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ABSTRACT: Grasscutter (cane rat/*Thryonomys swinderianus*) digesta is used as a spice in Ghana. Research shows that heavy metals from the environment may accumulate in the internal organs of grasscutters, which raises concerns about the possible contamination of grasscutter digesta, too, with heavy metals. Although grasscutter meat in Ghana has been described as safe for consumption, information is lacking on the health risks associated with ingesting the digesta. This study, therefore, aimed to assess the knowledge and perceptions of a merchant and a consumer about the safety of ingesting grasscutter digesta and to evaluate potential health risks from exposure to heavy metals from the spice. A total of 12 digesta samples were analyzed to evaluate potential health risks from exposure to Cd, Fe, Hg, and Mn using a Varian AA240FS Atomic Absorption Spectrometer. The levels of Cd, Hg, and Mn were below the detection limit of 0.01 mg/kg digesta. Also, the estimated daily intake of Fe (0.02 mg/kg) was less than the maximum allowable dose recommended by the US EPA (0.7 mg/kg). The hazard indices of Fe for daily and weekly consumption were <1, suggesting that the consumers may be safe from iron poisoning. Because grasscutter digesta is a relatively expensive spice, it is unlikely to be consumed daily by the average Ghanaian. Moreover, if 10 g of digesta is consumed daily, it can be safely ingested about 971 times in a month. Domestication of grasscutters may be a useful approach to monitor their diet and consequently the quality of their digesta.

KEYWORDS: Human health risk assessment, heavy metals, grasscutter digesta, spice, Ghana

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Introduction

Spices generally refer to dried parts of plants that contain aromatic flavors, and they are used to enhance the sensory qualities of food.[1] While some spices like pepper are commonly used all over the world, others evolve within particular geographic areas and are unique to specific ethnicities. In Ghana, spices are commonly used in preparing household and commercially-sold foods.[2]

There exists a peculiar spice on the Ghanaian market prepared from the digesta of grasscutters. Previous studies have documented its use as seasoning in some dishes.[3-5] A survey revealed that grasscutter digesta is well-patronized by Ghanaians and is a preferred spice for making soups. According to consumers, this spice improves the taste and aroma of food.[3]

The grasscutter is a large herbivorous rodent native to West Africa and is the most sought-after bushmeat in Ghana.[5-7] Although grasscutter meat is a good protein source, there are concerns that it may be contaminated with heavy metals from polluted environments like mining sites.[5,8] In Ghana, for example, illegal small-scale mining activities (popularly known as galamsey) have led to the contamination of surrounding land and water bodies with mercury, lead, and iron.[9,10] Additionally, the increase in anthropogenic activities such as the application of pesticides in agriculture and the use of leaded fuels increase the exposure of wild animals to heavy metals.[11] These contaminants are transferred from the soil to plants and water bodies and then to the animals that feed and drink from these sources. Consequently, humans who consume these animals risk heavy metal poisoning.[12] Moreover, some hunters in Ghana use chemicals that contain high amounts of heavy metals to bait wild animals.[5,13] Thus, there may be a serious threat to the lives of people who consume grasscutter digesta.

Heavy metals like iron (Fe), copper (Cu), and zinc (Zn) are vital for cellular metabolism and are toxic only at elevated levels. However, metals such as arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg) are toxic even at low levels; causing cancer, as with the cases of As and Cd, and neurological disease, as with the cases of Pb and Hg.[14,15] It is, therefore, necessary to monitor the levels of heavy metals ingested per meal of bushmeat and/or products of bushmeat.

Regarding health risks from exposure to heavy metals, grasscutter meat in Ghana has been described as safe for consumption.[8] However, evidence of heavy metal accrual in animal feces[16,17] raises concerns about the safety of ingesting grasscutter digesta. Currently, there is a paucity of data on the risk of heavy metal poisoning from consuming grasscutter digesta. This study, therefore, aimed to assess the knowledge and perceptions of a merchant and a consumer about the safety of ingesting grasscutter digesta and to evaluate potential health risks from exposure to heavy metals from the spice.

Materials and Methods

Study area and sample collection

The study was conducted at the Adabraka market in Accra, the capital city of Ghana. A total of 12 fresh grasscutter digesta samples were purchased from a merchant of the spice. The samples were placed in clean plastic bags and transported on ice to the laboratory immediately for processing.

Interviews

One merchant of the digesta was interviewed to obtain information about the demand for the spice and health concerns regarding its intake. One customer who approached the merchant to purchase some digesta was also interviewed to obtain information about how the spice is used in food preparation, why it is used as a seasoning, and if there are health concerns from the perspective of the consumer.

Sample processing

The samples were processed as previously described.[18] Briefly, approximately 1 g of each digesta sample was weighed and homogenized mechanically. A mixture of nitric acid and hydrogen peroxide at a ratio of 8:3 was added to each sample tube to make a final volume of 11 mL. The mixtures were digested for 50 minutes using a microwave digestion system set to 170°C at 50 bar of pressure and 1000 W energy. Following digestion, the samples were allowed to cool at room temperature and transferred into clean 50 mL falcon tubes. Deionized water was added to a final volume of 25 mL, mixtures were centrifuged at 1500 rpm for 10 minutes and 1 mL of supernatants were collected for subsequent analyses.

Heavy metal analyses

The concentrations of Cd, Fe, Hg, and Mn were measured with a Varian AA240FS Atomic Absorption Spectrometer (Agilent Technologies Inc., Palo Alto, CA 94306, USA). Fe and Mn levels were measured with the flame atomic absorption technique, Cd levels were measured with the graphite furnace atomization technique, and Hg levels were determined with the cold vapor technique.[19] The limit of detection for all the metals was 0.01 mg/kg digesta. The instrument was calibrated with analytical grade standard solutions supplied by the manufacturer. The standard solutions were first diluted serially with double distilled water (spectroscopic pure) and then used for calibration per the manufacturer's instruction. The stabilities of the standard solutions were checked periodically. The amount of heavy metal in each sample was measured in triplicates and the mean of the triplicate measurements was recorded as the concentration of heavy metal in the sample.

Data analysis

Estimated Daily Intake (EDI). This estimates the amount of heavy metal ingested by the average consumer of grasscutter digesta per meal. EDI was calculated using the formula:

$$EDI = (MC \times AC) \times BW^{-1}$$

MC represents the concentration of heavy metal; AC is the average daily intake rate of digesta, and BW is the average body weight of an adult (60 kg).[20] We assumed the average daily intake rate of grasscutter digesta is similar to that of other spices estimated to be 10 g/person/day.[20] We also assumed that the concentrations of heavy metals in digesta would not be altered during cooking, and ingested dose equals the absorbed dose.[8]

Targeted Hazard Quotient (THQ). This represents the ratio between exposure to heavy metal and its reference dose. $THQ < 1$ means non-carcinogenic health effects are not expected, whereas $THQ > 1$ suggests that systemic effects may occur.[8,21] THQ was calculated as:

$$THQ = (EF \times ED \times MC \times AC) \times (BW \times RfD \times AT)^{-1}$$

EF is exposure frequency measured in days/year (ie, 365 days/year for people who eat digesta 7× per week, and 52 days/year for people who eat digesta 1× per week); ED is the duration of exposure (equivalent to an average lifetime of 64 years for Ghanaians);[22] MC, AC, BW, and RfD are heavy metal concentration, average daily intake rate, the average body weight of an adult, and reference dose, respectively. AT is averaging time (365 days/year × ED).

Hazard index (HI). This is the summation of individual THQs of the assessed heavy metals. HI assumes that consuming grasscutter digesta would result in simultaneous exposure to several metals, resulting in adverse health effects from the cumulative exposure. $HI > 1$ signifies a potential for adverse non-carcinogenic health effects.

$$HI = THQ(Cd) + THQ(Fe) + THQ(Hg) + THQ(Mn)$$

*Maximum allowable daily consumption (CR*lim*).* The CR*lim* of grasscutter digesta was calculated using the formula:

$$CRlim = (BW \times RfD) \times MC^{-1}$$

BW, RfD, and MC represent the average body weight of an adult, reference dose, and heavy metal concentration, respectively. CR*lim* was expressed as maximum allowable monthly consumption (CR*mm*); which signifies the number of times grasscutter digesta can be safely consumed in a month (30 days)

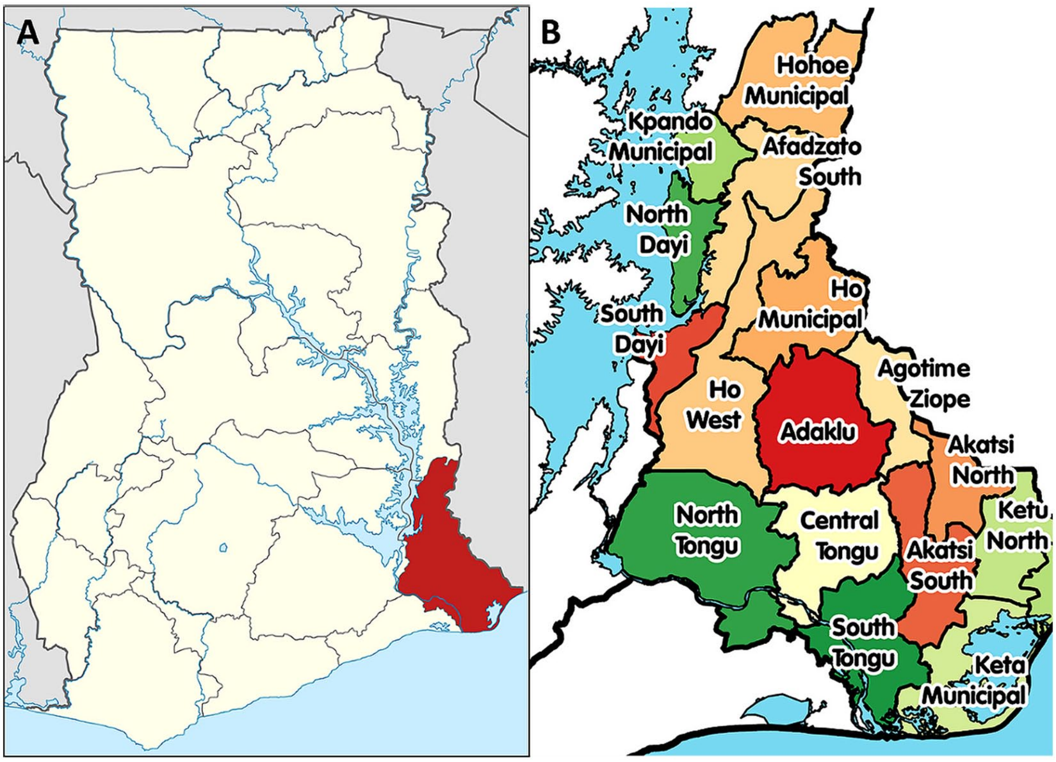

Figure 1. Map showing the geographical area where the animals were captured: (A) map of Ghana showing the Volta Region (shown in red) and (B) map of the Volta Region showing Adaklu (labeled) (Sources: Wikipedia and Wikimedia, respectively).

by the average Ghanaian if 10 g of digesta is consumed per person per day in 1 meal.

$$CR_{mm} = \left(CR_{lim} \times T_{ap}\right) \times MS^{-1}$$

T_{ap} is the time averaging period of 30.44 days/month, and MS denotes meal size for adults assumed to be 10 g of grasscutter digesta per meal. Since there are ~30 days per month, CRmm < 30 implies that consuming 10 g of digesta per meal per day is unsafe.

Results

Interviews

The interview with the merchant revealed that the grasscutters are captured in a forest in Adaklu; a district located in the central part of the Volta Region of Ghana (Figure 1). The digesta is then extracted and transported to the Adabraka market in Accra where it is sold. Adaklu has a total land area of about 1060.61 km^2 and has at least 14 rivers and streams that provide water for communities. Few areas within the district have semi-deciduous forests and high amounts of naturally occurring fodder on which wild animals like grasscutters can feed.[23]

Many Ghanaians perceive that adding grasscutter digesta to soup brings out the needed taste.[3] Accordingly, we asked the merchant how much digesta is sold daily, to have an idea of its demand. She said:

> *This business was started by my mother, and I have taken over. In a day, I can sell as high as 350 GH₵ ($47) and a minimum of 50 GH ₵ ($7). Some people purchase the dried product and package it to be sent abroad. Besides me, there are other merchants here who also have regular customers.*

To the consumer, we asked how grasscutter digesta is used in food preparation, and why it is used as a seasoning. This was her response:

> *The digesta is first mixed with water to form a paste, which is then boiled for some minutes and filtered to get rid of debris. The filtrate is added to the soup. Adding digesta greatly enhances the taste and aroma of foods.*

Accumulation of environmental pollutants in the tissues of bushmeat is not uncommon. Given that the gut may store polluted food and water ingested by wild animals,[16,17] we inquired from the merchant and consumer if they had any health concerns regarding the intake of grasscutter digesta. The merchant stated:

> *Nothing from the grasscutter goes to waste; from the meat to the intestines and its digesta. The animals are hunted with guns instead of poison traps because we use their digesta for food. Therefore, I have no concerns involving health.*

The consumer had the following to say:

Table 1. Concentrations of heavy metals in samples.

SAMPLE NUMBER	CD (MG/KG)	FE (MG/KG)	HG (MG/KG)	MN (MG/KG)
1	<DL	112.24	<DL	<DL
2	<DL	117.46	<DL	<DL
3	<DL	124.37	<DL	<DL
4	<DL	97.27	<DL	<DL
5	<DL	143.02	<DL	<DL
6	<DL	120.27	<DL	<DL
7	<DL	133.01	<DL	<DL
8	<DL	126.83	<DL	<DL
9	<DL	145.39	<DL	<DL
10	<DL	189.76	<DL	<DL
11	<DL	144.98	<DL	<DL
12	<DL	124.70	<DL	<DL
Mean of samples	<DL	131.61 ± 23.14*	<DL	<DL

<DL: Below detection limit of 0.01 mg/kg.
*Presented as mean ± standard deviation (SD).

> *Since childhood, we were told that the grasscutter eats only maize, cassava, and sugarcane. These are foods we also eat as humans. Also, we take the digesta directly from the intestines, without waiting for it to be passed as feces. As such I do not believe there is any health risk associated with its consumption.*

Human health risk assessment

The concentrations of heavy metals in the samples are shown in Table 1. All the heavy metals except Fe were below the limit of detection of 0.01 mg/kg digesta. The mean concentration of Fe was 131.61 ± 23.14 (range 97.27-189.76) mg/kg digesta; and its EDI was 0.02 mg/kg/day, which is below the reference dose recommended by the US EPA (0.7 mg/kg/day). The daily and weekly THQs of Fe were <1. Since THQ was calculated only for Fe, HI equals the THQ. In addition, the CR*mm* of Fe was >30, implying that taking 10 g of digesta per meal per day is unlikely to result in iron poisoning (Table 2).

Table 2. Health risk assessment parameters of heavy metals.

PARAMETER	HEAVY METALS				HI
	CD	FE	HG	MN	
EDI (mg/kg/day)	-	0.02	-	-	
THQ					
1× per week	-	0.005	-	-	0.005
7× per week	-	0.031	-	-	0.031
CR*mm*	-	971.42	-	-	

Abbreviations: CR*mm*, Maximum allowable monthly consumption; EDI, Estimated daily intake; THQ, Targeted hazard quotient; HI, Hazard index.

Discussion

Heavy metals may exist naturally in the environment or because of human activities. They are deposited into the soil and are transferred to plants and water bodies which serve as food and water for wild animals including grasscutters. For instance, some studies have demonstrated that heavy metals from the environment may bioaccumulate in commonly consumed fruits, vegetables, and cereals.[24-26] Upon ingesting these contaminated crops, the heavy metals may accumulate in the meat and guts of the animals,[16,27] which raises concerns about the health of individuals who consume grasscutter digesta. Here, we assessed the knowledge and perceptions of respondents about the safety of consuming grasscutter digesta and evaluated the potential risk of heavy metal poisoning from ingesting this spice.

The respondents had no concerns about the safety of ingesting grasscutter digesta; based on their knowledge of what grasscutters eat and how they are captured. Although the merchant stated that guns are used for hunting, it has been reported that hunters in some parts of Ghana use poisons like carbofuran and yellow oleander root powder to kill grasscutters. As such, individuals in those areas avoid poisoning by discarding the entire digestive system of the hunted animals while ensuring that the digesta does not spill on the meat.[3,28] This is however not the case for people who consume grasscutter digesta. Grasscutters eat foods like maize, cassava, and potatoes,[29] which are also consumed by humans and are not detrimental to human health. However, the increasing use of agrochemicals in agriculture in Ghana threatens the quality of grasscutter digesta. Indeed, some farmers in Ghana use poisons to deter grasscutters from destroying their farm produce.[3] This implies that consumers of the spice are at risk of poisoning by toxic chemicals. While the situation in the Adaklu district may be different, it is important to evaluate the hunting and farming practices in the district as well as educate hunters and farmers on the subject, to reduce the risk of food poisoning.

We found undetectable levels of Cd, Hg, and Mn in the tested samples. Gbogbo et al (2020) recorded low levels of Cd and Hg in grasscutter meat and concluded that its consumption at a rate of 0.104 kg per day is safe.[8] Conversely, Soewu et al[27] found higher than recommended levels of Cd and Mn in grasscutter meat collected in Southwestern Nigeria. The disparities in the abundance of heavy metals in grasscutter meat from different geographical locations suggest that the abundance of heavy metals in grasscutter digesta may be a function of the animal's habitat. It is therefore imperative to monitor the toxicological risk of ingesting grasscutter digesta obtained from different parts of Ghana. Cd is an environmental contaminant that is associated with an increased risk of cancer, cardiovascular disease, and osteoporosis. Excessive amounts of Mn result in manganism, a neurodegenerative disorder characterized by dopaminergic neuronal death. Mercury poisoning results in sensory impairment, abnormal sensation, and loss of coordination.[14,30] The undetectable levels of Cd, Hg, and Mn in the samples we analyzed indicate no perceived risk to consumers for the ailments caused by these metals.

The Fe (range 97.27-189.76 mg/kg) detected in the studied samples may be attributed to a contaminated food chain or drinking water, or reduced absorption of the metals from the gut due to phytochelatins in plant foods. Although our study did not probe the source of Fe or the presence of phytochelatins in the samples, research has established a relationship between heavy metal burden in animals and contaminated environments.[31,32] Compared to the dose recommended by the US EPA (0.7 mg/kg/day), the EDI of Fe (0.02 mg/kg/day) which we estimated was within limits, indicating no perceived risk to consumers. In addition, the daily and weekly hazard indices of Fe were <1, confirming the low probability of iron toxicity. Grasscutter digesta is a relatively expensive spice and is used only for some soups. This means that it is highly unlikely to be consumed daily by the average Ghanaian. Moreover, the $CR_{mm} > 30$ indicates that if 10 g of the spice is consumed daily, it can be taken safely 971 times per month. Altogether, we conclude that regarding the metals considered in this study, digesta from grasscutters captured in the Adaklu district of Ghana is safe for consumption.

Although this study addresses an important research question, some limitations need to be acknowledged. Firstly, we tested the levels of 4 heavy metals in 12 samples obtained from a single geographical area. This limits the scope of our assessment. Moreover, the assumption made for the daily intake rate may be inaccurate and may exaggerate or underestimate the true values. Future studies should consider a larger sample size from different parts of Ghana and should ascertain the actual rate at which the spice is consumed.

Conclusion

The present study was performed to assess the knowledge and perceptions of a merchant and a consumer about the safety of ingesting grasscutter digesta and to assess heavy metal levels in the spice. This study found that consumers of grasscutter digesta have no health concerns regarding its consumption. The levels of Cd, Hg, and Mn in the digesta samples were undetectable. Furthermore, the level of Fe was below the permissible limit of the US EPA, and so raised no concern. Regarding Fe content in the samples, the hazard quotient and maximum allowable monthly consumption values indicate that consuming 10 g of digesta daily is unlikely to result in iron poisoning. Altogether, with regards to the heavy metals we studied, grasscutter digesta obtained from the Adaklu district in the Volta Region of Ghana is safe for consumption.

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Author Contributions

JTQ contributed to conceptualization, data interpretation, and original draft preparation. JKC and FSD were involved in the literature review, data acquisition, and analysis. OQ and ARA reviewed and edited the manuscript. All authors read and approved the final manuscript.

Consent for Publication

All the authors give their consent for publication of the manuscript.

Ethical Consideration

Ethical approval was sought from the Ethics Committee of the College of Basic and Applied Sciences (ECBAS) of the University of Ghana (Ref no. ECBAS1/21-22).

Informed Consent

Informed consent was obtained from study participants before conducting interviews.

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Supplemental Material

Supplemental material for this article is available online.

REFERENCES

1. Motti R. Wild plants used as herbs and spices in Italy: an Ethnobotanical Review. *Plants*. 2021;10:563.
2. Adegbenu P, Aboagye G, Amenya P, Tuah B. Susceptibility of bacterial and fungal isolates to spices commonly used in Ghana. *Sci Afr*. 2020;9:e00530.
3. Essuman EK, Duah KK. Poisonous substances used to capture and kill the greater cane rat (Thryonomys swinderianus). *Vet Med Sci*. 2020;6:617-622.
4. Jori F, Mensah G, Adjanohoun E. Grasscutter (Trynonomys swinderianus) production: an example of rational exploitation of wildlife. *Biodivers Conserv*. 1995; 4:257-265.
5. Ampofo H, Emikpe B, Asenso T, et al. Hunting practices and heavy metals concentrations in fresh and smoked wildmeats in Kumasi, Ghana. *J Res Forestry Wildlife Environ*. 2017;9:43-49.
6. Kuukyi F, Amfo-Otu R, Wiafe E. Consumer views of bushmeat consumption in two Ghanaian markets. *Appl Res J*. 2014;1:20-27.
7. Morrison-Lanjouw SM, Coutinho RA, Boahene K, Pool R. Exploring the characteristics of a local demand for African wild meat: a focus group study of long-term Ghanaian residents in the Netherlands. *PLoS One*. 2021;16:e0246868.
8. Gbogbo F, Rainhill JE, Koranteng SS, Owusu EH, Dorleku WP. Health risk assessment for human exposure to trace metals via bushmeat in Ghana. *Biol Trace Elem Res*. 2020;196:419-429.
9. Mantey J, Nyarko KB, Owusu-Nimo F, et al. Mercury contamination of soil and water media from different illegal artisanal small-scale gold mining operations (galamsey). *Heliyon*. 2020;6:e04312.
10. Duncan AE. The dangerous couple: illegal mining and water pollution—a case study in Fena River in the Ashanti Region of Ghana. *J Chem*. 2020;2020:2378560.
11. Okereafor U, Makhatha M, Mekuto L, Uche-Okereafor N, Sebola T, Mavumengwana V. Toxic metal implications on agricultural soils, plants, animals, aquatic life and human health. *Int J Environ Res Public Health*. 2020;17:2204.
12. Njoga EO, Ezenduka EV, Ogbodo CG, et al. Detection, distribution and health risk assessment of toxic heavy Metals/Metalloids, arsenic, cadmium, and lead in goat carcasses processed for human consumption in south-eastern Nigeria. *Foods*. 2021;10:798.
13. Wiafe ED. Hunted species and hunting equipment used by rainforest poachers in Ghana. *J Threat taxa*. 2018;10:11285-11289.
14. Jyothi NR. Heavy metal sources and their effects on human health. In: Nazal MK, Zhao H, eds. *Heavy Metals - Their Environmental Impacts and Mitigation*. IntechOpen; 2020, p. 95370.
15. Koch W, Czop M, Iłowiecka K, Nawrocka A, Wiącek D. Dietary intake of toxic heavy metals with major groups of food products-results of analytical determinations. *Nutrients*. 2022;14:1626.
16. Eeva T, Raivikko N, Espín S, et al. Bird feces as indicators of metal pollution: pitfalls and solutions. *Toxics*. 2020;8:124.
17. Yang X, Li Q, Tang Z, et al. Heavy metal concentrations and arsenic speciation in animal manure composts in China. *Waste Manag*. 2017;64:333-339.
18. Bader NR. Sample preparation for flame atomic absorption spectroscopy: an overview. *Rasayan J Chem*. 2011;4:49-55.
19. Helaluddin A, Khalid R, Alaama M, Abbas S. Main analytical techniques used for elemental analysis in various matrices. *Trop J Pharm Res*. 2016;15:427-434.
20. Quartey NA. *Heavy Metal Contaminants of Selected Culinary Herbs and Spices Available in Some Ghanaian Markets*. Kwame Nkrumah University of Science and Technology; 2018.
21. Gbogbo F, Arthur-Yartel A, Bondzie JA, et al. Risk of heavy metal ingestion from the consumption of two commercially valuable species of fish from the fresh and coastal waters of Ghana. *PLoS One*. 2018;13:e0194682.
22. United Nations Development Programme. Ghana Human Development Reports. Published 2022. Accessed December 28, 2022. https://hdr.undp.org/data-center/specific-country-data#/countries/GHA
23. Ministry of Food & Agriculture (Republic of Ghana). Adaklu Anyigbe. Published 2020. Accessed December 28, 2022. https://mofa.gov.gh/site/directorates/district-directorates/volta-region/274-adaklu-anyigbe
24. Laboni FA, Ahmed MW, Kaium A, et al. Heavy metals in widely consumed vegetables grown in industrial areas of Bangladesh: a potential human health hazard. *Biol Trace Elem Res*. 2023;201:995-1005.
25. Afrin S, Alam MK, Ahmed MW, et al. Determination and probabilistic health risk assessment of heavy metals in widely consumed market basket fruits from Dhaka city Bangladesh. *Int J Environ Anal Chem*. 2022;5:1-16.
26. Kabir S, Kaium A, Chowdhury MTI, et al. Environmental pollution, ecological and human health risk assessment of heavy metals in rice farming system near the Buriganga River in Dhaka, Bangladesh. *Int J Environ Anal Chem*. 2022; 102:1-20.
27. Soewu D, Agbolade O, Oladunjoye R, Ayodele I. Bioaccumulation of heavy metals in cane rat (Thryonomys swinderianus) in Ogun State, Nigeria. *J Toxicol Environ Health*. 2014;6:154-160.
28. Deikumah JP. Vulture declines, threats and conservation: the attitude of the indigenous Ghanaian. *Bird Conserv Int*. 2019;30:103-116.
29. Yani J, Peter D, Enoch B, Vandi S. Feed preferences and feeding habit of grass cutters in captivity; case of J. J. Musa farm. *J Agric Environ Sci*. 2020;9:54-61.
30. Briffa J, Sinagra E, Blundell R. Heavy metal pollution in the environment and their toxicological effects on humans. *Heliyon*. 2020;6:e04691.
31. Shen X, Chi Y, Xiong K. The effect of heavy metal contamination on humans and animals in the vicinity of a zinc smelting facility. *PLoS One*. 2019;14: e0207423.
32. Amadi CN, Frazzoli C, Orisakwe OE. Sentinel species for biomonitoring and biosurveillance of environmental heavy metals in Nigeria. *J Environ Sci Heal C Toxicol Carcinog*. 2020;38:21-60.