Towards safer edible insects: assessing contaminant bioaccumulation and depuration capacity in Tenebrio molitor

Diogo N. Cardoso[1], Paula Alvito*[1,2], Marthe de Boevre[3], Ana Rita R. Silva[1], José N. Pinto[1], Ana Eduardo Rodrigues[1], Marija Prodana[1], Patrícia V. Silva[1], Amid Mostafaie[1], Susana Loureiro[1]

[1]CESAM - Centre for Environmental and Marine Studies, Department of Biology, Campus Universitário de Santiago, University of Aveiro, 3810-193 Aveiro, Portugal; [2]National Institute of Health Dr. Ricardo Jorge (INSA), Department of Food and Nutrition, Lisboa, Portugal; [3]Centre of Excellence in Mycotoxicology and Public Health, Ghent University, Ghent, Belgium.

Abstract

The integration of insects into sustainable food and feed chains demands a robust evaluation of their capacity to accumulate and eliminate contaminants. Understanding these dynamics is fundamental to ensuring consumer safety and supporting the development of regulatory standards for insect-derived products. This study assessed the bioaccumulation and depuration kinetics of metal(loid)s (As, Cd, Pb) and mycotoxins (Aflatoxin B1, Ochratoxin A, Deoxynivalenol, and Zearalenone) in the yellow mealworm *Tenebrio molitor*, a species already authorized for human consumption in the EU. Larvae were reared on feed substrates artificially spiked at the maximum levels allowed for animal feed under EU legislation. The experimental design included 21 days of exposure followed by a 21-day elimination phase on uncontaminated substrate, to evaluate both uptake and depuration efficiency under realistic production conditions. Distinct toxicokinetic patterns were observed among metals. Arsenic displayed the highest accumulation potential, reaching internal concentrations of approximately 7 mg/kg dry weight (DW) at the end of exposure, with a progressive but incomplete decline during depuration. Cadmium accumulated steadily to ~2.5 mg/kg DW, exceeding the current feed limit, but was rapidly eliminated below regulatory thresholds within one day of clean feeding. Lead, in contrast, showed low assimilation and rapid clearance, remaining consistently below EU maximum levels. Mycotoxins and their metabolites were not detected above quantification limits in any treatment, confirming the species' limited bioaccumulation potential for these compounds. Overall, the results highlight *Tenebrio molitor*'s high depuration capacity and resilience to transient contaminant exposure. These findings highlight the need to apply toxicokinetic principles in insect risk assessment to define effective depuration periods and ensure safe, circular production systems.

Acknowledgements: This work is funded by national funds through FCT—Fundação para a Ciência e a Tecnolo gia I.P., under the project/grant UID/50006 + LA/P/0094/2020(doi.org/10.54499/LA/P/0094/2020) and supported by the project ENTOSAFE (PTDC/CTA AMB/0730/2021, https://doi.org/10.54499/PTDC/CTA-AMB/0730/ 2021), financially supported by national funds (OE), through FCT/ MCTES. D. Cardoso is hired under the Scientific Employment Stimulus- Individual Call (CEECIND/01190/2018, https://doi.org/10.54499/CEECIND/01190/2018/CP1559/CT0006).