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Risk Assessment of Toxic Elements in Buckwheat Produced in Armenia

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ABSTRACT

Buckwheat provides essential nutrients crucial for the human body's regular functioning, however, studies have indicated that it may also contain potentially toxic elements. Therefore, this study aims to assess the health risks associated with buckwheat produced in Armenia, focusing on dietary exposure to toxic elements (lead, cadmium, and arsenic). Risk assessment was conducted using the margin of exposure (MOE) method, involving calculating daily intakes for toxic elements. The study findings suggest that the levels of toxic elements in the investigated buckwheat samples were within acceptable limits. This indicates that there is no significant health risk to consumers.

Introduction

Buckwheat, belonging to the Polygonaceae family, is classified as pseudocereals. Cultivated globally, it is commonly processed, particularly as a key ingredient in functional foods (Sofi, et al., 2023). Notably, buckwheat surpasses rice and legumes such as wheat and corn in nutritional profile. It contains essential nutrients like proteins, vitamins, and essential amino acids. Its well-balanced amino acid composition adds significant value to the human diet (Huang, et al., 2013). While the digestibility of buckwheat proteins is about 80 %, which is lower than animal proteins like hemoglobin and ovalbumin, it is higher than that of cereal proteins (e.g., sorghum 55-59 %, corn 66-75 %) and is comparable to the content found in rice bran (89 %) and wheat germ (77-93 %) (Džafić, et al., 2022). Moreover, buckwheat provides essential nutrients crucial for the human body's regular functioning, including vitamins, fatty acids, and trace elements. However, studies have highlighted the importance of considering that they may also contain potentially toxic elements such as heavy metals (Pipoyan, et al., 2022; Zhou, et al., 2016).

Heavy metals can pose various adverse health effects, including carcinogenic, mutagenic, teratogenic, and neurotoxic impacts (Zhang, et al., 2018). Furthermore, exposure to these elements through contaminated foods can lead to a weakened immune system and damage to the gastrointestinal tract, among other consequences. It is noteworthy that each metal possesses distinct physicochemical properties that play a vital role in determining toxicological mechanisms (Zhang, et al., 2018; EFSA, 2012). Among heavy metals, lead (*Pb*), cadmium (*Cd*), and arsenic (*As*) are known as toxic elements, as exposure to even low levels can lead to public health issues. Lead has toxic effect on the central and peripheral nervous system, kidneys, cardiovascular system, gastrointestinal tract, and male reproductive system (EFSA 2010). Long-term exposure to high doses of cadmium can lead to teratogenesis, mutagenicity, and carcinogenesis (Zhou, et al., 2016). Long-term exposure to high doses of inorganic arsenic can lead to skin, lung, and bladder cancers (EFSA, 2009).

Notably, diet is one of the key sources of exposure to toxic elements for the population (Jolly, et al., 2013). As cereals and cereal-based products constitute a valuable component of the typical diet of the population, it is crucial to investigate the levels of toxic elements in these products and evaluate the potential health risks associated with dietary exposure. Additionally, it is important to note that in recent years, not only imported but also locally cultivated buckwheat has been sold on the markets and consumed by the population. Therefore, this study's objective is to assess the health risks associated with the consumption of buckwheat produced in Armenia. It focusing on dietary exposure to toxic elements: lead (*Pb*), cadmium (*Cd*), and arsenic (*As*).

Materials and methods

Sampling and analysis

Buckwheat sampling was conducted as part of the state monitoring program, from agricultural plots in six rural communities in the Gegharkunik and Aragatsotn regions. Sampling was carried out by standard operating procedures (SOPs) developed in the Centre for Ecological-Noosphere Studies (CENS) of the National Academy of Sciences of the Republic of Armenia, using the guidelines of Codex Alimentarius Commission (CAC, 1993) and recommendations of the ISO sampling standard (ISO 874-1980, 2017). Preparation and further chemical analysis of the samples was carried out at the Republican Center for Veterinary and Sanitary and Phytosanitary Laboratory Services, accredited according to ISO 17025 standard.

The buckwheat samples underwent standard preparation procedures, including washing and removal of non-edible particles. The samples were mixed and ground. For analysis, 0.5 g of each sample was taken, treated with 3.0 ml concentrated nitric acid and 0.5 ml hydrogen peroxide in specific tubes, and microwaved. After mineralization, the cooled tubes were vented, and the mineralized sample was degassed in an ultrasonic bath. The final step involved dilution of the mineralizer with deionized water to 10 ml. To detect lead (*Pb*), cadmium (*Cd*), and arsenic (*As*) in buckwheat, samples were analyzed using atomic absorption spectrometry (AAS, Thermo Fisher iCE-3500). To ensure quality, the Multi-Element Aqueous CRM US EPA 23 standard solution was employed. Each composite sample underwent a replicate analysis, with recovery ratios consistently ranging from 95 to 98.8 % during the analytical procedures.

Risk assessment

The daily intake of toxic elements (*Pb, As,* and *Cd*) through buckwheat consumption is estimated using the following formula (US EPA, 1997):

$$EDI = \frac{C * IR}{BW},$$

where *EDI* (mg/kg/day) represents the estimated daily intake of the toxic element via buckwheat consumption, *C* is the content (mg/kg) of the investigated element in buckwheat, and *BW* is the average body weight in kilograms (kg) for the population. *IR* is the average daily buckwheat consumption in kilograms per day (kg/day). According to data from the RA Statistical Committee, the daily consumption data on buckwheat in dry form is 10.9 g/day (ARMSTAT, 2021).

To assess the potential health risk to the population, the margin of exposure (MOE) for each toxic element was calculated using the following formula:

$$MOE = \frac{HBGV}{EDI},$$

where *HBGV* is the health-based guidance values of each investigated toxic element presented in Table 1.

Table 1. Health-based guidance values for toxic elements*

Element	HGBVS	Value (mg/kg/day)	Health impact	Reference
Pb	BMDL10	6.3E-04	Increased incidence of chronic kidney disease in adults	EFSA, 2010
As	BMDL01	3.0E-04	Skin, lung and bladder cancer	EFSA, 2009
Cd	TWI	2.5E-03	Renal failure	EFSA, 2011

Note: *BMDL - Benchmark Dose Lower Confidence Limit, TWI - Tolerable Weekly Intake.*

*Composed by the authors.

Results and discussions

Contents of toxic elements in buckwheat

Toxic elements lead (*Pb*), cadmium (*Cd*), and arsenic (*As*) were found in all buckwheat samples produced in RA (Table 2). The obtained results showed that *Pb, Cd,* and *As* contents in buckwheat were 0.02 mg/kg, 0.05 mg/kg, and 0.15 mg/kg, respectively. This did not exceed the maximum allowable limits (MAL) established by the EAEU Technical Regulation (TR CU 021/2011).

Table 2. Toxic element contents in buckwheat samples*

Mean/SD	*Pb*	*Cd*	*As*
Mean	0.02	0.05	0.02
±SD	0.003	0.004	0.01
MAL	0.2	0.15	0.25

Note: *MAL - maximum allowable limit.*

*Composed by the authors.

This study was compared with studies conducted in Armenia and other countries. In previous studies conducted in Armenia, heavy metals content was determined in samples of cereals sold in Yerevan, including buckwheat. Data from the study showed that higher concentrations of lead were found in samples of cooked buckwheat than in samples of other cereals, but they were within acceptable limits. However, the levels of lead and cadmium found in all cereal samples studied, including buckwheat, were far below(Pipoyan, et al., 2022).

According to another study conducted in the Ryazan region (Russia), buckwheat exhibits a high capacity for absorbing heavy metals. The analysis of the empirical series of heavy metal supply revealed that buckwheat absorbs cadmium from the soil more intensively than lead (Huang, et al., 2013). According to studies conducted in Bangladesh, the arsenic content cereals, especially in buckwheat, did not exceed the permissible level (Parvin, et al., 2021).

Exposure assessment and risk characterization

The estimated daily intake (EDI) of the investigated toxic elements due to buckwheat consumption is illustrated in Figure 1. Among the studied elements, cadmium had the highest average daily intake at 4.84E-06 mg/kg/day, followed by lead (Pb) at 2.25E-06 mg/kg/day and arsenic at 1.65E-06 mg/kg/day, respectively.

The obtained EDI values (Figure 1) of toxic elements did not exceed the established HBGVs (Table 1).

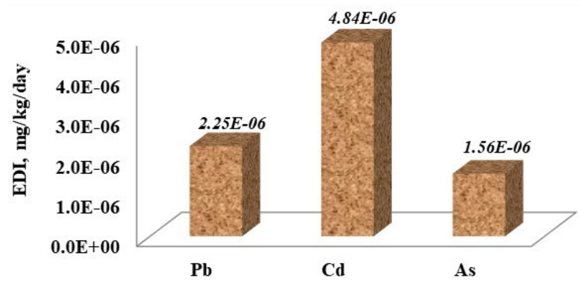

Figure 1. Estimated daily intake (EDI) of toxic elements via buckwheat consumption *(composed by the authors)*.

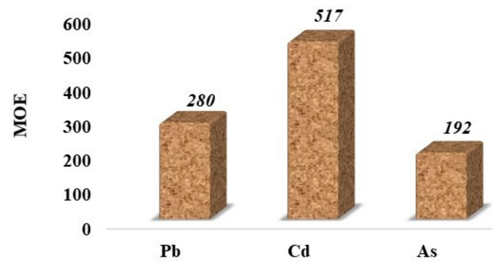

Figure 2. Estimated daily intake (EDI) of toxic elements via buckwheat consumption *(composed by the authors)*.

To gain a better understanding of the health risks associated with toxic elements in buckwheat, the margin of exposure (MOE) was calculated based on health-based guidance values (HGBVs). Following the methodology recommended by the European Food Safety Authority (EFSA), if the MOE values exceed 10 (MOE>10), there is no risk to public health. For all toxic elements detected in samples of the investigated buckwheat, the MOE results (Figure 2) were significantly higher than 10, indicating that the detected contents of toxic elements do not present a health risk to the population.

It is essential to note that this study presents risk assessment results concerning dry, non-culinary processed buckwheat produced in Armenia. In contrast, previous studies in Armenia were performed using the total diet study (TDS) approach, where all buckwheat samples were treated according to culinary recipes. In a previous study in Armenia (Pipoyan and Beglaryan, 2019), an assessment of the carcinogenic and non-carcinogenic risks associated with exposure to heavy metals from imported buckwheat consumption was conducted. The calculated results, expressed as Target Hazard Quotients (THQ), were consistently below 1 (THQ<1). According to established criteria THQ values below 1 are acceptable and pose no risk to human health. The results obtained indicated no significant health risks associated with heavy metal exposure from buckwheat for both men and women. Although higher lead concentrations were detected in buckwheat samples than other cereals, these concentrations remained within acceptable limits. It is noteworthy that the levels of lead and cadmium in all buckwheat samples were below the established acceptable levels. These findings assure that buckwheat consumption, even with higher lead concentrations, does not pose a health risk based on the applied assessment method.

Conclusion

This study assessed the possible health risks associated with the ingestion of toxic elements, namely lead (*Pb*), cadmium (*Cd*), and arsenic (*As*), detected in buckwheat cultivated in Armenia. Considering average buckwheat consumption, dietary exposure to the studied toxic elements (*Pb, Cd,* and *As*) did not pose potential health risks.

In comparing these results with our previous studies, it is crucial to highlight that, despite the high consumption of imported buckwheat in Armenia, no contribution to the health risks of toxic elements was identified in the case of locally grown buckwheat. However, regular assessments are needed continuously to ensure the safety of buckwheat consumption, especially considering its susceptibility to accumulating toxic elements from the environment.

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Declarations of interest

The authors declare no conflict of interest concerning the research, authorship, and/or publication of this article.

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