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Target-Oriented Risk Assessment of AFB_1 in Buckwheat Consumed in Armenia

S.A. Stepanyan, D.A. Pipoyan, M.R. Beglaryan
Center for Ecological-Noosphere Studies (CENS) of National Academy of Sciences (NAS), RA
seda.stepanyan@cens.am, david.pipoyan@cens.am, meline.beglaryan@cens.am

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ABSTRACT

Cereals, including buckwheat are consumed as an essential source of energy, minerals, fiber, and vitamins. However, these products are susceptible to aflatoxin B_1 (AFB_1) infection from various fungi. Considering the wide consumption of buckwheat in Armenia, this study aims to assess the dietary exposure of AFB_1 to Armenian adult population. 24-hour recall method was used to evaluate buckwheat consumption. While AFB_1 contents do not exceed the maximum residue levels, dietary exposure estimates exceed the toxicological reference value for females residing in Tavush region, as well as for consumers of cluster 2 (buckwheat consumption of 64.59 g/day). Hence, the consumption of buckwheat alone has the potential to cause adverse health effects.

Introduction

Throughout the world's healthy food market, buckwheat grains and their products are considered to have a high nutritional value and low inputs for cultivation (Keriene, et al., 2018, Christa and Soral-Śmietana, 2008). However, many crops, including buckwheat are of concern for mycotoxin contamination, especially in the light of recent rapid changes in the weather conditions which affect all the aspects of food security (Leggieri, et al., 2012, Keriene, et al., 2018). Mycotoxins are produced by fungi which colonize many crops and adapt to a wide range of environmental conditions (Khodaei, et al., 2021, Xiong, et al., 2021). In the food and feed industry, the most concerning mycotoxins are produced by Aspergillus, Fusarium and Penicillium (Das, et al., 2021).

Till now, 400 types of mycotoxins have been identified, out of which a few are dangerous to humans and animals, including aflatoxins (AFs), ochratoxins, deoxynivalenol, fumonisins, and zearalenone (Khodaei, et al., 2021). A key point of interest in relation to buckwheat are the AFs which are potent carcinogens that exist in five ways: AFB_1, AFB_2, AFG_1, AFG_2 and M_1 (EFSA, 2013, Mahapatra, 2021). The International Agency for Research on Cancer (IARC) has classified AFB_1 as a Group 1A carcinogen (carcinogenic to humans) (IARC, 1993). About 4.5 billion people worldwide are chronically exposed to low aflatoxin levels due to the daily consumption of products contaminated with it (Fan, et al., 2021, Pickova, et al., 2021). At high concentrations, the consumption can lead to serious health problems, including damage to the liver and other organs, causing liver cancer, and death (WHO, 2020).

Considering the adverse health effects of mycotoxins on humans and animals, many countries, including the European Union (EU), set up standards for maximum levels of total aflatoxins in food products intended for both human and animal consumption. The EU established the maximum acceptable limits for AFs in nuts, dried fruits, cereals and cereal products, spices, and milk (Kortei, et al., 2021, Palumbo, et al., 2020).

To protect human health, it is essential to assess the presence of mycotoxins in cereals, including buckwheat. Previously, the Center for Ecological Noosphere Studies of Armenia (CENS) carried out investigations regarding concentrations of mycotoxins, including AFB_1 in cereals and cereal-based products and health risk assessment through cereal consumption in Yerevan, Armenia. The results of these studies indicate that contamination level of AFB_1 in cereal crops such as rice, buckwheat, maize and wheat sold in markets of the city of Yerevan range from 1.06 to 3.11 μg/kg, though the concentrations do not exceed the acceptable level (Pipoyan, et al., 2016). Meanwhile, the daily intake of AFB_1 via total consumption of cereal crops, in particular rice, buckwheat, maize and wheat, consumed by Yerevan population exceeds the toxicological reference value for AFB_1, indicating a potential health risk (Pipoyan, et al., 2017). However, individual consumption of the studied cereals didn't exceed the reference value. It is worth mentioning, that the previous investigations were carried out for the whole studied population, without taking into consideration different groups of population. Taking into consideration the absence of similar studies in the whole territory of Armenia, this is the first-ever attempt to carry out a target-oriented dietary exposure assessment of AFB_1 in buckwheat both in the capital of Armenia, as well as in other regions.

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Materials and methods

Data collection and statistical analysis

The data on AFB_1's concentrations in buckwheat samples was obtained from previous studies (Pipoyan, et al., 2016, Pipoyan, et al., 2017). Detailed information regarding sample collection and analysis is presented there. The ELISA method was used to determine AFB_1 concentrations and the limit of detection (LOD) of the method has been estimated to be 0.001 mg/kg.

To obtain buckwheat consumption data, a 24-hour dietary recall (24HR) was developed and used for conducting surveys. The survey was conducted in the frame of the research project on "Strengthening scientific and methodological capacity for assessing food security and nutrients" (20TTCG-4A001).

The 24HR study was conducted in 2021 and included all the regions of Armenia, as well as all the districts of Yerevan to ensure national representativeness. One thousand and four hundred people (18–80 years old and over) residing in Armenia took part in the survey. The 24HR survey was paper-based and interviewer-administered. The average daily consumption of buckwheat was calculated considering the consumption frequency and the portion size. All the statistical analyses were conducted using SPSS software (version 22). Kolmogorov-Smirnov and Shapiro-Wilk tests were used to check for normality. To get a normal distribution of consumption values, the K-means cluster analysis method was applied. Two homogeneous cluster groups were revealed.

Exposure assessment

By combining AFB_1's concentration data with consumption data, estimated daily intake (EDI) was calculated:

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

where EDI is the exposure to AFB_1 (ng/kg bw/day), C is the mean concentration of contaminant (μg/kg), IR is the rate of ingestion of food (g/day), BW is the body weight (kg) (mean body weights for males and females in studied regions were 77 and 66 kg, respectively). Data regarding weight was self-reported through 24HR.

Results and discussions

Content of AFB1 in buckwheat

The contents of AFB_1 in buckwheat samples ranged from 1.06 μg/kg to 1.89 μg/kg, with a mean of 1.475 μg/kg. According to the Customs Union's Technical Regulation on Food Safety (TR CU 021/2011), the content of AFB_1 in cereals do not exceed 5 μg/kg. In contrast, the European Commission Regulation No. 1881/2006 has set a maximum residue level (MRL) of 2 μg/kg of AFB_1 in all cereals and cereal products (buckwheat is included in cereals) (EC, 2006). Although the detected AFB_1 contents do not exceed the MRL, they make up 53 %-73 % of it.

The AFB_1 concentrations of the current study are comparable with the values estimated in other countries. A study towards risk assessment for aflatoxin B_1 in Japan indicated that buckwheat is among the major contributors of AFB_1 intake. The contents of AFB_1 in buckwheat flour ranged from 0.04 – 0.08 µg/kg (Sugita-Konishi, et al., 2010). These values are substantially lower than the ones of the current study (1.06 – 1.89 µg/kg).

Buckwheat consumption

The average buckwheat consumption for the studied population is 40.52 g/day; 54 % of consumers are female (with an average buckwheat consumption of 40.5 g/day) and 46 % are male (with an average consumption of 40.4 g/day). A mean consumption data for Armenia, as well as a separate data for all 11 regions is represented in Figure 1. The amounts ranged from 36.45 g/day in Ararat region to a maximum of 52.28 g/day in Tavush region.

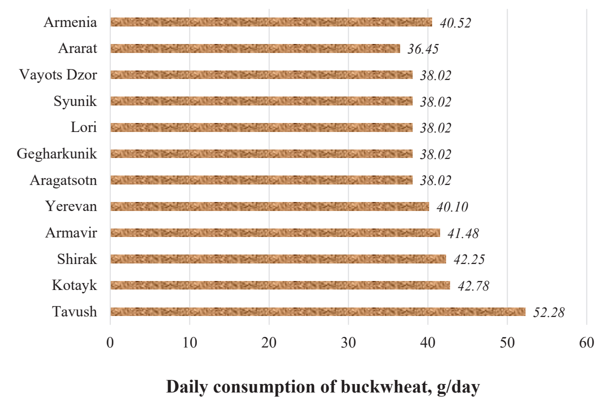

Figure 1. Buckwheat consumption (g/day) across Armenia *(composed by the authors).*

According to the cluster analysis 2 clusters were revealed. The consumption amounts of buckwheat for two different clusters are presented in Figure 2. For the first and second clusters, the consumption amounts are equal to 36.53 g/day and 67.59 g/day, respectively. While the consumption amount increases from the first to the second cluster, the amount of people in each cluster decreases. While cluster 1 includes most consumers (87 %), cluster 2 includes only a small portion of it (13 %).

EDI of AFB_1

The EDI values have been calculated for the whole country, each region, as well as for each cluster and gender. The amounts for cluster 1 and 2 are equal to 0.753 and 1.394 ng/kg bw/day, respectively. The average EDI obtained for the whole studied population is equal to 0.835 ng/kg bw/day. The average EDI obtained for the Yerevan population is equal to 0.827 ng/kg bw/day. Overall, the exposure to AFB_1 contamination is higher among females (0.771 ng/kg bw/day) than males (0.771 and 0.904 ng/kg bw/day). The highest daily intake of AFB_1 has been estimated in Tavush region and the lowest in Ararat region (Figure 3).

Considering the toxicological reference value of 1 ng/kg bw/day for AFB_1 defined by Scientific Committee on Food (SCF) and Expert Committee on Food Additives (JECFA), the EDI values obtained for females residing in Tavush region, as well as for consumers of cluster 2 exceed the threshold in 1.07 and 1.39 times, respectively (Leblanc, et al., 2005). It is of particular importance to state that the rest of the EDI values make up from 75 % to 88 % of the toxicological reference value. Therefore, there is a very high risk that the intake of AFB_1 through buckwheat alone can pose potential health risks for humans, particularly for the diabetic consumers who have the highest intake of buckwheat.

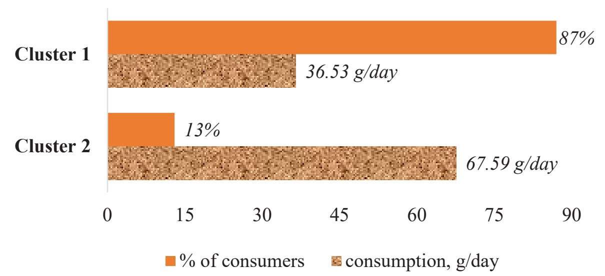

Figure 2. Buckwheat consumption (g/day) based on clusters *(composed by the authors).*

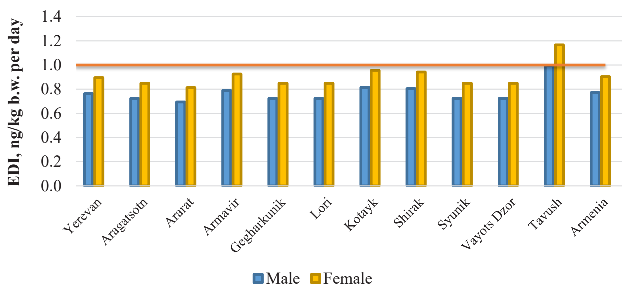

Figure 3. Estimated daily intake of AFB_1 (ng/kg bw per day) *(composed by the authors).*

Conclusion

The obtained results indicate, that although in the buckwheat samples contents of AFB_1 do not exceed the MRL, they make up 53 % – 73 % of it. Meanwhile, the consumption of buckwheat leads to EDI values exceeding the toxicological reference value in case of females residing in Tavush region, as well as for consumers of cluster 2 in 1.07 and 1.39 times, respectively.

Due to fact that buckwheat can contain other toxic substances, including heavy metals, constant monitoring and exposure assessment are important for protecting consumer health. It has been shown that heavy metals such as nickel, arsenic, lead, chromium, mercury, and cadmium share the main target organ, liver, with AFs, and it is therefore important to research their interactions (Renu, et al., 2021). This is particularly relevant for Armenia, since many risk assessment studies conducted in various regions of Armenia indicated the adverse effects of the above stated heavy metals for human health through the consumption of various food items (Pipoyan, et al., 2019, 2020, 2022).

Hence, in future investigations, it is recommended to assess the risk of other substances in buckwheat, as well as in other commonly consumed cereal-based products to better understand the overall risk of cereal products consumed in Armenia.

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