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*Corresponding author: Mathew Kolawole Bolade, Department of Food Science and Technology, Federal University of Technology, P.M.B. 704, Akure, Nigeria
E-mail: mkbolade@futa.edu.ng

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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

An investigation into the level of metallic pollutants in roadside-sundried food products from selected areas of Ondo and Osun states, Nigeria

Mathew Kolawole Bolade^{1*}

Abstract: The extent of atmospheric metallic pollution in roadside-sundried food products from selected areas of Ondo and Osun states, Nigeria, was investigated. Nine different road networks in the selected states were covered while the food products collected along these highways were fermented cassava (*Manihot esculenta* Crantz) mash, unripe plantain (*Musa AAB*) slices, white yam (*Dioscorea rotundata*) slices and pepper (*Capsicum frutescens*). The concentrations of the metallic pollutants (lead, cadmium, zinc, nickel, iron and copper) in the food products were found to vary from one product to the other. The minimum and maximum levels of these metallic pollutants generally present were lead (0.0024–0.0083 mg/100 g), Cadmium (0.0014–0.0131 mg/100 g), zinc (0.0078–5.41 mg/100 g), nickel (0.0016–0.0098 mg/100 g), iron (0.104–24.13 mg/100 g) and copper (0.0001–3.42 mg/100 g). The level of atmospheric metallic pollutants as found in roadside-sundried food products was generally below the recommended maximum limits by the FAO/WHO, yet their continuous consumption might lead to a potential health risk. The roadside-sundrying practitioners were observed to be ignorant of the potential health challenges the metallic pollutants might cause, via the cumulative consumption of roadside-sundried food products. Therefore, an enlightenment programme is highly desirable such that the roadside-sundrying practice could be discouraged.

ABOUT THE AUTHOR

The author is an associate professor in the Department of Food Science and Technology, Federal University of Technology, Akure, Nigeria; and holds a PhD degree. His research focus has been in the areas of cereal, root and tuber crop processing and utilization. He has also worked in the areas of enhancement of consumers' acceptability, nutritional benefits and commercialization potentials of traditional food products through quality attribute assessment and improvement. He has published an appreciable number of research articles in reputable journals.

PUBLIC INTEREST STATEMENT

Roadside-sundrying of food materials is a common scene in most parts of southwestern region of Nigeria, made up of Lagos, Ogun, Oyo, Ondo, Osun and Ekiti states. The food materials usually sundried along the major highways include fermented cassava mash, unripe plantain slices, white yam slices and pepper, among others. Many travellers along these roads usually patronize these roadside-sundrying practitioners to purchase the dried food products for ultimate processing and consumption. The public interest of this study is that the atmospheric metallic pollutants (lead, cadmium, zinc, nickel, iron and copper), emanating from vehicular exhaust and wear and tear of some vehicle components, do settle on these roadside-sundried food materials. The metallic pollutants have been implicated of capable of causing different types of diseases in human. Evaluating the degree of such pollutants in the food products concerned will therefore create a great awareness in the region.

Subjects: Bioscience; Environment & Agriculture; Food Science & Technology

Keywords: roadside; sundrying; metallic pollutant; food preservation; vehicular exhaust

1. Introduction

Food preservation is an age-long practice by all races of the world with entirely all food commodities involved (Shafiur Rahman, 2007). The significance of food preservation is to extend the shelf life of food commodity such that the time span in which it stays qualitatively good and acceptable is extended or elongated (Kordylas, 1990). Different preservation methods are usually applied to different food commodities which include fermentation, smoking, heat processing, refrigeration, freezing, curing, sundrying, dehydration, irradiation, among others (Ihekoronye & Ngoddy, 1985). However, only few of these methods are appropriate for use in the developing countries due to fundamental socio-economic problems. For instance, irradiation method of food preservation cannot be afforded by most developing countries as a result of its technological complexity coupled with capital intensiveness of equipment acquisition. Similarly, freezing method requires adequate electricity supply which, to a great extent, is epileptic and inadequate in most developing countries. Therefore, the most commonly found food preservation practices in these countries are fermentation, smoking, curing and sundrying, which are less sophisticated in operation and are affordable.

In Nigeria, sundrying is a major preservation method being used by people and the food commodities to which it is applied include cereal grains, chips from plantain, root and tuber crops, pepper, meat, cocoa beans, vegetables, coffee berries, among others (Kordylas, 1990). Sundrying operation is usually carried out, within the periphery of a household, on concrete platform, raffia mats, raised platform, polypropylene mats, plantain and banana leaves, naturally formed igneous rock, or bare floor. The operation usually takes about 3–5 days for sufficient drying depending on the climatic conditions, shape, size and composition of the food commodity involved as well as the prevailing temperature, humidity and velocity of the air (Ihekoronye & Ngoddy, 1985). Sundried food products are usually meant for household income generation as well as for personal consumption.

Roadside-sundrying of food commodities is relatively a new dimension to drying operations in Nigeria, particularly in the southwestern region comprising Lagos, Ogun, Oyo, Ondo, Osun and Ekiti states. The advent of this practice is not known but it appears it all began in the late 1940s during the colonial era when the region was witnessing massive construction of modern road networks. The practice is common among communities through which major highways traversed. It is generally believed that sundrying seems to be faster on the roadside, particularly the road verges, coupled with the fact that the location is believed to belong to the government and no individual could lay claim to its ownership. Nevertheless, the practice is prone to contamination by pollutants such as faeces from roaming animals, dust, exhaust emissions and abrasive particulates from the moving vehicles while there had been instances of road accidents involving people engaged in roadside-sundrying.

Emissions from vehicular traffic on the roads have been observed to contain metals such as lead (Pb), cadmium (Cd), zinc (Zn) and nickel (Ni), which are present in fuel as anti-knock agents (Ikeda et al., 2000). Similarly, metals such as iron (Fe), copper (Cu) and Zn have been observed to be essential components of many alloys, wires and tyres in motor vehicles and are usually released into the roadside environment as a result of mechanical abrasion and normal wear and tear (Harrison, Laxen, & Wilson, 1981). Many researchers have noted the toxicological implications of these metals in human systems. The presence of Pb in human system can lead to negative effect on mental development particularly in children, an effect that persists into adulthood (Needleman, Schell, Bellinger, Leviton, & Allred, 1990). Inhalation of Cd fumes or particles can lead to kidney damage (Jarup, Berglund, Elinder, Nordberg, & Vahter, 1998; WHO, 1992) while excessive consumption of Zn can cause diarrhoea, pancreatitis and damage of hepatic parenchyma (Salgueiro et al., 2000). Excessive dietary Ni ingestion can cause allergic contact dermatitis (Zirwas & Molenda, 2009); liver cell necrosis and heart failure can be caused

by excessive dietary Fe ingestion (Schümann, 2001), while excessive dietary exposure of Cu can lead to liver and kidney damage, among others (Auza, Olson, Murphy, & Linn, 1999; Bidewell & Livesey, 2002).

Some research works had been carried out particularly on the evaluation of metallic pollution of food products found by the roadside in Nigeria. An earlier study by Obanijesu and Olajide (2009) was essentially on the evaluation of trace metal pollution of a single roadside-sundried food product (cassava flour) at five different locations in Nigeria. Adebayo and Rapheal (2011) also carried out a survey of heavy metal contamination in cassava mash and maize grains being sundried along the highways in three states (Benue, Nassarawa and Taraba) of northern Nigeria. Another study by Dibofori-Orji and Edori (2015) was on heavy metal pollution assessment of a cassava product (garri) being sold along some busy highways in Nigeria. All these studies revealed the presence of heavy metals in the respective samples.

Therefore, due to the serious toxicological challenges that the metallic pollutants may cause in humans, there is the need to assess their level of contamination in the available roadside-sundried food products in two major southwestern states in Nigeria; and this is the general objective of this study.

2. Materials and methods

2.1. Location of the study

Two states from southwestern region of Nigeria, Ondo and Osun, were used for the study. Figure 1 shows the map of southwestern Nigeria indicating road networks joining towns/cities. In Ondo state, the road networks covered under the study were Akure to Ondo, Akure to Owo, Owo to Ifon and Akure to Owena-Ijesha. In Osun state, the road networks covered were Owena-Ijesha to Ilesha, Ilesha to Ile-Ife, Ile-Ife to Gbongan, Ilesha to Oshogbo and Gbongan to Ikire. The selected road networks constitute the busiest ones in the two states.

2.2. Survey of the sundrying locations on the highways and interview of the practitioners

Survey of the sundrying locations on the highways was carried out through direct contact, while information from the practitioners was collected using direct interviews, direct observations and structured questionnaire. A total of thirty-three (33) respondents were interviewed from different locations in the survey.

2.3. Sample collection

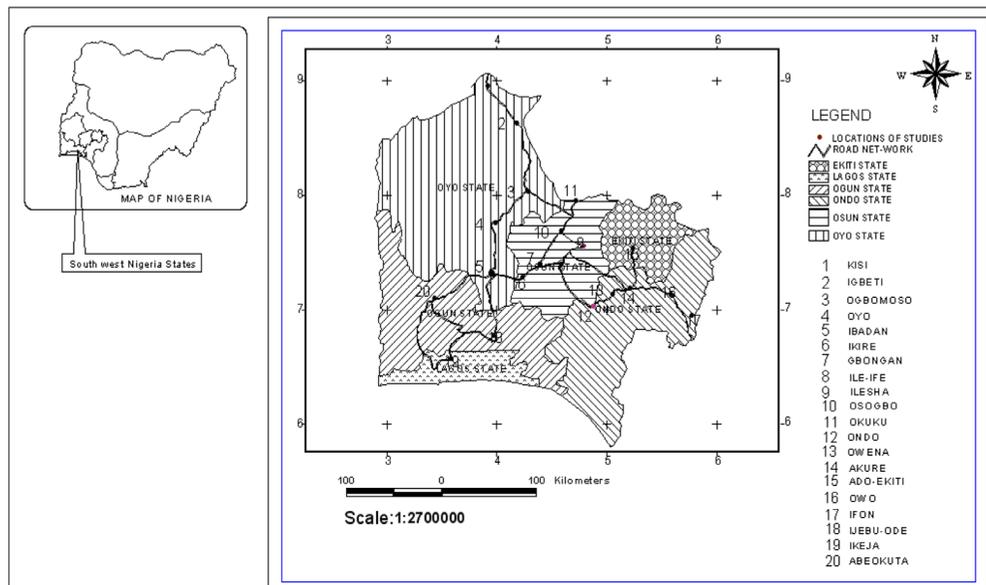
The samples collected from all the selected roadside-sundrying spots are fermented cassava (*Manihot esculenta* Crantz) mash, unripe plantain (*Musa AAB*) slices, white yam (*Dioscorea rotundata*) slices and pepper (*Capsicum frutescens*). Freshly prepared sample of each material (not yet sundried) was first collected (by purchasing) from the practitioners and taken to the laboratory for oven-drying. The oven-drying of samples was carried out at $55 \pm 2^\circ\text{C}$ for 72 h after which they were separately kept in black polyethylene bags for subsequent analysis. The oven-dried samples are to serve as the control. The roadside-sundried samples were later collected (also by purchasing) from the practitioners after about 6–7 days of initial collection of respective freshly prepared samples. For each roadside-sundried material sample, it was randomly collected from three different locations in the bulk in order to ensure representative sampling. The samples so collected were separately kept in black polyethylene bags during transportation and finally brought to the laboratory for analysis.

2.4. Determination of metallic content in the samples

The presence of metallic pollutants (lead, cadmium, zinc, nickel, iron and copper) was determined in each of the samples collected according to the method as described by Edem, Iniama, Osabor, Etiuma, and Ochelebe (2009). Each sample was, respectively, ground properly using laboratory pestle and mortar. Thereafter, 5 g of the sample was weighed into a 100-ml beaker for digestion using 20 ml of HNO_3 and HCl (1:1, v/v) on an electro mantle at $98 \pm 2^\circ\text{C}$. In some cases, more solution of HNO_3/HCl was added in order to ensure complete digestion of the sample. After the digestion, the

Figure 1. Map of southwestern Nigeria showing road network joining towns/cities.

Note: Inset is the map of Nigeria showing southwestern region.



solution was allowed to cool followed by filtration using laboratory funnel and filter paper (Whatman No. 42 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 metallic content determination with the aid of Atomic Absorption Spectrophotometer (Buck Scientific, model 210 VGP, USA). The samples oven-dried in the laboratory (control) were similarly subjected to the same procedures for analysis.

2.5. Statistical analysis

The socio-demographic characteristics of the respondents as well as the perceptions of the respondents to roadside-sundrying practice were analysed using frequency distribution (Steel & Torrie, 1980). All other determinations reported in this study were carried out in triplicates. In each case, a mean value and standard deviation were calculated. Analysis of variance was also performed and separation of the mean values was done by Duncan's Multiple Range Test at $p < 0.05$ using Statistical Package for Social Scientists software, version 16.0; on a personal computer.

3. Results and discussion

3.1. Socio-demographic characteristics of practitioners and their perceptions of roadside-sundrying practice in selected areas of southwestern Nigeria

The preliminary survey carried out on roadside-sundrying practice revealed that all the practitioners ($n = 33$) involved in roadside-sundrying, from the nine different road networks in southwestern Nigeria, were female (Table 1). This observation is deep-rooted in the cultural belief of the people that women are to be involved in household food processing, preservation and marketing while men are for planting of crops, weeding where necessary and ultimate harvesting. Majority (58%) of the roadside-sundrying practitioners fell within 41–50 years of age, while 27% of them were within 31–40 years. None was observed to be more than 60 years of age and this may be attributed to the dangerous nature of roadside-sundrying practice in terms of possible motor accidents while crossing the roads. Older people are generally considered vulnerable to this form of road accidents due to their reduced agility. It had earlier been observed that all older road users, whether pedestrians, drivers, riders or passengers, share natural decline in functional capacities and increased fragility associated with ageing which predispose them towards increased risk during mobility (CARRS, 2016). The marital status of roadside-sundrying practitioners showed that all the people were married. This observation is suggesting that there might be a strong linkage between the practice and family-related matters.

Table 1. Socio-demographic characteristics of practitioners of roadside-sundrying practice in selected areas of Ondo and Osun states, Nigeria

Socio-demographic variable	Road network									Percentage of respondents (n = 33)
	Akure to Owena-Ijesha	Akure to Ondo	Akure to Owo	Owo to Ifon	Owena-Ijesha to Ilesha	Ilesha to Ile-Ife	Ilesha to Oshogbo	Ile-Ife to Gbongan	Gbongan to Ikire	
<i>Gender</i>										
(i) Female	2	3	2	5	4	3	2	7	5	100
(ii) Male	0	0	0	0	0	0	0	0	0	0
<i>Age</i>										
(i) 21–30 years	0	0	0	0	0	0	0	2	1	9
(ii) 31–40 years	1	1	0	1	1	1	0	2	2	27
(iii) 41–50 years	1	2	2	3	3	1	2	3	2	58
(iv) 51–60 years	0	0	0	1	0	1	0	0	0	6
(v) 61 and above	0	0	0	0	0	0	0	0	0	0
<i>Marital status</i>										
(i) Single	0	0	0	0	0	0	0	0	0	0
(ii) Married	2	3	2	5	4	3	2	7	5	100
<i>Formal education</i>										
(i) Post secondary education	0	0	0	0	0	0	0	0	0	0
(ii) Secondary education	0	1	0	2	1	1	1	2	2	30
(iii) Primary education	1	1	1	2	2	2	1	4	2	49
(iv) Non-formal education	1	1	1	1	1	0	0	1	1	21
<i>Tribe</i>										
(i) Hausa-speaking	0	0	0	0	0	0	0	0	0	0
(ii) Igbo-speaking	0	0	0	1	0	0	0	0	0	3
(iii) Yoruba-speaking	2	2	1	2	4	3	2	6	4	79
(iv) Tiv-speaking	0	1	1	2	0	0	0	1	1	18
(v) Others	0	0	0	0	0	0	0	0	0	0

The educational background of the roadside-sundrying practitioners revealed that majority (48%) of them had primary school education, while 30% had secondary school education. Some of them (21%) had no formal education, while none was observed to have post-secondary education. The roadside-sundrying practice was observed to cut across diverse ethnic groups in southwestern Nigeria. Majority (79%) of the practitioners came from Yoruba-speaking tribe and this is expected because the southwestern Nigeria is made up of Yoruba-speaking communities. Other tribes found in the practice include Tiv-speaking (18%) and Igbo-speaking (3%) people. Both Tiv-speaking and Igbo-speaking roadside-sundrying practitioners can be regarded as migrants to the areas because the tribes are naturally located in the north-central and southeastern geopolitical regions of Nigeria, respectively.

The perception of roadside-sundrying practice by the practitioners in selected areas of Ondo and Osun states, Nigeria, is presented in Table 2. About 58% of the respondents had been involved in the practice for 6–10 years, while 9% were only involved for 11–15 years (Table 2). Greater number (61%) of the respondents stated that the main reason for their involvement in roadside-sundrying practice was that the location (road verges), on which the sundrying normally takes place, is a ready-made spot for drying and does not require any other logistics such as provision of drying mats. It had similarly been observed that sundrying of food commodities along the roadside is for cost optimization (Adebayo-Oyetoro, Oyewole, Obadina, & Omemu, 2013). About 30% were involved in the practice

Table 2. Perception of roadside-sundrying practice by the practitioners in selected areas of Ondo and Osun states, Nigeria

S. No.	Item in the questionnaire	Percentage of respondents (n = 33)
1	How long have you been in the roadside-sundrying practice?	
	(i) 1–5 years	33
	(ii) 6–10 years	58
	(iii) 11–15 years	9
2	(iv) 16 years and above	0
	What are the reasons for your roadside-sundrying practice?	
	(i) There is no claim to land ownership	6
	(ii) Location is secured as there is no animal threat to the commodity	3
	(iii) Location is very close to the place of owner's commercial activity which can facilitate proper monitoring	30
(iv) The commodity takes shorter time to dry properly	0	
(v) The location (road verges) is a ready-made spot for drying devoid of certain logistics like provision of drying mats, etc	61	
3	Are you aware of possible contamination of the commodity particularly by the vehicular exhaust?	
	(i) Yes	100
4	(ii) No	0
	Are you aware of possible danger or health hazard the vehicular exhaust can cause?	
5	(i) Yes	0
	(ii) No	100
6	Are you aware of other dangers like road accident due to your roadside activities?	
	(i) Yes	100
6	(ii) No	0
	Who are the ultimate consumers of your roadside-sundried commodity?	
	(i) The commodity is primarily meant for income generation for the family	24
(ii) The commodity is for both income generation and family consumption	64	
(iii) The commodity is for family consumption only	12	

simply because of the proximity of the drying spot (road verges) to the place of their commercial activities. Other reasons given for their involvement in roadside-sundrying practice include the absence of claim to land ownership (6%) and security of the commodity undergoing sundrying from animal threat (3%).

All the respondents ($n = 33$) were aware of possible contamination which the vehicular exhaust could cause to the food commodities undergoing roadside-sundrying, but were equally ignorant of possible danger or health hazard the exhaust could cause. However, they were aware of other dangers such as road accidents which they were carefully guiding against. Majority of the respondents (64%) were using the roadside-sundried food commodities for both income generation and family consumption. Only 24% of the respondents were using the commodities for just income generation for the family, while about 12% were using them for family consumption alone.

3.2. Degree of metallic pollution in roadside-sundried fermented cassava (*Manihot esculenta* Crantz) mash

Table 3 shows the level of metallic pollutants in roadside-sundried fermented cassava (*Manihot esculenta* Crantz) mash. The concentration of Pb found in the roadside-sundried fermented cassava mash (FCM) ranged between 0.0045 and 0.0068 mg/100 g, while Pb was not detected in the control samples. These values are relatively low when compared to the recommended maximum limit for Pb (0.2 mg/100 g) (FAO/WHO, 2002). The atmospheric Pb pollution in the fermented cassava mash was found to be the highest along Owo-Ifon highway, while Akure-Owo road contributed the lowest. The possible source of atmospheric Pb on the roadside-sundried food commodities has been traced to the presence of organometallics such as tetramethyl lead [(C₂H₅)₄Pb] in the petrol (gasoline) as an additive and is an important source of lead in automobile exhaust emission (Ademoroti, 1986).

The cadmium (Cd) content of the roadside-sundried FCM ranged between 0.0042 and 0.068 mg/100 g, while none was detected in the control samples. Appreciable level of significant differences ($p < 0.05$) was observed in the roadside-sundried samples. The Cd pollution level in FCM along Akure-Owena Ijesha highway (0.0068 mg/100 g) was the highest, while that of Gbongan-Ikire highway (0.0042 mg/100 g) was the lowest. The differences in the level of metallic pollutants

Table 3. Level of metallic pollutants in roadside-sundried fermented cassava (*Manihot esculenta* Crantz) mash

Source of fermented cassava mash	Category	Metallic pollutant (mg/100 g) ¹					
		Pb	Cd	Zn	Ni	Fe	Cu
Akure to Owena-Ijesha	RS-(a) ²	0.0052 ± 0.0007 ^b	0.0068 ± 0.0004 ^a	0.271 ± 0.021 ^a	0.0061 ± 0.0008 ^b	0.151 ± 0.029 ^a	0.062 ± 0.008 ^{ab}
	Control-(a)	ND ³	ND	0.182 ± 0.034 ^c	ND	0.089 ± 0.012 ^{cd}	0.048 ± 0.006 ^{cde}
Owo to Ifon	RS-(b)	0.0068 ± 0.0003 ^a	0.0044 ± 0.0003 ^c	0.215 ± 0.022 ^{bc}	0.0052 ± 0.0006 ^{bc}	0.104 ± 0.017 ^{bc}	0.071 ± 0.004 ^a
	Control-(b)	ND	ND	0.184 ± 0.051 ^c	ND	0.067 ± 0.009 ^d	0.052 ± 0.007 ^{bcd}
Ilesha to Ile-Ife	RS-(c)	0.0057 ± 0.0005 ^b	0.0051 ± 0.0007 ^b	0.255 ± 0.031 ^{ab}	0.0042 ± 0.0009 ^d	0.117 ± 0.011 ^{bc}	0.059 ± 0.009 ^{abc}
	Control-(c)	ND	ND	0.182 ± 0.011 ^c	ND	0.069 ± 0.009 ^d	0.035 ± 0.006 ^f
Akure to Owo	RS-(d)	0.0045 ± 0.0002 ^c	0.0064 ± 0.0008 ^a	0.246 ± 0.021 ^{ab}	0.0048 ± 0.0005 ^{cd}	0.131 ± 0.023 ^{ab}	0.068 ± 0.008 ^a
	Control-(d)	ND	ND	0.186 ± 0.019 ^c	ND	0.062 ± 0.007 ^d	0.039 ± 0.005 ^{ef}
Gbongan to Ikire	RS-(e)	0.0063 ± 0.0006 ^a	0.0042 ± 0.0003 ^c	0.245 ± 0.021 ^{ab}	0.0071 ± 0.0009 ^a	0.161 ± 0.032 ^a	0.072 ± 0.006 ^a
	Control-(e)	ND	ND	0.179 ± 0.027 ^c	ND	0.071 ± 0.008 ^d	0.043 ± 0.009 ^{def}
Range:		RS = 0.0045–0.0068	RS = 0.0042–0.0068	RS = 0.215–0.271	RS = 0.0042–0.0071	RS = 0.104–0.161	RS = 0.059–0.072
		Control = ND	Control = ND	Control = 0.179–0.186	Control = ND	Control = 0.062–0.089	Control = 0.035–0.052

¹Values are mean value ± standard deviation. Mean values followed by different superscripts in each column are significantly different at $p < 0.05$.

²RS = Roadside-sundried.

³ND = Not detected.

generally along different road networks may be attributed to factors such as traffic density (Fatoki & Ayodele, 1991), volume of second-hand vehicles (imported used vehicles) plying the roads and the presence of uphill portions in the highways (Amusan, Bada, & Salami, 2003). Cadmium as a metallic pollutant in roadside-sundried food products had been observed to have originated from fuel, being one of its anti-knock agents (Ikeda et al., 2000). The Cd level in the roadside-sundried FCM was generally lower than the recommended maximum limit of 0.1 mg/100 g (FAO/WHO, 2002).

The concentration of Zn in the roadside-sundried FCM ranged between 0.215 and 0.271 mg/100 g while that of the control samples ranged between 0.179 and 0.186 mg/100 g. Zinc is naturally present in cassava (Lebot, 2009) and this accounted for its various levels in the control samples. The Zn concentration in the food product at different highways is significantly different ($p < 0.05$) with FCM from Akure–Owena Ijesha road axis exhibiting higher Zn level than others. It had earlier been observed that the atmospheric Zn along the highways is usually a function of traffic density (Amusan et al., 2003; Fatoki & Ayodele, 1991). However, the different levels of Zn as exhibited in the roadside-sundried FCM generally fell below the recommended maximum limit of 10 mg/100 g (FAO/WHO, 2001).

The nickel Ni concentration in the roadside-sundried FCM ranged between 0.0042 and 0.0071 mg/100 g, while Ni was not detected in the control samples. The implication of this observation is that Ni might have found its way into the food product through vehicular emission in the highways. Nickel is essentially present in the fuel as one of the anti-knock agents (Ikeda et al., 2000) and, through vehicular emission, exists in particulate form and is therefore forced to settle under gravity on anything by the roadside (Haygarth & Jones, 1992). The concentrations of Ni in the roadside-sundried FCM were generally lower than the recommended maximum limit of 6.7 mg/100 g in vegetables (FAO/WHO, 2001).

The iron (Fe) concentrations in the FCM ranged between 0.104 and 0.161 mg/100 g, while those of the control samples were between 0.062 and 0.089 mg/100 g. The control samples contained some degree of Fe in them and this is because the metal is nutritionally essential and is commonly found naturally in cassava root (Lebot, 2009). 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 (Harrison et al., 1981). The Fe level as found in the roadside-sundried FCM is generally lower than the recommended maximum limit of 42.5 mg/100 g in vegetables (FAO/WHO, 2001).

The amount of copper (Cu) pollution in the roadside-sundried FCM ranged between 0.059 and 0.072 mg/100 g, while that of the control samples ranged between 0.035 and 0.052 mg/100 g. The food commodity from Gbongan–Ikire road axis exhibited highest Cu level though not significantly different ($p < 0.05$) from that of other road networks. The Cu as a metallic pollutant on the highways might have originated from mechanical abrasion and normal wear and tear occurring in alloy rims, wires and tyres of motor vehicles plying the roads (Harrison et al., 1981). The recommended maximum limit of Cu in vegetables is 7.3 mg/100 g (FAO/WHO, 2001), but the Cu level in the roadside-sundried FCM was generally lower than this limit.

3.3. Level of metallic pollutants in roadside-sundried unripe plantain (*Musa AAB*) slices

Unripe plantain slices are one of the food commodities being sundried by the roadside in southwestern Nigeria. Lead as a metallic pollutant was detected in the slices and ranged between 0.0024 and 0.0083 mg/100 g, while the control samples had none (Table 4). The plantain slices from Ile Ife–Gbongan road axis contained the highest Pb concentration signifying a possible high traffic volume and/or vehicular emission with Pb pollution.

The Cd content in the roadside-sundried plantain slices ranged between 0.0081 and 0.0131 mg/100 g, while none was detected in the control samples. The level of Cd pollution in the

Table 4. Level of metallic pollutants in roadside-sundried unripe plantain (*Musa AAB*) slices

Source of unripe plantain slices	Category	Metallic pollutant (mg/100 g) ¹					
		Pb	Cd	Zn	Ni	Fe	Cu
Akure to Ondo	RS-(f) ²	0.0052 ± 0.0006 ^b	0.0128 ± 0.0007 ^a	5.22 ± 0.34 ^{ab}	0.0043 ± 0.0004 ^d	20.91 ± 0.87 ^c	3.42 ± 0.07 ^a
	Control-(f)	ND ³	ND	4.34 ± 0.21 ^d	ND	16.83 ± 0.45 ^g	3.07 ± 0.05 ^c
Owena-Ijesha to Ilesha	RS-(g)	0.0076 ± 0.0008 ^a	0.0091 ± 0.0006 ^c	4.66 ± 0.35 ^{cd}	0.0077 ± 0.0009 ^b	21.24 ± 0.38 ^c	3.16 ± 0.09 ^{bc}
	Control-(g)	ND	ND	3.41 ± 0.16 ^e	ND	18.32 ± 0.24 ^{ef}	2.88 ± 0.08 ^{de}
Ilesha to Ile-Ife	RS-(h)	0.0024 ± 0.0003 ^c	0.0131 ± 0.0008 ^a	4.89 ± 0.42 ^{abc}	0.0062 ± 0.0007 ^c	23.15 ± 0.31 ^b	2.91 ± 0.04 ^d
	Control-(h)	ND	ND	4.28 ± 0.32 ^d	ND	17.61 ± 0.63 ^{fg}	2.46 ± 0.07 ^f
Ilesha to Oshogbo	RS-(i)	0.0045 ± 0.0007 ^b	0.0116 ± 0.0007 ^b	5.12 ± 0.27 ^{abc}	0.0046 ± 0.0005 ^d	19.56 ± 0.77 ^d	3.21 ± 0.05 ^b
	Control-(i)	ND	ND	4.78 ± 0.29 ^{bcd}	ND	15.81 ± 0.64 ^h	2.77 ± 0.09 ^e
Ile-Ife to Gbongan	RS-(j)	0.0083 ± 0.0006 ^a	0.0081 ± 0.0005 ^{cd}	5.41 ± 0.22 ^a	0.0098 ± 0.0008 ^a	24.13 ± 0.59 ^a	2.93 ± 0.04 ^d
	Control-(j)	ND	ND	5.02 ± 0.17 ^{abc}	ND	19.27 ± 0.44 ^{de}	2.51 ± 0.07 ^f
Range:		RS = 0.0024–0.0083	RS = 0.0081–0.0131	RS = 4.66–5.41	RS = 0.0043–0.0098	RS = 19.56–24.13	RS = 2.91–3.42
		Control = ND	Control = ND	Control = 3.41–5.02	Control = ND	Control = 15.81–9.27	Control = 2.46–3.07

¹Values are mean value ± standard deviation. Mean values followed by different superscripts in each column are significantly different at $p < 0.05$.

²RS = Roadside-sundried.

³ND = Not detected.

sundried food material varied from one road network to the other with the highest Cd content found in slices from Ilesha–Ile Ife road axis, while the lowest came from that of Ile Ife–Gbongan.

The concentration of Zn in the roadside-sundried unripe plantain slices was found to be 4.66–5.41 mg/100 g with slices from Ile Ife–Gbongan road giving the highest value, while that from Owena Ijesha–Ilesha gave the lowest value. The control samples also ranged between 3.41 and 5.02 mg/100 g with significant differences ($p < 0.05$). The unripe plantain naturally contains some levels of Zn (Offem & Njoku, 1993) as reflected in the control samples and the roadside pollution was responsible for the significant increase in the Zn level of the sundried products.

The Ni level in the roadside-sundried unripe plantain slices was 0.0043–0.0098 mg/100 g with the control samples containing none. Samples from Ile Ife–Gbongan road exhibited the highest Ni pollution, while the lowest came from Akure–Ondo road. The highest Ni pollution level may be a reflection of high traffic volume with a concomitant release of high vehicular emission.

The Fe concentration in the roadside-sundried unripe plantain slices was 19.56–24.13 mg/100 g with significant differences ($p < 0.05$). The range of Fe for the control samples was 15.81–19.27 mg/100 g lower than that of the roadside-sundried samples. The Fe is one of the nutritionally essential metals found naturally in plantain (Offem & Njoku, 1993), while the additional concentration in the roadside-sundried samples might have arisen from wear and tear of motor vehicle tyres and rims.

The highest Cu pollution (3.42 mg/100 g) was found in roadside-sundried unripe plantain slices from Akure–Ondo road axis, while the lowest (2.91 mg/100 g) was from that of Ilesha–Ile Ife. The range for Cu concentration in the control samples was 2.46–3.07 mg/100 g. The atmospheric Cu had been observed to have emanated from mechanical abrasion and normal wear and tear of vehicular components such as tyres and alloy rims (Harrison et al., 1981). The Cu pollutant usually exists in

particulate form and is therefore forced to settle under gravity closer to the roadsides (Haygarth & Jones, 1992).

3.4. Roadside-sundried white yam (*Dioscorea rotundata*) slices and degree of their metallic pollution

Table 5 shows the level of metallic pollutants in roadside-sundried white yam slices. The Pb pollution level ranged between 0.0057 and 0.0078 mg/100 g while the metal was not detected in the control samples. The highest pollution level was from Gbongan–Ikire road axis and the lowest was from Ile Ife–Gbongan. The Pb pollution in roadside-sundried food products can said to be a function of traffic density coupled with whether the petrol being used by the vehicles was highly leaded or not.

The Cd concentration in the roadside-sundried white yam slices was 0.0048–0.0075 mg/100 g with no detection in the control samples. Product from Ilesha–Ile Ife road axis exhibited highest Cd pollution, while the lowest pollution came from Ile Ife–Gbongan.

The Zn pollution level in the roadside-sundried white yam slices ranged between 0.169 and 0.211 mg/100 g, while that of the control samples was 0.087–0.121 mg/100 g. The highest Zn pollution came from Ilesha–Ile Ife road axis, while the lowest was from Ile Ife–Gbongan. The metallic Zn is naturally found in white yam (Lebot, 2009) and its higher concentration as found in the roadside-sundried white yam slices was a reflection of atmospheric pollution.

The pollution of roadside-sundried white yam slices by atmospheric Ni ranged between 0.0048 and 0.0089 mg/100 g with no detection in the control samples. The lowest pollution level was found in product from Ilesha–Ile Ife road axis, while the highest level came from Ile Ife–Gbongan. Heavily travelled highways had earlier been implicated to cause high metallic pollution on roadside materials such as crops and food products (Ademoroti, 1986).

Table 5. Level of metallic pollutants in roadside-sundried white yam (*Dioscorea rotundata*) slices

Source of white yam slices	Category	Metallic pollutant (mg/100 g) ¹					
		Pb	Cd	Zn	Ni	Fe	Cu
Owena-Ijesha to Ilesha	RS-(l) ²	0.0064 ± 0.0007 ^{bc}	0.0063 ± 0.0005 ^b	0.181 ± 0.021 ^{ab}	0.0072 ± 0.0008 ^{bc}	0.546 ± 0.043 ^a	0.109 ± 0.009 ^{cd}
	Control-(l)	ND ³	ND	0.092 ± 0.015 ^{cd}	ND	0.344 ± 0.021 ^{cd}	0.076 ± 0.007 ^e
Ilesha to Ile-Ife	RS-(m)	0.0073 ± 0.0008 ^{ab}	0.0075 ± 0.0008 ^a	0.211 ± 0.022 ^a	0.0048 ± 0.0007 ^d	0.476 ± 0.049 ^b	0.116 ± 0.004 ^{bc}
	Control-(m)	ND	ND	0.102 ± 0.013 ^{cd}	ND	0.271 ± 0.018 ^e	0.078 ± 0.006 ^e
Ilesha to Oshogbo	RS-(n)	0.0069 ± 0.0005 ^{ab}	0.0055 ± 0.0006 ^c	0.194 ± 0.025 ^{ab}	0.0063 ± 0.0009 ^c	0.523 ± 0.056 ^{ab}	0.119 ± 0.009 ^{bc}
	Control-(n)	ND	ND	0.121 ± 0.011 ^c	ND	0.287 ± 0.033 ^{de}	0.098 ± 0.005 ^d
Ile-Ife to Gbongan	RS-(o)	0.0057 ± 0.0006 ^c	0.0048 ± 0.0004 ^c	0.169 ± 0.017 ^b	0.0089 ± 0.0005 ^a	0.488 ± 0.041 ^{ab}	0.132 ± 0.002 ^a
	Control-(o)	ND	ND	0.087 ± 0.008 ^d	ND	0.237 ± 0.032 ^e	0.075 ± 0.004 ^e
Gbongan to Ikire	RS-(p)	0.0078 ± 0.0009 ^a	0.0069 ± 0.0006 ^{ab}	0.171 ± 0.016 ^b	0.0076 ± 0.0008 ^b	0.395 ± 0.016 ^c	0.127 ± 0.007 ^{ab}
	Control-(p)	ND	ND	0.098 ± 0.012 ^{cd}	ND	0.242 ± 0.023 ^e	0.086 ± 0.008 ^e
Range:		RS = 0.0057–0.0078	RS = 0.0048–0.0075	RS = 0.169–0.211	RS = 0.0048–0.0089	RS = 0.395–0.546	RS = 0.109–0.132
		Control = ND	Control = ND	Control = 0.087–0.121	Control = ND	Control = 0.237–0.344	Control = 0.075–0.098

¹Values are mean value ± standard deviation. Mean values followed by different superscripts in each column are significantly different at $p < 0.05$.

²RS = Roadside-sundried.

³ND = Not detected.

The Fe content in the roadside-sundried white yam slices ranged between 0.395 and 0.546 mg/100 g, while that of control samples was between 0.237 and 0.344 mg/100 g. The highest Fe pollution level came from Owena Ijeshā-Ilesha road axis, while the lowest level came from Gbongan-Ikire. The metallic Fe is a natural constituent of white yam (Lebot, 2009) and this accounted for the varying levels of Fe in the control samples.

The concentration of Cu in the roadside-sundried white yam slices was found to range between 0.109 and 0.132 mg/100 g with the control samples ranging between 0.075 and 0.095 mg/100 g. Product from Ile-Ife-Gbongan road axis exhibited the highest Cu pollution, while that from Owena Ijeshā-Ilesha exhibited the lowest. Copper is a nutritionally important metal naturally present in white yam (Lebot, 2009), while its varying levels in the control samples may be as a result of possible diverse preliminary processing techniques adopted by the roadside-sundrying practitioners.

3.5. Degree of metallic pollution in roadside-sundried pepper (*Capsicum frutescens*)

The atmospheric Pb pollution in roadside-sundried pepper ranged between 0.0026 and 0.0041 mg/100 g with pepper from Owo-Ifon road axis exhibiting the highest pollution level, while the lowest came from Ile-Ife-Gbongan (Table 6). The control samples did not exhibit any Pb pollution which implies that the automobile exhaust emission was responsible for the pollution of roadside-sundried pepper. It had earlier been observed that the vehicular emission, usually in particulate form, has a high tendency of settling on any material closer to the roadside under gravity (Haygarth & Jones, 1992).

Table 6. Level of metallic pollutants in roadside-sundried pepper (*Capsicum frutescens*)

Source of pepper	Category	Metallic pollutant (mg/100 g) ¹					
		Pb	Cd	Zn	Ni	Fe	Cu
Akure to Owena-Ijeshā	RS-(z) ²	0.0032 ± 0.0004 ^{bc}	0.0016 ± 0.0003 ^c	0.0098 ± 0.0005 ^{bc}	0.0031 ± 0.0003 ^a	1.53 ± 0.06 ^{bc}	0.0005 ± 0.0001 ^{ab}
	Control-(z)	ND ³	ND	0.0071 ± 0.0009 ^e	ND	1.34 ± 0.03 ^{ef}	0.0002 ± 0.0 ^c
Akure to Ondo	RS-(aa)	0.0028 ± 0.0007 ^c	0.0022 ± 0.0005 ^b	0.0116 ± 0.0011 ^a	0.0018 ± 0.0002 ^c	1.46 ± 0.09 ^{cd}	0.0001 ± 0.0 ^d
	Control-(aa)	ND	ND	0.0084 ± 0.0007 ^d	ND	1.25 ± 0.05 ^f	ND
Owo to Ifon	RS-(ab)	0.0041 ± 0.0008 ^a	0.0014 ± 0.0003 ^c	0.0102 ± 0.0009 ^b	0.0023 ± 0.0004 ^b	1.72 ± 0.08 ^a	0.0002 ± 0.0 ^c
	Control-(ab)	ND	ND	0.0087 ± 0.0005 ^{cd}	ND	1.49 ± 0.07 ^{bcd}	ND
Ilesha to Ile-Ife	RS-(ac)	0.0036 ± 0.0005 ^{ab}	0.0029 ± 0.0004 ^a	0.0085 ± 0.0004 ^d	0.0028 ± 0.0005 ^a	1.38 ± 0.04 ^{de}	0.0006 ± 0.0001 ^a
	Control-(ac)	ND	ND	0.0058 ± 0.0007 ^f	ND	1.13 ± 0.05 ^g	0.0001 ± 0.0 ^d
Ile-Ife to Gbongan	RS-(ad)	0.0026 ± 0.0003 ^c	0.0031 ± 0.0005 ^a	0.0078 ± 0.0006 ^{de}	0.0016 ± 0.0003 ^c	1.59 ± 0.08 ^b	0.0002 ± 0.0 ^c
	Control-(ad)	ND	ND	0.0051 ± 0.0005 ^f	ND	1.24 ± 0.09 ^{fg}	ND
Range:		RS = 0.0026–0.0041	RS = 0.0014–0.0031	RS = 0.0078–0.0116	RS = 0.0016–0.0031	RS = 1.38–1.72	RS = 0.0001–0.0006
		Control = ND	Control = ND	Control = 0.0051–0.0087	Control = ND	Control = 1.13–1.49	Control = 0.0001–0.0002

¹Values are mean value ± standard deviation. Mean values followed by different superscripts in each column are significantly different at $p < 0.05$.

²RS = Roadside-sundried.

³ND = Not detected.

The Cd content in the roadside-sundried pepper was found to range between 0.0014 and 0.003 mg/100 g with no detection in the control samples. Pepper from Ile Ife–Gbongan highway exhibited the highest Cd pollution level, while that from Owo–Ifon exhibited the lowest.

The Zn level in the roadside-sundried pepper was 0.0078–0.0116 mg/100 g, while that of the control samples was 0.0051–0.0087 mg/100 g. Pepper from Akure–Ondo road axis exhibited the highest Zn pollution level, while that from Ile Ife–Gbongan exhibited the lowest. Zinc is a naturally occurring metal in pepper (Otunola, Oloyede, Oladiji, & Afolayan, 2010) and the variation in its concentration in the control samples might be due to diverse soil fertilities in the areas of cultivation respectively (Jolocam, Vlasswa, Kwetegyeka, & Bokyaita, 2010).

The atmospheric Ni pollution in roadside-sundried pepper was 0.0016–0.0031 mg/100 g while there was no detection in the control samples. Pepper from Ile Ife–Gbongan highway exhibited the lowest Ni pollution level, while that from Akure–Owena Ijesha exhibited the highest level. The existence of variation in Ni pollution level in the sundried pepper may be attributed to factors such as varying traffic density, category of petrol being used by the vehicles, age of the vehicles plying the highways and the quality of the roads themselves.

The concentration of Fe pollution in the roadside-sundried pepper was 1.38–1.72 mg/100 g, while that of the control samples ranged from 1.13–1.49 mg/100 g. The highest Fe pollution level was found in pepper sundried along Owo–Ifon highway, while the lowest pollution level came from that of Ilesha–Ile Ife. Metallic Fe is naturally found in pepper (Otunola et al., 2010) and the variation in its concentration in the control samples may be due to diverse soil fertilities (Anjula & Sangeeta, 2011; Lokeshwari & Chandrappa, 2006).

The atmospheric Cu pollution level in roadside-sundried pepper was found to range between 0.0001 and 0.0006 mg/100 g, while that of the control samples was between 0.0001 and 0.0002 mg/100 g. The very low level of Cu pollution as observed in the sundried pepper along different highways implies that different roadside-sundried products exhibited diverse receptivity levels to the metallic pollutant. The absence of metallic Cu in some of the control samples may be due to different soil types on which the pepper had been grown (Akaninwor, Onyeike, & Ifemeje, 2006; Jolocam et al., 2010).

4. Conclusion

The conclusion from this study is that all the roadside-sundried food products contained varying degrees of atmospheric metallic pollutants (Pb, Cd, Zn, Ni, Fe and Cu). Some highways generated higher metallic pollution than others most probably due to factors such as traffic density, types of petrol being used by vehicles (i.e. whether highly leaded or not), ratio of old and new vehicles plying the roads and the quality of the roads themselves, among others. The concentration of a specific metallic pollutant varied from one food product to the other. The concentrations of metallic pollutants found in the roadside-sundried food products were generally below the recommended maximum limit set by FAO/WHO, yet their continuous bioaccumulation in the vital organs of consumers poses a potential health risk. The roadside-sundrying practitioners were virtually ignorant of the potential health risk associated with the continual consumption of the metallic pollutants and so an educational enlightenment programme is highly needed such that the practice could be discouraged. This step is highly desirable due to the toxicological implications of the metallic pollutants in human systems. These include retardation of mental development caused by lead; kidney damage caused by cadmium; damage to hepatic parenchyma caused by zinc; allergic contact dermatitis caused by nickel; liver cell necrosis and heart failure caused by excessive dietary iron ingestion and liver and kidney damage caused by copper.

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Author details

Mathew Kolawole Bolade¹

E-mail: mkbolade@futa.edu.ng

¹ Department of Food Science and Technology, Federal University of Technology, P.M.B. 704, Akure, Nigeria.

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