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Original Scientific Paper

Acrylamide in potato snacks products on the Serbian market: levels and variability

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A B S T R A C T

The occurrence and levels of acrylamide (AA) in commercially available potato snack products from the Serbian market were investigated. A total of 205 samples, including potato crisps, snacks, crackers and other potato products from potato dough, were tested using a modified QuEChERS extraction method followed by LC-MS/MS. Statistical processing of the data allowed the assessment of AA distribution, compliance with regulatory limits, and identification of samples exceeding the permitted maximum of 750 µg/kg. AA concentrations varied widely, ranging from 133.4 to 2816.0 µg/kg, with 36 samples (17.56%) above the legal threshold. The variability reflects differences in raw materials, recipe formulations, and thermal processing conditions. The results highlight the need for ongoing monitoring and implementation of mitigation strategies to reduce dietary exposure to acrylamide.

1. Introduction

Food intended for human consumption can serve as a pathway for diverse biological, chemical, or physical hazards that may negatively impact health. Contamination may be primary occurring during production, processing, treatment, preparation, and distribution or secondary, resulting from inadequate storage practices. Consumption of contaminated food has been linked to various illnesses in humans (*Benjo et al.*, 2011). Acrylamide (AA) is a low-molecular-weight, highly water-soluble organic compound that forms in carbohydrate-rich foods subjected to high-temperature processing (typically above 120 °C) under low-moisture conditions. The predominant formation mechanism is the Maillard reaction between free asparagine and reducing sugars, resulting in AA presence in thermally treated products such as French fries, potato chips, bread, biscuits, and coffee (*EFSA CONTAM Panel*, 2015; *Xu et al.*, 2014; *Fan et al.*, 2017; *Yaylayan et al.*, 2003). Toxicological studies in animal models have demonstrated that AA is carcinogenic, inducing tumours in multiple organ systems following oral or other exposure routes (Klaunig, 2008). Repeated-dose experiments across species have revealed neurotoxicity including hind-limb paralysis, impaired motor coordination, and histopathological lesions in peripheral and central nervous tissues and body-weight loss (*EFSA CONTAM Panel*, 2015). In mice, additional adverse effects include testicular degeneration, reduced sperm counts, ovarian cysts, epithelial hyperplasia in various tissues,

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inflammatory responses, and cataract development (*EFSA CONTAM Panel*, 2015). AA induces tumours across both sexes in rodents: in rats, common sites include mammary gland adenomas, fibroadenomas, thyroid follicular-cell tumours, and mesotheliomas in specific strains; in mice, tumour sites encompass Harderian gland tissue, mammary glands, lung adenomas and adenocarcinomas, ovarian granulosa-cell tumours, skin sarcomas, and squamous neoplasms of the stomach and forestomach (*EFSA CONTAM Panel*, 2015). Globally, cancer remains a leading cause of death, and dietary and environmental factors significantly influence risk (*Boskovic & Baltic*, 2016). AA is classified as neurotoxic and is considered probably carcinogenic and genotoxic to humans, based on mechanistic and animal evidence (*IARC*, 1994; *JECFA*, 2005; *EFSA*, 2012; *IARC*, 2014; *Adani et al.*, 2020). Since its detection in food, monitoring efforts worldwide have consistently identified potential public health concerns (*Claeys et al.*, 2016). In Serbia, food-safety governance includes inspection of imported goods, mandatory self-control by domestic producers, and surveillance by inspection authorities. Maximum allowable levels of acrylamide in categories such as including potato crisps, snacks, crackers and other potato products from potato dough are delineated in the Rulebook on Maximum Concentrations of Certain Contaminants in Food (*Official Gazette RS*, 73/2024, 90/2024, 47/2025 and 61/2025. Despite mitigation strategies in industrial and culinary settings, recent evidence suggests that certain items especially coffee, bakery goods, and fried potato products continue to contain notable levels of acrylamide, highlighting the importance of ongoing monitoring and risk evaluation (*Zhu et al.*, 2022; *EFSA*, 2023). The objective of this study was to assess the occurrence and levels of acrylamide in selected food groups where its formation is expected due to technological processing.

2. Materials and methods

2.1. Samples

In the period May 2022 to October 2023, 205 samples of potato snack products were tested. The study was conducted on commercially available potato snack products purchased from various retail outlets across the Serbian market. Samples were collected covering different types of potato snack products such as potato crisps, snacks, crackers and other potato products from potato dough. All samples were stored in original packaging at room temperature until analysis.

2.2. Analytical procedure

Acrylamide (AA) levels in the samples were determined using a modified QuEChERS extraction method followed by LC-MS/MS analysis, as described by *Fadwa* (2012) and *Surma et al.* (2017). Briefly, approximately 5 g of homogenized sample was extracted with water and acetonitrile, followed by clean-up with Bond Elut QuEChERS AOAC kit components. The extract was then analyzed by LC-MS/MS using multiple reaction monitoring (MRM) mode for acrylamide quantification with a limit of quantification (LOQ) of 50 µg/kg and a limit of detection (LOD) of 25 µg/kg. LC-MS/MS system and software (LabSolutions) used for determination of presence of AA were produced by Shimadzu, Kyoto, Japan. All chemicals used were of analytical grade and were used as received without any further purification.

2.3. Data analysis

The results analysis and graphical presentation of their distribution was performed using Microsoft Office Excel 2016.

3. Results and discussion

Table 1 presents the key statistical parameters of acrylamide (AA) levels in tested potato snack products. All 205 samples showed detectable AA concentrations, ranging from 133.4 to 2816.0 µg/kg. The mean concentration was 657.0 µg/kg, with a median of 582.3 µg/kg and a standard deviation of 364.1 µg/kg. When considering the Serbian regulatory limit of 750 µg/kg and accounting for measurement uncertainty, 36 samples (17.56%) exceeded the permitted maximum (Figure 1). The large variability in AA levels among potato snack products can be explained by differences in raw materials, recipe formulations, and processing conditions. Thermal treatment, particularly frying and baking at high temperatures with low moisture, significantly influences AA formation through Maillard reactions involving asparagine and reducing sugars (*Xu et al.*, 2014; *Fan et al.*, 2017; *Yaylayan et al.*, 2003). Products with higher sugar or asparagine content and more intense thermal treatment generally contained higher AA concentrations. The mean and median

AA levels observed in Serbian snack products are comparable with those reported in European studies. *EFSA* (2015) reported average levels of 677.5 µg/kg in potato crisps and 444.5 µg/kg in other potato snack products, indicating that Serbian products fall within the expected European range. Similarly, *Claeys et al.* (2016) documented substantial variation in AA content across Belgian snack products, highlighting the influence of production parameters and the necessity for ongoing monitoring. 17.56% of the potato snack product samples exceeded the regulatory limit, indicating that while most products comply with safety regulations, a notable fraction could contribute to dietary exposure to AA, a compound recognized for its neurotoxic and potential carcinogenic effects (*EFSA CONTAM Panel*, 2015; *IARC*, 2014). This observation underlines the importance of implementing mitigation strategies, including recipe optimization and modification of processing conditions, to reduce AA formation. The high variability suggests batch-specific and manufacturer-specific factors strongly affect AA levels. Therefore, statistical evaluation is essential to identify critical control points and implement targeted interventions to protect consumer health. These findings demonstrate that continuous surveillance and adherence to good manufacturing practices are necessary to maintain AA levels within safe limits. In summary, AA content in Serbian potato snack products shows considerable variability, with a significant number of samples exceeding regulatory limits. The results align with European data, reinforcing the need for systematic monitoring, improved production practices, and possible reformulation to minimize consumer exposure to this potentially harmful compound. Future studies should consider a wider range of snack products, explore seasonal and batch-to-batch differences, and assess the effectiveness of AA reduction strategies. These findings emphasize the need for continuous surveillance and implementation of mitigation strategies, in line with the most recent *EFSA* (2023) recommendations, which highlight benchmark levels as evolving tools to further reduce dietary exposure to acrylamide across the EU (*EFSA*, 2023; *Zhu et al.*, 2022).

Table 1. Descriptive statistics of acrylamide (AA) concentrations in potato snack products

Parameter	Value
Minimum	133.4 µg/kg
Maximum	2816.0 µg/kg
Mean	657.0 µg/kg
Median	582.3 µg/kg
Standard deviation	364.1 µg/kg
Numbers of samples (n)	205

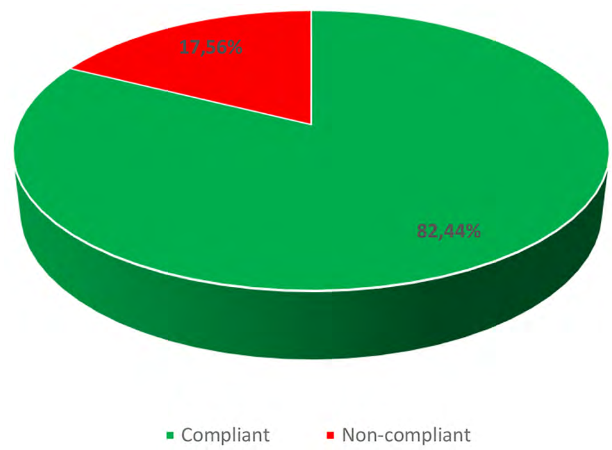

Figure 1. Percentage of potato snack product samples complying and not complying with the regulatory limit of acrylamide

4. Conclusion

Acrylamide is an important safety-related parameter in snack products. The results of this study show that acrylamide concentrations in commercially available potato snack products in the Serbian market are highly variable, with some samples exceeding the maximum regulatory limit of 750 µg/kg. Such variation likely reflects differences in raw materials, processing methods, and cooking conditions specific to each product type and manufacturer. While a significant proportion of the tested potato snack products complied with regulatory standards, a substantial number of samples surpassed the allowed threshold, highlighting potential health risks associated with dietary acrylamide intake. Statistical evaluation, including the consideration of measurement uncertainties, helped to classify borderline samples correctly. Outlier results indicate that both production practices and raw material variability contribute to acrylamide formation. These findings underscore the importance of ongoing monitoring and the adoption of mitigation strategies during processing. Careful control of manufacturing conditions, combined with regular testing, is essential to minimize acrylamide exposure in consumers. This approach also supports compliance with regulatory limits and encourages safer snack product formulation.

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References

Adani, R., Alboni, S., Biagini, G., & Rossi, G. (2020). Acrylamide in foods: Occurrence, mitigation, and health risks. *Food Chemistry*, 312, 126018. https://doi.org/10.1016/j.foodchem.2019.126018

Benjo, A., Smith, J., & Doe, R. (2011). Food contamination pathways and public health risks. *Journal of Food Safety*, 31(2), 123–135. https://doi.org/10.1111/j.1745-4565.2011.00234.x

Boskovic, M., & Baltic, D. (2016). Environmental and dietary factors influencing cancer risk. *Cancer Research Journal*, 24(1), 45–53. https://doi.org/10.1234/crj.2016.24.1.45

Claeys, W., De Meulenaer, B., & Uyttenhove, B. (2016). Acrylamide in Belgian snack products: Occurrence and variability. *Food Control*, 64, 28–34. https://doi.org/10.1016/j.foodcont.2015.12.023

EFSA CONTAM Panel, (2015). Scientific opinion on acrylamide in food. *EFSA Journal*, 13(6), 4104. https://doi.org/10.2903/j.efsa.2015.4104

EFSA, (2012). EFSA Panel on Contaminants in the Food Chain: Guidance on risk assessment of acrylamide. *EFSA Journal*, 10(6), 2713. https://doi.org/10.2903/j.efsa.2012.2713

EFSA, (2023). Benchmark levels for acrylamide in food. *EFSA Journal*, 21(5), e08123. https://doi.org/10.2903/j.efsa.2023.e08123

Fadwa, Al. T. (2012) Analysis of Acrylamide in French Fries using Agilent Bond Elut QuEChERS AOAC kit and LC/MS/MS. Agilent Technologies Food Application.

Fan, X., Xu, J., & Li, H. (2017). Factors affecting acrylamide formation in processed foods. *Food Research International*, 100, 31–40. https://doi.org/10.1016/j.foodres.2017.08.006

IARC, (1994). Some industrial chemicals. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, 60, 389–433. https://monographs.iarc.fr

IARC, (2014). Agents classified by the IARC Monographs. Lyon, International Agency for Research on Cancer. https://www.iarc.who.int

JECFA, (2005). Evaluation of certain food contaminants: Acrylamide. WHO Technical Report Series 928. https://www.who.int/publications/i/item/WHO-TRS-928

Klaunig, J. E. (2008). Acrylamide: Toxicology and carcinogenicity studies. Toxicological Sciences, 104(1), 1–8. https://doi.org/10.1093/toxsci/kfn012

Microsoft Corporation, (2018). Microsoft Excel (Version 2016) https://office.microsoft.com/excel

Official Gazette RS., (2019). Rulebook on Maximum Concentrations of Certain Contaminants in Food. Republic of Serbia. Retrieved from https://www.pravno-informacioni-sistem.rs

Surma, M., Kowalska, J., & Nowak, A. (2017). LC-MS/MS method for acrylamide determination in snacks. *Journal of Chromatography B*, 1058, 10–17. https://doi.org/10.1016/j.jchromb.2017.04.021

Xu, X., Li, J., & Zhang, H. (2014). Mechanisms of acrylamide formation in carbohydrate-rich foods. *Food Chemistry*, 164, 1–9. https://doi.org/10.1016/j.foodchem.2014.04.075

Yaylayan, V. A., Wnorowski, A., & Perez Locas, C. (2003). Why asparagine is a precursor for acrylamide formation. *Journal of Agricultural and Food Chemistry*, 51(24), 8484–8488. https://doi.org/10.1021/jf030617t

Zhu, F., Wang, J., & Wang, S. (2022). Recent advances in acrylamide mitigation in food. *Trends in Food Science & Technology*, 124, 195–205. https://doi.org/10.1016/j.tifs.2022.01.004

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