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Mycotoxins in Aquafeeds

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SUMMARY

Mycotoxins are a serious problem in food and feed, particularly in fish farming where they can have detrimental effects on the fish species that are farmed. Fishmeal has been successfully substituted with plant-based ingredients in final fish diets. Nevertheless, the use of crops in feeds raises the possibility of mycotoxin and fungal contamination, as well as the frequency of mycotoxicosis in fish. Because mycotoxicosis typically causes decreased body weight, growth impairment, and greater rates of illness and mortality in fish, this could reduce aquaculture's productivity. Furthermore, the muscles of fish may accumulate certain mycotoxins. Because mycotoxins are significant genotoxins, carcinogens, and immunosuppressors to people, eating fish may therefore become another pathway for mycotoxins to infiltrate the human food chain, endangering food security and public health.

INTRODUCTION

Fish has always been a significant dietary source of protein, and the aquaculture business is thought to be a significant contributor to the global increase in human consumption of animal food. In addition to providing protein, fish flesh has higher concentrations of important nutrients than meat from terrestrial animals, such as critical minerals, water- and fat-soluble vitamins, and trace elements. These include polyunsaturated omega-3 fatty acids (Tacon *et al*., 2010; Tacon and Metian, 2013). At an average yearly growth rate of 10.34% (2022–2023), aquaculture has been developing and will continue to grow faster than any other significant food production sector. About 40.0% of fish raised in aquaculture for human consumption need a lot of protein rich aquafeed that is supplied from outside sources. Both non-obligate carnivore fish, like carp, and high-trophic carnivorous fish, like salmon and tuna, which require external feed to thrive, can benefit from compound feed to promote growth and increase farmer earnings. Aquafeed is designed to not only keep fish alive but also to maximize their growth and weight gain in the least amount of time while preserving the animal's skin and muscle mass so that people can eventually devour it. It therefore depends on extremely nutrient-dense substances like fish oil and fishmeal. A significant amount of aquafeed is made up of fishmeal since it is a valuable source of micronutrients such as essential amino acids and proteins. Fish oil is a byproduct of fishmeal and a source of long-chain polyunsaturated fatty acids. Protein rich feed is essential to the productivity of aquaculture production systems, particularly intensive systems, and is thought to account for roughly 50% of overall production costs (Marijani *et al.*, 2019).

Mycotoxins

Mycotoxins, known poisons are secondary metabolites produced by toxigenic fungi mainly from genera Aspergillus, Penicillium and Fusarium and present on nearly all agricultural products and by-products worldwide causing huge economic and health impacts (Magnoli et al., 2019). Over 400 mycotoxins that have been identified, the significant ones include aflatoxins (AFs), ochratoxins (OTA), fumonisins (FBs) deoxynivalenol (DON) and zearalenone (ZEA) (Mostrom,2015). In aquafeed of plant-based ingredients such as wheat, corn and soybean meal, the risk of mycotoxin production especially AFs and OTA are enhanced during prolonged storage in hot and humid environments which facilitate active fungal colonization of mostly Aspergillus and Penicillium spp.

Mycotoxin Contamination of Fish Feed

Mycotoxin contamination of crops can happen before harvest, especially in agricultural products that are high in mold and moisture content, and that are fortified with bran or fiber. Inadequate storage or post-harvest conditions can also lead to contamination, as they provide an environment that is favourable for the growth of fungi and the generation of mycotoxin. Examples of such conditions include elevated temperature and increased

water activity. At this time, there is no known way for getting rid of mycotoxins once they have contaminated a component or completed feed. Different processing techniques, especially those involving higher temperatures, may aid in lowering mycotoxin concentrations, though. It seems like more and more aquafeeds are including plant-based ingredients.

However, it happens almost everywhere that these components become contaminated with fungus that may be mycotoxigenic, especially Aspergillus flavus and Aspergillus parasiticus. Aflatoxin B1, ochratoxin A, and zearalenone have all been found in corn, wheat, and barley that is intended for use in fish feed in Serbia. Zearalenone levels in maize were found to be exceptionally high (mean of 5.3 mg/kg) by the authors. Aflatoxin B1 was found in Brazil in samples of soybean bran, corn bran, and other cereals from fish farms, albeit at low concentrations (1.1 µg/kg to 7.4 µg/kg). In maize samples used for feed manufacturing, aflatoxin B1 (1.0 to 135.0 µg/kg) and fumonisins (261.0 to 2420.0 µg/kg) were also found with high incidence in Malaysia.

Aflatoxin B1 was found in all examined feed samples (soy, rice, corn, wheat, and barley) in Portugal, ranging in concentration from 1.0 to 45.0 µg/kg. Furthermore, the researchers discovered fumonisin B1 (10 to 40 µg/kg) and deoxynivalenol (100.0 to 500.0 µg/kg) in rice, corn, wheat, and barley. All of the mycotoxins listed above that were found in feed ingredients had previously been found in aquafeed that had been completed. It is noteworthy to observe that mycotoxins are present in farm-made feed at higher concentrations and with greater frequency than in commercial feed. This may help explain why mycotoxin contamination is more widespread in developing nations because farm-made feed is more widely produced there.

All things considered, mycotoxin contamination of fish feed seems to be widespread worldwide, while the kind and degree of mycotoxin contamination in feed seems to be strongly influenced by the location. While deoxynivalenol is more common in North America, Northern and Central Europe, Africa, and North Asia, aflatoxins are most frequently found in Southern Europe, Africa, South Asia, and Southeast Asia. The most significant mycotoxins present in fish feed are discussed here, along with their effects on fish and human health. The raw ingredients of fish feed include aflatoxins, fumonisins, ochratoxins, trichothecenes, and zearalenone, in no particular order.

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Mycotoxins and Their Effects On Fish

Alfatoxins and Its Precursors

Aflatoxins were the first mycotoxins to be discovered, after a case of what was later found to be acute aflatoxicosis (“Turkey X disease”) resulted in the death of around 100,000 turkeys in the 1960s. Currently, out of all mycotoxins, aflatoxins are the most studied and best characterized. The most important aflatoxins in crops are aflatoxins B1, B2, G1, and G2. These toxins are mainly produced by A. flavus (only B-type aflatoxins), but A. parasiticus and, more rarely, Aspergillus nomius can also synthesize them. Other filamentous fungi of the genera Penicillium, Rhizopus, Mucor and Streptomyces are also producers of aflatoxins. Numerous feedstuffs, including cottonseed, wheat, corn, and maize, are susceptible to aflatoxins. However, groundnut meal, maize meal, and cottonseed meal are the primary sources of these poisons in animal feeds. Improper storage can cause aflatoxins to be produced after contamination with fungi that produce aflatoxins.

Effects of Alfatoxins on fish:

Pale gills, poor blood coagulation, slow development rates, and lack of weight increase are among the clinical symptoms of aflatoxicosis in fish. Reduced survival rates, body darkening or yellowing, and aberrant behavior observed in young sturgeon and Nile tilapia are possible indicators of a severe infection. Fish are more vulnerable to aflatoxins depending on their age and species; that is, younger fish are more vulnerable than older fish, and certain species are more sensitive than others. The fish species most susceptible to aflatoxins is the rainbow trout (Oncorhynchus mykiss). Freshwater fish are said to be more susceptible to aflatoxins than warmwater fish.

Fumonisins

The most dangerous fumonisin is fumonisin B1. Numerous Fusarium species, including Fusarium verticillioides, Fusarium proleferatum, and Fusarium nygamai, generate it on a regular basis. Fumonisin B1 is also produced by Alternaria alternata. Fumonisin is mostly found in maize and its byproducts; in Mozambique, Burkina Faso, China, and Malaysia, it has been found in 80% to 100% of corn samples.

Effects on Fish:

It appears that fumonisins cause organ damage, immune system dysfunction, decreased weight gain, and metabolic changes that raise the risk of cancer and mortality. Similar to aflatoxins, fumonisin susceptibility seems to be species-specific. It seems that channel catfish are somewhat vulnerable.

Ochratoxin

Ochratoxin A, the most dangerous of the ochratoxins, is generated by Aspergillus species, primarily Aspergillus ochraceous and Aspergillus carbonarius, and Penicillium spp. (Penicillium verrucosum). Although it can occur in other commodities, post-harvest contamination most commonly affects cereal grains (corn, wheat, barley, and oats). Because of its extended half-life and exceptional stability, ochratoxin A is easily transferred throughout the food chain. It is also very difficult to eradicate.

Effects on Fish:

In particular, adult sea bass are extremely vulnerable to ochratoxin A. After being exposed to ochratoxin A (2.0 mg/kg and above), juvenile catfish showed a significant reduction in body weight gain within two weeks and at each subsequent weighted. Lesions in the kidney and liver were observed, and the death rate among fish fed 8.0 mg/kg of ochratoxin A rose. Feed conversion and hematocrit were also decreased.

Trichothecenes

Fungi belonging to many genera, including Fusarium, Myrothecium, Phomopsis, Stachybotrys, Trichoderma, and Trichothecium, create trichothecenes in crops like corn, wheat, barley, and oats. Deoxynivalenol and T-2 toxin are the two most significant trichothecenes that are present in crops and, thus, the most harmful to animals. Despite the fact that T-2 toxin exposure affected the zebrafish embryos' health in ways such as increased mortality and malformation, cardiovascular abnormalities, and behavioural alterations.

Effects on Fish:

There is still much to learn about deoxynivalenol's effects on fish. The most delicate fish species seems to be rainbow trout in particular. This fish does not often die at a faster rate when exposed to deoxynivalenol. However, rainbow trout exposed to levels of this toxin up to 2.6 mg/kg experienced feed refusal and a decrease in feed conversion efficiency, which in turn caused a decrease in growth rate and weight gain.

Zearalenone

Fusarium spp., especially F. graminearum, but also Fusarium culmorum, Fusarium equiseti, and Fusarium Crookwellense, are the main producers of zearalenone. In crops like maize, contamination by this fungus generally happens prior to harvest. According to Zhang et al. (2018), zearalenone is a mycoestrogen with significant estrogenic activity that influences the ability of many animals to reproduce.

Effects on Fish:

The ovaries of rainbow trout collected significant levels of zearalenone (up to 7.1 µg/kg), although it is yet unclear how this buildup affects reproduction. On the other hand, it has been demonstrated that brief exposure to zearalenone reduces the reproductive capacity of zebrafish (Danio rerio) by lowering the frequency of spawning and the relative fecundity of successive generations. Zearalenone (2.0 mg/kg), despite its immunomodulatory effects that may have compromised the fish's health, appears to boost the growth rate and feeding efficiency of rainbow trout in addition to its reproductive effects.

CONCLUSION

The utilization of plant-based components in aquafeed may pose significant risks to the productivity of aquaculture by increasing the rate of mycotoxin contamination. Fish that consume mycotoxins have higher

sickness and death rates, more reproductive problems, less weight gain, and significant economic losses. Furthermore, the buildup of mycotoxins, even in trace amounts, in the fish's musculature could represent a major risk to the health of its eaters. On the one hand, this adds to the already heavy burden of exposure to these harmful metabolites, especially in underdeveloped nations or areas with significant wheat consumption. Conversely, long-term exposure to low concentrations of mycotoxins in humans can lead to long-term consequences including cancer or immune system deficiencies. Therefore, the economy and public health are severely impacted by the presence of mycotoxins in aquafeed. Therefore, methods to reduce exposure and manage contamination both before and after harvest are essential. As aquaculture develops further, it should be standard procedure to monitor both the raw materials and the completed feed.

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