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Review

Mycotoxins Adsorbents in Food Animal Production

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Abstract: Mycotoxins, toxic secondary metabolites produced by molds, pose a significant threat to food animal production, as they can lead to adverse health effects, reduced productivity, and economic losses. In response to this challenge, mycotoxin adsorbents have emerged as a promising solution to mitigate the harmful effects of mycotoxins in livestock. This paper presents a comprehensive review of the positive influence of mycotoxin adsorbents in food animal production. The review discusses the mechanisms by which mycotoxin adsorbents function, including adsorption, binding, and inactivation of mycotoxins. Various types of mycotoxin adsorbents are explored, encompassing natural adsorbents such as clays, zeolites, and activated carbons, as well as synthetic polymers. The influence of mycotoxin adsorbents on the immune system, gut health, and overall well-being of food animals is examined. Furthermore, the review delves into the challenges and limitations associated with mycotoxin adsorbents, including variability in mycotoxin contamination, dosage, and timing of administration. Strategies for optimizing their use, such as mycotoxin monitoring and mycotoxin binder selection, are discussed to ensure maximum effectiveness. In conclusion, the positive influence of mycotoxin adsorbents in food animal production cannot be understated. By offering a proactive and cost-effective means of mycotoxin management, mycotoxin adsorbents play a pivotal role in safeguarding animal health and the economic viability of livestock operations. This review underscores the significance of mycotoxin adsorbents as essential tools in ensuring the safety and productivity of food animal production systems.

Keywords: mycotoxins; contamination; poultry; pigs; fish.

1. Introduction

Mycotoxins, toxic secondary metabolites produced by molds, have long been recognized as insidious threats to food animal production worldwide. These potent contaminants, which include aflatoxins, ochratoxins, trichothecenes, zearalenone, and many others, can infiltrate animal feed and forages, thereby jeopardizing the health and productivity of livestock [1]. The adverse consequences of mycotoxin exposure range from reduced growth rates and feed efficiency to immunosuppression, organ damage [2], and even mortality [3], casting a shadow over the livestock industry and global food security [4,5].

In response to this formidable challenge, the scientific community and animal producers have been driven to explore innovative strategies aimed at mitigating the deleterious effects of mycotoxins in animal husbandry [6]. One such approach that has garnered considerable attention and acclaim is the use of mycotoxin adsorbents. These specialized materials, designed to adsorb, bind, or otherwise neutralize mycotoxins in the digestive tract of food animals, have emerged as a promising solution to counter the mycotoxin menace [1,7].

The application of mycotoxin adsorbents in food animal production is not merely a response to an agricultural crisis; it represents a proactive and strategic effort to safeguard the health and well-being of livestock, as well as to ensure the economic sustainability of the industry [8]. By minimizing the adverse effects of mycotoxins on animal health, growth, and production, mycotoxin adsorbents contribute to the overall food safety and security, fostering a healthier, more productive livestock sector [9].

Mycotoxin adsorbents becomes innovative tools with the potential to revolutionize the landscape food animal production [10], safeguarding animal health, welfare, and economic viability [11]. This review underscores the significance of mycotoxin adsorbents as invaluable assets in the ongoing quest for safer and more productive livestock systems.

Also, this review will shed light on the profound benefits that mycotoxin adsorbents bring to the livestock sector, elucidate the underlying mechanisms, and address the challenges and strategies associated with their application.

2. Mechanisms by which mycotoxin adsorbents function

Mycotoxin adsorbents operate through a combination of physical and chemical interactions that ultimately lead to the reduction of mycotoxin bioavailability within the gastrointestinal tract of animals [12,13]. These mechanisms are primarily centered around adsorption, binding, and inactivation of mycotoxins [14]. The key mechanisms by which mycotoxin adsorbents function are adsorption [15], binding [16], inactivation [17], and excretion [18].

Adsorption: Mycotoxin adsorbents possess a high surface area and porous structure, which allows them to adsorb mycotoxins through physical adsorption. This mechanism involves the non-covalent bonding of mycotoxins to the surface of the adsorbent material [19]. The mycotoxins are attracted to and trapped within the porous structure of the adsorbent, effectively preventing them from entering the bloodstream of the animal [20].

Binding: Mycotoxin adsorbents can also chemically bind with mycotoxins, forming strong and stable complexes [17]. This binding can occur through various interactions, including hydrogen bonds, ionic interactions, and hydrophobic interactions. By forming these complexes, mycotoxin adsorbents render mycotoxins inert and less biologically active [12].

Inactivation: Some mycotoxin adsorbents possess the ability to chemically transform mycotoxins into less toxic or non-toxic metabolites [21]. This inactivation mechanism may involve enzymatic reactions within the adsorbent or chemical reactions with the adsorbent material itself. Inactivated mycotoxins are less harmful to the animal upon ingestion [22].

Excretion: In some cases, mycotoxin adsorbents promote the excretion of mycotoxins from the animal's body [23]. This may occur through various mechanisms, including binding mycotoxins in the digestive tract and facilitating their elimination via feces, thereby preventing their absorption into the bloodstream [24].

The overall effectiveness of mycotoxin adsorbents is influenced by factors such as the type of adsorbent material used, the mycotoxin in question, the dosage of adsorbent administered, and the timing of administration relative to feed consumption. Understanding these underlying mechanisms is essential for optimizing the use of mycotoxin adsorbents in food animal production and mitigating the adverse effects of mycotoxin exposure in livestock.

3. The influence of mycotoxin adsorbents on the immune system of poultry and pigs

The influence of mycotoxin adsorbents on the immune system of poultry and pigs is a critical aspect of mycotoxin management in these animal species. Mycotoxins have the potential to compromise the immune system, leading to increased susceptibility to diseases and reduced overall health [25].

Poultry.

Enhanced Immune Response: Mycotoxin adsorbents, when included in poultry diets, can help reduce mycotoxin exposure. By minimizing mycotoxin absorption, these adsorbents aid in

preserving the integrity of the immune system [26]. Poultry exposed to lower levels of mycotoxins are better equipped to mount effective immune responses against pathogens, resulting in improved disease resistance [27].

Strengthened Gut Health: Mycotoxin adsorbents often have positive effects on gut health. A healthy gut is vital for effective immune function [28]. Adsorbents can help maintain the structural and functional integrity of the intestinal barrier, reducing the risk of pathogens entering the bloodstream and affecting the immune system [29].

Reduction of Immunotoxicity: Certain mycotoxins, such as aflatoxins and deoxynivalenol, are known to have immunotoxic effects [30]. Mycotoxin adsorbents, by reducing mycotoxin bioavailability, can mitigate the immunosuppressive impact of these toxins, allowing the immune system of poultry to function more efficiently [31].

Pigs.

Improved Immune Function: Mycotoxin adsorbents can contribute to enhanced immune function in pigs. By reducing the negative impact of mycotoxins on the immune system, these adsorbents help maintain a robust defense against infectious agents. Pigs fed mycotoxin-contaminated feed along with adsorbents exhibit better immune responses [32].

Reduction of Stress: Mycotoxin exposure can induce stress responses in pigs, which can weaken the immune system. Mycotoxin adsorbents alleviate this stress by minimizing mycotoxin absorption and subsequent immunosuppression [33]. Pigs under reduced stress conditions have more effective immune defenses.

Support for Respiratory Health: Certain mycotoxins, like fumonisins, can impair the respiratory health of pigs, making them more susceptible to respiratory infections [34]. Mycotoxin adsorbents can lessen the respiratory health risks by reducing mycotoxin-related lung damage and supporting the immune system's ability to combat respiratory pathogens.

In both poultry and pigs, mycotoxin adsorbents play a vital role in maintaining immune system integrity and effectiveness. By reducing mycotoxin exposure, supporting gut health, and minimizing the immunosuppressive effects of mycotoxins, these adsorbents contribute to healthier and more disease-resistant animals, ultimately leading to improved overall productivity and well-being in food animal production.

4. The influence of mycotoxin adsorbents on the gut health of fishes

Mycotoxin adsorbents can also have a positive influence on the gut health of fishes, which is vital for their overall well-being and growth [35].

Gut Barrier Protection: Mycotoxin adsorbents, when included in the diet of fish, can help protect the integrity of the gut barrier. The gastrointestinal tract is the first line of defense against ingested mycotoxins [36]. Adsorbents can physically bind mycotoxins, preventing them from coming into direct contact with the gut lining. This helps to maintain the structural and functional integrity of the intestinal epithelium.

Reduced Inflammation: Mycotoxin exposure can trigger inflammation in the gut, which can lead to damage and impaired nutrient absorption. Mycotoxin adsorbents can mitigate this by reducing the influx of mycotoxins into gut tissues. Less inflammation in the gut promotes a healthier environment for digestion and nutrient absorption [37].

Prevention of Nutrient Loss: Mycotoxins can interfere with nutrient absorption in the gut, leading to malnutrition and reduced growth in fish. Mycotoxin adsorbents help to reduce mycotoxin-induced nutrient losses by preventing mycotoxin binding to essential nutrients, allowing for better nutrient utilization by the fish [38].

Improved Feed Conversion: Fish fed mycotoxin-contaminated feeds with the inclusion of adsorbents may exhibit better feed conversion ratios [39]. This improvement is partly due to the preserved gut health and enhanced nutrient absorption, allowing the fish to utilize the ingested feed more efficiently.

Enhanced Disease Resistance: Maintaining a healthy gut is closely linked to disease resistance in fish. By protecting gut health and preventing the immunosuppressive effects of mycotoxins, adsorbents can indirectly contribute to a stronger immune system, making fish less susceptible to opportunistic infections [40].

Optimized Growth: Healthy gut function is critical for growth in fish. Mycotoxin adsorbents can contribute to optimized growth rates by ensuring that the gut remains a conducive environment for nutrient absorption and growth processes [41].

It's important to note that the effectiveness of mycotoxin adsorbents in fish may vary depending on factors such as the type of mycotoxin present, the dosage of adsorbents used, and the specific fish species [42]. Nevertheless, in aquaculture, mycotoxin adsorbents serve as a valuable tool for maintaining gut health, supporting growth, and ensuring the overall well-being of fish, ultimately contributing to the success and sustainability of the aquaculture industry.

5. Challenges and limitations associated with mycotoxin adsorbents dietary usage in poultry, pig, and fish production

The dietary usage of mycotoxin adsorbents in poultry, pig, and fish production offers numerous benefits in mitigating the harmful effects of mycotoxin contamination [43]. However, there are several challenges and limitations associated with their usage that need to be considered such as mycotoxin variability, timing and dosage, specificity of adsorbents, mycotoxin transformation, cost and availability, monitoring and testing, and regulatory and labeling issues [1].

Mycotoxin contamination in feed ingredients can be highly variable in terms of type and concentration [44]. Different mycotoxins may require different adsorbents or combinations of adsorbents for effective mitigation. A single adsorbent may not effectively adsorb or neutralize all mycotoxins. Therefore, selecting the appropriate adsorbent or combination of adsorbents can be complex and may require continuous monitoring of feed ingredients [45].

The timing and dosage of mycotoxin adsorbent supplementation can greatly influence their efficacy. Administering adsorbents too early or too late in relation to mycotoxin exposure may reduce their effectiveness [46]. Achieving the optimal timing and dosage can be challenging, especially when there is uncertainty about mycotoxin presence and levels in feed ingredients.

Mycotoxin adsorbents are not always highly specific; they may also bind beneficial nutrients, medications, or other compounds in the digestive tract [47]. This can lead to reduced nutrient utilization and potentially affect animal health. The non-selectivity of some adsorbents can limit their use in situations where nutrient absorption is of utmost importance [48].

Some mycotoxin adsorbents have the capacity to transform mycotoxins into modified forms [49]. These transformation products may still retain some level of toxicity or be biologically active. Understanding the nature of mycotoxin transformations and their potential impact on animal health is an ongoing challenge, as it may vary with different adsorbents and mycotoxin types.

Mycotoxin adsorbents can add to the cost of animal feeds, making them less economically viable [31]. The availability of suitable adsorbents may also vary regionally, affecting their practicality for some producers. High costs and limited access to effective adsorbents can pose financial constraints for small-scale producers or those in resource-constrained regions.

Regular monitoring and testing of feed ingredients for mycotoxin contamination are essential to ensure effective adsorbent usage [1]. These tests can be time-consuming and may require specialized equipment and expertise. Some producers may lack the resources or knowledge to implement comprehensive monitoring and testing programs [50,51].

Regulatory frameworks for mycotoxin adsorbents can vary by region, and there may be challenges related to product approval, labeling, and compliance. Navigating these regulatory issues can be complicated and may limit the use of certain adsorbents.

In summary, while mycotoxin adsorbents offer valuable tools for mycotoxin management in poultry, pig, and fish production, their effective use is subject to various challenges and limitations.

Producers and researchers must carefully consider these factors to maximize the benefits of mycotoxin adsorbents while addressing potential drawbacks and uncertainties.

6. Conclusion

In conclusion, the utilization of mycotoxin adsorbents in food animal production, encompassing poultry, pigs, and fishes, represents a multifaceted approach to tackle the pervasive threat of mycotoxin contamination. These specialized materials have demonstrated their potential to significantly improve the health, productivity, and overall well-being of animals exposed to mycotoxins. While mycotoxin adsorbents offer substantial benefits, it is essential to consider the following key points. Firstly, mycotoxin adsorbents operate through mechanisms involving adsorption, binding, inactivation, or excretion of mycotoxins. These mechanisms help prevent mycotoxins from exerting their harmful effects, thus enhancing animal health and performance. Secondly, mycotoxin adsorbents contribute to the preservation of the immune system, especially in poultry and pigs. By reducing mycotoxin-induced immunosuppression, adsorbents enable animals to mount more robust immune responses, increasing their resistance to diseases and infections.

Furthermore, mycotoxin adsorbents can enhance gut health in these animals. They protect the gut barrier, reduce inflammation, prevent nutrient losses, and facilitate nutrient absorption, all of which are vital for maintaining health and supporting growth.

However, the practical application of mycotoxin adsorbents is not without its challenges and limitations. These include variability in mycotoxin contamination, the need for precise timing and dosage, potential non-selectivity, the possibility of mycotoxin transformation, cost implications, and regulatory complexities. Overcoming these hurdles requires informed decision-making, ongoing monitoring, and adaptation of strategies.

Mycotoxin adsorbents offer a valuable tool in food animal production to combat mycotoxin-related challenges. Their use represents a proactive approach to ensure the safety and productivity of livestock systems, which, in turn, impacts food security and the economic sustainability of the industry. Careful consideration of the specific circumstances and vigilant management are essential to maximize the benefits while addressing the limitations, ultimately contributing to healthier, more productive, and resilient food animal production systems. As our understanding of mycotoxins and their management evolves, the potential for mycotoxin adsorbents to make a positive impact in animal agriculture remains a dynamic and promising field of research and application.

Conflicts of Interest: The authors declare no conflict of interest.

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