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ORIGINAL ARTICLE

Levels of heavy metals in corn and potato-based food products in district Nowshera Pakistan

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ABSTRACT

Background: Heavy metal contamination in food products poses a major public health challenge worldwide, with children being particularly vulnerable due to their dietary habits and physiological sensitivity. Processed snacks, especially potato and corn-based varieties, are widely consumed in Pakistan, yet limited research has examined their safety in relation to heavy metal exposure. The objective of this study was to assess the toxicity of Lead (Pb), Cadmium (Cd), Chromium (Cr), and Copper (Cu) in branded and local snack products commonly sold in District Nowshera, Khyber Pakhtunkhwa, Pakistan.

Methods: A cross-sectional study was conducted between December 2023 and May 2024 where Ninety-six samples of potato-based, corn-based, and mixed snacks were collected from three tehsils of District Nowshera using convenience sampling. After acid digestion, the concentrations of heavy metals were analyzed using Atomic Absorption Spectrophotometry (AAS). Results were compared against World Health Organization (WHO) and Food and Agriculture Organization (FAO) permissible limits. Data analysis was performed in SPSS v27, applying descriptive statistics, independent samples t-tests, and ANOVA.

Results: Branded snacks dominated the market (55.2%) compared to local products (44.8%), with potato-based snacks being the most common (62.5%). Chromium was detected at the highest levels (mean 2.21 ± 0.05 mg/kg), exceeding WHO/FAO limits in all samples. The observed differences were significant between local and branded snacks for Cd ($p = 0.001$) and Cr ($p = 0.013$), with higher levels in local products. Lead and copper showed no significant differences between the two groups, though Pb levels approached permissible thresholds.

Conclusion: The study underscores a concerning burden of heavy metals, particularly chromium, in snacks available in the markets of district Nowshera. Levels of lead also approaching unsafe limits. These observations highlight the urgent need for stricter regulatory enforcement, improved quality control measures, and public awareness campaigns.

Keywords: Corn, Food Safety, Heavy Metals, Potato, Snacks

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Introduction

Food safety is a critical aspect of public health worldwide and holds particular importance in densely populated countries like Pakistan (1). While many food safety issues are linked to microorganisms,

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contamination by potentially toxic metals has emerged as an increasing problem and a significant global concern (2). Heavy metals are among the naturally occurring elements having high atomic weight and density which is greater than five times that of water (3). While some, such as zinc and copper, are essential micronutrients, others like lead and cadmium are non-essential and highly toxic even at low concentrations (4). They can accumulate in food products through contaminated soil, irrigation with industrial wastewater, fertilizer use, and industrial emissions (5, 6).

Global studies consistently highlight the risks of heavy metals in food chains. Human exposure to lead is estimated to cause around 143,000 deaths annually and contributes to 0.6% of the global disease burden. It affects multiple body systems including the neurological, hematological, gastrointestinal, cardiovascular, and renal systems often without producing noticeable symptoms, particularly in children (7, 8). Cadmium exposure is linked to renal damage and bone demineralization (9) while chronic chromium exposure is a known carcinogen, causing gastrointestinal and respiratory cancers(10). Although copper is essential, excessive intake leads to gastrointestinal distress, liver damage, and neurological disorders (11).

Snacks, particularly potato and corn-based processed foods, are widely consumed due to convenience and taste, especially among school-aged children. According to preliminary statistics, their consumption in some countries has already reached 17.49 million tonnes in 2018. Major concerns associated with these products include contamination by pathogenic bacteria and potentially toxic metals, the use of illegal or excessive additives, and the predominance of low-cost snacks lacking formal trademarks (12). In lower socioeconomic communities, these challenges are further compounded by limited access to fresh products and the widespread availability of inexpensive, convenient, but nutritionally poor snack foods. Studies in Iraq, Philippines, and China have documented concerning levels of heavy metals in such snacks (13-15). In Pakistan, research primarily focuses on vegetables irrigated with contaminated wastewater, with little attention to processed snacks (16, 17). Keeping the above-mentioned facts in mind, this study was designed to quantify heavy metal contamination in branded and local snacks in Nowshera, a major agricultural and industrial district attempt to bridge the existing gaps.

Methods

A cross-sectional study was conducted between December 2023 and May 2024 to assess the levels of selected heavy metals in potato and corn-based snack products available in the markets of District Nowshera, Khyber Pakhtunkhwa, Pakistan. The study was approved by Institutional Research and ethical review board via letter no 353/DME/KMC dated 3/6/2023. The study was carried out in three tehsils of the district, namely Pabbi, Nowshera, and Jahangira. Nowshera was selected due to its significant agricultural activity and growing industrial expansion, both of which may contribute to heavy metal contamination in the food chain (18).

For the purpose of this study, the heavy metals analyzed included cadmium (Cd), lead (Pb), chromium (Cr), and copper (Cu). Permissible levels were set in accordance with WHO/FAO guidelines, with thresholds of ≤0.5 mg/kg for lead, ≤0.1 mg/kg for cadmium, ≤1 mg/kg for chromium, and ≤0.4 mg/kg for copper (19). Snacks were defined as potato and corn-based products including both branded and locally manufactured varieties such as Lays, Kurkure, Slanty, Super Crisps, Oye Hoye, Pringles, and simple chip packets commonly available in local shops and supermarkets.

A total of 96 snack samples were collected using convenience sampling. Among these, 53 samples were branded and 43 were local products. Expired products were excluded from the study. All collected samples were transported to the Public Health Laboratory, Khyber Medical College, Peshawar, for laboratory analysis. The samples were digested using nitric acid and perchloric acid following standard procedures (20). Quantitative determination of Pb, Cd, Cr, and Cu was carried out using Atomic Absorption Spectrophotometry (AAS). The obtained concentrations were compared with the permissible limits established by WHO/FAO.

Data were analyzed using SPSS version 27. Mean concentrations and standard deviations of heavy metals were calculated. Independent sample t-tests were used to compare heavy metal levels between branded and local snack products, while one-way analysis of variance (ANOVA) was applied to assess differences among potato, corn, and mixed snacks.

Results

The analysis of snack samples (n=96) revealed that the majority were branded, accounting for 55.2% (n=53) of the total, while 44.8% (n=43) were local. In terms of product category, potato-based snacks were the most prevalent, representing 62.5% (n=60) of the total. Corn-based snacks followed with 25% (n=24), whereas mixed-type snacks comprised 12.5% (n=12). This distribution indicates that branded products dominate the market, particularly potato-based items, suggesting their greater accessibility and consumer preference in the study area.

The descriptive analysis of heavy metal concentrations indicated variability across the tested samples. Lead (Pb) ranged from 0.057 to 0.422 mg/kg, with a mean concentration of 0.214 ± 0.094 mg/kg, demonstrating notable spread. Cadmium (Cd) levels were lower overall, ranging from 0.004 to 0.045 mg/kg, with a mean of 0.012 ± 0.009 mg/kg. In contrast, Chromium (Cr) concentrations were consistently higher, between 2.137 and 2.328 mg/kg, with a mean of 2.211 ± 0.047 mg/kg, showing minimal variability. Copper (Cu) levels ranged from 0.009 to 0.102 mg/kg, averaging 0.043 ± 0.019 mg/kg. These findings suggest that chromium was the most abundant heavy metal across all snacks, whereas cadmium was detected at comparatively minimal levels. **(Figure 1)**

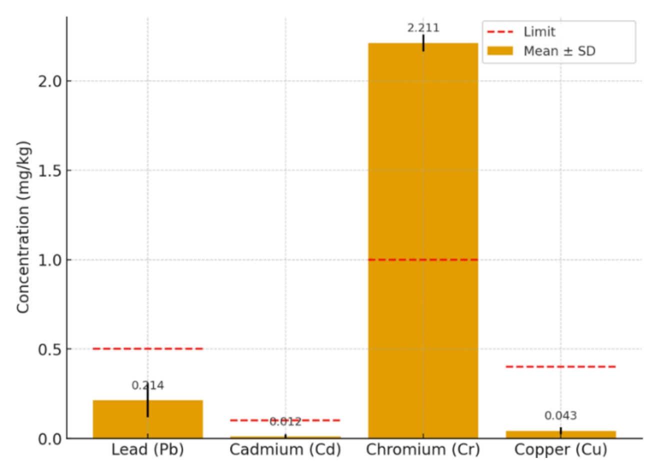

Figure 1. Mean concentrations of heavy metals in Snack Samples vs WHO/FAO Limits

The independent samples t-test demonstrated statistically significant differences in Pb, Cd, Cr, and Cu concentrations between branded and local snacks as shown in **Figure 2** thus, highlighting disparities in safety and quality standards.

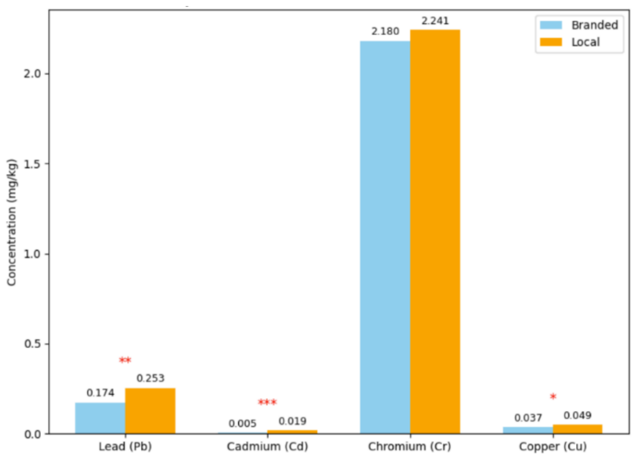

Figure 2. Heavy metal concentrations in branded vs local Snacks

The one-way ANOVA analysis comparing heavy metal concentrations across different snack types revealed both significant and non-significant differences as mentioned in **Table 1**. Lead (Pb) and Copper (Cu) levels showed no variation among the three categories of snacks. In contrast, cadmium (Cd) and chromium (Cr) showed considerable variation across potato-based, corn-based, and mixed snacks, indicating that their concentrations were influenced by the type of base ingredient.

Table 1. Comparison of heavy metal levels across snack types

Heavy Metal	Snack Type	P-Value
Lead (Pb)	Potato based	0.442
	Corn Snacks	
	Mixed	
Cadmium (Cd)	Potato based	0.001
	Corn Snacks	
	Mixed	
Chromium (Cr)	Potato based	0.013
	Corn Snacks	
	Mixed	
Copper (Cu)	Potato based	0.326
	Corn Snacks	
	Mixed	

Discussion

This study assessed heavy metal concentrations in local and branded snacks, including potato, corn, and mixed-based products in the District Nowshera. The findings indicated that branded snacks were more readily available in the market and consumed more frequently, contrasting with previous reports from low and middle-income countries (LMICs), where locally manufactured foods are generally more accessible and affordable than branded alternatives (21).

Our study found that chromium had the highest concentrations across both local and branded samples. Elevated chromium levels in snacks have also been documented in studies from South Asia, largely attributed to contamination during processing, packaging, and the use of stainless-steel equipment (12). Moreover, Cr usually originate from natural processes such as the weathering of parent rocks, or from human activities including industrial operations, mining, wastewater irrigation, and the use of inorganic fertilizers and pesticides. Industrial activities, in particular, play a major role in elevating their levels in the ecosystem, leading to the contamination of soil, water, and crops, which ultimately impacts human health.

In current study, Cadmium concentrations were significantly higher in local snacks compared to branded ones. Similar trends have been observed in food safety assessments in Pakistan and neighboring countries (22). In China, the Cadmium (Cd) contamination in agricultural soils has risen between 1981 and 2016, primarily due to human activities such as mining, smelting, and fertilizer use (23). Although it presents relatively low ecological risks, it poses significant health concerns, particularly contributing to chronic renal diseases and related ailments.

Our results showed the presence of lead, with no significant differences between local and branded products. However, the mean concentrations were higher than those reported in some previous studies on packaged snacks, indicating ongoing contamination risks. Lead exposure is especially concerning because of its neurotoxic effects, particularly in children, and the fact that there is no known safe threshold for consumption (24).

Copper is an essential micronutrient required for various physiological functions; however, when consumed in excess, it can become harmful, leading to gastrointestinal problems and liver toxicity. In this study, copper levels were found to remain within acceptable ranges, and no significant differences were observed between local and branded snacks (25).

Conclusion

The study concluded that the snacks sold in District Nowshera contain concerning levels of heavy metals, particularly chromium, with lead approaching unsafe limits. These findings underscore the urgent need for stricter enforcement of safety regulations, safer agricultural practices, and consumer education to protect end users, especially children.

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Data acquisition, analysis and interpretation	BA, HK, NH
Manuscript writing and approval	MSF, LK, KUR
All the authors agree to take responsibility for every facet of the work, making sure that any concerns about its integrity or veracity are thoroughly examined and addressed.	