}). The levels in *kuli-kuli* and groundnut were higher than the maximum permissible limit (15 μg kg^{-1}). Dietary exposure to aflatoxins ranged from 0.23 to 116.4 ng/kg-b.wt./day, which was higher than the permissible exposure level. The margin of exposure ranged from 1.5 to 378 in children and from 4.3 to 739.1 in adults, which were lower than the benchmark dose lower limit (BMDL) of 10,000, indicating high public health concerns. **Conclusion:** Higher levels of total aflatoxins than the maximum permissible limits in the studied samples call for public health concerns considering the level of exposure.

Key words: Total bacterial count, fungi, aflatoxins, groundnut, popcorn, chin-chin, (*kuli-kuli*), dietary exposure

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Snacks are smaller foods usually taken between meals and are found in various forms: Some are packaged and some are not. The grade and quality of snacks depends on the level of preparation /processing and the type of packaging. Though the general idea is that they are usually consumed in smaller quantities between meals, in Nigeria and some other African countries[1], street snacks constitute a major meal for some folks because they are cheap and readily available. The street-vendor snacks that are common in Nigeria include biscuits, sandwiches, popcorn, groundnut, groundnut cake (*kuli-kuli*), chin-chin (made of flour without yeast), cake, meat pie, sausage rolls, doughnuts, peanuts, etc. Children of school age have a special interest in consuming *kuli-kuli* and some adults also do[2]. Some of these snacks are prepared either on the street, in shops, kiosks, factories, motor parks, or schools. They are consumed by people without minding the process of preparation, place of preparation, packaging methods and safety levels. In addition to the fact that the vendors of these categories of food lack the required knowledge about good hygiene, the foods are usually prepared and sold in outdoor environments-predisposing them to microbial contamination, this has been reported to be a common practice in low- and middle-income countries[1]. In other words, the activities of the street-vended foods are highly informal, lack official data and are largely unregulated.

Generally, the sources of food contamination may be from raw food materials[3] or through improper handling including exposure to contaminants by the roadside[4]. Most often, groundnut cakes (*kuli-kuli*) are not packaged. They are displayed openly on trays by the roadside and may therefore be prone to the accumulation of dust, development of fungi and microbial and heavy metal contamination. Due to a low standard of preparation, improper or faulty packaging and shorter shelf life, popcorn and chin-chin are also prone to contamination.

Food contaminants are harmful substances (microbes or chemicals) present in food, they are from natural sources, environmental pollution, or formed during food processing. Bacteria and molds are examples of such microorganisms. They are multicellular fungi and like many fungi, they are major spoilage organisms of foods or raw materials of food products[5]. Molds produce secondary metabolites called mycotoxins. These include aflatoxins, ochratoxin, citrinin, ergot, patulin and fusarium. Aflatoxin B1 (AFB1), B2 (AFB2), G1 (AFG1) and G2 (AFG2) are naturally occurring forms of aflatoxins and are usually produced by *Aspergillus* (*A. flavus* and *A. parasiticus*)[6]. Some toxigenic molds affect maize, wheat, barley, oats, rice and groundnuts[7].

Mycotoxins are of public health concern because they cause a condition known as mycotoxicoses[8] and adverse health effects like cancer and nerve defects[9,10]. They are often found in improperly stored foods or food ingredients.

Studies have shown that snacks may also be contaminated with various kinds of bacteria species[11,12] and this is common with street vended foods[13]. Similar observations have been made for heavy metals contamination of snacks or street vended-foods[14-16].

Among the street vended snacks, groundnut, *kuli-kuli*, popcorn and chin-chin are very common and consumed by both children and adults. This study therefore aimed to assess them for microbial and aflatoxin contamination and potential human exposure. The study was carried out from the month of January to June, 2018.

MATERIALS AND METHODS

Study area: The study was carried out at the Bells University of Technology, Ota, Nigeria. The samples were collected from locations in Lagos, Nigeria.

Sample collection: Four samples each of groundnut, *kuli-kuli* (groundnut cake), chin-chin and popcorn were collected from roadside vendors in selected locations in Lagos, Nigeria, making 20 samples each and a total of 80 samples. The selected locations were Surulere (Latitude, N 6°30'0.0000", Longitude, E 3°21'0.0000"), Oshodi (Latitude, N 6°33.2378', Longitude, E 3°20.1824'), Iyana-Ipaja (Latitude, N 6°36.6026', Longitude, E 3°17.3645'), Ojota (Latitude, N 6°34.7386', Longitude, E 3°23.1252') and Festac (Latitude, N 6°27.9867' and Longitude, E 3°17.0108'). The sample codes were presented in Table 1.

Precautions were taken during the collection of snacks, preservation and transport to the laboratory to ensure that the qualities between the collection points and laboratory identification and isolation of the pathogenic microorganisms were not altered. The microbial and aflatoxin analysis were carried out using AOAC standard procedures (AOAC 999:07) method (2016, 20th edition).

Determination of micro-organisms in the samples: Ten gram of each sample was added to ninety mL buffer peptone water and vortexed. One mL of each dilution was transferred into disposable petri-dishes in duplicates. Twenty mL nutrient agar maintained at 48+1°C was added into the duplicate plates. Potato dextrose agar (PDA) was added for yeast and mold (5 days at 25°C), plate count agar (PCA) for aerobic mesophilic plate counts (72 hrs at 30°C).

Table 1: Sample codes and description

Samples codes	Description
SAG	Surulere Area Groundnut
FAG	Festac Area Groundnut
IAG	Iyana-Ipaja Area Groundnut
OAG	Oshodi Area Groundnut
OJAG	Ojota Area Groundnut
SAK	Surulere Area *kuli-kuli*
FAK	Festac Area *kuli-kuli*
IAK	Iyana-Ipaja Area *kuli-kuli*
OAK	Oshodi Area *kuli-kuli*
OJAK	Ojota Area *kuli-kuli*
SAP	Surulere Area popcorn
FAP	Festac Area popcorn
IAP	Iyana-Ipaja Area popcorn
OAP	Oshodi Area popcorn
OJAP	Ojota Area popcorn
SAC	Surulere Area chin-chin
FAC	Festac Area chin-chin
IAC	Iyana-Ipaja Area chin-chin
OAC	Ojota Area chin-chin
OJAC	Ojota Area chin-chin

Estimation of aflatoxins in the samples: The analysis was carried out as described by the procedure for the determination of total aflatoxins in cereal in the AOAC 999:07 method (2016, 20th edition) using High Performance Liquid Chromatography (HPLC). Each sample was processed for the determination of total aflatoxins.

One hundred and fifty mL of methanol water (80:20) was added to 25 g of homogenous sample. The mixture was blended for 3 min using warring blender (Model HGB2WT, by Warring Commercial, USA). Filtration was carried out using pre-folded filter paper. The 10 mL filtrate was added to 60 mL of PBS. For clean-up, 50 mL of immune-affinity clean-up was used. The 10 mL of de-ionized water was used to wash twice, while elution was done with 500 µL and 750 µL after 1 min using lichrosome methanol. The elute was made up to mark in a 5 mL volumetric flask. The 200 µL was injected into the HPLC system (Model DIONEX ULTIMATE 3000, by Thermo Scientific, USA). The HPLC system was equipped with an auto sampler and a fluorescence detector with excitation and emission wavelength of 360 and 420 nm, respectively.

Risk assessment of aflatoxins: The US EPA human health risk models reported by Ekhator *et al.*[16] and calculation procedure reported by Ali and Watt[17] and Knowledge Platform[6] were adopted for the risk assessment in this study.

Dietary exposure (DE):

$$DE = \frac{C_{af} \times D_a}{BW_{av}} \quad (1)$$

where, C_{af} is the contamination level of aflatoxin in food (ng g^{-1}), D_a is the daily amount of the street-vended snack consumed (g/day) and BW_{av} is average body weight in kg (kg-b.wt.). For this study, the average body weight of 70 kg was assumed for adults and 24 kg for children)[16]. Generally, the street-vended *kuli-kuli*, groundnut, chin-chin and popcorn are packaged in approximately 74, 41, 79 and 35 g, respectively. Each of this is sold for N50 and the weight is used for the calculation as the daily amount consumed per person in this study.

Margins of exposure (MoE): Since aflatoxins are both genotoxic and carcinogenic, the risk assessment will involve margins of exposure (MoE) and a value below 10,000 is considered to be a health concern[6]. The MoE is given by the ratio between a toxicological threshold (e.g. Benchmark Dose Lower Limit [BMDL]) and dietary exposure (DE) in an individual. For aflatoxins, 170 ng/kg b.wt./day is the recommended BMDL[6]:

$$MoE = \frac{BMDL}{DE} \quad (2)$$

Probable daily intake (PDI): For an individual who consumes all the street-vended snacks studied, a probable daily intake (PDI) in µg/kg-b.wt./day) is calculated as:

$$PDI = ED_k + ED_g + ED_c + ED_p \quad (3)$$

where, k is *kuli-kuli*, g: Groundnut, c: Chin-chin and p: Popcorn.

Statistical analysis: The statistical analysis was done using Statistical Package for Social Sciences (SPSS) version 20.

RESULTS

Total bacterial count: As presented in Table 2, the total bacterial count in the samples showed a minimum mean of 1.25 CFU $g^{-1} \times 10^1$ in popcorn from Oshodi Area (OAP) and a maximum of 28 CFU $g^{-1} \times 10^1$ in *kuli-kuli* from Ojota Area (OJAK). All the *kuli-kuli* samples except some from Festac Area showed significant total bacterial count compared with the others and for groundnut and chin-chin samples, only some from Festac and Oshodi showed none-detected. Among the four different snacks (*kuli-kuli*, groundnut, chin-chin and popcorn), popcorn samples showed more of the none-detected. The mean ranged from 3.25-22 CFU $g^{-1} \times 10^1$ for groundnut, 7.5-28 CFU $g^{-1} \times 10^1$, *kuli-kuli*, 2-21.5 CFU $g^{-1} \times 10^1$, popcorn and 7-22.5 CFU $g^{-1} \times 10^1$, chin-chin. Generally, the

Table 2: Total bacteria count (CFU $g^{-1} \times 10^1$)

Samples	N	Minimum	Maximum	Mean (±Std. Deviation)
SAG	4	4	17	9.75±5.38
FAG	4	ND	36	9±18
IAG	4	6	18	11.5±5
OAG	4	ND	13	3.25±6.5
OJAG	4	10	44	22±15.06
SAK	4	5	9	7.5±1.91
FAK	4	ND	52	13±26
IAK	4	8	22	15±6.22
OAK	4	10	21	15.25±5.56
OJAK	4	22	38	28±7.12
SAP	4	3	11	6.25±3.40
FAP	4	ND	8	2±4
IAP	4	ND	32	14±13.37
OAP	4	ND	5	1.25±2.5
OJAP	4	15	34	21.5±8.50
SAC	4	3	11	7±3.27
FAC	4	ND	28	7±14
IAC	4	12	46	22±16.08
OAC	4	ND	10.5	2.63±5.25
OJAC	4	14	36	22.5±9.98

ND: None detected

Table 3: Levels (CFU $g^{-1} \times 10^1$) of total bacterial count in the selected four snacks

Snacks	N	Minimum	Maximum	Mean (±Std. Deviation)
Groundnut	20	0	44	11.1±11.89
Kuli-kuli	20	0	52	15.75±13.19
Popcorn	20	0	34	9±10.38
Chin-chin	20	0	46	12.23±12.92

Table 4: Yeast/mold count (CFU $g^{-1} \times 10^1$)

Samples	N	Minimum	Maximum	Mean (±Std. Deviation)
SAG	4	3	7	4.25±1.89
FAG	4	ND	33	18.75±14.57
IAG	4	ND	9	5.25±3.86
OAG	4	3	13	7.25±4.65
OJAG	4	2	8	3.5±3
SAK	4	3	6	3.75±1.5
FAK	4	3	45	17.5±18.79
IAK	4	5	12	7.5±3.11
OAK	4	ND	17	9.25±7.41
OJAK	4	4	9	6.75±2.22
SAP	4	3	9	4.5±3
FAP	4	9	19	13.25±4.35
IAP	4	5	16	10.75±5.12
OAP	4	3	7	4.5±1.73
OJAP	4	4	6	4.88±0.85
SAC	4	3	5	4.25±0.96
FAC	4	ND	21	6.75±9.91
IAC	4	4	16	9±5.03
OAC	4	4	49	22.75±22.07
OJAC	4	ND	15	5.75±6.90

ND: None detected

levels were highest in *kul-ikuli* (15.75±13.19 CFU $g^{-1} \times 10^1$), followed by chin-chin (12.23 CFU $g^{-1} \times 10^1$), groundnut (11.1 CFU $g^{-1} \times 10^1$) and lowest in popcorn (9 CFU $g^{-1} \times 10^1$) (Table 3).

Total yeast/mold count: The total yeast/mold counts showed a minimum mean of 3.5 CFU $g^{-1} \times 10^1$ in the samples of groundnut from Ojota Area (OJAG) and a maximum of 22.75 CFU $g^{-1} \times 10^1$ in chin-chin samples from Oshodi Area (OAC) (Table 4). Tangible total yeast/mold were detected in all the popcorn samples from all the studied locations, some *kuli-kuli* samples from only one location (OAK) showed none-detected, while for groundnut and chin-chin, samples from two locations showed none-detected. The mean ranged from

Table 5: Levels (CFU $g^{-1}\times 10^1$) of total yeast/mold in the selected four snacks

Snacks	N	Minimum	Maximum	Mean (±Std. Deviation)
Groundnut	20	0	33	7.8±8.63
Kuli-kuli	20	0	45	8.95±9.47
Popcorn	20	3	19	7.58±4.85
Chin-chin	20	0	49	9.7±12.30

Table 6: Total aflatoxins (μg kg^{-1}) in the samples

Aflatoxin	N	Minimum	Maximum	Mean (±Std. Deviation)
Groundnut				
Surulere	4	ND	9.45	2.42±4.69
Festac	4	0.08	32.12	9.24±15.39
Iyana-ipaja	4	0.5	191.21	54.44±91.92
Oshodi	4	ND	81.88	35.85±42.22
Ojota	4	ND	16.34	4.27±8.05
Kuli-kuli				
Surulere	4	ND	104.98	26.54±52.29
Festac	4	ND	77	19.48±38.35
Iyana-ipaja	4	15.73	356.41	111.17±163.79
Oshodi	4	ND	76.26	19.39±37.92
Ojota	4	ND	27.55	12.17±11.41
Popcorn				
Surulere	4	ND	ND	ND
Festac	4	ND	2.21	0.63±1.06
Iyana-ipaja	4	ND	0.34	0.16±0.18
Oshodi	4	ND	4.86	1.22±2.43
Ojota	4	ND	0.49	0.26±0.25
Chin-chin				
Surulere	4	ND	0.45	0.11±0.22
Festac	4	0.58	59.67	16.03±29.12
Iyana-ipaja	4	ND	0.85	0.29±0.40
Oshodi	4	ND	10.11	2.63±4.99
Ojota	4	ND	0.5	0.33±0.24

ND: None detected

Table 7: Levels of total aflatoxins (μg kg^{-1}) in the four samples

Snacks	N	Minimum	Maximum	Mean (±Std. Deviation)
Groundnut	20	ND	191.21	21.24±45.93
Kuli-kuli	20	ND	356.41	37.75±81.17
Popcorn	20	ND	4.86	0.45±1.15
Chin-chin	20	ND	59.67	3.88±13.32

ND: None detected

3.5-18.75 CFU $g^{-1}\times 10^1$ for groundnut, 3.75-17.5 CFU $g^{-1}\times 10^1$, *kuli-kuli*, 4.5-13.25 CFU $g^{-1}\times 10^1$, popcorn and 4.25-22.75 CFU $g^{-1}\times 10^1$, chin-chin. Generally, the level was highest in chin-chin (9.7 CFU $g^{-1}\times 10^1$), followed by *kuli-kuli* (8.95 CFU $g^{-1}\times 10^1$), popcorn (7.58 CFU $g^{-1}\times 10^1$) and lowest in groundnut (7.80 CFU $g^{-1}\times 10^1$) (Table 5).

Total aflatoxins in the samples: The results of aflatoxins are presented in Table 6. The maximum aflatoxin level (356.41 μg kg^{-1}) was observed in a *kuli-kuli* sample from Iyana-Ipaja area (IAK). None was detected in all the popcorn samples from Surulere (SAP). For groundnut samples, the mean concentrations ranged from 2.42-54.44 μg kg^{-1}, *kuli-kuli*, 12.17-111.17 μg kg^{-1}, popcorn, ND-1.22 μg kg^{-1}, chin-chin, 0.11-16.03 μg kg^{-1}. Among the selected four different snacks (Table 7), the level of aflatoxin was highest (37.75 μg kg^{-1}) in *kuli-kuli*, followed by groundnut (21.24 μg kg^{-1}), chin-chin (3.88 μg kg^{-1}) and lowest in popcorn (0.45 μg kg^{-1}).

Risk assessment: For children, the results showed that the dietary exposure (DE) ranged from 0.66 ng/kg-b.wt./day (from consumption of popcorn) to 116.4 ng/kg-b.wt./day (from consumption of *kuli-kuli*) and the margin of exposure (MoE) were 1.5 (from consumption of *kuli-kuli*) to 378 (from consumption of popcorn) (Table 8). For adults, DE ranged from 0.23 ng/kg-b.wt./day (from consumption of popcorn) to 39.91 ng/kg-b.wt./day (from consumption of *kuli-kuli*), while the MoE ranged from 4.3 to 739.1 from consumption of *kuli-kuli* and popcorn, respectively.

Table 8: Exposure to aflatoxins from consumption of the street-vended snacks

Snacks	Concentration of TAF (ng g^{-1})	Daily amount consumed (g/day)	DE (ng/kg-b.wt./day)	MoE
Children				
Kuli-kuli	37.75	74	116.40	1.5
Groundnut	21.24	41	36.30	4.7
Chin-chin	3.88	79	12.80	13.3
Popcorn	0.45	35	0.66	378
PDI	-	-	-	-
Adults				
Kuli-kuli	37.75	74	39.91	4.3
Groundnut	21.24	41	12.40	13.7
Chin-chin	3.88	79	4.38	38.8
Popcorn	0.45	35	0.23	739.1
PDI	-	-	-	-

TAF: Total aflatoxins, DE: Dietary exposure and MoE: Margin of exposure

DISCUSSION

The higher levels of bacterial load in *kuli-kuli* may be expected because it is often poorly packaged or left exposed for a longer time when displayed for sale. In most cases, it is packaged at the point of sale when consumers are ready to buy. It is likely it would have absorbed moisture and accumulated dust and hence prone to microbial contamination. Similar handling applys to groundnut before processing for consumption. However, the results were lower than the bacteria load of 10^3 CFU g^{-1} limit recommended in foods by the International Commission on Microbiological Specification for Foods[18]. Kigigha *et al.*[19] obtained results lower than the regulatory limit, similar to those observed in this study. Their results for unpeeled groundnut ranged from 3.68-4.56 log CFU g^{-1}, 1.92-2.57 log CFU g^{-1}, 1.92-2.29 log CFU g^{-1} and 2.61-3.94 log CFU g^{-1} for total heterotrophic bacteria, total coliform, total Staphylococci and total fungi counts respectively.

Studies have shown that microbial pathogens are key threats to food safety and these are challenged on one hand by the food vendors' lack of food safety knowledge and on the other hand, lack of appropriate legislation and enforcement by the government[20]. Right from the choice of raw materials from the farm, especially groundnut and corn, street food vendors can afford to compromise the best quality to achieve profit maximization, hence, the source of contamination may begin from the raw materials[21]. Other sources of contamination include exposure to dusts and other airborne particles. In most cases, *kuli-kuli* is not packaged and is often not covered when displayed for sale. Furthermore, faulty packaging materials and longer time on the shelf may predispose groundnut, popcorn and chin-chin to contamination.

The results of total yeast/mold count were lower than fungi load of 10^5 CFU g^{-1} limit recommended in foods by the International Commission on Microbiological Specification for Foods[18]. The presence of yeasts/molds in the samples may be expected because they are usually dispersed in the form of spores. Spores are abundant in the environment and can be introduced to food items that are left open through dust. These studied samples (*kuli-kuli*, groundnut, chin-chin and popcorn) were usually subjected to heating during processing for consumption. The fungi load may therefore be lower than what may be the case for unprocessed or raw materials. For instance, Adetunji *et al.*[18] reported high levels of 4.00×10^3 CFU g^{-1} to 24.00×10^3 CFU g^{-1} fungi load for raw groundnuts sourced from Fidiwo and Mowe in Ogun State. However, though the raw materials may go through some heating in the course of processing, some fungi spores and mycotoxins may survive the processing conditions[22].

Compared with 15 µg kg^{-1} set by Codex Alimentarius Commission, the mean levels of aflatoxins in groundnut (from Iyana-Ipaja and Oshodi), *kuli-kuli* (all the locations except Ojota) and chin-chin (Festac) exceeded the limit. Among the four street-vended snacks, the levels in *kuli-kuli* and groundnut were higher. The mean levels of total aflatoxins in *kuli-kuli* (37.75 µg kg^{-1}) and groundnut (21.24 µg kg^{-1}) were higher than the maximum permissible limit. Other maximum limits for total aflatoxins in food are 20 µg kg^{-1} (United States), 4 µg kg^{-1} (EU) and 10 to 20 µg kg^{-1} (in developing countries) with 10 µg kg^{-1} being the most frequently set level[6]. Aflatoxin limits for commodities for direct consumption in Nigeria[23] are 4 µg kg^{-1} (maize), 20 µg kg^{-1} (groundnut) and 4 µg kg^{-1} (*kuli-kuli*). The street-vended snacks considered in this study were ready-to-eat foods. Therefore, their levels of aflatoxins exceeding the regulatory limit several folds call for public health concern.

Other studies have reported similarly high levels. Adjou *et al.*[24] reported a range of 25.5 to 455 µg kg^{-1} of AFB_1, 33.9 to 491 µg kg^{-1} of AFB_2 and 22.0 to 87.7 µg kg^{-1} of AFG_2 for 45 samples of *kuli-kuli* obtained in Benin. Afolabi *et al.*[25] reported levels of 1.3 to 59.1 µg kg^{-1} for AFB_1 and 1.3 to 134 µg kg^{-1} for total aflatoxins in samples of roasted groundnut obtained in Nigeria. The results of aflatoxins in this study are comparable to those reported by Makinde *et al.*[1]. They reported aflatoxin B1 levels of 25.5 to 455 µg kg^{-1} in *kuli-kuli* samples from Benin, 0.59 to 15.8 µg kg^{-1} in corn-based snacks from Egypt, 6.0 to 30.0 µg kg^{-1} in corn-based snacks from Nigeria, 0.1 to 12.3 µg kg^{-1} in skinned roasted groundnut, 1.3 to 59.1 µg kg^{-1} roasted groundnut from Nigeria, 0.75 to 7.25 µg kg^{-1} in chin-chin (kokoro) from Nigeria.

All the results obtained for dietary exposure (ranging from 0.23 to 36.30 ng/kg-b.wt./day) were higher than the permissible exposure level of 0.017 ng/kg-b.wt./day. Adetunji *et al.*[18] reported similar high values of 25.13-29.28 ng/kg-b.wt./day for groundnut samples from Obafemi Owode Local Government, Ogun State. The MoE in this study ranged from 4.7 to 378 in children and from 13.7 to 739.1 in adults, which were lower than the benchmark dose lower limit (BMDL) of 10,000, indicating high public health concern. Similar lower levels than the BMDL were reported for groundnut (6.10) and cashew nut (1000) in other studies[18].

Finally, Alimi[21] identified the risk factors in street food practices in developing countries as agricultural practices, sources and quality of raw foods and ingredients, food preparation, handling and vending, vending environments, hygiene practices, knowledge and attitude of street food vendors to food safety practices, attitude of consumers to the hazards of street food. These risk factors are true for the selected snacks in this study, hence, the need for constant monitoring and enforcement of appropriate standards for street-vended foods.

The results showed that the street-vended snacks considered in this study were contaminated with bacteria, fungi/mold and aflatoxins. The higher levels of aflatoxins than the various available regulatory limits call for public health concerns. The risk factors for street food practices in developing countries should be given due attention. There is a need for constant monitoring and enforcement of standards for street-vended foods.

CONCLUSION

The levels of total aflatoxins in *kuli-kuli* and groundnut were higher than the maximum permissible limit. Higher levels of total aflatoxins than the maximum permissible limits in the studied samples call for public health concerns considering the level of exposure. Dietary exposure to aflatoxins ranged from 0.23 to 116.4 ng/kg-b.wt./day, which was higher than the permissible exposure level. The margin of exposure ranged from 1.5 to 378 in children and from 4.3 to 739.1 in adults, which were lower than the benchmark dose lower limit (BMDL) of 10,000, indicating high public health concerns.

SIGNIFICANCE STATEMENT

Among the street vended snacks, groundnut, *kuli-kuli*, popcorn and chin-chin are very common and consumed by both children and adults in Nigeria. However, processing, handling and packaging are usually poorly done, constituting the sources of contamination. This study therefore aimed to assess the snacks for microbial and aflatoxin contamination and potential human exposure. The results showed that the margin of exposure ranged from 1.5 to 378 in children and from 4.3 to 739.1 in adults, which were lower than the Benchmark Dose Lower Limit (BMDL) of 10,000, indicating high public health concerns. And higher levels of total aflatoxins than the maximum permissible limits in the studied samples call for public health concerns.

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