Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in Food Science

# Application of Risk Management Metrics for ochratoxin-A control in the coffee chain

Fernando Rubio-Lopez[1,2,4], Marta Taniwaki[3], Jonathan Morris[4] and Esther Garcia-Cela[1,4]

Coffee is one of the most consumed beverages worldwide. Like other agricultural products, coffee is susceptible of colonization by mycotoxin-producing fungi and therefore, the presence of mycotoxins. These chemical hazards can pose a risk for consumers, as some of them are potentially carcinogenic, neurotoxic, or immunosuppressive. Several countries worldwide have established maximum legal limits on the final product regarding ochratoxin A (OTA), but this leads to inefficiencies in the coffee value chain, as there is uncertainty if a batch may be under the legal limits at the time of reaching the consumers. The application of Risk Management Metrics can be a useful tool for managers to forecast if a particular batch of coffee could be suitable for a determined target market. In this study, a cross-case analysis of the coffee production chain was performed, and quantitative thresholds were established along the different steps. This information can provide managers with up-to-date information regarding the potential use of each batch, minimizing food waste, assuring food safety, and improving chain efficiency.

**Addresses**

[1] Clinical, Pharmaceutical and Biological Sciences, School of Life and Medical Sciences, Centre for Agriculture, Food and Environmental Management Research, MycoLab, University of Hertfordshire, Hatfield AL10 9AB, UK

[2] JBA Consulting, Pipe House, Lupton Rd, Wallingford OX10 9BS, UK

[3] Institute of Food Technology – ITAL, CEP 13.070-178 Campinas, SP, Brazil

[4] Centre for Agriculture, Food and Environmental Management Research, Office of the Vice Chancellor, University of Hertfordshire, AL10 9AB, UK

Corresponding author: Garcia-Cela, Esther (e.garcia-cela@herts.ac.uk)

**Current Opinion in Food Science** 2023, **54**:101100

This review comes from a themed issue on **Food Mycology**

Edited by **Juliane Welke**

Available online 13 October 2023

https://doi.org/10.1016/j.cofs.2023.101100

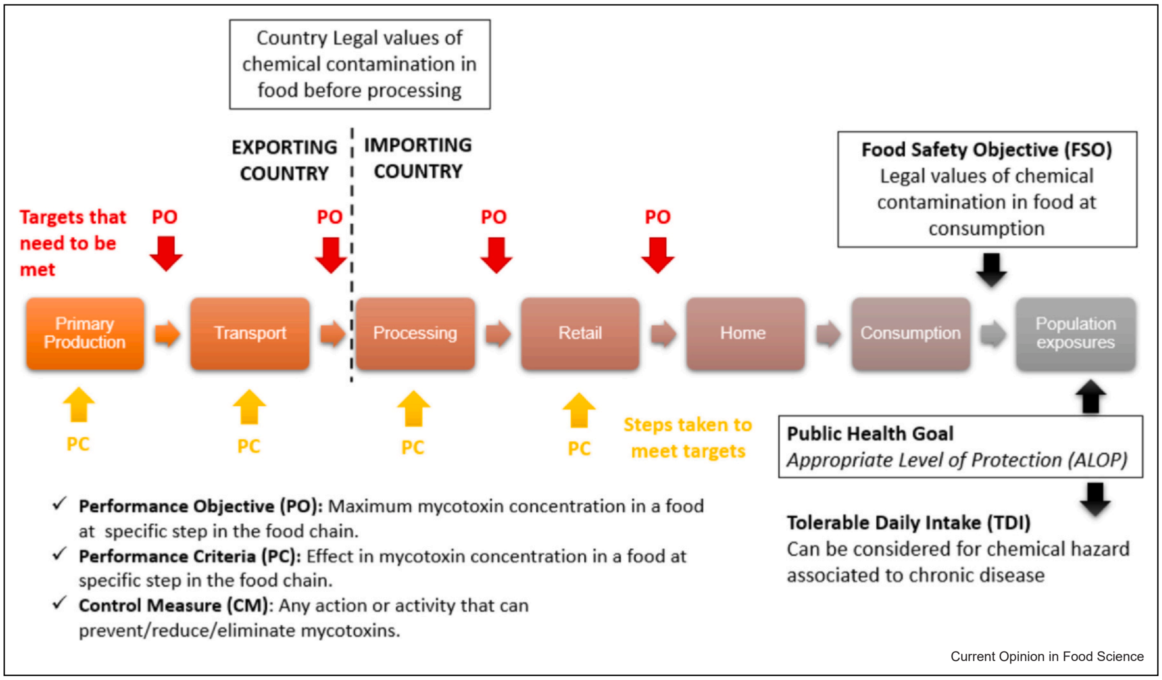


## Introduction

Mycotoxins are natural secondary metabolites produced by filamentous fungi that can be presented in raw materials, food, and feeds. These natural toxins can cause auto-immune illnesses, have allergenic properties, and some of them are teratogenic, carcinogenic, or mutagenic [1]. Consequently, regulatory efforts internationally have focused on the use of risk assessment tools to drive food safety policy and standards away from prescriptive to outcomes based on concepts such as the Food Safety Objective (FSO) [2,3]. An FSO specifies the maximum level of a hazard that can be tolerated in the final food product at the time of consumption. This concept has become a key parameter for the assessment of the risk associated with a particular hazard and for the development and implementation of effective and appropriate mitigations [4]. FSO concept has generally been applied to issues regarding safety from pathogenic and toxigenic bacteria in which presence can vary along the food process. As opposed to microbiological hazards, chemical hazards usually only enter foods in the raw food or ingredients, or through certain processing steps, and the level of hazard present in a food after the point of introduction often does not significantly change. In the particular case of mycotoxins, as chemical hazards from microbiological origin, they may increase in concentration through the processing steps if conditions are conducive for fungal growth.

The FSO concept recognizes that the ultimate objective of a food safety system is to prevent illnesses by focusing food-manufacturing attention and activities on preventing or minimizing exposure of the consumer to pathogens. This concept specifies a goal that can be incorporated into the design of control measurements in the food chain corresponding to the maximum permissible level of a hazard in a food at the moment of consumption [5]. The agro-food industry would use FSOs as means to coordinate risk management in the production process throughout the farm-to-fork production chain [6] (Figure 1). Specific targets that need to be met in the different stage (Performance Objective, PO) can be proposed by each government as guidance to help meet the FSO, but also can be decided by operation food safety managers as an integral part of the design of the production of a food in a supply chain [7]. Predictive models assessing the impact/effect of each stage in the

**Figure 1**




Application of food safety metrics in the food industry.

mycotoxin contamination (prevention/reduction/increase) can be developed and therefore the achievement of FSO of each batch can be estimated/predicted considering the initial mycotoxin contamination level ($H_o$) by using the following equation:

$$Ho - \Sigma I + \Sigma R \leq FSO \quad (1)$$

Ho, initial mycotoxin level.

ΣI, increase in mycotoxin levels.

ΣR, reduction in mycotoxin levels.

The application of FSOs for mycotoxin management allows an accurate understanding of the fate of mycotoxin contamination at each processing stage. By following a Risk Management approach, FSOs can help to ensure food safety but also to reduce food waste by anticipating potential rejections and improving chain efficiency. An example would be the early repurpose for a particular batch based on the initial mycotoxin contamination levels. FSOs have become a valuable decision support tool that can help managers to understand in advance the market potential of the batch and the specific technological procedures required to achieve customer requirements. However, the achievement of FSO not only requires updated regulations and industrial/technological optimization, but also consumer's best practice. Therefore, it is crucial to provide clear instructions regarding how to store and handle food products to avoid increase of the contamination levels and increase food safety awareness among the population.

The application of risk assessment approach and novel graphical methods for visualizing the application of metrics for mycotoxins is currently at the forefront of research [7–11]. However, there is still a lack of quantitative models that can be applied in the food chain, as none of the already-published predictive models covers the whole global value chain. In the current paper, the application of food safety approaches to the ochratoxin-A (OTA) hazard in coffee using quantitative data is discussed.

## Ochratoxin A in coffee — a case study

Coffee is one of the most consumed nonalcoholic beverages worldwide. According to the International Coffee Organization (ICO) in 2022, the total world coffee consumption was 178.574 million bags (60 kg each), which is equivalent to 10.06 million metric tons [12]. The global coffee industry is worth over $100 billion. Coffee is grown in more than 80 countries situated along the Equatorial zone called 'The Bean Belt,' located between latitudes 25° north and 30° south, but mostly consumed elsewhere in the world. Nevertheless, coffee is susceptible to fungal contamination and consequently mycotoxin accumulation during the growing steps but also along the food chain [13]. Undoubtedly, OTA is the most important chemical

**Table 1**

**OTA maximum intake recommended worldwide.**

| | Tolerable daily intake ng/kg-day | TWI ng/kg-weekly | Comments | Reference |
|---|---|---|---|---|
| EFSA | | — | Previous TWI is no longer valid | EFSA (2020) [17] |
| Health Canada | 4 | | | Kuiper-Goodman et al. (2010) |
| JEFCA (The Joint Food and Agriculture Organization/World Health Organization Expert Committee on Food Additives) | | 100 | Revaluated and keep it by JEFCA 2008 | JEFCA (1995, 2008) |

hazard in terms of food safety in this commodity, as exposure can cause teratogenesis, multiorgan toxicity, promotes neurodegeneration, and there is unambiguous evidence of its carcinogenic effects [14,15]. To protect consumers, maximum tolerable OTA intake has been proposed for international agents (Table 1). Nevertheless, these values are constantly reviewed based on new data available. For example, in 2020, the European Food Safety Authority (EFSA) considered that it was not appropriate to establish a health-based guidance value because although the mechanisms of genotoxicity are inconclusive, OTA causes DNA damage. Therefore, the tolerable weekly intake (TWI) of 120 ng/kg body weight established by the authority in 2006 was consequently no longer valid [16].

Currently, there is no global approach; thus, each country establishes its own appropriate level of protection (ALOP). As part of the risk assessment, toxicological information in the case of nongenotoxic compounds and consumption patterns is considered, and the specific maximum legal limit of contamination in a particular food commodity is established [15–18]. Therefore, these values can be used as FSO that contributes to achieve the specific national ALOP [8]. Legislation of mycotoxins of 64 countries and the EU was assessed [19–22]. However, only a few countries including the EU have legal limits from OTA among different food categories such as cereals, snacks, nonalcoholic malt beverages, dried fruits, date syrup, wine, licorice, species, gingers, several seeds, pistachios, cocoa, and coffee. Values range from a minimum of 0.2 μg/kg (beer, Indonesia) to 80 μg/kg (licorice, EU and Morocco). Only a small number have a maximum legal limit for coffee (Table 2). Interestingly, most of the countries have set the same legal limit apart from Uruguay (50 μg/kg) and the EU, which have recently halved the maximum OTA limits for coffee. So, there is a big harmonization compared with other food commodities. Nevertheless, these values are focused on the final roasted product, as, according to our knowledge, there are no regulations applied to green coffee. Therefore, the industrial process needs to assure that OTA reduction can be achieved and assure the final project compliance with each country's law.

**Table 2**

**Maximum legal limits of OTA in coffee (EC 2022/1370; [20,21]).**

| Country OTA legislation | | Number[a] | Range (μg/kg) | Green coffee (μg/kg) | Roasted coffee beans and ground roasted coffee (μg/kg) | Soluble coffee (μg/kg) | Instant or decaffeinated coffee (μg/kg) |
|---|---|---|---|---|---|---|---|
| Asia | Philippines | 3 | 5.0–10 | NR | 5 | 10 | |
| | Vietnam | 9 | 0.5–10 | NR | 5 | 10 | |
| | China | 3 | 2.0–10 | NR | 5 | 10 | |
| | Indonesia | 8 | 0.2–20 | NR | 5 | 10 | |
| | Malaysia | 3 | 0.5–10 | NR | 5 | | 10 |
| | Singapore | 1 | 0.5–20 | NR | 5 | 10 | |
| | South Korea | 5 | 0.5–20 | NR | 5 | 10 | |
| Africa | Egypt | 5 | 3.0–20 | NR | 5 | | |
| | Morocco | 14 | 0.5–80 | NR | 5 | 10 | |
| South America | Cuba | 1 | 5 | NR | 5 | 5 | |
| | Uruguay | 1 | 50 | NR | 50 | 50 | |
| | Brazil | 11 | 2.0–30 | NR | 10 | 10 | |
| EU | EU/UK | 20 | 0.5–80 | NR | 3 | 5 | |
| | Turkey | 10 | 0.5–80 | NR | 5 | 10 | |

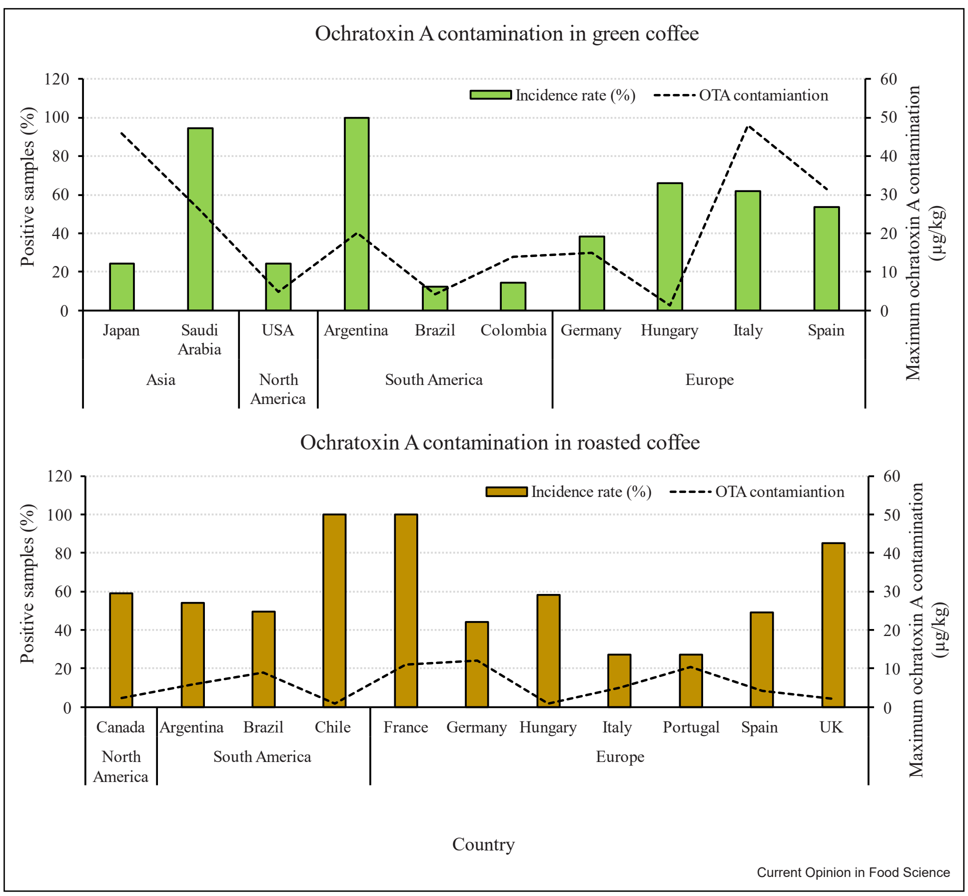
NR — no specific regulation.
[a] Number of food commodities/food combinations legislated for OTA contamination.

The presence of OTA in green and roasted coffee has been confirmed in several countries [23,24]. However, OTA concentration in roasted coffee usually is lower than in green coffee, showing that despite the reported chemical thermostability, reduction of OTA during the processing can be achieved. Figure 2 depicts information extracted from the scientific literature regarding OTA presence both in green and roasted coffee. Still, in some cases, values are over the legislation limits, such as ground coffee withdrawn from the market in Switzerland in 2021 (7.6 μg/kg) and spray-dried instant coffee from Vietnam in Rumania in 2022 (17.36 μg/kg) [25]. However, other authors have demonstrated that the final concentration can also be controlled by following good agricultural and manufacturing practices such as avoiding collection of berries from the ground or those damaged by insects, proper drying, and good storage conditions. Therefore, it is critical to establish thresholds throughout the entire process, helping to forecast the final OTA concentrations. Thus, a quantitative analysis of each step along the value chain of coffee is required.

## Risk Management Metrics to estimate ochratoxin-A contamination in coffee

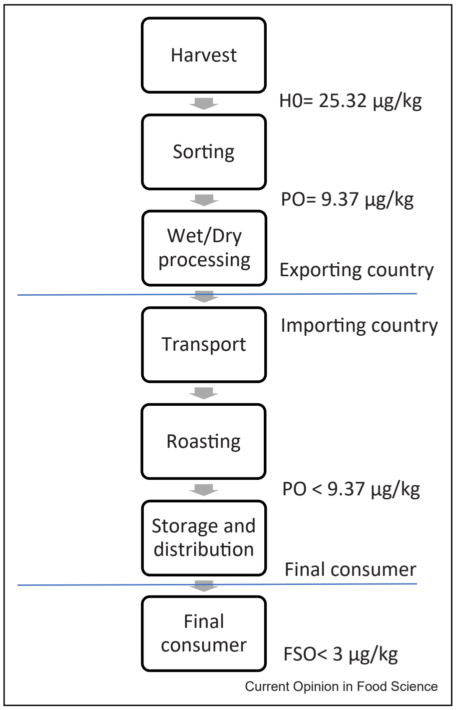
The last step of the application of Risk Management Metrics focuses on the risk characterization, thus, the assessment of the appropriate level of risk at each of the steps along the coffee value chain. To adequately establish a PO, it is critical to establish relevant performance criteria (PC, change in hazard level required at a specific step in order to reduce the hazard level at the start of the step), process criterion (PcC, effect in the frequency and/or concentration of a hazard in a food that must be achieved by the application of one or more control measures to provide or contribute to a PO or an FSO), and product criterion (PdC, effect on the product properties required to assure that the hazard level never overtakes safety levels before cooked or consumed) for

Figure 2




Presence of OTA in green and roasted coffee among different consuming countries.

**Figure 3**




Flow diagram of the coffee value chain, including estimated food safety metrics required for the coffee value chain. H0: initial concentration required to achieve the final FSO.

each of them. These metrics can be derived by food industry from FSOs by chain-reversal, in effect articulating appropriate food safety standards for individual links in the chain. The correct definition of these metrics can give managers adequate measures and parameters of control to achieve the required reduction/control. Considering the equation presented at the beginning of this case study, ∑I and ∑R have been assigned to each of the steps described in the flow diagram (Figure 3) and fully assessed based on the literature available.

### Increase of ochratoxin A during storage and transport (∑I)

As in the case of other commodities susceptible to fungal colonization, water availability is the most critical parameter to consider for the assurance of food safety. Since harvested cherries contain enough water to support mold growth and OTA formation, the early reduction of the outer layers of the cherries is critical. Storage of freshly harvested cherries is not recommended, and immediate processing is encouraged to minimize this effect [26]. After harvesting, ripe coffee cherries can be processed using a variety of alternatives, which can be divided into two forms: dry processing and wet processing. During the wet treatment, beans are processed to remove the pulp, mucilage, parchment, and silver skin at once, which reduces water availability for fungal development and thus OTA production. It starts with a sorting stage using water tanks that also allow for the removal of unripe/damaged beans. One of the three subprocesses can follow: the fermentation of the outer layers for easier removal, the mechanical removal of the mucilage to permit immediate drying, or drying of pulped parchment without mucilage removal. These alternatives mostly depend on the location and operational size of the farms. In all cases, the early reduction of the outer layers of the cherries helps to reduce the water availability required for fungal growth, as harvested cherries contain enough water to support mold growth and OTA formation. This factor is key, especially during the initial 3–5 days of latter drying [27].

On the other hand, dry processing consists of spreading the harvested coffee beans in thin layers to dry in the sun or by using artificial drying, despite the latter becoming more expensive due to the cost of fuel or electricity (when available). One variation on the usual dry method is to allow most of the fruit to dry on the tree. The results indicate that this method can produce safe and good-quality coffee, but only in regions where the harvest season is reliably arid. As in the case of other dry products (sultanas, figs, and pistachios), the main risk following this method is the rewetting of beans due to inadequate weather conditions (in the case of sun drying), unsatisfactory drying rate, and cross-contamination caused by debris or residues from previous batches. Thus, this method requires the application of good practices and management, to assure reaching adequate moisture levels promptly and avoiding wet pockets of beans that can lead to further mold development and mycotoxin production. The varietal effect has also been studied, with authors reporting higher incidence of OTA in the case of robusta compared with arabica, but it also depends on how the drying process is carried out.

Therefore, water content becomes critical for mold control and therefore OTA management. Previous studies reported increases up to 54% of OTA content when storage is not performed adequately, thus, it is crucial to maintain operating limits of 12.5% m.c. for cherry coffee, and 11.5% m.c. (wb) for parchment and green coffee. In this sense, changes in temperature that commonly occurred during transport can also generate transfer to the beans, what is called rewetting, leading to increases up to 13.13 μg/kg if bags were wet due to condensation or 7.91 μg/kg if the container was in the ship deck [28]. Table 3 depicts the different steps along the value chain of coffee as well as the establishment of the application of Risk Management Metrics: PC's, PcC's, PdC's, PO's, as well as the references used.

**Table 3**

**Application of food safety metrics on the coffee value chain. Definition of PC for each of the steps, the process parameters required (PcC), the parameters required to assure that the hazard level never overtakes safety levels (PdC), and the PO based on the initial OTA concentration (H0) and the final FSO.**

| Stage | Step | Application of Risk Management Metrics on the coffee value chain | | | | |
|---|---|---|---|---|---|---|
| | | PC | PcC | PdC | PO (μg/kg) | Reference |
| Coffee cherries | Harvest | | | | Ho < 25.32 | |
| | Sorting | Reduction up to 63% | Removal of unriped, defective, or damaged cherries | Follow established good hygiene practice and to avoid delays before processing. In the case of dry processing, this means immediate, efficient, drying. In the case of wet processing, this means expediting pulping and well-managed fermentation | < 9.37 | CFC/ICO/06-GCP/INT/743/CFC/. EFSA panel on contaminants in the food chain (CONTAM), 2020, VArgas [17] |
| | Drying | No increase | Size of drying yard, drying technology, loading rates, stirring, or turning rates | Objective to reduce moisture level to +/−13% m.c. (whole batch). Decrease of m.c below 40–30% to reach unfavorable conditions for fungal infection | < 9.37 | CFC/ICO/06-GCP/INT/743/CFC |
| | Storage | No increase | Operating limits of 12.5% m.c. for cherry coffee, and 11.5% m.c. (whole batch) for parchment and green coffee | Maintain m.c below favorable conditions for fungal development and toxin production | < 9.37 | Project CFC/ICO/06-GCP/INT/743/ CFC/ Taniwaki et al. (2003) [27] |
| Green coffee | Transport | No increase | Operating limits of 11.5% m.c. | Maintain m.c below favorable conditions for fungal development and toxin production | < 9.37 | Final Technical Report — Project CFC/ ICO/06-GCP/INT/743/CFC |
| | International transport | No increase | Operating limits of 11.5% m.c. | Maintain m.c below favorable conditions for fungal development and toxin production. Avoid transport on areas directly exposed to sunlight due to potential condensation within the container or impervious weather that may lead to rewetting | < 9.37 | Palacios-Cabrera et al. (2007) [28] |
| Roasted coffee | Roasting | Reduction 68% | | | < 3 | Leitao (2019) [24] |
| | Transport | No increase | Operating limits of 11.5% m.c. | Maintain m.c below favorable conditions for fungal development and toxin production | < 3 | Final Technical Report — Project CFC/ ICO/06-GCP/INT/743/CFC |
| Consumer | | | | | FSO < 3 | |

Thus, drying, storage, and transport remain as the critical steps to prevent fungal development and the consequent mycotoxin production, especially if beans have achieved safe moisture content levels.

### Decrease of ochratoxin A during sorting and roasting (ΣR)

Several authors have reported low levels of OTA contamination during the growing phase of coffee. At this stage, the main source of fungal and OTA contamination may be related to ripe cherries picked up from the ground, thus, susceptible to contamination with soil-borne OTA producers or insect-damaged/-defective cherries that may led to previous fungal colonization [29]. Successive steps carried out before or after the beans are dried to safety moisture content levels (10–12% m.c.) such as sorting are critical for preventing contamination and further mycotoxin production. Removal of unripened, defective, or damaged cherries can lead to reductions of up to 63% on the OTA content [26] (Table 3).

Thermal treatments have been proved as an effective means of reducing mycotoxins in different matrix types [29–33]. The percentage of reduction achieved will depend on the duration, temperature, and batch size used during the treatment. Several authors have assessed the effect of roasting, for example, reporting reductions from 15.17%, 46.78%, and 57.43, depending on the temperature and duration of the treatment [32]. However, when following current industry procedures, a 68% reduction was reported as a mean value when pooling data from different authors [27].

## Conclusion

Despite extensive literature has reported coffee as a safe commodity in terms of OTA presence, the current legislation on OTA content of the final product entails inefficiencies on coffee's global value chain. Early detection of contaminated batches that may lead to values over the legal limits on the final product becomes critical when aiming to reduce food waste, assure food safety, and improve chain efficiency. Therefore, the definition of quantitative thresholds along the different steps, such the ones estimated in this study, are valuable tools for the achievement of these objectives. However, it is important to stress the impact of the uncertainty related to the broad use of different technological approaches and conditions in which coffee can be produced, stored, processed, and transported. The application of holistic approaches, by merging quantitative data, prediction models, and toxicology-based approaches, is key for an accurate assessment of health exposure assessment and potential final contamination, thus facilitating food safety and increasing efficiency across the whole global value chain. The present case study can provide valuable information for managers, who must consider current contamination at each of the steps in order to understand better which alternatives are required to achieve the final FSO established by the legislation.

## Funding

This work was supported by the Centre for Agriculture, Food and Environmental Management Research at the University of Hertfordshire, through their quality research funding.

## Data Availability

Data will be made available on request.

## Declaration of Competing Interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

## References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. Omotayo OP, Omotayo AO, Mwanza M, Babalola OO: **Prevalence of mycotoxins and their consequences on human health**. *Toxicol Res* 2019, **35**:1-7.

2. Working Principles for Risk Analysis for Food Safety for Application by Governments (CAC/GL 62-2007): World Health Organization; 2007.

3. ICMSF (International Commission on Microbiological Specifications for Foods): **Microbiological testing in food safety management**. Microorganisms in Foods Kluwer Academic/Plenum Publishers; 2002.

4. • Pitt JI, Taniwaki MH, Cole MB: **Mycotoxin production in major crops as influenced by growing, harvesting, storage and processing, with emphasis on the achievement of Food Safety Objectives**. *Food Control* 2013, **32**:205-215.
This study was the first qualitative approach toward the application of FSOs in the food industry, comprehensively assessing several crops along the value chain, while establishing guidelines for adequate mycotoxin management.

5. ICMSF (International Commission on Microbiological Specifications for Foods): **Microbial ecology of food commodities**. Microorganisms in Foods Blackie; 1998.

6. •• Indrawan D, Daryanto A: **Food control and biosecurity roles in the global value chain: supporting producers or safeguarding consumers?** *IOP Conf Ser: Earth Environ Sci* 2020, **519**:012040.
The article introduces readers to the different food control operational designs currently applied and their support by biosecurity procedures. Moreover, raise awareness, technical capacity, and the impact of these aspects on the policy dynamics in the global trade.

7. Bolívar A, Saiz-Abajo MJ, García-Gimeno RM, Petri-Ortega E, Díez-Leturia M, González D, Vitas AI, Pérez-Rodríguez F: **Cross contamination of *Escherichia coli* O157:H7 in fresh-cut leafy vegetables: derivation of a food safety objective and other risk management metrics**. *Food Control* 2023, **147**:109599.

8. • Gorris LGM, Cole MB: **A simplified guide to understanding and using food safety objectives and performance objectives**.

Ensuring Global Food Safety: Exploring Global Harmonization. Elsevier; 2022.
The article provides simplified and clear information about the application of FSOs and POs toward food safety considering the heterogeneity present on the world market.

9. García-Cela E, Ramos AJ, Sanchis V, Marin S: **Risk management towards food safety objective achievement regarding mycotoxins in pistachio: the sampling and measurement uncertainty issue**. *Food Control* 2013, **31**:392-402.

10. Nada S, Nikola T, Bozidar U, Ilija D, Andreja R: **Prevention and practical strategies to control mycotoxins in the wheat and maize chain**. *Food Control* 2022, **136**:108855.

11. •• Fakhri Y, Mahdavi V, Ranaei V, Pilevar Z, Sarafraz M, Mahmudiono T, Khaneghah AM: **Ochratoxin A in coffee and coffee-based products: a global systematic review, meta-analysis, and probabilistic risk assessment**. *Rev Environ Health* 2022, https://doi.org/10.1515/reveh-2022-0115 PMID: 36372738.
The authors performed a meta-search among international databases. The concentration and prevalence of OTA in coffee products were meta-analyzed according to country subgroups. Health risk assessment was conducted based on margin of exposures (MOEs) using the Monte Carlo simulation (MCS) technique, assessed pooled OTA concentration, and prevalence among different countries.

12. •• ICO (International Coffee Organization): **Monthly Coffee Market Report**, April 2023; 2023.
This is the monthly coffee market report, published by the ICO, where all the relevant information regarding coffee trade is published, together with technical information and advice both for growers and traders.

13. Maman M, Sangchote S, Piasai O, Leesutthiphonchai W, Sukorini H, Khewkhom N: **Storage fungi and ochratoxin A associated with arabica coffee bean in postharvest processes in Northern Thailand**. *Food Control* 2021, **130**:108351.

14. Bhat PV, Anand T, Manu TM, Khanum F: **Restorative effect of l-Dopa treatment against Ochratoxin A induced neurotoxicity**. *Neurochem Int* 2018, **118**:252-263.

15. • Khoi CS, Chen JH, Lin TY, Chiang CK, Hung KY: **Ochratoxin A-induced nephrotoxicity: up-to-date evidence**. *Int J Mol Sci* 2021, **22**:11237.
This review discloses the molecular mechanism of OTA-induced nephrotoxicity, providing opinions and strategies against OTA toxicity.

16. Heintz MM, Doepker CL, Wikoff DS, Hawks SE: **Assessing the food safety risk of ochratoxin A in coffee: a toxicology-based approach to food safety planning**. *J Food Sci* 2021, **86**:11.

17. •• EFSA CONTAM Panel (EFSA Panel on Contaminants in the Food Chain), Schrenk D, Bodin L, Chipman JK, del Mazo J, Grasl-Kraupp B, Hogstrand C, Hoogenboom L, Leblanc J-C, Nebbia CS, Nielsen E, Ntzani E, Petersen A, Sand S, Schwerdtle T, Vleminckx C, Wallace H, Alexander J, Dall'Asta C, Mally A, Metzler M, Binaglia M, Horváth Z, Steinkellner H, Bignami M: **Scientific opinion on the risk assessment of ochratoxin A in food**. *EFSA J* 2020, **18**:6113.
The aim of this study was to analyze findings available on aflatoxins, OTA, and Fusarium toxin occurrence in several commodities in order to assess the exposure level and cancer risk.

18. • Heintz MM, Doepker CL, Wikoff DS, Hawks SE: **Assessing the food safety risk of ochratoxin A in coffee: a toxicology-based approach to food safety planning**. *J Food Sci* 2021, **2021**:4799-4810.
The study combined food safety and toxicology risk assessment principles to examine the available information on OTA hazard and risk in coffee.

19. •• EU 2002/1370 **European Commission 2022/1370 of 5 August 2022 Amending Regulation (EC) No 1886/2006 as Regards Maximum Levels of Ochratoxin A in Certain Foodstuffs**.
Relevant legislation approved in the EU amending the maximum legal limits of Ochratoxin A in foodstuffs.

20. • Chilaka CA, Obidiegwu JE, Chilaka AC, Atanda OO, Mally A: **Mycotoxin regulatory status in Africa: a decade of weak institutional efforts**. *Toxins* 2022, **14**:442.
The study discusses the status of mycotoxin regulation in Africa, with emphasis on the impact of weak mycotoxin legislations and enforcement on African trade, agriculture, and health and the factors limiting the establishment and control of mycotoxins in the region.

21. Prognosis Biotech.: **Mycotoxins Legislation**. Consulted on the 15th of May 2023. ⟨https://www.prognosis-biotech.com/mycotoxins-legislation/⟩.

22. •• Brazil: Agência Nacional de Vigilância Sanitária (ANVISA). RDC No 722, **dispõe sobre limites máximos tolerados (LMT) de contaminantes de alimentos, os princípios gerais para o seu estabelecimento e os métodos de análises para fins de avaliação de conformidade**. Instrução Normativa No 160 Anexo II, estabelece os limites máximos tolerados para micotoxinas em alimentos. 01 de julho de 2022; 2022.
Relevant legislation published in Brasil amending maximum mycotoxin legal limits in foodstuffs.

23. • Almasoud YF, Aldosari ZM, Almutairi MA, Alowaifeer AM: **Occurrence of ochratoxin A in green and roasted coffee beans from the Saudi market and a possible exposure assessment**. *JSFA Rep* 2022, **2**:255-260.
First-time assessment of the occurrence of OTA in green and roasted coffee beans in Saudi markets and a subsequent exposure assessment.

24. • Leitão AL: **Occurrence of ochratoxin A in coffee: threads and solutions — a mini-review**. *Beverages* 2019, **5**:36.
This is an overview of OTA contamination in roasted coffee beans in different countries and suggested mitigation strategies for OTA reduction.

25. •• RASFF: European Commission, Directorate-General for Health and Consumers, **The rapid alert system for food and feed (RASFF)**; 2023. Available in ⟨https://webgate.ec.europa.eu/rasff-window/screen/search⟩. Consulted on 12/04/2023.
RASFF is the system that ensures the exchange of information between EU member countries to support swift reaction by food safety authorities in case of risks to public health resulting from the food chain and provide up-to-date information of the hazards detected in the EU borders.

26. FAO: **Final Technical Report – Project CFC/ICO/06-GCP/INT/743/CFC. Enhancement of Coffee Quality through the Prevention of Mould Formation**; 2006.

27. Taniwaki MH, Pitt JI, Copetti MV, Teixeira AA, Iamanaka BT: **Understanding mycotoxin contamination across the food chain in Brazil: challenges and opportunities**. *Toxins* 2019, **11**:411.

28. Palacios-Cabrera HA, Menezes HC, Iamanaka BT, Canepa F, Teixeira AA, Carvalhaes N, Santi D, Leme PTZ, Yotsuyanagi K, Taniwaki MH: **Effect of temperature and relative humidity during transportation on green coffee bean moisture content and ochratoxin A production**. *J Food Prot* 2007, **70**:164-171.

29. Alves da Silva S, Fonseca Alvarenga Pereira RG, de Azevedo Lira N, Micotti da Glória E, Chalfoun SM, Batista LR: **Fungi associated to beans infested with coffee berry borer and the risk of ochratoxin A**. *Food Control* 2020, **113**:107204.

30. Aguilar-Alvarez ME, Saucedo-Castañeda G, Durand N, Perraud-Gaime I, González-Robles RO, Rodríguez-Serrano GM: **The variety, roasting, processing, and type of cultivation determine the low OTA levels of commercialized coffee in Chiapas State, Mexico**. *Food Control* 2021, **126**:108088.

31. Cwiková O, Komprda T, Šottníková V, Svoboda Z, Simonová J, Slováček J, Jůzl M: **Effects of different processing methods of *Coffee arabica* on colour, acrylamide, caffeine, chlorogenic acid, and polyphenol content**. *Foods* 2022, **11**:3295.

32. Da Costa DS, Albuquerque TG, Costa HS, Bragotto APA: **Thermal contaminants in coffee induced by roasting: a review**. *Int J Environ Res Public Health* (8) 2023, **20**:5586.

33. Sousa TMA, Batista LR, Passamani FRF, Lira NA, Cardoso MG, Santiago WD, Chalfoun SM: **Evaluation of the effects of temperature on processed coffee beans in the presence of fungi and ochratoxin A**. *J Food Saf* 2019, **39**:e12584.