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Research Article

Heavy Metals Contaminants in Honey and Dry-Cured Meat Sold in Northern Nigeria Markets

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Abstract: Honey and dry-cured meat are common products for consumption and export in Nigeria but with a paucity of reports on their chemical contamination status. The occurrence of heavy metal residue in honey and dry-cured meat (Kilishi) for export in Kano and the Federal Capital Territory (FCT), Abuja, Nigeria and their safety status were investigated. The toxic metals profile in ninety samples of each animal product was established by Atomic Absorption Spectrometry (AAS, M5 Thermo Fisher Scientific, USA). The mean prevalence of Copper (Cu) in the honey samples from Kano Central was statistically higher than from other locations. Cadmium (Cd) contaminants occurred in the products at a range of 0.001-0.041 mg kg^{-1}. Lead (Pb) and Cobalt (Co) were below detectable levels in all the samples. Due to the relatively high profile of Cu in both products, Cr in honey and Cd in the dry-cured meat, which was slightly higher than the permissible level in humans by the World Health Organization, there is a health risk concern. The Nigerian regulatory entities should always routinely monitor and enforce the set legislative laws to ensure a safe animal product for local consumption or export in Nigeria.

***Keywords*:** food safety, toxic element, Atomic absorption spectrometry, occurrence, contaminant, Nigeria

1. Introduction

The safety of animal products and animal-sourced foods is a global concern as it affects the entire health of consumers and international trade. Unsafe animal products containing harmful chemical substances or pathogens could cause several diseases to consumers and could also affect their export potential [1, 2]. A wide range of edible animal products that are processed, handled, and sold locally or exported abound in Nigerian markets. These include honey, processed milk, meat from snails, animal skins, and dry-cured meat (Kilishi) [3]. Meat is categorized as one of the six major agricultural commodities in Nigeria [4] and processed meat could be classified as ham and bacon, sausages, cold and roast meat [5]. Nigeria meat exports were at the level of 52 thousand US dollars in 2018, down from 236 thousand US dollars the previous year which was a change of 77.97% possibly due to safety concerns [6]. The report further projected revenue in the processed meat market to amount to US$12.18 bn in 2024.

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Nigeria was the 122nd greatest honey exporter in the world in 2021 with $12.7 k in exports. Honey ranked 661 among Nigeria's most exported goods in that same year. The United States ($6.77 k), Canada ($2.1 k), Hong Kong ($1.25 k), Niger ($1.05 k), and Kuwait ($802) are the primary destinations for Nigerian honey exports [7]. Stored and marketed honey which is a viscous, sweet semi-liquid substance made by honeybees has been reported to contain contaminants such as heavy metals, agrochemicals, charcoal, plant part, or adulteration with sugar molasses or starch [8, 9].

Kilishi is a traditionally prepared, sun-dried, roasted meat product made primarily of beef but also occasionally from sheep or goat meat. The food is well-liked and highly desired throughout the Sahelian region of Africa, particularly in Northern Nigeria, Cameroun, Chad, Niger Republic, and other nations. It has also been a significant export product to the majority of Eastern countries, including Saudi Arabia and the United Arab Emirates, where it is also commonly consumed [10]. Kilishi is known to be very palatable but its safety status is often taken with levity. Snack meat is prone to chemical and microbial contaminants due to exposure to poor processing and packaging, poor handling, protracted length and poor storage conditions before being sold [11-13].

Soil is the principal source of toxic metals in edible plants that are frequently ingested by ruminant animals or from where honey bees extract honey from the nectars [14]. The level of pollution rises higher with the presence of metal wastes, as well as with soil fertilization, animal fertilizers, sewage waste, pesticides, irrigation with wastewater, and air buildup [15]. Certain metals are well known for their toxicity when the reported concentration in a given food commodity is over the critical value or maximum limit above an international norm [16]. The analysis of honey samples in Plateau State Nigeria indicated that Manganese (Mn) and Iron (Fe) were found across the honey samples while Cd was detected only in the sample obtained from Maraban Jos (0.0013 mg kg^{-1}) [17]. Analysis of honey samples for heavy metals from Enugu State Nigeria, showed that Cd had the highest carcinogenic risk with values of 1.26*E*-02-1.07*E*-01 [18]. It is reported that Contaminations by heavy metals like Pb. Cd, Co, Mercury (Hg) and Zinc (Zn) in honey samples from Brinin-Gwari were below the WHO standard for tolerance level for man [19]. In Bangladesh, three heavy metals [Cu -1.54-2.85 mg kg^{-1}; Co -0.02-0.05 mg kg^{-1} and Cd -0.006-0.06 mg kg^{-1}] were detected in the 12 honey samples using an AAS [20].

Dry-curing of meats is common and one of the most patronized forms of meat processing in Nigeria [21]. It was reported that there was a reported significant concentrations of nickel (Ni), chromium (Cr), Fe, Cd and Pb in some roasted meat samples sold in Port Harcourt, Nigeria by hawkers [22]. Thirteen samples of cured meat products of diverse origin marketed in South-west Nigeria were analyzed and assessed for lead, cadmium, chromium and nickel (Ni) contents. It was found that all the samples contained cadmium between 0.35 and 1.20 ppm, levels considered higher than acceptable limits in consumable products, but lead, chromium and nickel were not detected in any of the samples [23]. The concentration of heavy metals in bush meats in New Bussa and its environs in Nigeria was assessed and it revealed that Zinc concentration in muscle tissues of the selected bushmeat had a mean value of 815.00 mg kg^{-1} and was the highest mean value of all meat samples. Pb level in bushbuck (213.00 ± 3.00 mg kg^{-1}) was outrageously the highest. Thus creating a health concern for bush meat consumers in the study area [24].

The safety of these animal-sourced commodities can be compromised by various contaminants, entering any point of the food chain, including production, storage, processing, transport, and other handling processes. Pesticides, agrochemicals, and toxic metals are all responsible for the environmental toxicity in livestock. Despite the patronage and huge benefits of these products in terms of provision of quality nutrients for local consumers and export in developing countries like Nigeria, less significance is attached to the profile of possible chemical contaminants in them. There is a shortage of information on the current chemical contamination profile of ready-to-eat animal products such as honey and cured meat in Northern Nigerian markets. This study therefore investigated the prevalence and occurrence of heavy metal residue in honey and dry-cured meat (Kilishi) for export in Kano and the Federal Capital Territory, Abuja, Nigeria.

2. Material and methods

2.1 *The study location*

The Federal Capital Territory (FCT), Abuja is located in the country's geographic center and spans an area of 8,000 square kilometers. Between Lat. 8.25° N and 9.21° N of the Equator and Long. 6.45° E and 7.39° E of the Greenwich

Meridian is where the FCT, Abuja is located. One of the largest urbanized areas in Nigeria is the FCT, Abuja. The region is well connected to and accessible from the States and Federal roadways due to its central location and status as the seat of Nigeria's government [25]. Six area councils make up the Federal Capital Territory (FCT) Abuja: Abaji, Bwari, Gwagwalada, Kuje, Kwali, and Abuja Municipal Area Council (AMAC). The investigation's main focus is on the animal products sold in the Territory's Area Councils.

Kano State is located in the North-west region of Nigeria, with a total land area of 20,131 km^2, which represents 3.13% of the entire total area of Nigeria. It is bordered to the West by Katsina State, to the southwest by Kaduna State, to the east by Jigawa and Southeast by Bauchi. It is located between Lat. 8.592° E and Long. 12.00 2° N. The State has 44 Local Government Areas (LGA) within three geo-political zones, namely Kano Central, Kano South and Kano North. Kano is an agro-economy-based State, where most population depends on agriculture, especially agro-processing and marketing, which has gradually become an important part of the Nigerian economy. Many animal products such as honey, dry-cured meat, hide and skin and milk are processed and marketed in Kano State.

2.2 *The study population and sampling method*

The targeted population of this study was the collection of honey and dry-cured meat for export in Kano and the FCT, Abuja (Figure 1). The samples were the honey products and dry-cured meat available in the market for export. The collection was carried out from November 2021 to February, 2022. The sampling was focused on locations with a higher number of units where animal products were processed for export. The sample collection points were from the suppliers or exporters who sourced their products from different honey and dry-cured meat producers and/or processors in each of the three zones of Kano State and from the FCT, Abuja respectively. Their locations include markets, supermarkets and export warehouses. The materials used for the collection of packed honey samples were clean polystyrene bags, labels, and laboratory seals.

Figure 1. Bottled honey and packaged dry-cured meat sold in Kano and the FCT, Abuja markets

Ninety (90) processed dry-cured meat specimens; $N = 15$ for each zone were chosen at random from authorized retail markets, supermarkets, marts and export warehouses in the 3 different zones in each of the FCT, Abuja and Kano State, Nigeria (Table 1). The gathered samples were labeled, packaged in sterile zip lock bags, and delivered right away under strict aseptic conditions to the Chemistry Advanced Laboratory, Sheda Science and Technology Complex (SHESTCO), Nigeria, for heavy metal analysis.

2.3 *Sample preparation*

Dry-cured meat samples were crushed using a pestle and mortar and then a Romer RAS mill (Romer Labs, Austria) prior to examination. Each specimen weighed twenty-five grams (25 g), which were aseptically chopped in the grinder using a 4 mm sterilized plate (AC110V, China). Twenty-five (25 g) of each specimen were aseptically chopped in the grinder using a 4 mm sterilized plate (AC110V, China). The powdered materials were kept in a freezer at -18 °C pending analysis. Ten grams of the blended specimen were combined in an agate mortar with sixty grams of anhydrous sodium sulphate to absorb the moisture that was evaporating.

Table 1. Sample collection from the study area

Location	Zone	No. of *LGAs/Area councils	No. of samples for each of the Honey and dry-cured meat
Kano State	Kano North	3 (Bichi, Tofa, Shanono)	15
	Kano Central	3 (Kumboso, Dawaki Kudu, Kura)	15
	Kano South	3 (Bebeji, TudunWada, Wudil)	15
FCT, Abuja	Abuja East	2 (AMAC, Bwari)	15
	Abuja Central	2 (Gwagwalada, Kwali)	15
	Abuja South	2 (Kuje and Abaji)	15
Total			90 each

*LGA = Local Government Area

2.4 *Determination of heavy metals*

The examination of heavy metals was conducted using Atomic Absorption Spectrophotometer equipped with a titanium burner system (M5 Thermo Fisher Scientific, USA) , adapting the protocol described by Quarcoo and Adotey [26]. The meat samples were pulverized and homogenized to aid digestion using agate mortar but the honey samples were only homogenized. The ground and homogenized samples (~3 g) were measured and placed in a digestion flask, along with 20 mL of 1 M solution of nitric acid in a 100 mL volumetric flask and subsequently heated at 100 °C for two hours to produce a clear digest. The digest was diluted with distilled H_2O to the mark using a 100 mL standard volumetric flask. The digested sample was permitted to cool before filtration into a fifty-milliliter conical flask using a Whatman filter paper. The digestate was quantified, and assayed for heavy metals ion determination using AAS (SOLAAR AA Report Model), and values obtained were reported in mg kg^{-1}. The reference standards (Fluka Analytical, Sigma-Aldrich Chemie GmbH, Switzerland) for the detected element, were prepared and used to calibrate the AAS and blank determination was done. When the analyte was obtained in the computer report, each metal concentration (mg/g) was computed using the formula by dividing the blank by the weighted sample.

Where:

-The sample weight was 3 g.

-Blank for Cu = -0.08625; Mn = 0.1826; Co = -0.1561; Pb = 0.4411; Cr = 0.0382; Cd = 0.0188.

The concentration level and blank were calculated from the result of the analysis.

2.5 *Statistical data analysis*

Elemental concentrations were analyzed in triplicates from each location and recorded as means ± standard errors (SE). Prevalence rate (%) was computed using the formula - number of samples in which contaminant is detected during the analysis/total sample size subjected to analysis × 100. Shapiro-Wilk test (i.e. $x = \mu + Az$) was employed to obtain the normality test by involving the descriptive statistics of SPSS (version 21.0, SPSS Inc., Chicago, IL, USA). The data on the incidence of the elements were subjected to Analysis of Variance (ANOVA). Duncan's test was used to establish the differences in the elements' load in the samples across the different locations. The value of the probability level was set at $p \leq 0.01$ to indicate the level of significant differences. The prevalence and incidence of the contaminants in Kano and the FCT Abuja were graphically represented using bar charts.

3. Results

3.1 *Detection of heavy metals (Cu and Co) in honey for export in Kano and the FCT, Abuja*

There were traces of Cu contaminants in the range of 0.045-0.675 mg kg^{-1} in honey samples from the three zones in Kano and the FCT, Abuja. The percentage of contaminated samples from Kano South and Abuja South was substantially higher ($p < 0.01$) than those from Abuja East. The Cu mean concentration in samples from Kano Central was substantially higher than from other locations. Cobalt was below the detectable level in all the samples (Table 2).

Table 2. Detection of heavy metals in honey for export in Kano and the FCT, Abuja

Location	Heavy metals in honey samples (mg kg^{-1})				
	Cu				Co
N = 15 (samples/location)	No. of + ve samples	Prevalence (%)	Range (mg kg^{-1})	Mean ± SE	No. of *+ ve samples
Kano North	4	26.67[b**]	0.045-0.340	0.2975 ± 0.02[c]	0
Kano Central	7	46.67[a]	0.167-0.675	0.4145 ± 0.10[a]	0
Kano South	6	40.0[a]	0.134-0.521	0.3580 ± 0.06[b]	0
Abuja East	2	13.33[c]	0.231-0.601	0.3124 ± 0.03[b]	0
Abuja Central	4	26.67[b]	0.104-0.451	0.2914 ± 0.04[c]	0
Abuja South	6	40.00[a]	0.062-0.636	0.3214 ± 0.09[b]	0

*+ ve samples = sample in which the heavy metal analyzed for is detected;
**Mean followed by the same letters within a column are not substantially different at $p \geq 0.01$

Table 3. Detection of Cd and Pb contaminants in honey for export in Kano and the FCT, Abuja

Location	Heavy metals in honey samples (mg kg^{-1})				
	Cu				Co
N = 15 (samples/location)	No. of + ve samples	Prevalence (%)	Range (mg kg^{-1})	Mean ± SE	No. of + ve samples
Kano North	10	66.67[a*]	0.001-0.027	0.0181 ± 0.009[a]	0
Kano Central	9	60.00[a]	0.009-0.019	0.0181 ± 0.007[a]	0
Kano South	7	46.67[b]	0.001-0.021	0.0143 ± 0.004[b]	0
Abuja East	0	0	0	0.0 ± 0.0	0
Abuja Central	4	26.67[bc]	0.002-0.008	0.005 ± 0.0009[c]	0
Abuja South	0	6.67[c]	0	0.00 ± 0.0	0

*At the 0.01 level of probability, the mean in a column followed by identical letters does not differ substantially;
Mean followed by the same letters within a column is not substantially different at 0.01 level of probability

3.2 *Detection of Cd and Pb contaminants in honey for export in Kano and the FCT, Abuja*

Cadmium was present in the honey from the three zones of Kano and in only the Abuja central zone of the FCT, Abuja. The concentration of Pb was however below the detectable level in all the honey samples analyzed (Table 3). Cadmium contaminants occurred in all the honey samples from Kano and the FCT at the range of 0.005-0.0181 mg kg^{-1}). The concentration level of Cd in Kano North and Central was considerably higher ($p < 0.01$) than in other zones.

3.3 *Detection of Cr and Mn contaminants in honey for export in Kano and the FCT*

Chromium (Cr) contaminants were detected only in the honey samples from Kano North and the FCT, Abuja at the range of 0.002-0.071 mg kg^{-1}) and at a mean concentration of 0.0416 mg kg^{-1} (Table 4). The percentage of positive samples with Mn from the Kano (80.0%) and Abuja central (66.67%) were substantially higher ($p \leq 0.01$) than from other zones. but with a low range of 0.01-0.124 mg kg^{-1}. The highest mean concentration of Mn (0.0680 ± 0.002 mg kg^{-1}) was found in the honey samples from Kano Central. The occurrence of Mn in all the samples from Kano South and Abuja South was below the detectable level.

Table 4. Detection of Cr and Mn contaminants in honey for export in Kano and the FCT, Abuja

Location	Heavy metals in honey samples (mg kg^{-1})							
N = 15 (samples/ location)	Cr				Mn			
	No. of + ve samples	Prevalence (%)	Range (mg kg^{-1})	Mean ± SE	No. of + ve samples	Prevalence (%)	Range (mg kg^{-1})	Mean ± SE
Kano North	5	33.33[a*]	0.02-0.071	0.0416 ± 0.009[a]	5	33.33[c*]	0.004-0.016	0.0093 ± 0.001[b]
Kano Central	0	0	0	0	12	80.00[a]	0.03-0.124	0.0680 ± 0.002[a]
Kano South	0	0	0	0	6	0	0	0.00 ± 0.0
Abuja East	0	0	0	0	8	53.33[b]	0.001-0.002	0.0017 ± 0.0007[c]
Abuja Central	0	0	0	0	10	66.67[a]	0.002-0.014	0.0064 ± 0.001[b]
Abuja South	0	0	0	0	7	0	0	0.0 ± 0.0

[*]At the 0.01 level of probability, the mean in a column followed by identical letters does not differ substantially;
Mean followed by the same letters within a column is not substantially different at 0.01 level of probability

3.4 *Detection of Cu and Co contaminants in dry-cured meat (Kilishi) for export in Kano and FCT, Abuja*

The cured meat samples from the three zones in Kano and the FCT, Abuja were contaminated with Cu with a concentration range of 0.01-0.80 mg kg^{-1}) Cobalt (Co) was below the detectable level in all the samples from both Kano and the FCT, Abuja (Table 5). The percentage of positive samples to Cu was statistically highest in samples from Kano Central (80.00%) and was lowest in samples from Kano South and Abuja Central (53.00%). The mean concentration of Cu in samples from Abuja East was statistically higher than from other locations but not substantially different ($p \geq 0.01$) from the samples in other locations.

3.5 *Detection of Cd and Pb contaminants in dry-cured meat (Kilishi) for export in Kano and FCT, Abuja*

Cadmium (Cd) contaminants occurred in only the cured meat samples from Kano North and Kano Central zones at a range of 0.001-0.041 mg kg^{-1}). Lead (Pb) was below the detectable level in all the dry-cured meat samples (Table

6). The percentage of positive samples from Kano Central and Kano South were 40.00% and 26.67% respectively. There was no substantial difference ($p \geq 0.01$) in the concentration level of Cd between the two zones. However, the concentration level of Cd in kilishi from Kano Central was statistically higher ($p \leq 0.01$).

Table 5. Detection of Cu and Co contaminants in dry-cured meat (Kilishi) for export in Kano and FCT, Abuja

Location	Heavy metals in dry-cured meat (Kilishi) samples (mg kg^{-1})				
N = 15 (samples/ location)	Cu				Co
	[*]No. of + ve samples	Prevalence (%)	Range	Mean ± SE	No. of [*]+ ve samples
Kano North	10	66.67^{a**}	0.142-0.745	0.4596 ± 0.09^{a}	0
Kano Central	12	80.00^{a}	0.20-0.73	0.4612 ± 0.19^{a}	0
Kano South	8	53.33^{b}	0.01-0.80	0.4706 ± 0.08^{a}	0
Abuja East	10	66.67^{ab}	0.03-0.71	0.4711 ± 0.09^{a}	0
Abuja Central	8	53.33^{ab}	0.12-0.68	0.4684 ± 0.013^{a}	0
Abuja South	9	60.00^{b}	0.03-0.87	0.4687 ± 0.08^{a}	0

[*]+ ve samples = sample in which the heavy metal analyzed for is detected;
[**]At the 0.01 level of probability, the mean in a column followed by identical letters does not differ substantially

Table 6. Detection of Cd and Pb contaminants in dry-cured meat (Kilishi) for export in Kano and FCT, Abuja

Location	Heavy metals in dry-cured meat (Kilishi) samples (mg kg^{-1})				
N = 15 (samples/ location)	Cd				Pb
	No. of + ve samples	Prevalence (%)	Range	Mean ± SE	No. of [*]+ ve samples
Kano North	0	0	0	0	0
Kano Central	6	40.00^{a**}	0.001-0.03	0.0213 ± 0.007^{a}	0
Kano South	4	26.67^{b}	0.009-0.041	0.0192 ± 0.009^{a}	0
Abuja East	0	0	0	0	0
Abuja Central	0	0	0	0.0	0
Abuja South	0	0	0	0.0	0

[*]+ ve samples = sample in which the heavy metal analyzed for is detected;
[**]At the 0.01 level of probability, the mean in a column followed by identical letters does not differ substantially

3.6 *Detection of heavy metals contaminants in dry-cured meat (Kilishi) for export in Kano State and FCT, Abuja*

Manganese (Mn) contaminations were detected in kilishi from all the zones but at relatively low concentrations (Table 7). The percentage of positive samples with Mn from Kano North and Abuja central zones was substantially higher than from other zones. The highest mean concentration of Mn (0.0894 mg kg^{-1}) was found in samples from Kano North. Chromium (Cr) contaminants were below detectable levels in all the kilishi samples from Kano State and the FCT, Abuja.

Table 7. Detection of toxic metals (Mn and Cr) contaminants in dry-cured meat (Kilishi) for export in Kano and FCT, Abuja

Location	Heavy metals in dry-cured meat (Kilishi) samples (mg kg^{-1})				
	Mn				Cr
N = 15 (samples/ location)	No. of + ve samples	Prevalence (%)	Range	Mean ± SE	No. of *+ ve samples
Kano North	8	53.33^{a**}	0.020-0.102	0.0894 ± 0.009^{a}	0
Kano Central	7	46.67^{b}	0.032-0.091	0.0528 ± 0.008^{b}	0
Kano South	3	20.00^{c}	0.011-0.102	0.0603 ± 0.004^{b}	0
Abuja East	5	33.33^{b}	0.021-0.093	0.0626 ± 0.01^{b}	0
Abuja Central	9	60.00^{a}	0.004-0.089	0.0795 ± 0.01^{a}	0
Abuja South	6	40.00^{b}	0.008-0.092	0.0802 ± 0.012^{a}	0

*+ ve samples = sample in which the heavy metal analyzed for is detected;
**Mean followed by the same letters within a column are not significantly different at 0.01 level of probability

The prevalence and incidence mean values of the contaminants in Kano and the FCT Abuja were graphically represented using bar charts Figures 2 and 3 respectively. It is indicated that Cd was most prevalent in dry-cured meat (66.67%) in the FCT, Abuja. It was also shown that the Cu profile was highest in cured meat from Kano and Abuja.

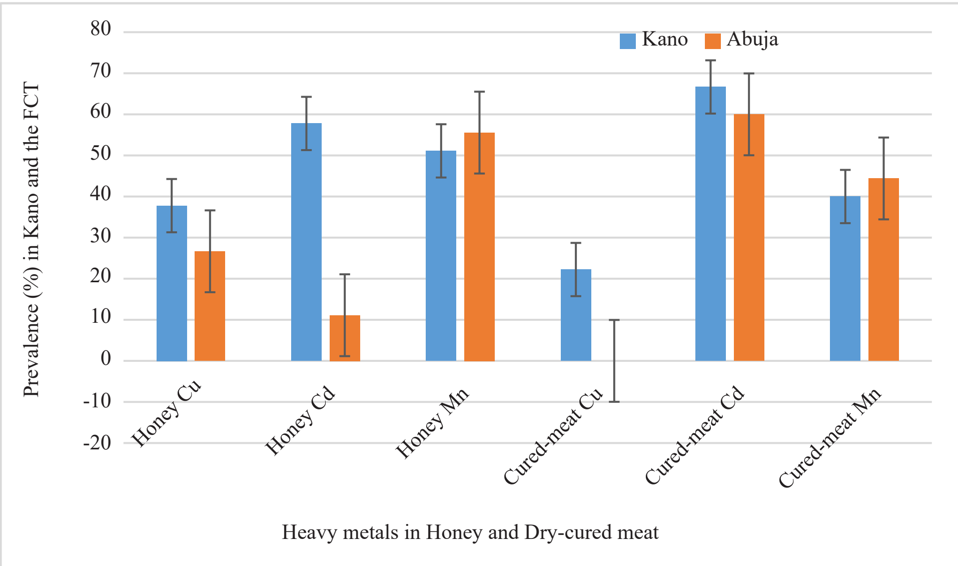

Figure 2. Prevalence of heavy metals in honey and dry-cured meat in Kano and the FCT, Abuja

3.7 Comparison of the detected heavy metal contents in honey and dry-cured meat samples with results from locations in Kano and FCT, Northern Nigeria

From all the specimens analyzed for toxic metal residues, it was only Cr that was relatively higher and above the permissible limit in the honey. For the dry-cured meat samples, it was Cu and Cd that were slightly above the permissible level by EU (Table 8). Cadmium Lead and cobalt (Co) were below detectable levels in all the samples.

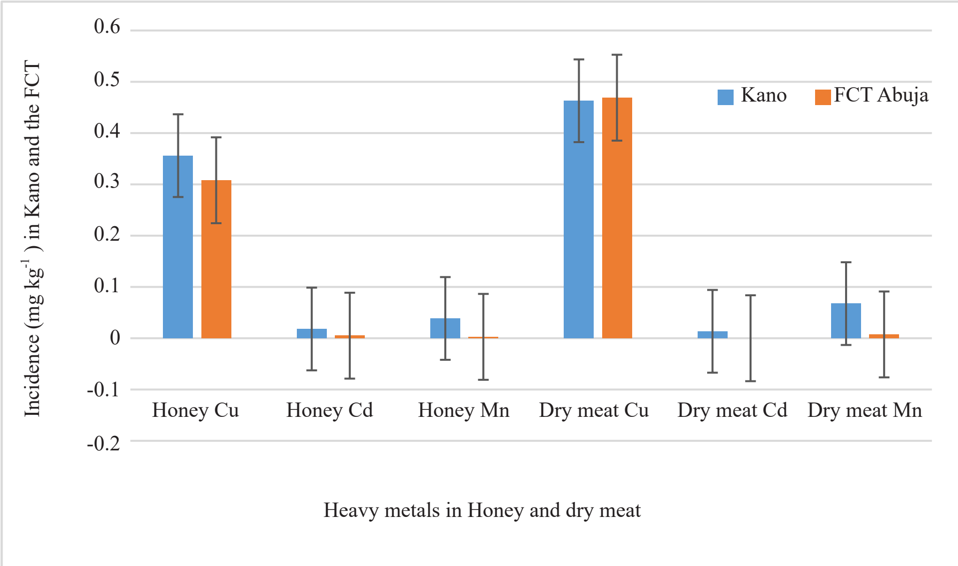

Figure 3. Incidence of heavy metals in honey and dry-cured meat in Kano and the FCT, Abuja

Table 8. Heavy metal contents in honey and dry-cured meat samples from Kano and the FCT-Abuja, Nigeria, their possible health effects and permissible level

Animal product	Heavy metal contaminant	Possible health effects	Range of conc. level (mg kg^{-1}) in Northern Nigeria	*Permissible level (children-adult) (mg kg^{-1}) [27]	Comparison with WHO standard
Honey	Cu	Abdominal disorders, Metabolic activity abnormalities [28]	0.2914-0.4145	0.34-0.9	Slightly above
	Cd	Renal dysfunction, lung disease, lung cancer, bone defects, kidney damage, bone marrow [29]	0.005-0.0181	0.062-0.088	Below
	Cr	Damage to the nervous system, irritability	0.002-0.071	0.011-0.035	Slightly above
	Mn	Inhalation or contact damage to the central nervous system	0.0017-0.068	1.5-2.3	Below
Dry-cured meat	Cu	As above	0.459-0.471	0.34-0.9	Slightly above
	Cd	,,	0.019-0.213	0.062-0.088	Mostly above
	Mn	,,	0.0528-0.089	1.5-2.3	Below
	Pb		0	0.1	Below detectable level

*EU Commission Regulation (EC) No. 1881/2006 and from Dietary Reference Intakes (DRIs): Recommended Dietary Allowances and Adequate Intakes, Elements, Food and Nutrition Board, National Academies, 2023 report

4. Discussion

Food safety has a significant influence on food markets and is of great societal importance because it protects human health and life. Based on the findings from this study, dried cured meat and honey sold in Kano and FCT, Abuja Nigeria were not completely immune to heavy metal contaminants and might render them unacceptable for export and not safe for consumption if caution is not taken. According to a study by the International Atomic Energy Agency (IAEA) that was conducted on various food samples collected from 12 countries (Commission Regulation (EC) No 1881/2006), Pb, Cd, Hg, and As are significant in terms of health and contamination risk, whereas antimony (Sb), Fe, Cu, and Zn are less significant.

The observed levels of Cu in honey and dry-cured meat were higher than the permissible limit (0.1 mg/L) of WHO Codex Allimentarius, 2003 while Co was below detectable level in both products. Its low concentration in the dry-cured meat might be a result of the high requirements for and rapid turnover of the element in cattle [30]. Though Cu is a necessary component of various enzymes and plays a major function in bone formation, skeletal mineralization, and maintaining the integrity of connective tissues but should not exceed the permissible level in animal or human bodies [31]. Dos Reis [32] recommended that monitoring and prevention of both deficiency and toxicity of necessary minor elements are needed for livestock health and high production. The National Institute of Health (NIH) of the US Department of Health and Human Services recommended an average daily amounts of 340-700 µg kg^{-1} for Cu in children and a mean of 900 µg kg^{-1} for adults. The recommended average daily intake of Mn for male adult is 2.3 mg kg^{-1} and for the adult female is 1.8 mg kg^{-1} and 10-20 µg kg^{-1} day for Co are required for average body functioning [33]. Since Cu and Co play a vital role in erythrocyte physiology and metabolism, there is a need for nutritional supplementation to curb deficiencies [34, 35].

No lead (Pb) contaminant was detected in the two animal products under investigation. Lead is known to cause damage to human kidneys and liver 1 (FAO, IFAD, UNICEF, WFP, WHO 2020) if present above the recommended daily consumption limit. Similar to our findings, Pb was not detected in all honey samples from Ethiopia. They however found from their study concentrations of the heavy metals in the honey samples at a range of 1.97 to 2.04 µg/g for Zn, 1.93 µg/g to 2 µg/g for Cu, 0.83 to 1.01 µg/g for Mn, 0.25 to 0.45 µg/g for Cr, 0.025-0.031 µg/g for Cd. In contrast, among the heavy metals from honey from Bangladesh, only lead (0.17-2.19 mg kg^{-1}) was detected. Though Mn concentration levels in the animal product were lower than the permissible in this study, the metal is essential for the good health of animals and its deficiency can result in severe skeletal and reproductive anomalies in mammals [36].

There were higher concentrations of Cd in the dried cured meat above the maximum residue level in the study areas where it was detected. International Agency for Research on Cancer (IARC) has specified Cd and Cd components as Group I carcinogens for human health i.e. they induce lung tumors. Cadmium is one of 25 compounds that may be hazardous to human health, and because it cannot be eliminated from the body, it frequently accumulates there instead [37]. Food is the main source of cadmium exposure for humans, and the typical adult daily intake is around 0.062-0.088 mg kg^{-1} [38]. The cumulative intake of 3 to 15 µg of cadmium is the threshold for acute poisoning. When 326 µg is consumed, there are reports of severe toxic effects occurring. According to tests, the largest concentration of Cd has been discovered in crustaceans (IARC as well as the kidneys of numerous species, including cattle, poultry, pigs, sheep, and turkeys. The daily permissible intake by EU is Cd is 1 µg kg^{-1} of body weight [39]. Some heavy metals such as Cd, As and Hg are toxic at very minimal concentrations and have no unique biological functions but will rather bio-accumulate to toxic concentration in animal tissue and subsequently into human tissues following consumption of contaminated meat [40, 41]. Cadmium, as an illustration, can replace calcium or act freely on bone tissue, leading to bone diseases [42].

The majority of our organs are negatively impacted by heavy metals because of their basic structure and affinity for organic ligands throughout biological processes. Metals are eliminated from the body very slowly and accumulate because they are tightly linked to tissues. Typically, samples of blood, urine, and hair are utilized as markers to assess the degree of metal exposure [43]. Toxic metals are dispersed in nature through biological and geological cycles and then often penetrate the food web by contaminating crops from the environment, animals and animal products from contaminated crops, and fish from the polluted waters [44]. The load of toxic metals in the human body is dependent on their concentration in specific animal products, cooking methods, frequency of consumption, amount consumed, and the rate of detoxication of such contaminants in the human body. The admission of heavy metals into the human body poses severe health implications as they could result in the malfunctioning of certain cellular processes through the displacement of essential metals from their respective locations [45]. Some of the symptoms of metal poisoning in humans include a reduction in immunological resistance and probably upper gastrointestinal disorder, intellectual disability in children, dementia in adults, central nervous system disorders, kidney diseases, liver diseases, insomnia, emotional instability, depression and vision disturbances [46].

5. Conclusion

The difficulties associated with ensuring the safety of animal products could be overcome by increasing public awareness, improving role coordination along the supply chain for food and animal products, building capacity, upgrading infrastructure, and providing training and retraining from the farm to levels of processing or preparation as well as on proper storage practices. There is a necessity for the provision of specific certification requirements in line with EU standards for Nigerian animal products for export, to be implemented by relevant government Ministries, Departments and Agencies. An efficient and robust Residue Monitoring and Control Plan (RMCP) Unit for animal products such as honey and processed meat should be established and implemented under the National Agency for Food and Drug Administration and Control (NAFDAC) in Nigeria.

There should be public enlightenment and advocacy by the Nigerian Export Promotion Council (NEPC); and NAFDAC for the stakeholders on the necessity for registration of all animal products for sale or export and the effects of grazing of cattle in heavy metals-prone areas such as automobile workshops, construction sites and paint factory premises. Good Honey Practices (GHP) and dry-cured meat sold in the studied area should be properly packaged as they could be susceptible to chemical or microbial contaminants. The people especially the consumers and the exporters should always check food labels, check the certification mark from the Food and Drug Administration, the channel for reporting suspicious products found in the community, modifying various consumption behaviors to reduce the amount of heavy metal accumulation in the body. This is in order to protect our own health, which is an important issue. It is vital to note that ongoing surveillance of food pollutants is a crucial concern for the long-term defense of the public's health.

Human and animal rights and informed consent

This article does not contain any studies with human participants or animals performed by any authors.

Conflict of interest

There is no conflict of interest among the authors.

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