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Editorial

Mycotoxins in the Dairy Industry

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Dairy animals' diets may be naturally and simultaneously contaminated by several fungi that are able to produce different secondary toxic metabolites, known as mycotoxins. Several species in the genera, *Aspergillus*, *Fusarium* and *Penicillium*, among others, are responsible for mycotoxin production in cereals, forage and silages for dairy cattle. The consumption of contaminated feed with mycotoxins can trigger acute or chronic disorders in dairy cattle, known as mycotoxicosis, which is also observed in other animals and humans. In acute cases, hormonal, gastrointestinal and renal disorders, as well as immunosuppression, are sometimes observed. The chronic ingestion of these mycotoxins can induce cases of cancer, hepatopathies, mutagenicity, a reduction in hematopoiesis and severe failures in the immune, intestinal, urinary, digestive, nervous and reproductive systems of animals. These conditions are associated with the intake of, exposure to and interaction with these toxins.

Certain groups of mycotoxins, including aflatoxins (AFs), fumonisins (FBs) and zearalenone (ZEN), as well as trichothecenes such as deoxynivalenol (DON) and T-2 toxin, are especially important in terms of their economic impacts on dairy animals. The presence of these toxins in the diets of dairy cattle leads to a series of health disorders, resulting in a reduction in milk volume and quality, as well as the possible excretion of mycotoxin residues in milk. For example, the main toxic compound in one Afs group (AFB_1) produced by a certain *Aspergillus* species has a greater potential for toxic bioaccumulation in lactating animals, as well as promoting mutagenic, teratogenic and carcinogenic effects. Dairy cows, when consuming feed contaminated with AFB_1, metabolize this toxin in the liver via the cytochrome P450 (CYP1A2) to produce aflatoxin M_1 (AFM_1), which is excreted and commonly found in the milk [1]. Studies have shown that the concentration of AFM_1 detected in milk significantly increases with the amount of AFB_1 ingested, and the transfer rates of AFB_1 to AFM_1 in cow milk from the beginning to end of lactation are 6.2% and 1.8%, respectively [2]. This causes additional human exposure to AFs via the ingestion of contaminated milk products [3]. AFM_1 has already been found in human breast milk from lactating mothers who consume contaminated food with AFB_1 [4].

Similarly, *Fusarium*-produced FBs have a variety of toxic effects on cattle, including apoptosis, neurotoxicity, immunotoxicity, tissue and organ toxicity, reproductive toxicity and carcinogenicity. In addition to inducing various disorders on their own, FB_1, the most frequent and toxic component of the FB group, also potentiates toxic effects when combined with other mycotoxins, such as AFs. The toxic mechanism of FB_1 is complex and has not yet been fully elucidated. Its toxicity modulates a sphingolipid metabolism and induces cellular oxidative stress [5], leading to the production and accumulation of aerobic free radicals that are not neutralized by cellular antioxidants. These free radicals cause lipid peroxidation and oxidative impairment to DNA, as well as reductions in glutathione and peroxidase, and superoxide dismutase, compromising the physiological activity of the cellular tissues. Moreover, it can cause significant injury to sperm chromosomes, resulting in reproductive toxicity. Another *Fusarium* mycotoxin is ZEN, which has been categorized as a xenoestrogen because it causes hormonal disorders and reproductive imbalances

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in cows, such as hyperestrogenicity. The metabolism of ZEN begins in the rumen and continues via hepatic pathways, involving hydroxylation, glucuronidation, or conjugation reactions of the toxin. These reactions allow for the synthesis of different metabolites, including alpha-zearalenol (α-ZEL), which is 60 times more potent than ZEA, and beta-zearalenol (β-ZEL), which is 0.2 times more potent. Animals with reproductive toxicity induced by ZEA exhibit infertility, ovarian and uterine expansion, reductions in sperm cells, decreases in reproductive hormone levels and decreased pregnancy rates. Residues of FB_1 and ZEN metabolites have been reported in commercially available milk [6]; therefore, the exposure of cows to these mycotoxins via their diets is a grave concern.

Dairy cows are more resistant to DON compared to monogastric animals, with 90% of the ingested DON being converted to de-epoxy-deoxynivalenol (DOM-1) by ruminal bacteria, either naturally occurring or supplemented via feed additives. However, the adverse effects generated by this toxin should not be neglected in cows, as DOM-1 can be detected in cattle's blood at levels up to 20 times higher than those of ingested DON from contaminated feed [7]. The exposure of bovine cells to DON triggers hypoxic, hypertonic and ribotoxic responses. These cellular responses contribute to a reduction in cow productivity, reflected in a decrease in protein and fat content in milk [8], as well as lower milk production [9]. Dairy cows can also experience deficiencies in protein synthesis due to DON toxicity, which can be problematic for highly proliferative immune cells. The inhibition of proliferation in bovine T cell subsets ($CD4^+$, $CD8\beta^+$ and γδ T cells) is primarily caused by DOM-1 [10]. As mentioned for DON, ruminants also have a low sensitivity to T-2 toxin when compared with monogastrics due to de-epoxidation and deacetylation activity in the rumen [11]. However, the frequent exposure of dairy cows to T-2 toxins is associated with feed refusal, production losses, gastroenteritis lesions, intestinal hemorrhages, and death. The degree of T-2 intoxication is related to the administered dose and route of administration. T-2 toxin affects the bone marrow of animals, promoting the induction of apoptosis, cellular necrosis, immunosuppression and organic injuries often associated with lipid peroxidation. It is considered the most acutely toxic trichothecene, with variable sensitivity among species. However, the public health implications of T-2 residues in milk and other animal-derived products are yet to be determined.

To avoid the health risks posed by mycotoxins, more than 60 countries have set maximum permitted levels for these contaminants in feedstuffs for dairy animals, as well as for AFM_1 in milk and dairy products. However, failure to implement suitable preventive measures to avoid mycotoxin contamination in feed may require additional strategies to prevent the occurrence of these toxins, such as chemisorption via mineral or biological sources to reduce the bioavailability of mycotoxins in the diet. Several studies have focused on decontamination methods for AFM_1 due to the high stability of this toxin during conventional heat treatments used in dairy processing. Moreover, understanding the occurrence of multiple mycotoxins in dairy cattle feed is crucial for developing precise and reliable analytical methods to detect them and provide acceptable information regarding the degradation or removal of mycotoxins from feed or milk products [12]. This knowledge enables the implementation of strategies to mitigate the economic and health issues caused by mycotoxins to the dairy industry [13].

Considering the interdisciplinary aspects of the topics briefly described above, this Special Issue, entitled "Mycotoxins in the Dairy Industry", focuses on the most recent studies on mycotoxin contamination in the dairy industry, the exposure of dairy animals to dietary mycotoxins and new analytical methodologies for identifying mycotoxins in dairy food matrices.

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