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Review

A review of novel physical and chemical decontamination technologies for aflatoxin in food

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ABSTRACT

Background: Conventional strategies for mycotoxin reduction includes both prevention and decontamination strategies. Decontamination of aflatoxin has been a continuing challenge for the food industry. Novel processing methods are continuously explored to achieve complete aflatoxin degradation in food products.

Scope and approach: The present review provides an update on recent research for aflatoxin decontamination by conventional methods including thermal processing and chemical treatments. Novel aflatoxin decontamination technologies like microwave heating, gamma and electron beam irradiation, ultraviolet and pulsed light, electrolyzed water and cold plasma are reviewed in detail. This review provides a brief introduction, decontamination mechanism, degradation efficiency, advantages and limitations of these novel technologies.

Key findings and conclusion: Although conventional thermal technologies are known to cause aflatoxin degradation, they are not adequate for complete aflatoxin degradation in food products. Novel technologies like pulsed light, electrolyzed water and cold plasma have shown complete degradation of aflatoxin on different substrates. However, application on food products need further studies along with the degradant toxicology and its interaction with food components. Novel processing technologies shows significant potential for future applications in decontaminating aflatoxin in the food industry.

1. Introduction

Mycotoxins are toxic secondary metabolites produced by filamentous fungi contaminating various food and feed crops posing serious health risks for both human and animals. According to the Food and Agriculture Organization of the United Nations (FAO), 25% of the world's crop are contaminated with mycotoxins during growth or storage (Wu, 2007). Although hundreds of fungal toxins are known, only few of them play important role in food safety (Shephard, 2008). Up to now, approximately 400 secondary metabolites with toxigenic potential, produced by more than 100 molds have been reported (Jard, Liboz, Mathieu, Guyonvarc'h, & Lebrihi, 2011). Fungal toxins of most concern are produced by species within the genera of *Aspergillus*, *Fusarium*, and *Penicillium,* which frequently contaminate major food crops in the field and also during storage (Reddy et al., 2010). Among all mycotoxins, aflatoxin, fumonisins, zearelenone, ochratoxin and deoxynivalenol are five major groups of mycotoxins that are most toxic to mammals (Karlovsky et al., 2016). Food and feed are often contaminated by more than one mycotoxin, and residues of some mycotoxins may also be found in food of animal origin (meat, milk, eggs and cheese) as a consequence of contaminated feed (Awad, Ghareeb, Böhm, & Zentek, 2010).

Many of the mycotoxins have been proven to be carcinogenic, mutagenic and genotoxic. The diversity in the mycotoxins structure results in variety of adverse health effects. For example, aflatoxin forms deoxyribonucleic acid (DNA) adducts with guanine inducing cancerous cell formation, fumonisins inhibit ceramide synthase adversely changing sphinganin/sphingosin ratio, ochratoxins affect protein synthesis and inhibit adenosine triphosphate (ATP) production, deoxynivalenol induces apoptosis in haemopoietic progenitor cells and immune cells, whereas zearalenone mimics 17β-estradiol disrupting fertility and reproduction ability (Bren, Guengerich, & Mavri, 2007; Gaumy, Bailly, Burgat, & Guerre, 2001; Jard et al., 2011; Parent-Massin, 2004; Soriano, Gonzalez, & Catala, 2005; Xiao et al., 1996). Among the 5 major mycotoxins, aflatoxin (B_1, B_2, G_1 and G_2) are the most toxic. They have been classified as type one carcinogens by the International Agency for Research on Cancer (Stoloff, 1989). Aflatoxin (AF) are toxins produced by the *Aspergillus* species, mainly from *Aspergillus flavus* or *Aspergillus parasiticus*. According to the FDA regulatory levels for aflatoxin in the feed, the maximum allowable aflatoxin levels are 300 μg/kg for

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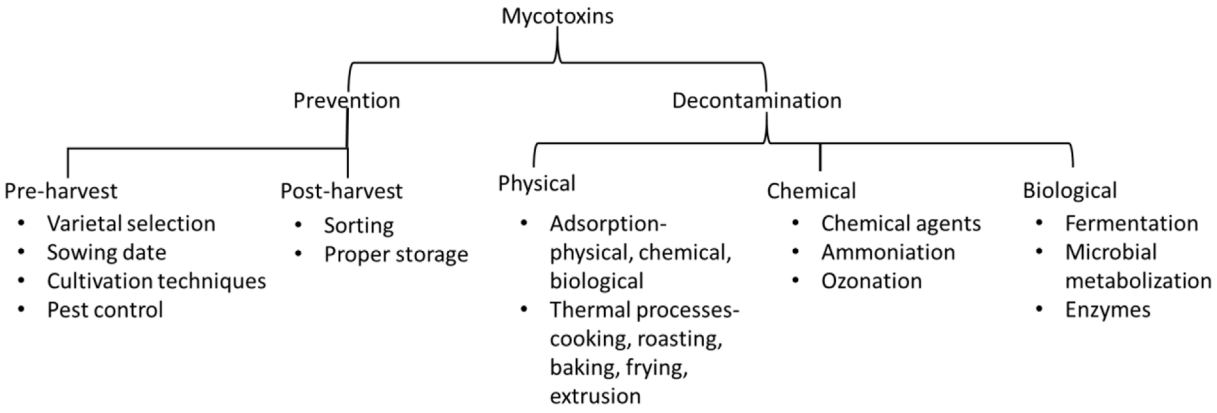

Fig. 1. Conventional prevention and decontamination strategies for mycotoxins.

finishing cattle, swine and poultry, 100 μg/kg for breeding cattle, swine and poultry, and 20 μg/kg for all other animals (NGFA., 2011).

Conventional strategies for prevention of mycotoxins poisoning often require both pre and post-harvest approaches (Fig. 1). Pre-harvest approaches deal with controlling the fungal contamination in the field while post-harvest approach deals with sorting and proper storage. Often these approaches are not sufficient requiring additional processing for decontamination and detoxification of the food and feed products. Mycotoxins are very heat stable and are difficult to eliminate by conventional thermal operations. For example, decomposition temperatures of aflatoxin range from 237 to 306 °C. Under dry heating condition, aflatoxin B_1 is quite stable at temperature below its decomposition point. When heated to the point of decomposition, it emits acrid smoke (Lewis, 2004). Degradation of aflatoxin by thermal operations was reviewed by Samarajeewa, Sen, Cohen, and Wei (1990). A more recent review on aflatoxin reduction by thermal food processing was presented by Kabak (2009). A summary of recent (2000 A.D. and after) studies on aflatoxin reduction by conventional thermal operations are presented in Table 1. Moisture content, heating temperature, food substrates, and processing methods are important parameters in determining the reduction of aflatoxin during thermal food processing.

Chemical treatments for aflatoxin degradation in food products includes use of chemical agents like citric acid and lactic acid (Méndez-Albores, Martínez-Bustos, Gaytán-Martínez, & Moreno-Martínez, 2008), hydrogen peroxide (Tripathi & Mishra, 2009), ozone gas (Inan, Pala, & Doymaz, 2007) and ozonated water (Zorlugenç, Zorlugenç, Öztekin, & Evliya, 2008). Other methods like mineral, organic and biological adsorption, fermentation and ammoniation are also used for aflatoxin decontamination. However, these methods are mainly used for feed processing and are considered out of scope for this review.

The thermal stability of aflatoxin even at higher temperatures and resistance for complete inactivation by conventional processing presents a limitation for traditional food processing technologies. This has led to active research in the field of novel processing technologies in past decades forming the impetus of this work. Numerous reviews are available in the literature for conventional techniques used in mycotoxin decontamination, however there is a lack of updated review on the application of novel processing techniques for aflatoxin decontamination. This present work aims to update our understanding of aflatoxin decontamination with emphasis on novel processing technologies.

Table 1
Summary of recent studies (2000 A.D. and after) on aflatoxin reduction by conventional thermal food processing operations.

Substrate	Treatment methods	Observations	Reference
No substrate	Heating at 150 °C for 1 h 180 °C for 1h	70% degradation of AFB_1 Complete degradation of AFB_1	(Raters & Matissek, 2008)
No substrate Soya protein Carbohydrate Polyphenol	Heating at 150 °C for 1 h	70% degradation of AFB_1 Complete degradation of AFB_1 50% degradation of AFB_1 90% degradation of AFB_1	(Raters & Matissek, 2008)
Dried wheat	Heating at 150 °C 30min at 200 °C 30min	50% degradation 90% degradation	(Hwang & Lee, 2006)
Green coffee beans	Roasting at 150–180 °C for 10–15 min	42.2–55.9% reduction	(Soliman, 2002)
Peanuts	Roasting 90–150 °C, 30–120 min	Max reduction AFB_1 78.4%, AFB_2 57.3%, AFG_1 73.9%, and AFG_2 75.2%	(Arzandeh & Jinap, 2011)
Pistachio nuts	Roasting at 150 °C for 30min or 120 °C for 120min	63% degradation	(Yazdanpanah, Mohammadi, Abouhossain, & Cheraghali, 2005)
Pistachio nuts	Roasting at 120 °C for 1h with lemon juice and citric acid	49-93% reduction of AFB_1	(Rastegar et al., 2017)
Rice	Normal cooking	AFB_1 34% reduction	(Park, Lee, & Kim, 2005)
Rice	Cooking in rice cooker	AFB_1 25% reduction	(Sani, Azizi, Salehi, & Rahimi, 2014)
Rice	Pressure cooking (0.1 Mpa)	AFB_1 78–88% reduction	(Park & Kim, 2006)
Corn	Nixtamalization (Alkaline cooking) and deep frying	51.7, 84.5, and 78.8% reduction of the aflatoxin in tortilla, tortilla chips, and corn chips	(Torres, Guzman-Ortiz, & Ramirez-Wong, 2001)
Corn	Nixtramalization (Alkaline cooking)	AFB_1 94% reduction, AFM_1 90% reduction	(Elias-Orozco, Castellanos-Nava, Gaytan-Martinez, Figueroa-Cardenas, & Loarca-Pina, 2002)
Peanut meal	Extrusion at 150 C with 40% MC	77.6% AFB_1 degradation	(Zheng, Wei, Xu, & Fan, 2015)
Corn	Extrusion with lime	with 0 and 0.5% lime reduced AFB_1 levels by 46 and 85% respectively	(Elias-Orozco et al., 2002)