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LEAD AND CADMIUM LEVELS IN SMOKED AND OVEN DRIED *Heterotis niloticus* AND *Protopterus annectens* FROM KASUWAR JANBULO, JIGAWA STATE, NIGERIA

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Abstract
Fish is an important and affordable source of animal protein; however, contamination by heavy metals poses significant public health concerns due to their persistence and bioaccumulative nature. This study assessed lead (Pb) and cadmium (Cd) concentrations in smoked and oven-dried Heterotis niloticus and Protopterus annectens obtained from Kasuwar Janbulo Market, Hadejia, Nigeria. A completely randomized design (CRD) was employed with four treatments: smoked Protopterus annectens (A), smoked Heterotis niloticus (B), oven-dried Protopterus annectens (C), and oven-dried Heterotis niloticus (D). A total of seventy-two (72) fish samples were collected monthly over a six-month period (February–July) using a systematic sampling design. Samples were prepared by acid digestion and analyzed for Pb and Cd using Atomic Absorption Spectrophotometry (AAS). Data were analyzed using multivariate analysis of variance (MANOVA) to determine significant differences among treatments. The results showed that Pb concentrations ranged from 0.325 to 0.531 mg/kg, while Cd concentrations ranged from 0.020 to 0.029 mg/kg. Cd levels were within the permissible limit of 0.05 mg/kg set by the World Health Organization and Food and Agriculture Organization. However, Pb concentrations in several samples exceeded the permissible limit of 0.30 mg/kg. Significant variations ($p < 0.05$) in Pb concentrations were observed among treatments, whereas Cd showed no significant differences ($p > 0.05$). The findings indicate potential health risks associated with Pb contamination in the fish samples, highlighting the influence of processing methods and environmental exposure on heavy metal accumulation.

Key word: Heavy metal contamination, *Heterotis niloticus, Protopterus annectens*, Lead (Pb) and Cadmium (Cd), Bioaccumulation.

INTRODUCTION

Heavy metals are metallic elements characterized by relatively high density and toxicity at low concentrations, with the ability to persist in the environment and bioaccumulate in living organisms, thereby posing serious ecological and public health risks (Jomova *et al*., 2025). Their persistence and tendency to accumulate in living organisms have attracted global concern (Raychuduri, 2021). Contamination by heavy metals has been widely documented in water (Ali *et al.,* 2019) and soil (Alsbou *et al*., 2018). Major anthropogenic sources include mining, smelting, agricultural practices, and industrial operations (Rajput *et al*., 2020). Among various forms of pollution, heavy metal contamination is particularly dangerous due to its irreversible effects and should be strictly controlled (Briffa *et al*., 2020). These metals are non-biodegradable and can enter the food chain, where they accumulate in organisms and increase in concentration at higher trophic levels through bioaccumulation and biomagnification (Ali *et al*., 2019). This process can result in concentrations exceeding safe limits, leading to severe health issues and increased mortality rates in both humans and animals (Ali et al., 2019). Cadmium (Cd), with atomic number 48, is a soft, silvery-white metal chemically related to zinc and mercury (Prohaska *et al.,* 2022). Lead (Pb), derived from the Latin *plumbum* and having atomic number 82, is another toxic heavy metal. It is dense, soft, malleable, and characterized by a relatively low melting point (*Singh*, 2017)

In many communities across Nigeria, including Hadejia, smoked fish constitutes an important and affordable source of animal protein and essential nutrients for human consumption. However, contamination of fish by heavy metals above permissible safety limits has become a major public health concern due to the persistence, bioaccumulative nature, and biomagnification potential of these metals within the food chain. Continuous consumption of contaminated fish may expose humans and animals to toxic effects associated with heavy metals, including organ damage, neurological disorders, carcinogenic effects, and increased risk of mortality (Clark et al., 2016). Therefore, monitoring heavy metal concentrations in processed fish products is essential to ensure food safety and protect public health.

The objective of this study was to determine the concentrations of lead (Pb) and cadmium (Cd) in smoked and oven-dried *Heterotis niloticus* and *Protopterus annectens* obtained from Kasuwar Janbulo Market, Hadejia, Nigeria, and to compare the observed levels with the maximum permissible limits established by the World Health Organization, Food and Agriculture Organization, and the Codex Alimentarius Commission, in order to evaluate the potential public health risks associated with their consumption.

MATERIALS AND METHODS

Study Area

Kasuwar Jan Bulo is a prominent fish market located within Hadejia Local Government Area in the eastern part of Jigawa State. The market is geographically positioned at approximately latitude 12.4506°N and longitude 10.0404°E. It is bounded to the north by Makara Huta, to the east by Dubuntu, to the south by Gawon Dogari (also known as Tsohuwar Kara), and to the west by Sabuwar Tasha. The market is widely recognized as one of the largest and most significant fish trading centers in Jigawa State.

Experimental Design

A completely randomized design (CRD) was adopted for this study. Four treatment groups were used based on fish species and processing methods: smoked *P. annectens* (Treatment A), smoked *H. niloticus* (Treatment B), oven-dried *P. annectens* (Treatment C), and oven-dried *H. niloticus* (Treatment D). Each treatment was replicated using samples collected monthly over a six-month period (February–July), giving a total of 72 fish samples. Samples were systematically collected from Kasuwar Janbulo Market, Hadejia, Nigeria, to ensure representation across sampling periods. Heavy metal concentrations (Pb and Cd) were determined using Atomic Absorption Spectrophotometry (AAS) following standard acid digestion procedures. Data obtained were subjected to multivariate analysis of variance (MANOVA) to test for significant differences among treatments and sampling periods.

Collection of Smoke Fish Sampling

Samples of smoked and fresh *P. annectens* and *H. niloticus* were collected from Kasuwar Jan Bulo. Sampling was conducted once every month over a period of six months (February to July). During each sampling period, three smoked and three fresh specimens of each fish species were obtained from the study area. All samples were carefully handled to prevent contamination and preserve their quality. In total, seventy-two (72) fish samples were collected and analyzed throughout the duration of the study.

Data Analyses

Multivariate Analysis of Variance (MANOVA) was employed to evaluate significant differences in the mean concentrations of heavy metals, across different parts of the fish species. Additionally, descriptive statistical methods were used to analyze data obtained from the questionnaire.

RESULTS

MANOVA Showing Means of Heavy Metals (Pb, Cd) in Two Species of Fishes (mg/kg)

The concentrations of lead (Pb) and cadmium (Cd) in *H. niloticus* and *P. annectens* varied slightly across the sampling period (Table 1). Lead concentrations differed between species and processing methods, with *H. niloticus* generally exhibiting higher values than *P. annectens*. The highest Pb concentration was recorded in smoked *H. niloticus* in July, while the lowest value occurred in oven-dried samples collected in March. Multivariate analysis of variance (MANOVA) revealed significant effects ($p < 0.05$) of species and processing methods on Pb concentrations, indicating that both biological factors and post-harvest handling influenced Pb variability. In contrast, Cd concentrations remained consistently low across all samples and sampling periods. No significant differences ($p > 0.05$) were observed for Cd with respect to species or processing methods, indicating minimal variation among treatments. Overall, Cd concentrations were within the permissible limits established by the World Health Organization and Food and Agriculture Organization, suggesting low contamination levels. The observed variations in Pb levels may reflect combined influences of species-specific accumulation patterns and processing techniques, although further investigation is required to clarify the underlying environmental sources.

Table 1: Monthly Variation in Lead (Pb) and Cadmium (Cd) Concentrations (mg/kg) in *Heterotis niloticus* and *Protopterus annectens* from Kasuwar Janbulo, Jigawa State, Nigeria (Mean ± SD)

Species	Lead (mg/kg)	Cadmium (mg/kg)
FEBRUARY		
Smoked *Propteprus annentene*	0.37 ± 0.0031	0.02 ± 0.0010
Oven dry Propteprus Annentene	0.39 ± 0.0076	0.021 ± 0.0021
Oven dry *Heterosis niloticus*	0.38 ±0.0084	0.02 ± 0.0021
Smoked *Heterosis niloticus*	0.40 ± 0.0269	0.02 ± 0.0012
Sig.	**0.053**	**0.071**
MARCH		
Smoked *Propteprus annentene*	0.389 ± 0.0177	0.021 ± 0.0021
Oven dry *Propteprus annentene*	0.357 ± 0.0381	0.020 ± 0.0021
Oven dry *Heterosis niloticus*	0.332 ± 0.0216	0.020 ± 0.0012
Smoked *Heterosis niloticus*	0.435 ± 0.0775	0.025 ± 0.0038
Sig.	**0.000**	**0.073**
APRIL		
Smoked *Propteprus annentene*	0.425 ± 0.0270	0.022 ± 0.0036
Oven dry *Propteprus annentene*	0.344 ± 0.0252	0.021 ± 0.0021
Oven dry *Heterosis niloticus*	0.345 ± 0.0209	0.020 ± 0.0021
Smoked *Heterosis niloticus*	0.393 ± 0.0682	0.025 ± 0.0015
Sig.	**0.000**	**0.085**

MAY		
Smoked *Propteprus annentene*	0.342 ± 0.0205	0.022 ± 0.0012
Oven dry *Propteprus annentene*	0.325 ± 0.0145	0.023 ± 0.0015
Oven dry *Heterosis niloticus*	0.355 ± 0.0485	0.022 ± 0.0013
Smoked *Heterosis niloticus*	0.414 ± 0.0883	0.023 ± 0.0025
Sig.	**0.000**	**0.088**
JUNE		
Smoked *Propteprus annentene*	0.386 ± 0.0193	0.022 ± 0.002
Oven dry *Propteprus annentene*	0.335 ± 0.0202	0.023 ± 0.002
Oven dry *Heterosis niloticus*	0.349 ± 0.0149	0.021 ± 0.002
Smoked *Heterosis niloticus*	0.495 ± 0.0182	0.024 ± 0.0026
Sig.	**0.002**	**0.091**
JULY		
Smoked *Propteprus annentene*	0.422 ± 0.0105	0.023 ± 0.0021
Oven dry *Propteprus annentene*	0.396 ± 0.0078	0.020 ± 0.0007
Oven dry *Heterosis niloticus*	0.397 ± 0.0125	0.021 ± 0.0021
Smoked *Heterosis niloticus*	0.531 ± 0.0312	0.029 ± 0.0006
Sig.	**0.000**	**0.124**
(FOA/WHO) limit (mg/kg)	0.30	**0.05**

Discussions

The study revealed varying levels of Pb contamination in smoked and oven-dried fish products. The highest Pb concentration was observed in smoked *Heterotis niloticus* in July (0.5310 mg/kg), while the lowest was recorded in oven-dried *Protopterus annectens* in May (0.3250 mg/kg). Notably, some treatments and sampling months exceeded the FAO/WHO permissible limit of 0.30 mg/kg, indicating potential health risks to consumers. Smoked-dried samples generally exhibited higher Pb levels than oven-dried samples, suggesting that smoke-drying may contribute to increased Pb contamination, possibly due to environmental deposition or contamination from smoke sources (Ibanga *et al.,* 2020). Species-specific differences in Pb accumulation further highlight the need for targeted monitoring and control measures. Pb exposure has been associated with oxidative stress, endocrine disruption, and other adverse health effects, particularly among vulnerable populations (Atuanya *et al*., 2015; Daniel *et al.*, 2018). The findings are consistent with previous studies reporting Pb contamination in fish products, emphasizing the importance of continuous monitoring and regulatory enforcement (Sani *et al*., 2022). Similarly, the study revealed low levels of Cd contamination in smoked and oven-dried fish products. The highest Cd concentration was observed in smoked *Heterotis niloticus* in July (0.02867 mg/kg). Although all Cd concentrations were below the FAO/WHO permissible limit of 0.05 mg/kg, some values were relatively close to the upper threshold, indicating the need for continued monitoring. It is important to note that comparing Cd levels in fish tissue with drinking water standards (e.g., 0.003 mg/kg) is inappropriate, as regulatory limits must correspond to the specific food matrix. Cd exposure is associated with kidney dysfunction, bone damage, and other chronic health effects, underscoring the importance of food safety surveillance (Atuanya *et al*., 2015; Daniel *et al*., 2018). The results align with previous studies reporting low but detectable levels of heavy metals in fish products, highlighting environmental exposure as a persistent source of contamination (Sani *et al*., 2022). Therefore, effective monitoring, improved processing practices, and adherence to regulatory standards are essential to minimize heavy metal contamination and ensure the safety of dried fish products for consumption.

Conclusion

This study assessed Pb and Cd concentrations in smoked and oven-dried *Heterotis niloticus* and *Protopterus annectens* obtained from Kasuwar Janbulo Market, Hadejia, Nigeria. Lead concentrations varied significantly with fish species and processing method, with smoked *H. niloticus* recording the highest level in July. Several samples exceeded the FAO/WHO permissible limit of 0.30 mg/kg for Pb in fish, indicating a potential health risk to consumers. In contrast, Cd concentrations remained low across all samples and sampling periods and were within the FAO/WHO safety limit of 0.05 mg/kg. The elevated Pb levels in smoked samples suggest that the smoking process, possibly through contamination from fuel sources and environmental deposition, contributes to heavy metal accumulation. Additionally, *H. niloticus* exhibited higher Pb concentrations compared to *P. annectens*, indicating species-specific differences in metal uptake and accumulation patterns.

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