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A REVIEW OF EFFECTS OF AFLATOXINS IN AQUACULTURE

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ABSTRACT

Aquaculture is an activity that has many interactions with the surrounding environment using resources and producing changes in the ecological system. Aflatoxins are distributed worldwide. *Aspergillus* species are able to grow in a wide variety of substrates and under different environmental conditions. Toxin formation in aquacultural products occurs in hot and humid weather, and in inadequate or deficient storage facilities. In recent years, aflatoxins and its environmental effects are discussed in aquaculture. This review is focused on effects of aflatoxins in aquaculture.

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1. INTRODUCTION

Aquaculture is the fastest growing food producing sector in the world. It is developing, expanding and intensifying in almost all regions of the world [1]. With growing demand for aquaculture comes increasing concern about the reliable supply of raw materials needed to support this growth. Aqua feeds traditionally depend on fishmeal as a protein source, but the trend in recent years has moved towards replacing fish meal with less expensive sources of protein of plant origin. As a result of this trend, aquaculture feeds have a higher risk of contamination by one or more types of aflatoxins. Aflatoxins are distributed worldwide. *Aspergillus* species are able to grow in a wide variety of substrates and under different environmental conditions. Aflatoxins are predominantly produced by *Aspergillus flavus* and *A Aspergillus parasiticus*, but may also be produced by other strains, such as *A Aspergillus nomius*, *A Aspergillus tamari*, and *A Aspergillus pseudotamarii* [2, 3]. Aflatoxins were first characterized in 1962 in the aftermath of an unusual veterinary crisis near Long, England, during which approximately 100000 turkey poults died as reviewed by Bennett and Klich [4]. This mysterious disease was then linked to peanut meal contaminated with secondary metabolites from *Aspergillus flavus*. It alerted scientists to the possibility that other mold metabolites might also be deadly. Toxin formation in agricultural products occurs in hot and humid weather, and in inadequate or deficient storage facilities. The most important factors that influence growth and aflatoxin production are relative humidity, ranging from 88 to 95% in most of the cases, and temperature, ranging from 36 to 38 C for mold growth, and 25 to 27 C for maximum toxin production [5]. Aflatoxins were first isolated in turkeys and of cancer in rainbow trout fed on rations formulated from peanut and cottonseed meals. The toxins are produced as secondary metabolites by *Aspergillus flavus* and *Aspergillus parasiticus* fungi when the temperatures are between 24 and 35 °C, and they will form within many commodities whenever the moisture content exceeds 7% (10% with ventilation) [6–8]. Other factors may also influence aflatoxin production: substrate composition, water activity, pH, atmosphere (concentration of oxygen and carbon dioxide), microbial competition, mechanical damage to the seeds, mold lineage, strain specificity and variation, instability of toxigenic properties, plant stress, insect infestation, and use of fungicides or fertilizers It is important to remember that aflatoxin contamination is cumulative, and the moment of harvesting and drying, and storage conditions may also play an important role in aflatoxin production [3, 9, 10]. Aflatoxins

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represent a serious source of contamination in foods and feeds in many parts of the world. The toxin has been incriminated as the cause of high mortality in aquaculture and in some cases of death in human beings. The number of studies addressing the effects of aflatoxins in aquaculture is very limited. There are very few studies regarding the effect of aflatoxin in aquaculture. In recent years, aflatoxins and its environmental effects are discussed in aquaculture. This review is focused on effects of aflatoxins in aquaculture.

2. TOXICOLOGICAL PROPERTIES OF AFLATOXINS

There are 18 similar compounds called aflatoxins. However, the most important types in terms of health and medical interest are identified based on their fluorescence under ultraviolet light (B = Blue and G = Green), such as aflatoxin B1 (AFB1), B2 (AFB2), G1 (AFG1) and G2 (AFG2). From these compounds, AFB1 is the most prevalent and toxic one when AFB1 is ingested by domestic animals in contaminated feed or foodstuffs, such as by dairy cows, the toxin undergoes liver biotransformation and is converted into aflatoxin M1 (AFM1), becoming the hydroxylated form of AFB1, which is excreted in milk, tissues and biological fluids of these animals [3, 11–14]. In animals the toxin is processed through a number of competing pathways. The differences in susceptibility to aflatoxin across species and between persons depend largely on the fraction of the dose that is directed into the various possible pathways, with harmful “biological” exposure being the result of activation to the epoxide and the reaction of the epoxide with proteins and DNA. There is also evidence that the fractions that follow the different possible pathways are influenced by dosage, perhaps because of the saturation of the most chemically competitive processes. Susceptibility to aflatoxin is greatest in the young, and there are very significant differences between species, persons of the same species (according to their differing abilities to detoxify aflatoxin by biochemical processes), and the sexes (according to the concentrations of testosterone). The toxicity of aflatoxin also varies according to many nutritional factors, and recovery from protein malnutrition is delayed by exposure to aflatoxin [8]. As for human and animal health, biological effects of aflatoxins may be carcinogenic, mutagenic, teratogenic, hepatotoxic, and immunosuppressive [15]. All these aflatoxin effects are influenced by variations according to the animal species, sex, age, nutritional status, and effects of other chemical products, besides the dose of toxin and the length of exposure of the organism to it [3, 16].

Aflatoxicosis is the poisoning that results from ingesting aflatoxins [8]. Aflatoxicosis is a disease that can affect many species of fish, and results when feed contaminated with aflatoxins is eaten by the fish. Aflatoxins are chemicals produced by some species of naturally occurring fungi commonly known as molds. Aflatoxins are common contaminants of oilseed crops such as cottonseed, peanut meal, and corn. Wheat, sunflower, soybean, fish meal, and nutritionally complete feeds can also be contaminated with aflatoxins. Factors that increase the production of aflatoxins in feeds include environmental temperatures above 27°C, humidity levels greater than 62%, and moisture levels in the feed above 14%. The extent of contamination will vary with geographic location, feed storage practices and processing methods. Improper storage is one of the most important factors favoring the growth of aflatoxin producing molds, and it is a major element that can be controlled by the fish producer [17, 18]. Aflatoxins can cause disease indirectly through their effects on essential nutrients in the diet. For example, fat soluble antioxidants, such as vitamin A, and water soluble antioxidants and vitamins, such as vitamin C and thiamin, in feeds can be destroyed by these toxins. Hence, it is not surprising that aflatoxins depress the immune system, making fish more susceptible to bacterial, viral or parasitic diseases. These subtle effects often go unnoticed and profits are lost due to decreased efficiency in production, such as slow growth, reduced weights of the finished product, an increase in the amount of feed needed to reach market weight, and increased medical costs [18].

3. DETERMINATION OF AFLATOXIN

The aflatoxin content in food and fodder can be determined by analytical techniques such as: thin layer, gas or liquid chromatography, spectrofluorometry, spectrophotometry and ELISA [19].

4. EFFECTS OF AFLATOXINS IN AQUACULTURE

Available data on the effect of aflatoxins in aquaculture are very limited [20–23]. Among all aflatoxins, aflatoxin B1 (AFB1) is considered the most potent food-born hepatotoxicant frequently found in animal feedstuffs and responsible agent in unforeseen outbreaks of fish mortality attributed to aflatoxicosis, well documented in freshwater species since long time. The increased use of plant origin ingredients in aquafeed formulations has intensified the potential onset for aflatoxicosis in fish farming systems due to the carryover of high loads of aflatoxin contamination by vegetable sources [23–29]. Aflatoxin production by the most toxinogenic strains can occur directly in the field, during insiling, feed formula preparation, and also during improper feed storage in the farm. On the other hand, the thermal treatments, applying high temperature

pelleting procedures, even though destroy the mould but do not inactivate the heat-stable toxins present in spores and mycelium. Toxins accumulate in fish meal thus representing an high risk for the farmed species and then for the customer health and safety. As a result, the problem of aflatoxin contamination in aquaculture has amplified. Several studies revealed that AFB1 residues can be retained in aquatic animal tissues, giving rise to potential public health risks after ingestion [23, 30–33]. Moreover, the presence of aflatoxins decrease the nutritional value of administrated feed in fish farm, both affecting the fish welfare status and the product quality [27, 34]. In intensive aquaculture, the features of administrated feed play a main rule being the major alimentary source involved with the fish growing and their nutritional requirements. The cases of acute intoxication by aflatoxin are almost rare and exceptional, while the chronic toxicity is the serious and most prevalent problem, because of AFB1 carcinogenicity upon long term microexposures. When moderate to high doses of aflatoxin are ingested, fish develop an acute intoxication, called acute aflatoxicosis, that generally gives rise to poor health and fertility, loss in productivity, reduced weight gain, and immunosuppression. More insidious, pathological signs occur as a consequence of prolonged dietary exposure, causing genotoxic, tumorigenic and teratogenic, hormonal or neurotoxic effects in fish, as well as in humans. Chronic aflatoxicosis is of great concern in aquaculture systems, since it was found to be implicated both with a gradual decline of reared fish health status and with decreased stock quality. While considerable epidemiological data have been obtained on AFB1 adverse effects in humans, farm animals and freshwater species, there is a substantial need to obtain such data especially on aquacultured euryaline fish [23, 29].

The first documented incidences of aflatoxicosis affecting fish health occurred in the 1960s in trout hatcheries. Domesticated rainbow trout (*Oncorhynchus mykiss*) that were fed a pelleted feed prepared with cottonseed meal contaminated with aflatoxins, developed liver tumors. As many as 85% of the fish died in these hatcheries. Although cottonseed meal is no longer used as a major ingredient in feed formulations, poor storage of other feed ingredients and nutritionally complete feeds can lead to contamination with aflatoxins [17, 18]. Rainbow trout are extremely sensitive to AFB1, while channel catfish are much less responsive. Rainbow trout fed diets containing AFB1 at 0.0004 mg per kg feed (0.4 ppb) for 15 months had a 14% chance of developing tumors. Feeding rainbow trout a diet containing AFB1 at 0.02 mg per kg feed (20 ppb) for 8 months resulted in 58% occurrence of liver tumors, and continued feeding for 12 months resulted in 83% incidence of tumors. Channel catfish, fed a diet containing purified AFB1 at 10 mg per kg feed (10,000 ppb) for 10 weeks, exhibited decreased growth rates and moderate internal lesions [18, 35].

Aflatoxicosis is now rare in the rainbow trout industry due to strict regulations enforced by the U.S. Food and Drug Administration (FDA) for aflatoxin screening in oilseeds, corn and other feed ingredients. However, interest in the toxic effects on cultured warm-water fishes, such as tilapia (*Oreochromis* sp.) and channel catfish (*Ictalurus punctatus*), has increased as diets for these species are now being formulated to contain more plant and less animal ingredients. This increases the potential for development of aflatoxicosis in these species because, as noted earlier, plant ingredients have a higher potential than animal ingredients for contamination with aflatoxins. Studies on the Nile tilapia (*Oreochromis niloticus*) showed reduced growth rates when tilapia were fed diets containing 1.8 milligrams (mg) of AFB1 per one kilogram (kg) of feed for 75 days. In addition, tissue abnormality or lesions in the livers of these tilapia showed the beginnings of cancer development. Another study [36] tested effects of varying concentrations of AFB1 on 2.7 gram Nile tilapia. Fish fed diets that contained 2.5, 10, or 100 mg AFB1 per kg of feed for 8 weeks had reduced weight gain and reduced red blood cell counts. Fish fed the 10 mg AFB1 per kg feed had abnormal livers. Those fed 100 mg AFB1 per kg feed had weight loss and significant damage to the liver, and 60 % of these fish died by the end of the experiment. Other studies have shown that tolerance levels for tilapia can vary with the production system. In green water and flowthrough systems, the presence of aflatoxins at 25 to 30 parts per billion (ppb) in the water decreased growth without any noticeable signs of mortality. However, in cage culture, concentrations of aflatoxins above 5 ppb in the water caused an increase in mortality rates [18, 36].

5. CONCLUSION

Aquaculture is very important natural sources both strategic and vital for all in the world. Aquaculture will continue to play an important role in the global supply of fish in the future. Negative effects of waste from aflatoxins to aquatic environment are increasingly recognized in Aquaculture. To minimize the risk of aflatoxin exposure, close tripartite cooperation among the trade, the public and the government is essential. Properly planned use of aquaculture waste alleviates water pollution problems and not only conserves valuable water resources but also takes advantage of the nutrients contained in effluent. It is highly demanding to develop sustainable aquaculture which keeps stocking density and pollution loadings under

environmental capacity. Aquaculture development must be sustained by basic and applied research and development in major fields such as nutrition, genetics, system management, product handling, and socioeconomics. One approach is closed systems that have no direct interaction with the local environment. The goal of aquaculture is grow in a manner that does not harm to aquatic ecosystems. Therefore, monitoring of environmental effects of aflatoxins in aquaculture is very important for aquatic ecosystems conservation.

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