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Evaluation of heavy metals deposition on selected agricultural products dried in local kitchens and roadsides, Wukari, Nigeria

Bando Christopher David[ab*]; Ikwebe Joseph[b]; Imo chinedu[b]; Jummai Adamu Tutuwa[c]; Jesse Shingu Polly[a]; Imbasire Nuhu[a]; Rejoice Habila Tadawas[a]; Odiba Emmanuel Ogu[a]; Tsoken Danji Agbu[a]

[a]*Bioresources Development Centre, National Biotechnology Development Agency, Jalingo, Taraba State, Nigeria.*

[b]*Department of Biochemistry, Federal university Wukari, Taraba State, Nigeria.*

[c]*Federal institute of industrial research Oshodi, Lagos Nigeria.*

Corresponding author: bandomidase@gmail.com

ABSTRACT

Most agricultural products in Nigeria are often susceptible to environmental pollution due to anthropogenic activities and mode of preservation. As a case study, this work was aimed at evaluating the levels of heavy metals (Pb, Hg, As, Cd, Zn and Fe) depositions on selected agricultural products that are either stored at the rooftop of local Nigerian kitchens, sun-dried by roadsides or sun-dried away from local kitchens and roadsides. The selected agricultural samples (Zea mays, Manihot esculenta, Capsicum annuum, Solanum lycopersicum, Abelmoschus esculentus and Hibiscus sabdariffa) were sourced from Byepyi (Wukari – Jalingo highway), Gindin waya (Wukari – Ibi road) and Kente (Wukari – Kente road). Heavy metal was determined using Atomic Absorption Spectrophotometer (AAS). Generally, heavy metals depositions on the selected agricultural samples showed higher concentrations in samples stored at rooftops of local kitchens, compared to samples sun-dried by the roadsides and samples sun-dried under control conditions in the three locations. In Byepyi, heavy metal such as Pb, Hg, As, Cd, Fe levels were significantly higher (P≤0.05) in samples stored at rooftops of local kitchens. Slight change in the result trends was observed for Cu, which showed higher concentrations for samples sun-dried by roadsides. In Gindin waya, heavy metals such as Pb, As, Fe, Cu analytes levels were significantly higher (P≤0.05) in samples stored at rooftops of local kitchens, while Hg is at same level with samples sun-dried by the roadsides and Cd showed higher concentration in samples sun-dried by the roadsides. In Kente, levels of heavy metals such as Pb, Hg, As, Cd were significantly higher (P≤0.05) in samples stored at rooftop of local kitchens. Slight change in the trends was observed for Fe, Cu, which showed higher concentrations for samples sun-dried. The research showed appreciable levels of metallic contamination in selected agricultural products, although they were found to be below FAO/WHO permissible limits. Bioaccumulation of these food contaminants in humans could result to serious health problems.

Keywords: AAS; Cadmium (Cd); Lead (Pb); Arsenic (As); Mercury (Hg); Chromium (Cr); Kitchens; Roadsides.

INTRODUCTION

Food preservation has been practiced by all races in the world for centuries, and it involves all food items (Shafiur, 2007). The purpose of employing preservation techniques is to keep food commodities in good conditions, so that the time span during which they maintain their nutritive relevance is extended (Ikwebe *et al*., 2017). Some of the common preservation processes used on various food products is; Fermentation, irradiation, refrigeration, freezing, sun-drying, smoking, dehydration, heat processing and curing. However, through this drying techniques (Roadside sun-drying and kitchen drying), the foodstuff is subject to air pollution through the trace metals released from the exhaust pipes of vehicles driving past and smoke of burning wood.

Heavy metals are metalloids that have relatively high atomic weights and are discovered to be toxic to biological systems even at lower concentrations. Heavy metals contain both necessary elements such as iron, zinc, and copper, as well as harmful substances such as cadmium, lead, mercury, chromium, etc (Onyekwere *et al*., 2021; Bando *et al*., 2022). Environmental metallic contamination has become a major concern lately, due to their abilities to bioaccumulate in biosystems through air, soil and water (Onyekwere *et al*., 2021). Metals such as; Zinc (Zn), cadmium (Cd), nickel (Ni), and lead (Pb), which are constituents of fuel and serve as anti-knock agents, have been discovered in emissions from automobile activity on the roadways (Ikeda *et al*., 2000). Zinc (Zn), iron (Fe) and copper (Cu), have also been discovered form key components of numerous automobile tyres, alloys, and wires, consequently are released into the immediate environment through mechanical abrasion and natural wear and tear (Bolade, 2016). Heavy metals have also been reported to alter several vital plant processes such as absorption of light and water, as well as cell division. Usually, plants absorbed these heavy metals which subsequently accumulate in the food chain and become deleterious to human health (Onyekwere *et al*., 2021).

The research study was targeted at assessing the levels of heavy metals deposition on selected agricultural products in relation to preservation or storage practices amongst farmers/residents of Wukari LGA, Taraba state, Nigeria.

MATERIAL AND METHODS

Sample collection

Samples of agricultural products; *Zea mays* (Maize), *Manihot esculenta* (Cassava flakes), *Capsicum annuum* (pepper), *Solanum lycopersicum* (Tomato), *Abelmoschus esculentus* (okra) and *Hibiscus sabdariffa* (Jute plant) were collected from selected kitchen top and roadside sun-drying spots in Wukari. Agricultural products samples that were dried at home in an open field were collected and served as the control. The samples were randomly collected from three different locations; Byepyi village (Along Wukari-Jalingo highway), Gindin waya village (Along Wukari-Ibi highway) and Kente village, in order to ensure representative sampling. The samples were separately kept in black polyethylene bags during transportation to the laboratory for analysis as described by Bolade, (2016).

Sampling area

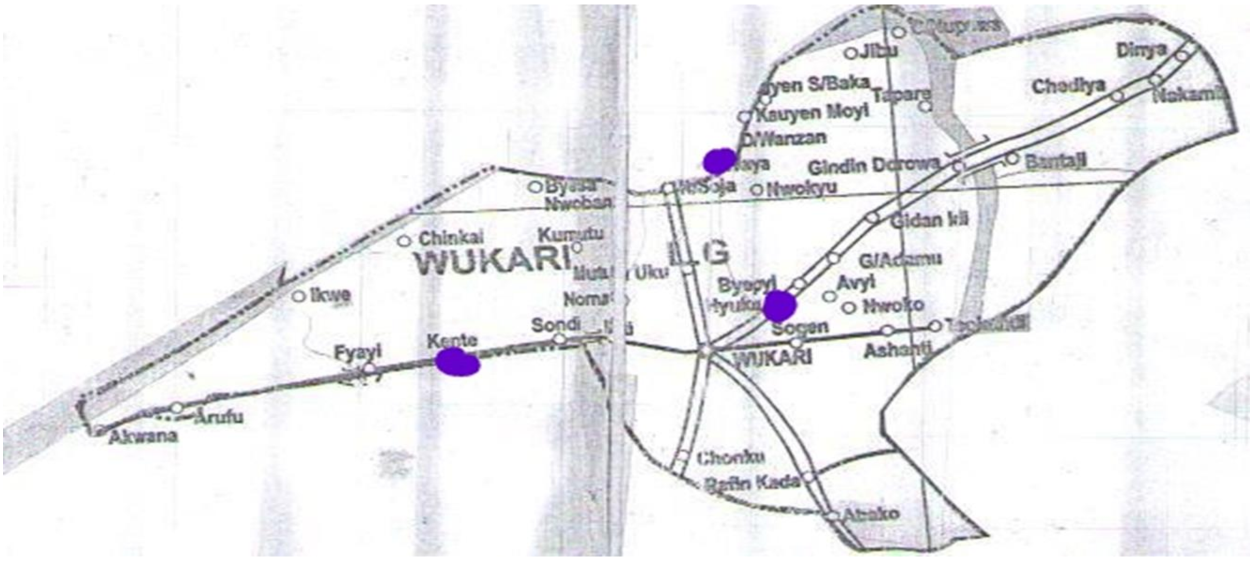

Figure 1: Map showing sampling points designated with blue box (Andrew *et al*., 2017)

Determination of metallic content in the samples

Heavy metals (Lead, Cadmium, Zinc, Arsenic, Iron and Copper) were determined in each of the samples collected according to the method as described by Edem *et al*., (2009). Each sample was homogenized and thereafter, 5 g of the sample was weighed into a 100ml beaker for digestion using 20 ml of HNO_3 and HCl (1:1, v/v) on an electro mantle at 98 ± 2°C for 1hr. In some cases, more solution of HNO_3 /HCl was added in order to ensure complete digestion of the sample. After the digestion, the solution was allowed to cool followed by filtration using laboratory funnel and filter paper. The filtrate was subsequently diluted with de-ionized water to 100 ml mark and 2 ml of the diluted solution was used for heavy metals content determination with the aid of Atomic Absorption Spectrophotometer (AAS).

Statistical analysis

Statistical analysis was carried out using the Statistical Package for Social Sciences (SPSS) version 23. The results were expressed as mean ± standard deviation in all parameters and the statistical difference was determined by Analysis of variance (ANOVA) at 95% confidence interval and Duncan multiple comparison test at $p < 0.05$.

RESULT AND DISCUSSION

Result of heavy metals and polyaromatic hydrocarbons depositions on agricultural samples

Table 1.Result of heavy metals depositions on roadside sundried agricultural samples sourced

from Byepyi, Wukari LGA

Result of heavy metals depositions on roadside sundried agricultural samples sourced from Byepyi (Table 1) revealed the presence of heavy metals depositions in this order: Copper> Iron > Lead > Arsenic > Mercury > Cadmium. There was statistically significant difference ($P \leq 0.05$) across agricultural samples for Lead, Arsenic, Iron and Copper, while there was no statistically significant difference ($p \geq 0.05$) across agricultural samples for Mercury and Cadmium.

Table 1: Heavy metals depositions on roadside sundried agricultural samples sourced from Byepyi

Sample	Parameter (ppm)					
	Lead	Mercury	Arsenic	Cadmium	Iron	Copper
Maize**R**	0.0283 ± 0.0001[c]	0.0006 ± 0.0001[a]	0.0152 ± 0.0004[b]	0.0005 ± 0.0001[a]	0.0996 ± 0.0003[d]	0.8976 ± 0.0008[e]
Cassava**R**	0.0337 ± 0.0008[c]	0.0008 ± 0.0001[a]	0.0293 ± 0.0006[b]	0.0008 ± 0.0000[a]	0.0558 ± 0.0011[d]	1.6576 ± 0.0001[e]
Okra**R**	0.0283 ± 0.0147[b]	0.0003 ± 0.0000[a]	0.0073 ± 0.0016[a]	0.0004 ± 0.0001[a]	0.1056 ± 0.0062[c]	0.6270 ± 0.0006[d]
Tomato**R**	0.0357 ± 0.0008[c]	0.0005 ± 0.0001[a]	0.0085 ± 0.0003[b]	0.0003 ± 0.0001[a]	0.0969 ± 0.0023[d]	0.2518 ± 0.0004[e]
Pepper**R**	0.0111 ± 0.0002[c]	ND	0.0054 ± 0.0003[b]	ND	0.0793 ± 0.0007[d]	0.1839 ± 0.0000[e]
Jute**R**	0.0039 ± 0.0006[a]	0.0002 ± 0.0001[a]	0.0026 ± 0.0013[a]	0.0003 ± 0.0001[a]	0.1231 ± 0.0373[a]	0.6201 ± 0.2971[b]
Average	**0.0235 ± 0.0029**	**0.0005 ± 0.0001**	**0.0114 ± 0.0008**	**0.0005 ± 0.0001**	**0.0934 ± 0.0080**	**0.7063 ± 0.0498**

Results are expressed as mean ± standard deviation of triplet determination. Results with same letter of the alphabet as superscript show no statistically significant difference ($P \geq 0.05$) while results with different letter of alphabet as superscript within the same column show statistically significant difference ($p \leq 0.05$). R is sample sundried by the roadside.

Table 2. Result of heavy metals depositions on agricultural samples stored at local kitchen roof top, sourced from Byepyi, Wukari LGA

Result of heavy metals depositions on agricultural samples stored at local kitchen roof top sourced from Byepyi (Table 2) revealed the presence of heavy metals depositions in this order: Copper> Iron > Lead > Arsenic > Cadmium > Mercury. There was statistically significant difference ($p \leq 0.05$) across agricultural samples for Lead, Arsenic, Iron and Copper, while there was no statistically significant difference ($p \geq 0.05$) across agricultural samples for Mercury and Cadmium.

Table 2: Heavy metals depositions on agricultural samples stored at local kitchen roof top, sourced from Byepyi

Sample	Parameter (ppm)					
	Lead	Mercury	Arsenic	Cadmium	Iron	Copper
Maize**K**	0.0405 ± 0.0039[b]	0.0012 ± 0.0001[a]	0.0428 ± 0.0012[b]	0.0011 ± 0.0002[a]	0.1164 ± 0.0072[c]	0.6576 ± 0.0064[d]
Cassava**K**	0.0337 ± 0.0008[ab]	0.0007 ± 0.0001[a]	0.0545 ± 0.0033[b]	0.0014 ± 0.0001[a]	0.1258 ± 0.0403[c]	0.8976 ± 0.0052[d]
Okra**K**	0.0393 ± 0.0008[c]	0.0004 ± 0.0000[a]	0.0240 ± 0.0003[b]	0.0001 ± 0.0000[a]	0.0425 ± 0.0023[d]	0.4642 ± 0.0003[e]
Tomato**K**	0.0373 ± 0.0008[c]	0.0006 ± 0.0003[a]	0.0218 ± 0.0043[b]	0.0004 ± 0.0001[a]	0.1138 ± 0.0142[d]	0.3171 ± 0.0002[e]
Pepper**K**	0.0309 ± 0.0004[b]	0.0003 ± 0.0001[a]	0.0160 ± 0.0021[ab]	ND	0.0551 ± 0.0163[c]	0.3860 ± 0.0029[d]
Jute**K**	0.0410 ± 0.0002[b]	0.0002 ± 0.0000[a]	0.0084 ± 0.0052[a]	ND	0.1082 ± 0.0047[c]	0.3529 ± 0.0301[d]
Average	**0.0371 ± 0.0012**	**0.0006 ± 0.0001**	**0.0279 ± 0.0027**	**0.0007 ± 0.0001**	**0.0936 ± 0.0141**	**0.5126 ± 0.0075**

* WHO standards for analyzed parameters (heavy metals) in ppm: Pb: 0.20; Hg: 0.10; As: 0.50; Cd: 0.10; Fe: 45.00; Cu: 0.15.

Results are expressed as mean ± standard deviation of triplet determination. Results with same letter of the alphabet as superscript show no statistically significant difference (P≥0.05) while results with different letter of alphabet as superscript within the same column show statistically significant difference (p≤0.05). K is sample stored at the local kitchen rooftop.

Table 3. Result of heavy metals depositions on agricultural samples dried away from roadside and local kitchen roof top, sourced from Byepyi, Wukari LGA

Result of heavy metals depositions on agricultural samples dried away from roadside and local kitchen roof top sourced from Byepyi (Table 3) revealed the presence of heavy metals depositions in this order: Copper> Iron > Lead > Arsenic > Mercury > Cadmium. There was statistically significant difference (p≤0.05) across agricultural samples for Lead, Arsenic, Iron and Copper, while there was no statistically significant difference (p≥0.05) across agricultural samples for Mercury and Cadmium.

Table 3: Heavy metals depositions on agricultural samples dried away from roadside and local kitchen roof top, sourced from Byepyi

Sample	Parameter (ppm)					
	Lead	Mercury	Arsenic	Cadmium	Iron	Copper
Maize**C**	0.0035 ± 0.0029^{ab}	0.0004 ± 0.0001^{a}	0.0068 ± 0.0001^{b}	0.0005 ± 0.0001^{a}	0.0687 ± 0.0021^{c}	0.3385 ± 0.0040^{d}
Cassava**C**	0.0337 ± 0.0001^{a}	0.0005 ± 0.0000^{a}	0.0067 ± 0.0006^{a}	0.0003 ± 0.0001^{a}	0.0851 ± 0.0136^{b}	0.7101 ± 0.0011^{c}
Okra**C**	0.0020 ± 0.0004^{a}	ND	0.0121 ± 0.0011^{b}	ND	0.0394 ± 0.0025^{c}	0.1205 ± 0.0006^{d}
Tomato**C**	0.0020 ± 0.0001^{b}	ND	0.0049 ± 0.0008^{c}	0.0001 ± 0.0000^{a}	0.0669 ± 0.0001^{d}	0.1339 ± 0.0005^{e}
Pepper**C**	0.0045 ± 0.0001^{a}	ND	0.0056 ± 0.0013^{a}	ND	0.0487 ± 0.0079^{b}	0.2265 ± 0.0066^{c}
Jute**C**	0.0011 ± 0.0004^{a}	ND	0.0011 ± 0.0002^{a}	ND	0.0801 ± 0.0056^{b}	0.1215 ± 0.0308^{c}
Average	**0.0078 ± 0.0007**	**0.0005 ± 0.0001**	**0.0062 ± 0.0007**	**0.0003 ± 0.0001**	**0.0648 ± 0.0053**	**0.2752 ± 0.0073**

Results are expressed as mean ± standard deviation of triplet determination. Results with same letter of the alphabet as superscript show no statistically significant difference (P≥0.05) while results with different letter of alphabet as superscript within the same column show statistically significant difference (p≤0.05). C is control sample.

Table 4. Result of heavy metals depositions on roadside sundried Agricultural samples sourced from Gindin waya, Wukari LGA

Result of heavy metals depositions on roadside sundried agricultural samples sourced from Gindin waya (Table 4) revealed the presence of heavy metals depositions in this order: Copper> Iron > Lead > Arsenic > Cadmium> Mercury. There was statistically significant difference (p≤0.05) across agricultural samples for Lead, Arsenic, Iron and Copper, while there was no statistically significant difference (p≥0.05) across agricultural samples for Mercury and Cadmium.

* WHO standards for analyzed parameters (heavy metals) in ppm: Pb: 0.20; Hg: 0.10; As: 0.50; Cd: 0.10; Fe: 45.00; Cu:

0.15.

Table 4: Heavy metals depositions on roadside sundried agricultural samples sourced from Gindin waya

Sample	Parameter (ppm)					
	Lead	Mercury	Arsenic	Cadmium	Iron	Copper
Maize**R**	0.0159 ± 0.0011^{a}	0.0003 ± 0.0001^{a}	0.0096 ± 0.0003^{a}	0.0005 ± 0.0001^{a}	0.0741 ± 0.0021^{b}	0.4460 ± 0.0273^{c}
Cassava**R**	0.0221 ± 0.0004^{b}	0.0008 ± 0.0002^{a}	0.0223 ± 0.0003^{b}	0.0006 ± 0.0001^{a}	0.0338 ± 0.0013^{c}	0.7792 ± 0.0051^{d}
Okra**R**	0.0152 ± 0.0045^{a}	0.0003 ± 0.0001^{a}	0.0071 ± 0.0003^{a}	0.0006 ± 0.0002^{a}	0.0704 ± 0.0024^{b}	0.6694 ± 0.0241^{c}
Tomato**R**	0.0128 ± 0.0006^{a}	0.0001 ± 0.0001^{a}	0.0039 ± 0.0005^{a}	0.0003 ± 0.0000^{a}	0.0093 ± 0.0001^{a}	0.3823 ± 0.4581^{a}
Pepper**R**	0.0066 ± 0.0005^{ab}	ND	0.0046± 0.0003^{ab}	0.0003 ± 0.0001^{a}	0.0174 ± 0.0006^{b}	0.0096 ± 0.0069^{c}
Jute**R**	0.0024 ± 0.0001^{a}	0.0002 ± 0.0001^{a}	0.0023 ± 0.0001^{a}	ND	0.1327 ± 0.0481^{b}	0.1494 ± 0.0086^{b}
Average	**0.0125 ± 0.0010**	**0.0003 ± 0.0001**	**0.0083 ± 0.0003**	**0.0005 ± 0.0001**	**0.0563 ± 0.0091**	**0.4060 ± 0.0884**

Results are expressed as mean ± standard deviation of triplet determination. Results with same letter of the alphabet as superscript show no statistically significant difference (P≥0.05) while results with different letter of alphabet as superscript within the same column show statistically significant difference (p≤0.05). R is sample s[1]undried by the roadside.

Table 5. Result of heavy metals depositions on agricultural samples stored at local kitchen rooftop, sourced from Gindin waya, Wukari LGA

Result of heavy metals depositions on agricultural samples stored at local kitchen roof top sourced from Gindin waya (Table 5) revealed the presence of heavy metals depositions in this order: Copper> Iron > Lead > Arsenic > Mercury/Cadmium. There was statistically significant difference (p≤0.05) across agricultural samples for Lead, Arsenic, Iron and Copper, while there was no statistically significant difference (p≥0.05) across agricultural samples for Mercury and Cadmium.

Table 5: Heavy metals depositions on agricultural samples stored at local kitchen rooftop, sourced from Gindin waya

Sample	Parameter (ppm)					
	Lead	Mercury	Arsenic	Cadmium	Iron	Copper
Maize**K**	0.0252 ± 0.0030^{ab}	0.0001 ± 0.0000^{a}	0.0448 ± 0.0023^{ab}	0.0006 ± 0.0001^{a}	0.0817 ± 0.0005^{b}	0.9555 ± 0.0753^{c}
Cassava**K**	0.0237 ± 0.0005^{a}	0.0003 ± 0.0000^{a}	0.0435 ± 0.0051^{a}	0.0002 ± 0.0001^{a}	0.3608 ± 0.0737^{b}	0.8965 ± 0.0083^{c}
Okra**K**	0.0339 ± 0.0011^{a}	0.0006 ± 0.0002^{a}	0.0120 ± 0.0012^{a}	0.0003 ± 0.0000^{a}	0.0534 ± 0.0030^{a}	0.5147 ± 0.1189^{b}
Tomato**K**	0.0210 ± 0.0002^{a}	0.0003 ± 0.0001^{a}	0.0034 ± 0.0017^{a}	0.0003 ± 0.0001^{a}	0.0919 ± 0.0026^{b}	0.6865 ± 0.0357^{c}
Pepper**K**	0.0413 ± 0.0019^{b}	0.0001 ± 0.0001^{a}	0.0084 ± 0.0010^{a}	0.0001 ± 0.0000^{a}	0.1045 ± 0.0081^{c}	0.1434 ± 0.0187^{d}
Jute**K**	0.0508 ± 0.0147^{bc}	0.0006 ± 0.0001^{a}	0.0332 ± 0.0027^{b}	ND	0.0711 ± 0.0155^{c}	0.3309 ± 0.0152^{d}
Average	**0.03265 ± 0.0036**	**0.0003 ± 0.0001**	**0.0242 ± 0.0023**	**0.0003 ± 0.0001**	**0.1272 ± 0.0172**	**0.5879 ± 0.0454**

* WHO standards for analyzed parameters (heavy metals) in ppm: Pb: 0.20; Hg: 0.10; As: 0.50; Cd: 0.10; Fe: 45.00;

Cu: 0.15.

Table 6. Result of heavy metals depositions on agricultural samples dried away from roadside and local kitchen rooftop, sourced from Gindin waya, Wukari LGA

Result of heavy metals depositions on agricultural samples dried away from roadside and local kitchen roof top sourced from Gindin waya (Table 6) revealed the presence of heavy metals depositions in this order: Copper> Iron > Lead > Arsenic > Mercury and Cadmium not detectable. There was statistically significant difference (p≤0.05) across agricultural samples for Lead, Arsenic, Iron and Copper, while there was no statistically significant difference (p≥0.05) across agricultural samples for Mercury and Cadmium.

Table 6: Heavy metals depositions on agricultural samples dried away from roadside and local kitchen rooftop, sourced from Gindin waya

Sample	Parameter (ppm)					
	Lead	Mercury	Arsenic	Cadmium	Iron	Copper
Maize**C**	0.0262 ± 0.0061^{b}	0.0001 ± 0.0001^{a}	0.0043 ± 0.0001^{a}	ND	0.1101 ± 0.0003^{c}	0.2047 ± 0.0016^{d}
Cassava**C**	0.0105 ± 0.0003^{a}	0.0002 ± 0.0001^{a}	0.0101 ± 0.0006^{a}	ND	0.0914 ± 0.0102^{b}	0.4787 ± 0.0432^{c}
Okra**C**	0.0317 ± 0.0022^{b}	ND	0.0063 ± 0.0003^{ab}	ND	0.0987 ± 0.0015^{c}	0.6424 ± 0.0295^{d}
Tomato**C**	0.0121 ± 0.0040^{a}	ND	0.0070 ± 0.0004^{a}	ND	0.1048 ± 0.0091^{b}	0.4842 ± 0.0725^{c}
Pepper**C**	0.0331 ± 0.0014^{a}	ND	0.0062 ± 0.0001^{a}	ND	0.1028 ± 0.0001^{b}	0.0766 ± 0.0318^{b}
Jute**C**	0.0453 ± 0.0082^{ab}	ND	0.0045 ± 0.0013^{a}	ND	0.0923 ± 0.0115^{bc}	0.1442 ± 0.0522^{c}
Average	**0.0265 ± 0.0037**	**0.0002 ± 0.0001**	**0.0064 ± 0.0004**	**ND**	**0.1000 ± 0.0055**	**0.3385 ± 0.0385**

Results are expressed as mean ± standard deviation of triplet determination. Results with same letter of the alphabet as superscript show no statistically significant difference (P≥0.05) while results with different letter of alphabet as superscript within the same column show statistically significant difference (p≤0.05). C is control sample.

Table 7. Result of heavy metals depositions on roadside sundried agricultural samples sourced from Kente, Wukari LGA

Result of heavy metals depositions on roadside sundried agricultural samples sourced from Kente (Table 7) revealed the presence of heavy metals depositions in this order: Copper> Iron > Lead > Arsenic > Cadmium > Mercury. There was statistically significant difference (p≤0.05) across agricultural samples for Lead, Arsenic, Iron and Copper, while there was no statistically significant difference (p≥0.05) across agricultural samples for Mercury and Cadmium.

Results are expressed as mean ± standard deviation of triplet determination. Results with same letter of the alphabet as superscript show no statistically significant difference (P≥0.05) while results with different letter of alphabet as superscript within the same column show statistically significant difference (p≤0.05). R is sample sundried by the roadside.

* WHO standards for analyzed parameters (heavy metals) in ppm: Pb: 0.20; Hg: 0.10; As: 0.50; Cd: 0.10; Fe: 45.00; Cu: 0.15.

Table 7: Heavy metals depositions on roadside sundried agricultural samples sourced from Kente

Sample	Parameter (ppm)					
	Lead	Mercury	Arsenic	Cadmium	Iron	Copper
Maize**R**	0.0362 ± 0.0033[b]	0.0014 ± 0.0001[a]	0.0095 ± 0.0004[a]	0.0014 ± 0.0003[a]	0.0871 ± 0.0017[c]	0.8185 ± 0.0163[d]
Cassava**R**	0.0372 ± 0.0001[b]	0.0009 ± 0.0002[a]	0.0195 ± 0.0033[ab]	0.0019 ± 0.0008[a]	0.0810 ± 0.0283[c]	0.6374 ± 0.0226[d]
Okra**R**	0.0107 ± 0.0014[a]	0.0006 ± 0.0000[a]	0.0062 ± 0.0001[a]	0.0004 ± 0.0001[a]	0.0398 ± 0.0003[b]	0.6779 ± 0.0250[c]
Tomato**R**	0.0194 ± 0.0008[a]	0.0009 ± 0.0001[a]	0.0104 ± 0.0013[a]	0.0008 ± 0.0001[a]	0.1051 ± 0.0025[b]	0.4867 ± 0.0190[c]
Pepper**R**	0.0083 ± 0.0012[b]	0.0006 ± 0.0001[a]	0.0054 ± 0.0004[ab]	0.0005 ± 0.0001[a]	0.0975 ± 0.0045[c]	0.5631 ± 0.0030[d]
Jute**R**	0.0084 ± 0.0011[a]	0.0001 ± 0.0000[a]	0.0043 ± 0.0000[a]	0.0009 ± 0.0002[a]	0.0801 ± 0.0174[b]	0.7707 ± 0.0557[c]
Average	**0.0200 ± 0.0013**	**0.0008 ± 0.0001**	**0.0092 ± 0.0009**	**0.0010 ± 0.0003**	**0.0817 ± 0.0091**	**0.6591 ± 0.0236**

Table 8. Result of heavy metals depositions on agricultural samples stored at local kitchen roof top, sourced from Kente, Wukari LGA

Result of heavy metals depositions on agricultural samples stored at local kitchen roof top sourced from Kente (Table 8) revealed the presence of heavy metals depositions in this order: Copper> Iron > Lead > Arsenic > Mercury > Cadmium. There was statistically significant difference ($p \leq 0.05$) across agricultural samples for Lead, Arsenic, Iron and Copper, while there was no statistically significant difference ($p \geq 0.05$) across agricultural samples for Mercury and Cadmium.

Table 8: Heavy metals depositions on agricultural samples stored at local kitchen rooftop, sourced from Kente

Sample	Parameter (ppm)					
	Lead	Mercury	Arsenic	Cadmium	Iron	Copper
Maize**K**	0.0790 ± 0.0017[c]	0.0018± 0.0004[a]	0.0137 ± 0.0003[b]	0.0029 ± 0.0006[a]	0.0821 ± 0.0013[c]	0.8055 ± 0.0062[d]
Cassava**K**	0.0511 ± 0.0004[b]	0.0018 ± 0.0001[a]	0.0479 ± 0.0013[b]	0.0020 ± 0.0009[a]	0.0474 ± 0.0030[b]	0.6487 ± 0.0011[c]
Okra**K**	0.0117 ± 0.0003[a]	0.0008 ± 0.0000[a]	0.0070 ± 0.0013[a]	0.0010 ± 0.0002[a]	0.0516 ± 0.0104[b]	0.6702 ± 0.0002[c]
Tomato**K**	0.0086 ± 0.0021[a]	0.0013 ± 0.0002[a]	0.0092 ± 0.0006[a]	0.0011 ± 0.0002[a]	0.0918 ± 0.0083[b]	0.7098 ± 0.0019[c]
Pepper**K**	0.0173 ± 0.0009[c]	0.0005 ± 0.0002[a]	0.0073 ± 0.0001[b]	0.0005 ± 0.0002[a]	0.0552 ± 0.0008[d]	0.3282 ± 0.0045[e]
Jute**K**	0.0133 ± 0.0011[a]	0.0005 ± 0.0002[a]	0.0136 ± 0.0001[a]	0.0008 ± 0.0001[a]	0.0469 ± 0.0042[b]	0.7311 ± 0.0144[c]
Average	**0.0302 ± 0.0011**	**0.0011 ± 0.0002**	**0.0165 ± 0.0006**	**0.0014 ± 0.0004**	**0.0625 ± 0.0047**	**0.6489 ± 0.0047**

Results are expressed as mean ± standard deviation of triplet determination. Results with same letter of the alphabet as superscript show no statistically significant difference ($P \geq 0.05$) while results with different letter of alphabet as superscript within the same column show statistically significant difference ($p \leq 0.05$). K is sample stored at the local kitchen rooftop.

* WHO standards for analyzed parameters (heavy metals) in ppm: Pb: 0.20; Hg: 0.10; As: 0.50; Cd: 0.10; Fe: 45.00; Cu: 0.15.

Table 9. Result of heavy metals depositions on Agricultural samples dried away from roadside and local kitchen rooftop, sourced from Kente, Wukari LGA

Result of heavy metals depositions on agricultural samples dried away from roadside and local kitchen roof top sourced from Kente (Table 9) revealed the presence of heavy metals depositions in this order: Copper> Iron > Lead > Arsenic > Mercury > Cadmium. There was statistically significant difference ($p \leq 0.05$) across agricultural samples for Lead, Arsenic, Iron and Copper, while there was no statistically significant difference ($p \geq 0.05$) across all agricultural samples for Mercury and Cadmium.

Table 9: Heavy metals depositions on agricultural samples dried away from roadside and local kitchen rooftop, sourced from Kente

Sample	Parameter (ppm)					
	Lead	Mercury	Arsenic	Cadmium	Iron	Copper
Maize**C**	0.0109 ± 0.0006^{a}	0.0006 ± 0.0003^{a}	0.0042 ± 0.0001^{a}	0.0014 ± 0.0001^{a}	0.0770 ± 0.0004^{b}	0.5395 ± 0.0004^{c}
Cassava**C**	0.0207 ± 0.0008^{b}	0.0008 ± 0.0001^{a}	0.0270 ± 0.0007^{c}	0.0009 ± 0.0001^{a}	0.0409 ± 0.0005^{d}	0.6262 ± 0.0056^{e}
Okra**C**	0.0060 ± 0.0006^{b}	0.0007 ± 0.0003^{a}	0.0041 ± 0.0008^{b}	0.0003 ± 0.0001^{a}	0.0606 ± 0.0002^{c}	0.6584 ± 0.0022^{d}
Tomato**C**	0.0098 ± 0.0016^{b}	0.0009 ± 0.0003^{a}	0.0100 ± 0.0011^{b}	0.0006 ± 0.0001^{a}	0.0590 ± 0.0012^{c}	0.4055 ± 0.0030^{d}
Pepper**C**	0.0057 ± 0.0002^{b}	0.0004 ± 0.0001^{a}	0.0018 ± 0.0006^{a}	0.0002 ± 0.0000^{a}	0.0573 ± 0.0015^{c}	0.2540 ± 0.0002^{d}
Jute**C**	0.0039 ± 0.0003^{a}	0.0001 ± 0.0000^{a}	0.0092 ± 0.0041^{a}	0.0007 ± 0.0001^{a}	0.0598 ± 0.0111^{b}	0.4869 ± 0.0018^{c}
Average	**0.0095 ± 0.0007**	**0.0006 ± 0.0002**	**0.0092 ± 0.0012**	**0.0007±0.0001**	**0.0591±0.0025**	**0.4951±0.0022**

Results are expressed as mean ± standard deviation of triplet determination. Results with same letter of the alphabet as superscript show no statistically significant difference ($P \geq 0.05$) while results with different letter of alphabet as superscript within the same column show statistically significant difference ($p \leq 0.05$). C is control sample.

* WHO standards for analyzed parameters (heavy metals) in ppm: Pb: 0.20; Hg: 0.10; As: 0.50; Cd: 0.10; Fe: 45.00; Cu: 0.15.

Table 10: Summary of heavy metals depositions on selected agricultural products Byepyi, Gindin waya and Kente in Wukari LGA

The table revealed an increase in heavy metals for each sample locations in the order: Gindin Waya<Kente<Byepyi for samples sundried by the roadside and Kente<Gindin Waya<Byepyi for samples stored at local kitchen rooftop.

	Parameters (ppm)					
Location	Lead	Mercury	Arsenic	Cadmium	Iron	Copper
Byepyi						
Sample**R**	0.0235 ± 0.0029	0.0005 ± 0.0001	0.0114 ± 0.0008	0.0005 ± 0.0001	0.0934 ± 0.0080	0.7063 ± 0.0498
Sample**K**	0.0371 ± 0.0012	0.0006 ± 0.0001	0.0279 ± 0.0027	0.0007 ± 0.0001	0.0936 ± 0.0141	0.5126 ± 0.0075
Sample**C**	0.0078 ± 0.0007	0.0005 ± 0.0001	0.0062 ± 0.0007	0.0003 ± 0.0001	0.0648 ± 0.0053	0.2752 ± 0.0073
Gindin waya						
Sample**R**	0.0125 ± 0.0010	0.0003 ± 0.0001	0.0083 ± 0.0003	0.0005 ± 0.0001	0.0563 ± 0.0091	0.4060 ± 0.0884
Sample**K**	0.0327 ± 0.0036	0.0003 ± 0.0001	0.0242 ± 0.0023	0.0003 ± 0.0001	0.1272 ± 0.0172	0.5879 ± 0.0454
Sample**C**	0.0265 ± 0.0037	0.0002 ± 0.0001	0.0064 ± 0.0004	ND	0.1000 ± 0.0055	0.3385 ± 0.0385
Kente						
Sample**R**	0.0200 ± 0.0013	0.0008 ± 0.0001	0.0092 ± 0.0009	0.0010 ± 0.0003	0.0817 ± 0.0091	0.6591 ± 0.0236
Sample**K**	0.0302 ± 0.0011	0.0011 ± 0.0002	0.0165 ± 0.0006	0.0014 ± 0.0004	0.0625 ± 0.0047	0.6489 ± 0.0047
Sample**C**	0.0095 ± 0.0007	0.0006 ± 0.0002	0.0092 ± 0.0012	0.0007 ± 0.0001	0.0591 ± 0.0025	0.4951 ± 0.0022

Generally, agricultural samples from Byepyi showed statistically significant higher concentrations of Lead, Arsenic, Iron and copper when compared to agricultural samples from Gindin waya and Kente. Agricultural samples from Kente showed statistically higher concentrations of Mercury and Cadmium than agricultural samples from Byepyi and Gindin waya.

Sample**R**: Samples sun-dried by the roadsides

Sample**K**: Samples stored at rooftop of local kitchens

Sample**C**: Samples sun-dried in controlled conditions

Discussion

This study showed the degree to which agricultural products are been contaminated by heavy metals following the mode of preservation or post-harvest handling. Heavy metals are environmental pollutants mostly generated as a result of anthropogenic activities (Jessica *et al*., 2020). Following the entrance into the body, heavy metals can bind to lipids, proteins, and nucleic acids. Binding to enzymes and proteins commonly occurs through thiol (–SH) groups and modifies cysteine residues in proteins. Such protein inactivation is capable of disrupting the intracellular redox state (Zhang *et al*., 2018). Consequently, an imbalanced antioxidant defense contributes to the development of liver injury. Similar reactions can occur with the other heavy metals. In complexation of heavy metals with thiol-containing proteins, the ligands are amino acids which contain the –SH functional group (Burford *et al*., 2005). Table 1 present the metallic depositions on some selected roadside sun-dried agricultural crops; Maize (*Zea mays*), Cassava (*Manihot esculenta*), Pepper (*Capsicum annuum*), Tomato (*Solanum lycopersicum*), Okra (*Abelmoschus esculentus*) and Jute (*Hibiscus sabdariffa*) sourced from Byepyi village; Wukari – Jalingo highway. Although mercury and cadmium were not detected in Pepper sample, a significant higher deposition of Copper (Cu), Iron (Fe), Lead (Pb) and

Arsenic (As) were found in all analyzed agricultural products, while lower amount of Mercury (Hg) and Cadmium (Cd) depositions were equally observed. The amounts of the metallic depositions are below FAO/WHO permissible limits (FAO/WHO, 2019). Hg and Cd are not detected in Pepper sample.

Studies have shown that vehicles/motor cycles constitute principal source of heavy metals (Kolawale and Odoh, 2011). The poor maintenance of the vehicles, their mode of operation, the longer driving times in narrow and crowded roads and perennial traffic jams often result in a larger fraction of the Pb in gasoline being released to the air. Furthermore, as the vehicles plow through the dusty roads, they cause the pre-released Pb and other toxic metals to be wafted back up into the air and agricultural products sun-dried by roadside (Adebayo *et al*., 2011). The concentration of metallic depositions on the selected roadside sun-dried agricultural samples ranges as follows; Pb concentration in Tomato sample highest while the lowest was observed in Jute sample, Hg concentration is higher in Cassava sample while lowest in Jute sample, As concentration is higher in Cassava and lower in Jute. Cd concentration was observed to be higher in Cassava sample while lowest in Tomato and Jute samples, concentration of Fe is observed to be higher in Jute sample while lowest in Cassava sample. Cu concentration in Cassava sample is the highest while in Pepper sample is the least, at appreciable level of statistically significant difference ($P \leq 0.05$). The high level of Cu in Cassava sample agreed with the findings of Bolade, (2016). There was no statistically significance difference ($P \geq 0.05$) in the amount of Hg and Cd depositions on the selected agricultural products analyzed. Pb concentration in Maize, Cassava, Tomato and Pepper samples show no statistically significance difference ($P \geq 0.05$) but are statistically significantly different ($P \leq 0.05$) with concentration of Pb in Okra and Jute samples. The study also revealed similar conditions in the concentration of As, Fe and Cu. The Cu deposition level in the selected agricultural products sun-dried along Wukari – Jalingo higway was the highest while Hg and Cd were the lowest. The amounts of metallic (Pb, As, Hg, Cd, Fe, and Zn) depositions in all selected agricultural samples sun-dried by the roadside (table 1) showed higher concentrations when compared to the selected agricultural products preserved or stored under controlled conditions sourced from Byepyi (table 3). These elevated levels of heavy metals depositions observed in selected agricultural samples sun-dried by the roadside is in agreement with research by Kolawale and Odoh, 2011. This is an indication that these heavy metals are the primary contaminant in the food crops dried along the highways which was also reflected in the low level of these heavy metals obtained from the control agricultural samples in comparison with those obtained from the samples along the highways

Preservation of agricultural products at kitchen rooftops is a popular method of preserving crops in most rural dwellings in Nigeria. Table 2 summarizes the level of heavy metal contamination of agricultural products stored at local kitchen rooftop sourced from Byepyi village along Wukari – Jalingo highway. Significant amount of heavy metal depositions were detected in the selected agricultural crops but are below FAO/WHO recommended permissible limit. Copper is the highest metallic deposition and Mercury is the least with others as; As, Cd, Fe and Pb in no particular order. Cadmium was not detected in Pepper and Jute samples. Concentration of Cd and Hg showed no statistically significant difference ($P \geq 0.05$) in all agricultural samples. Cd concentration is higher in Cassava and lower in Okra samples. Maize sample showed the highest deposition of Hg and Jute sample with the least. A higher amount of Pb contamination was observed in Jute and Pepper samples with the least contamination of Pb. The concentration of Pb in Maize, pepper and jute samples are statistically significantly related and statistically significantly different from the Pb concentration in Tomato and Okra samples. The concentration of Pb in cassava sample showed no statistically significant difference (P≥0.05) with its concentrations in maize, pepper and jute samples but showed statistically significant difference (P≤0.05) with its concentration in tomato and okra samples. The concentration of As is higher in Cassava and lowest in Jute samples.

There was no statistically significant difference (P≥0.05) in As concentration in Maize, Cassava, Tomato and Okra samples. Statistically significance difference (P≤0.05) was observed in the concentration of As in Jute while its concentration in Pepper sample is significantly similar to all other agricultural samples analyzed. Fe concentration in Tomato and Okra samples showed no statistically significance difference (P≥0.05) which is concurrently statistically significantly different (P≤0.05) with the Fe concentration in Maize, Cassava, Jute and pepper samples. Cassava sample was analyzed to contain the highest deposition of Fe while Okra sample expressed the least of Fe depositions. The study revealed that the concentration of Cu is higher in Cassava sample and least in Tomato sample. A statistically significance difference (P≤0.05) was observed on the concentrations of Cu in Tomato and Okra when compared to its concentrations in Maize, Cassava, Pepper and Jute samples. The amounts of metallic (Pb, As, Hg, Cd, Fe, and Zn) depositions in all selected agricultural samples stored at local kitchen rooftop (table 2) showed higher concentrations when compared to the selected agricultural products preserved or stored under controlled conditions sourced from Byepyi (table 3).

Analyzed selected agricultural products sun-dried along Wukari - Ibi road (table 4) showed reasonable quantities of metallic depositions. In all selected agricultural samples analyzed for heavy metals contamination, Cu showed the highest amount of depositions and Hg with the least amount of depositions, although Hg and Cd was not detected in Pepper and Jute samples respectively. The amount of depositions of Pb was observed to be higher in Cassava sample which is in agreement with research conducted by Adebayo *et al*., (2011) and Bolade, (2016). The least amount of Pb depositions was observed in Jute sample with varying levels of depositions in Maize, Okra, Pepper and Tomato samples in no particular order. The higher quantity of Pb depositions in the Cassava sample could be attributed to the long-term rate of sun-drying along the roadside. Statistically there was significant difference (P≤0.05) observed in the amount of Pb deposition in Cassava to the amount of its depositions in Maize, Okra, Tomato and Jute samples. The Pb deposition in Pepper sample is statistically similar to its depositions in Cassava, Maize, Okra, Tomato and Jute samples.

Tomato sample showed the least amount of Hg deposition while Cassava sample showed the highest amount of Hg deposition. There was no statistically significance difference (P≥0.05) in the amount of Hg depositions in all selected agricultural products. Cassava and Jute samples showed the highest and lowest amount of As depositions respectively. The amount of As deposition in Cassava showed statistically significant difference (P≤0.05) to the amount of As depositions in other analyzed selected agricultural samples (Maize, Okra, Tomato and Jute) except Pepper that showed Statistically similarities to both the former and later. Cd showed more deposition in Cassava and Okra samples, while Tomato and Pepper showed the least concentration of Cd. Statistically there was no significant difference (P≥0.05) in the amount of Cd depositions in all selected agricultural samples analyzed. Fe showed highest and lowest depositions in Jute and Tomato respectively. The deposition of Fe in Maize, Okra, Pepper and Jute showed no statistically significant difference (P≥0.05) but are statistically significant different (P≤0.05) to the amount of Fe depositions in Cassava and Tomato samples. The metallic Fe pollution on the highways can be traced to a possible mechanical abrasion taking place in the tyres and alloy rims of motor vehicles, of which Fe is an essential component (Bolade, 2016). Cu was found to deposit the highest and lowest in Cassava and pepper samples respectively. The amount of Cu concentration in Maize, Okra and Pepper showed no statistically significant difference (P≥0.05) but are statistically significant different (P≤0.05) with Cu depositions in Cassava, Tomato and Jute. Despite slight increase in metallic depositions in all selected agricultural samples sun-dried by the roadside in comparison to the selected agricultural samples preserved or stored under controlled conditions (table 6), the level of depositions are still below FAO/WHO permissible limit.

Lead is a harmful environmental pollutant which has high toxic effects to many body organs. It is mostly absorbed from respiratory and digestive systems but can also be absorbed from the skin. Exposure to Pb can induce neurological, respiratory, urinary, and cardiovascular disorders due to immune-modulation, oxidative, and inflammatory mechanisms. Furthermore, Pb could disturb the balance of the oxidant–antioxidant system and induce inflammatory responses in various organs. Exposure to Pb can also produce alteration in physiological functions of the body and is associated with many diseases (Joseph *et al*., 2005; Kianoush *et al*., 2012). In table 5, the selected agricultural samples were sourced from local kitchen rooftops in Gindin waya village (along Wukari – Ibi highway). A noticeable amount of heavy metals contamination was observed in all the selected agricultural samples although they are below the FAO/WHO acceptable daily intake in food. Jute and Tomato samples showed the highest and lowest amount of Pb depositions when analyzed for heavy metals. Varying degrees of Pb depositions was also noticed in Okra, Maize, Pepper and Cassava samples. Amount of metallic depositions in Maize, Cassava, Okra and Tomato showed no statistically significant difference (P≥0.05). A Statistical significant difference (P≤0.05) was observed in the amount of Pb contamination in Cassava, Okra and Tomato samples when compared to the amount of Pb depositions in Pepper and Jute samples. It was also observed that the amount of Pb depositions seen in Maize sample showed statistical similarity with amount of Pb depositions in Pepper and Jute samples.

The study revealed that the level of Hg deposition was higher in Okra and Jute samples and lower in Maize and Pepper samples. There was no statistically significant difference (P≥0.05) observed in the amount of Pb depositions in all selected agricultural products analyzed. The amount of As deposition were found to be highest and lowest in Maize and Tomato samples. A statistical significant difference was observed in the amount of As depositions in Cassava, Okra, Tomato and Pepper when compared to the amount of As deposition in Jute sample. The maize samples As deposition showed statistical similarities to the amount of As depositions noticed in all the selected agricultural samples analyzed. Cd was not detected in Jute sample but showed higher deposition in Maize sample and lower amount of deposition in Pepper sample. Statistically the amounts of Cd in all selected agricultural samples analyzed are related.

Cassava and Okra samples showed the highest and lowest amount of Fe depositions respectively. Statistically there is no significant difference (P≥0.05) in the concentration of Fe found in Maize, Cassava and Tomato samples and also between Pepper and Jute samples. The amount of Fe deposition in Maize, Cassava and Tomato samples statistically differ with the Fe deposition in Pepper and Jute samples. Fe deposition in Okra sample showed statistically significant difference (P≤0.05) when compared to the amount of Fe depositions in all the other selected agricultural samples analyzed. Cu was found to be deposited in higher amount in Maize sample when compared to other selected agricultural samples analyzed. Pepper sample showed the least of Cu deposition. Statistically Cu depositions in Maize, Cassava and Tomato samples showed similarities but differ from the amount of Cu depositions in Pepper and Jute samples; statistically significantly similar, and Maize sample. Generally, it was observed that all analyzed selected agricultural samples sun-dried by roadside (table 4) and stored at local kitchen rooftops (table 5) showed appreciable amount of metallic depositions when compared to the selected agricultural products preserved or stored under controlled conditions (table 6).

Analysis of selected agricultural samples sourced from Kente (Wukari – Kente road) showed heavy metals depositions on roadside sun-dried selected agricultural products at appreciable levels (table 7) but not exceeding the permissible limit set by FAO/WHO. The level of lead deposition was found to be higher in Cassava sample and lowest in Pepper sample. Pb depositions in Okra, Tomato and Jute samples showed no statistically significant difference ($P \geq 0.05$) but were observed to showed statistically significance difference ($P \leq 0.05$) with Pb depositions in Maize, Cassava, and Pepper which are statistically related. There was no statistically significant difference ($P \geq 0.05$) observed in the amount of depositions in all selected agricultural samples analyzed.

The Maize and Jute samples were found to be samples with the highest and lowest amount of Hg depositions respectively. The cassava sample was observed to possess the highest amount of As deposition with the least As deposition in Pepper sample. Although no statistically significant difference ($P \geq 0.05$) observed in the level of As depositions in all selected agricultural samples but the As depositions in Cassava and Pepper samples are more related. Cd levels of deposition showed higher amount in Cassava sample similar to research by Bolade, (2016) and least in Okra sample. Statistically there was no significant difference ($P \geq 0.05$) observed in the levels of depositions of Cd in all the selected agricultural samples analyzed. Severe exposure of Cd may result in pulmonary effects such as emphysema, bronchiolitis and alveolitis. Renal effect may also result due to sub-chronic inhalation of Cd (Young, 2005). Fe contamination of the selected agricultural samples was observed to be highest and lowest in Tomato and Okra samples respectively. Statistically Maize, Cassava and Pepper samples showed similarities in the amount of Fe deposition and Okra, Tomato and Jute samples were also statistically related in the level of Fe depositions in them. Maize and Tomato samples were analyzed to show the highest and lowest levels of Cu depositions respectively. Statistically Maize, Cassava and Pepper samples showed similarities in the amount of Cu deposition and Okra, Tomato and Jute samples were also statistically related in the level of Cu depositions in them.

The selected agricultural samples stored at local kitchen rooftops sourced from Kente village (table 8) showed varying levels of heavy metals depositions. Generally, Cu was found to be the heavy metal with the highest depositions in all the selected agricultural samples stored at local kitchen rooftops and least was Hg with varying degrees of depositions of Pb, As, Cd and Fe. Maize and Tomato samples analyzed revealed to be the samples with the highest and lowest levels of Pb depositions respectively. Okra, Tomato and Jute samples were observed to show statistical significant similarities and statistically significantly different ($P \leq 0.05$) from Maize and Pepper samples in the levels of Pb depositions. The levels of Pb depositions in Cassava sample were observed to be statistically significantly different when compared to all other analyzed agricultural samples. There was no statistical significant difference ($P \geq 0.05$) observed in the levels of Hg depositions in all analyzed agricultural products. It was observed that the highest and lowest levels of depositions of Hg were found in Maize/Cassava and Pepper/Jute samples respectively.

Arsenic as a harmful heavy metal is one of the main risk factors for the public health. Sources of As exposure are occupational or via the contaminated food and water (Mahdi, *et al*., 2016). In terms of the levels of As depositions in the analyzed agricultural samples, the Cassava and Okra samples showed the highest and least depositions. Statistically the levels of As depositions in Maize, Cassava and Pepper samples are same and statistically significantly different ($P \leq 0.05$) from the levels of As depositions in Tomato, Okra and Jute samples. Cd levels of depositions in all analyzed agricultural products were observed to be statistically insignificant ($P \geq 0.05$). It was observed that the samples with the highest and least levels of Cd depositions are Maize and Pepper samples respectively. Tomato and Jute samples were found to possess the highest and least amount of Fe depositions. The amount of Fe depositions in Cassava, Tomato, Okra and Jute samples are statistically the same. Fe depositions in Maize sample were observed to be statistically significantly different ($P \leq 0.05$) to the level of Fe depositions in Pepper sample and consequently to that of Cassava, Okra, Tomato and Jute samples. Generally, the levels of metallic depositions on the selected agricultural samples sun-dried by the roadside (table 7) and stored at local kitchen rooftops (table 8) sourced from Kente were revealed to be higher when compared to metallic depositions in all the analyzed agricultural samples preserved or stored under controlled conditions (table 9).

Table 10 showed the summary of metallic depositions on agricultural products from Byepyi, Gindin waya and Kente. Average of each heavy metal in all selected agricultural samples sun-dried by roadsides, local kitchen rooftops and sun-dried or stored under controlled conditions were analyzed for each location. Agricultural samples sun-dried by roadsides sourced from Byepyi were observed to possess the highest amount of metallic depositions, closely followed by agricultural samples sun-dried by roadsides sourced from Kente with roadside sun-dried agricultural samples sourced from Gindin waya having the least amount of depositions. The research results of agricultural samples stored at local kitchen rooftops sourced from Byepyi, Gundin waya and Kente villages, showed that metallic depositions were found to be higher in selected agricultural samples from Byepyi village and the samples sourced from Kente village having the least amount of metallic depositions in them. The agricultural samples stored at local kitchen rooftops sourced from Gindin waya revealed almost similar quantity of metallic depositions to those sourced from Byepyi village. Heavy metals were estimated to be higher in samples sourced from Byepyi than Gindin waya or Kente. Justification of this established result is not far fetch from the fact that Byepyi (Wukari – Jalingo) experience more vehicular activities. Probable higher depositions of heavy metals in soil, poor quality road and high volume of old vehicles/motorcycles could be the reasons for higher metallic contaminations of selected agricultural samples sourced from Kente than those sourced from Gindin waya despite having lower vehicular activities. The control samples showed some degree of closed values of Fe depositions in them compared to samples sun-dried by roadside or stored at local kitchen rooftops, this is because the metal is nutritionally essential and is commonly found naturally in most agricultural products (Lebot, 2009). The elevated levels of Cu depositions in all selected agricultural samples could be based on high amount of Cu deposit in the soul. Given the summary of heavy metal depositions, it showed that the amount of metallic depositions on selected agricultural samples were higher in samples stored at local kitchen rooftops than samples sun-dried at roadsides and under controlled conditions in all the research locations. The level of metallic depositions in the selected agricultural samples varies from one location to the other, this could be attributed to factors such as road quality, types of Vehicles plying the roads, types of wood used in cooking, duration of sun-drying and stored at local kitchen rooftops, traffic density and volume of old vehicles plying the highways (Amusan *et al*., 2003). Variations in the amount of heavy metals depositions between the control samples and experimental samples are lower in Kente village than Byepyi and Gindin waya villages.

CONCLUSION

The research overall results obtained revealed evidence of metallic pollutants depositions on selected agricultural products at varying degrees. The concentration of the metallic pollutants varied from one agricultural sample to the other and from one road to the other. These could be attributed to the factors such as traffic density, types of wood used in making fire, amount of pollutants in the soil, types of vehicles/motor cycles gas used, quality of road and possibly the ratio of new to old vehicles/motor cycles plying the roads. Although the concentration of metallic pollutants on the selected agricultural samples in Byepyi, Gindin waya and Kente were generally below FAO/WHO safe limit. Consumption of these agricultural products with reasonable concentration of heavy metals and PAHs levels may result to high level of bioaccumulation in the human system causing related health disorders.

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