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SUPPLEMENTARY MATERIAL

Navigating the nexus: unraveling the impact of sustainability and the circular economy on food safety

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Supplementary Table 1. Related risks associated with potential contaminants and mitigation measures due to use of upcycling technologies.

Growth media (food/feed product)	Type and class of hazards	Potential contaminant(s)	Potential risk(s)	Mitigation measures	Reference(s)
Risks to Human or Animal Health					
Brewers spent grains	Biological & Allergen (Gluten)	T. molitor	Gluten detected in resultant food product	Testing (washing and fasting) of mealworms for gluten presence	Mancini *et al.* (2020)
Dried distillers grains with solubles, dried sugar beet pulp or middlings	Chemical & heavy metals (Pb and Cd)	H. illucens	Exceeded limits of heavy metals in animal feeds	Testing of animal feed for heavy metals count before administering to animals	Tschirner and Simon (2015)
Vegetables and unknown side stream source	Biological & human pathogens (Mycotoxinogenic fungi, opportunistic pathogenic yeasts)	A. diaperinus	Health hazards to immunocompromised patients	Blanching treatment can significantly reduce bacterial count but further studies are needed	Wynants *et al.* (2018)
Olive pomace	Chemical & Heavy metals (Cd, Pb, Ni, As and Hg)	T. molitor	Presence of toxic metals in the substrate	Testing of food product for heavy metals before marketing	Truzzi *et al.* (2019)
Poultry manure	Chemical & Pesticides, PCBs, Dioxins, Heavy metals	M. domestica	Four times higher levels of dioxins, PCBs and other hazards in feed	Exclusive testing of animal feed before feeding	Nordentoft *et al.* (2014)
Pig offal	Veterinary pharmaceuticals, pesticides, heavy metals, dioxins, polychlorinated biphenyls & polyaromatic hydrocarbons (PAHs) and mycotoxins	M. domestica & C. vomitoria	Higher levels of Cd, Piperonyl butoxide and Chlorpyrifos was recorded in animal feed	Chlorpyrifos has been banned in EU since this study was conducted while others hazards can be controlled through application of proper SOPs during manufacturing, transportation and administration of feed	Charlton *et al.* (2015)
Vegetable waste	Biological & Opportunistic pathogenic yeasts, pathogenic bacteria	H. illucens	High microbial load	Heat drying, freeze drying and sterilisation (steam autoclave)	Varotto Boccazzi *et al.* (2017) & Tedesco *et al.* (2019)
Fruit and vegetable waste	Biological & Opportunistic pathogenic yeasts, pathogenic bacteria, pesticides, heavy metals, antibiotic residues, volatile organic compounds (VOCs)	E. fetida	High microbial load & overloaded conc. Of other contaminants	Heat drying, freeze drying and sterilisation (steam autoclave)	Conti *et al.* (2019) & Tedesco *et al.* (2019)

Coffee silver skin with or without addition of microalgae	Biological and Chemical & Antibiotic resistance genes (ARGs) e.g. erythromycin (erm), tetracycline (tet), vancomycin (vam), β-lactams (bla, mec), and aminoglycosides (aac-aph), multidrug-resistant bacteria and Heavy metals (Cd, Pb, As, Ni and Hg)	H. illucens	Heavy metals except Nickel (Ni) were below EU legal limits for in all growth substrates, prepupae and frass; tet(M) and tet(S) genes were widely present in all analysed substrates, usage of chitosan as biofertilizer and fish supplement posing risks to both the environment and humans	Holistic experimental approach to investigate not only main hazardous substances but also their side stream potential agents	Truzzi et al. (2020); Milanović *et al*. (2021) & Osimani *et al*. (2021
Risks to the Environment using life cycle assessment (LCA) methodology					
Risks arising from insects reared on waste	Greenhouse gas emissions (GHGs), energy use, land use, global warming potential, cumulative energy demand, climate change etc.	Insect species e.g. T. molitor	High energy requirement of the system; increase in global warming potential (GWP); more CO_2 and ammonia-nitrogen were emitted	Mitigation measures like air washer can make an ecologically sound system	Thévenot *et al*. (2018) & Parodi *et al.* (2021)
Risks arising from poultry by-products as animal feed	Global warming (CO2), abiotic depletion, acidification (SO2) and eutrophication potential of the systems	Insect's species e.g. T. molitor	Rendering process of poultry by-products causes global warming and abiotic depletion (mainly due to process heat) while poultry production is the main cause of acidification and eutrophication	Mitigation measures may include following proper SOPs during poultry production and rendering process	Campos *et al*. (2020
Risks arising from earthworms reared on vegetable waste	Greenhouse gas emissions (GHG), emissions of methane, dinitrogen monoxide and ammonia	Earthworms	High energy requirements of fruits and veg. waste (FVW) transport	Move to renewable energy sources to improve the sustainability of the production of earthworm meal	Tedesco *et al.* (2019)

Data courtesy European Food Safety Authority.

Supplementary Table 2. List of selected inputs and outputs and their corresponding identified hazards related to circular economy. Reproduced from: Focker *et al.*, 2022.

Plant-based food systems		**Animal-based food systems**		**Water-based food systems (aquaculture)**	
Supplies (in-puts)	**Hazards (identified)**	**Supplies (inputs)**	**Hazards (identified)**	**Supplies (inputs)**	**Hazards (identified)**
Composts	Heavy metals PFAS Pathogenic Bacteria Dioxins & PCBs	Plant by-products	Heavy metals Mycotoxins	Water (Waste/Treated)	Pathogenic Bacteria Heavy metals Pharmaceuticals Viruses
Water (Irrigation & Waste)	Pathogenic Bacteria Viruses Heavy metals Pharmaceuticals Antimicrobials Antibiotics	Animal by-products	Prions Viruses Pharmaceuticals	Fish by-products	Heavy metals PFAS Pharmaceuticals Dioxins & PCBs
Animal Manure	Pathogenic Bacteria Viruses Heavy metals Pharmaceuticals Antimicrobials	Fish by-products	Heavy metals Dioxins PFAS Pharmaceuticals	Insects	Pesticide residues Heavy metals Pharmaceuticals Dioxins & PCBs Pathogenic Bacteria
Sludge (waste-water/Bio-solids)	Heavy metals Pharmaceuticals PFAS Pathogenic Bacteria Dioxins & PCBs Viruse	Insects	Pesticide residues Heavy metals Pharmaceuticals Dioxins & PCBs Pathogenic Bacteria	Seaweeds	Pathogenic Bacteria Heavy metals Pharmaceuticals Viruses
		Seaweeds	Pathogenic Bacteria Heavy metals Pharmaceuticals Viruses	Organic Waste	Heavy metals PFAS Dioxins & PCBs Pathogenic Bacteria Viruses
Outputs	**Hazards (identified)**	**Outputs**	**Hazards (identified)**	**Outputs**	**Hazards (identified)**
Plant by-products	Heavy metals Mycotoxins	Manure	Pathogenic Bacteria Viruses Heavy metals Pharmaceuticals Antimicrobials	Seaweed	Pathogenic Bacteria Heavy metals Pharmaceuticals Viruses
Compost	Heavy metals PFAS Pathogenic Bacteria Dioxins & PCBs	Animal by-products	Prions Viruses Pharmaceuticals	Fish by-products	Heavy metals Dioxins PFAS Pharmaceuticals