Mycotoxins And Their Consequences In Aquaculture: A Review

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Mycotoxins and their consequences in aquaculture: A review

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Abstract

Fish consumption has been increasing worldwide, mainly due to the availability, access and price in relation to other kinds of meat consumption, such as beef, pork, and poultry. Consequently, some concerns begin to emerge, primarily regarding the quality of fish available in the market. Residues could be present in any product of animal origin causing economic losses and putting into a risk human and animal health. Food contamination by mycotoxins is a risk to human and animal health, and it is responsible for significant economic losses. It’s very difficult to prove that a disease is a mycotoxicosis, and even when mycotoxins are detected, it is not easy to show that they are the etiological agents in veterinary pathology or human health problem. In spite of inevitable and widespread, the presence of mycotoxins in feeds of fish cannot be neglected, as revealed by the sight of many researches, field outbreaks reported and pathologies related to mycotoxins, mainly because the toxic effects and safety levels of mycotoxins in the different species of fish are superficially still known. Setting mycotoxin regulations is a complex activity, which involves interested parties and several factors, both of a scientific and socio-economic nature may influence the establishment of mycotoxin limits and regulations. The first limits for mycotoxins were set in the late 1960s for the aflatoxins and by the end of 2003, several countries had developed specific limits for mycotoxins in foodstuffs and feedstuffs, and the number continues to grow, however the residual tolerable of mycotoxins in the fish is still non-existent.

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Abbreviations: AFB, aflatoxin B; AFB1, aflatoxin B1; AFB1/G1, aflatoxins B1 + G1; AFG1, aflatoxin G1; AFG2, aflatoxin G2; AFM1, aflatoxin M1; AFs, total aflatoxins; AGA, agamic acid; CAST, Council for Agricultural Science and Technology; CAC, Codex Alimentarius Commission; CIT, citrinin; DAS, diacetoxyscirpenol; DHA, docosahexaenoic acid; DON, deoxynivalenol; EC, European Commission; EPA, eicosapentaenoic acid; FAO, Food and Agriculture Organization of the United Nations; FDA, Food and Drug Administration — United States of America; FB, fumonisin; FB1, fumonisin B1; FB2, fumonisin B2; FB1/2, fumonisin B1 + B2; FB1/2/3, fumonisin B1 + B2 + B3; FBs, total fumonisins; HT-2, HT-2 toxin; MRLs, maximum residue limits; NRC, National Council Requirements; Nd, not detectable; OTA, ochratoxin A; PAT, patulin; PHO, phomopsins; TDI, tolerable daily intake; SD, standard deviation; T-2, T-2 toxin; x, unrealized; ZEN, zearalenone.

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1. Introduction

With the world’s population expected to reach 8.2 billion people by 2030, and with 842 million people estimated as having been undernourished in the period 2011–13, food supply will present a growing challenge in the next two decades. With increases in income along with demographic changes related to family size, population aging and urbanization, and consumer trends such as concerns for healthy eating and sustainable production, there will be great shifts in demand and major changes in the composition of demand. This scenario will in turn have an impact on food supply, which will need to increase and become more efficient if it is to grow within the constraints presented by the availability of natural resources and existing technology (FAO, Food And Agriculture Organization of the United Nations, 2014).

Currently, fish consumption by population has been increasing worldwide, mainly due to the availability, access and price in relation to meat consumption, such as beef, pork, and poultry. Consequently, some concerns begin to emerge, primarily regarding the quality of fish available in the market. Chemical residues could be present in any product of animal origin causing economic losses and putting into a risk human and animal health. According to Bostock et al. (2010), the aquaculture contributes nearly half of all food of aquatic origin intended for human consumption, as a vital part of the global food industry.

Global production of farmed fish, shrimp, clams, and oysters more than doubled in weight and value during the 1990s while landings of wild-caught fish remained level (Naylor et al., 2001). Myhr and Dalmo (2005) assert that fish and other aquatic animals represent an important food source for animal and human consumption; so, this demand had led to a fast development of aquaculture. The first important point is to control the feeding of fish produced, and obviously, control fungal and mycotoxins contamination to reduce economic losses, and to minimize hazards to human health (Barbosa et al., 2013; Cavaliere et al., 2005). According Naylor et al. (2001), as aquaculture production continues to expand and intensify, both its reliance and its impact on ocean fisheries are likely to increase. The balance between farmed and wild-caught fish, as well as the total supply of fish available for human consumption will depend on future trends in aquaculture practices. Increased aquaculture production has the potential to influence wild fish stocks via increased demand for feed (FAO, Food and Agriculture Organization of the United Nations, 2014).

Mycotoxins are toxic metabolites produced by a diverse group of fungi that contaminate agricultural crops prior to harvest or during storage post-harvest and different species including humans, poultry, swine, and fish all exhibit varying levels of mortality and morbidity upon the exposure to these harmful substances (Zychowski et al., 2013). Maintaining a safe global food and feed supply is a critical issue facing society. Natural contaminants, especially mycotoxins, pose a challenge since they are found in a wide range of crops and differ significantly in chemical structure and symptomatology in humans and signs of disease in animals following exposure (Kendra and Dyer, 2007) and can exhibit a broad range of effects including carcinogenicity, neurotoxicity, and developmental toxicity (Kolpin et al., 2014).

In addition to public health, the presence of undesirable and dangerous substances also limits or reduces the marketing of food products in international markets (French et al., 2014). Therefore, international organizations, like Food and Drugs Administration (FDA, Food and Drugs Administration, 1995) and European Commission (European Commission, EC, 2006) have established maximum residue limits (MRLs) for mycotoxins. At this moment, many countries have established legislation to reduce exposure to mycotoxins, but based on scientific risk assessment, and which allows small amounts of mycotoxins in foods or feeds, if these levels are lower than what is confirmed to not affect human’s and animal’s health (Henson and Caswell, 1999).

According to FAO, Food and Agriculture Organization of the United Nations (2004), the development of these regulations can be influenced by both scientific and socioeconomic factors including: i. the availability of scientifically sound toxicological data; ii. availability of occurrence data in commodities; iii. knowledge of the distribution and concentrations of toxins in commodities; iv. availability of detection methods, including conformational and analytical; and v. governmental legislation amid countries where trade contracts exist and vi. the need for a sufficient food supply. Because of their ubiquitous nature and the fact that current standards focus on regulating the product rather than the process, mycotoxin contamination of food and feed is unavoidable (Kendra and Dyer, 2007).

Food contamination by mycotoxins is a risk to human and animal health, and it is responsible for significant economic losses. Rodrigues et al. (2011) reported that these losses are supported by all participants along the chain of production animal, or animal producers, grain handlers and distributors, processors of crops, but also by consumers in society. An important element to reduce this type of contamination is prevention, because several products can be victims of contamination along the chain of livestock production and it is not easy to identify the contaminated product.

Mycotoxins represent a serious problem in livestock production worldwide. Its effects — including reduction of weight gain and feed efficiency worsening compromise the overall health of the animals, causing bruises on the carcass, liver and kidney damage, which can result in serious economic implications to farmers.

It is difficult to prove that a disease is a mycotoxicosis, and even when mycotoxins are detected, it is not easy to show that they are the etiological agents in a given veterinary or human health problem. Although it is hard to define, there is sufficient evidence from animal models and human epidemiological data to conclude that mycotoxins pose an important danger to human and animal health. In summary, in the absence of appropriate diagnostic criteria and reliable laboratory tests, the mycotoxicoses will remain diagnostically daunting diseases (Zain, 2011). An approach on the occurrence of mycotoxin-contaminated animal feed, as well as toxic effects that mycotoxins may produce in fish and their residues in meat and organs are outlined in this review.

2. Feed consumption in aquaculture and current market

World fish production has experienced tremendous growth, increasing from 20 million tonnes in 1950 to 156.2 million tonnes in 2012, of which 97% was used for direct human consumption. Per capita fish consumption increased from 9.9 kg in 1960 to 19.1 kg in 2012. The increase in production is attributed predominantly to aquaculture, which has maintained high growth rates since the 1980s. By 2012, aquaculture production had increased to 66.5 million tonnes, or about 43% of total fish supply. Productivity growth and technological progress have been essential factors underlying production growth in aquaculture (FAO, Food And Agriculture Organization of the United Nations, 2014).

Fishery resources are an important source of both macronutrients and micronutrients for humans. Even though globally fish accounts about 17% of animal protein intake, there is a significant difference in consumption between countries; low-income food-deficient developing countries consume on average 10.1 kg per capita while industrialized countries consume 28.7 kg per capita. However, when considering some economically disadvantaged countries, fish contributes more than 50% of animal protein intake (FSA — Food Standards Agency, 2012).

In 2010, the two species of fish most produced in the world during the period of 2002–2010 were grass carp and silver carp, with a production of 4,337,114 and 4,116,835 tonnes, respectively. Other species produced in high–scale in the world aquaculture are Catla, Japanese carpet shell, Common carp, Whiteleg Shrimp, Bighead carp, Nile tilapia, Crucian carp, Atlantic salmon, Robo Labeo and Milk fish. The countries that produce fish or other aquatic organisms are China, India, Vietnam, Indonesia, Bangladesh, Norway and Thailand. Other important producers are Egypt, Chile, Myanmar, the Philippines, Brazil, Japan, the Republic of Korea, the United States of America, Taiwan Province of...
The chemical and nutritional qualities are relevant for their efficiency of ingredients used in feed of 4 to 5 mm in diameter and grow out phase. With or four times a day at a rate of 3 to 5% of live weight, with extruded fish. Where they live, like subject to environmental conditions and health management difficulty. There are some differences in requirements between the cold-water fish (optimum temperature < 18 °C) and hot water (optimum temperature > 18 °C). Studies have shown that diet influences behavior, structural integrity, health, physiological functions, reproduction and growth of fish. For that reason, the determination of qualitative and quantitative requirements of essential nutrients is of fundamental significance for an adequate formulation of diets for fish. The fingersling between 5.0 and 20.0 g, after the first month, can be fed with extruded feeds and subsequently crushed in proportion of 5 to 8% of live weight and ration be provided at least four times a day. The fish in the juvenile stage (between 80 and 250 g), should be fed three or four times a day at a rate of 3 to 5% of live weight, with extruded feed of 4 to 5 mm in diameter and grow out phase. With fish above 250 g, the ration must be provided at a rate of 2 to 3% of live weight with 6.0 up to 10 mm in diameter. This same ration must continue until the final phase of fattening (finish), with 1 to 3 kg live weight, when fish ingest, 1 to 2% of live weight (Pontes et al., 2010).

The ingredients used in fish feed are made up basically of grain and its by-products, pies and bran of oilseeds, flour and bran of tubers (cassava), brewery waste, crushed, miscellaneous and hay products of animal origin (fish meal, bone, flesh and bone, flesh and blood). Approximate composition of ingredients used in fish feeds must be known, because their chemical and nutritional qualities are relevant for their efficiency (Pontes et al., 2010). According to European Commission (EC) (2013), the aquaculture production does not pose any problem in relation to compliance with the ban on recycling within the same species to the extent that existing ducting requirements for the use of fishmeal in feed for the aquaculture animals have already proved their effectiveness.

There are multiple criteria for assessing the economic impact of mycotoxins on humans and on livestock production, but the considerations include loss of human and animal life, health care and veterinary care costs, economic loss in livestock production, forage crops and feeds, regulatory costs, and research cost focusing on relieving the impact and severity of the mycotoxin problem. Formulas for worldwide economic impact have been difficult to develop and, therefore, most reports on economic impact are on a single aspect of mycotoxin exposure or contamination (Hussein and Brasil, 2001).

However, using a ration of quality, namely, quality raw materials and no contamination by mycotoxins or pesticides, but also adopt proper food management within each breeding may improve the adverse effects to the aquatic environment. As a result, it will improve the cost–benefit ratio, likewise results in a product of great quality for human consumption.

3. Occurrence and significance of mycotoxins in feeds fish

Mycotoxicoses in humans or animals are characterized as food or feed related, non-contagious, non-transferable, non-infectious, and non-traceable to microorganisms other than fungi. Clinical symptoms usually subside upon removal of contaminated food or feed (Zain, 2011).

Feed supply is central to all animal production systems and any factor that affects the security of the feed supply is a significant constraint to production (Bryden, 2012). The primary objective in fish nutrition is to provide a nutritionally balanced mixture of ingredients as finished feed to support the maintenance, growth, reproductive performance, flesh quality, and health of the animals at an acceptable cost (NRC, National Research Council, 1989). The quality of the products used in feeds for farmed fish has become a limiting aspect for activity because these feeds are ideal substrates for the growth of fungi, which, under positive conditions, may favor the synthesis of mycotoxins. The production of these toxic metabolites may occur during the growth of the crop, during post-harvest storage, or during the storage of the compounded feed (Council for Agricultural Science and Technology, CAST, 2003).

Field contamination depends strongly on several factors, including climatic conditions (rainfall, temperature, and humidity), genetic susceptibility of cultivars to fungal infection, soil type, nutritional factors and post-harvest storage (Bakan et al., 2002; Cavaliere et al., 2005; Council for Agricultural Science and Technology, CAST, 2003).

Experts estimate an annual loss of 140 million dollars due to reduced weight gain of poultry in the United States due to contamination of feed by mycotoxins in Australia, the loss in the poultry farming is of 4 to 20 million dollars. Latest data estimate that annual losses due to ingestion of mycotoxin-contaminated animal feed in the United States and Canada, are on the order of $5 billion (Marson and Bonin, 2013.).

The regulatory limits for mycotoxins are extremely varied, because it depends on the toxicity of each mycotoxin and the possible combinations; the legislations of each country: the type of cereal, grains, feed or food; and the geographical and ecological distribution of the mycotoxins produced (Biomim, 2011; Zain, 2011). However, many countries follow FDA guidelines, ESFA, CODEX alimentarius and EC for granted the acceptable level of mycotoxins. These guidelines suggest that the acceptable level for aflatoxin (AFB) in animal feeds and ingredients is 20 ppb, excluding cottonseed meal (300 ppb — its acceptable if the feed is for beef cattle, swine and poultry), and the acceptable levels for fumonisin (FB1, FB2, FB3) in animal feed for equids and rabbits is 5 ppm (no more than 20% of diet); for swine and catfish is 20 ppm (no more than 50% of diet); for breeding ruminants, poultry and mink is 30 ppm (no more than 50% of diet); for ruminants >3 months old and mink being raised for slaughter is 60 ppm (no more than 50% of diet); for poultry being raised for slaughter is 100 ppm (no more than 50% of diet) and for all the other species or classes of livestock and pet animals is 10 ppm (no more than 50% of diet) (European Commission, EC, 2006; European Food Safety Authority, EFSA, 2010; FDA, 2011a,b; FB — Food Ingredients Brasil, 2009).

Pettersson (2004) affirms that mycotoxins in cereals were found in pre-harvest (barley: deoxynivalenol [DON], nivalenol [NIV], zearalenone [ZEN], HT-2 toxin [HT-2], T-2 toxin [T-2]; maize: DON, fumonisin [FB], ZEN; oats: DON, NIV, HT-2, T-2; wheat: DON, NIV, ZEN, ergot; rye and sorghum: ergot) and post-harvest (barley: ochratoxin [OTA], AFB, citrinin [Cit]; maize: ZEN, AFB; oats: OTA, AFB, Cit; wheat: OTA, AFB, Cit; rye: OTA and sorghum: AFB).

In Table 1, is possible to observed the incidence of mycotoxins contamination of grain (maize, oats, wheat, barley; n = 4327 samples) around the world. Considering the data from Table 1, it can be affirmed that the occurrence of AFB1 found in countries like Middle East, Asia and Africa is very high and worrying. The incidence of ZEN in Northern of Asia; DON in North America and Northern of Europe and China; FBs in South America, Africa, Europe, Asia and the Middle East, but also, OTA in the Middle East were present in more than 50% of the samples analyzed (Biomim, 2011, 2014).

Ninety four samples of fish feeds were collected at different locations in Nigeria and the highest incidence of fish feed contamination was recorded for fumonisin B1 (FB1), fumonisin B2 (FB2), aflatoxin B1 (AFB1), and ZEN with mean of 900.9, 220.6, 103.0 and 4.5 μg/kg, respectively.
The toxic effects of mycotoxins in animals vary according to the type and amount of toxin, and period that the animal was exposed. Mycotoxins have a range of other health effects including carcinogenic effects, kidney damage, gastrointestinal disturbances, reproductive disorders or suppression of the immune system.

By the way, the toxins as AFB1 can be genotoxic and carcinogenic, and the affected organ is the liver (Bintvihok et al., 2003; Cagauan et al., 2004) in animals. The toxic effect of OTA is acute, and could lead to chronic kidney cell damage and impaired function. FB, in human, may be relationship the etiological agent of esophageal canceroma (Moss, 2002). Trichothecenes can cause chronic effects in animals, including suppression of the immune system. Estrogenic syndrome (hyperestroegen and vulvovaginitis) is the major toxic effect of ZEN as its structure resembles that of 17-beta-estradiol, an estrogen hormone (Ankul et al., 2013).

Mycotoxins can be responsible for the induction of many disorders in fish, such as induce to cell and organ alterations, produce functional and morphological effects and in more severe cases mortality (Deng et al., 2010; Cagauan et al., 2004; Sahoo and Mulkerjee, 2001). Thereby, losses in aquaculture caused by mycotoxins in feed can be significant, resulting in economic loss on fish production.

In studies of toxic effects on fish, there is not a standard for the amount or time of exposure to toxins produced by fungi, and that is an important factor to describe the possible toxic effects and consequences; therefore, there is a need to standardize the chronic tests, mainly in relation to the duration of the test. In Tables 2–3, it can be observed the various effects of mycotoxins reported in fish, as well as the related doses and time that fishes were exposed. In addition, it can be analyzed by the tests described in Table 2, that the AFB is the mycotoxin more studied in fish, possibly because its natural occurrence being most common and is a know human carcinogen, probably one the most potent know.

Reduced intake of mycotoxins-contaminated feed leading to reduced weight gain was reported in mice (Gouze et al., 2006) and fish (Doll et al., 2010; Hooft et al., 2011), but there are also reports of not interfering in the weight gain of fish (Pietsch et al., 2014c; Sanden et al., 2012). So, according to these results, weight gain does not appear to be a sensitive parameter to detect mycotoxin contamination. According Pietsch et al. (2014c) the activity of serum ALT and LDH together with lactate concentrations seems to be a sensitive indicator of the fish responses to DON (Table 3). Little is known about the ecotoxicological impact of mycotoxins at levels found in the environment and the consequence of exposure to aquatic organisms (Schwartz et al., 2011).

The majority of trials conducted with mycotoxins contamination in fish are of chronic character, contaminated feed management and several different doses as can be seen in Tables 2–3. However, it is important to keep a standard to perform the tests in relation to duration of the experiment and split the toxicology tests on acute, subchronic and chronic character, contaminated feed management and several different doses.
creased, as the AFB1 concentration increased in diets, and accumulated qual AFB1 in liver of chronics, but also consider route of administration and dose according to each type of mycotoxins, mainly to detect toxic effects on fish. In fact, the toxic effect of mycotoxins may be dependent of the type and quantity of mycotoxin content in the feed, but also depends on the duration of exposure, animal species, sex and age.

5. Mycotoxin residues in fish and risks for public health

In order to protect consumer’s safety, rules and safety limits for several mycotoxins in certain foodstuffs are contained in certain laws or regulations by governmental agencies of different countries. For most mycotoxins, a tolerable daily intake (TDI) has been established, which estimates the quantity of mycotoxin that someone can be exposed to daily over a lifetime without significant risk to health (FSA – Food Standards Agency, 2012).

The metabolism of different mycotoxins in fish is not fully elucidated, but there are some papers about AFB1 metabolism. So, after ingestion of AFB1 by the fish via dietary exposure, it is absorbed from the gastrointestinal tract into the circulatory system owing to its high lipid solubility. In the plasma, the AFB1 is carried thorough the portal blood into liver where is largely sequestered by hepatocytes. The biliary and the urinary systems represent the major excretion routes in trout and catfish. AFB1s are biotransformed in liver cells, to several types of metabolites by microsomal mixed-function oxidases and certain cytosolic enzymes (Santacroce et al., 2008). According to Santacroce et al. (2008) aquatic species have shown dissimilar susceptibility to the hepatotoxic and carcinogenic effects of AFB1 that depends on the particular species.

Deng et al. (2010) studied the bioaccumulation of dietary AFB1 for 15 and 20 weeks in muscle and liver of tilapia and they did not detect AFB1 residues in muscle, whereas quite high residues of AFB1 were determined in liver. These results revealed that the residual AFB1 in liver increased, as the AFB1 concentration increased in diets, and accumulated progressively as exposure prolonged. After 15 and 20 weeks, the residual AFB1 in liver of fish fed diets containing more than 638 μg/kg was significantly more than the control group, and consequently the residual AFB1 after 20 weeks was twice as high as the corresponding value after 15 weeks.

Some authors (Table 4) reported the presence of residues in tissues or organs of fish poisoned with mycotoxins, but still not well regulated what is the tolerable limit of waste for different species of fish, such as different tissues or organs.

Current legislation does not include limits for ZEN occurrence in food of animal-origin, since it has been suggested that the Fusarium mycotoxins are transferred from feed into meat, milk and eggs, only to a very limited extent (European Commission, EC, 2006).

However, the residue of AFB1 in biological tissues has been frequently reported fish (El-Sayed and Khalil, 2009). In the majority of these studies, the residual AFB1 level in liver is much higher than in muscle (Bintvihok et al., 2003; Deng et al., 2010; El-Sayed and Khalil, 2009; Nomura et al., 2011). The most accepted explanation is that the liver plays a prominent role in the metabolism of AFB1. Some authors agree that the residue of AFB1 present in tissues and organs can be due to dose and time-dependent (Bintvihok et al., 2003; Ding et al., 2013; El-Sayed and Khalil, 2009; El-Sayed and Khalil, 2009). The feeding for a long time of sea bass on low levels of AFB1 induced not only serious health problems in exposed-fish, but also representing a high risk to fish consumers through their residues in fish muscle.

In the current study, they describe that Aflatoxin B1 accumulated to a level of 4.25 ± 0.85 ppb in the muscle of sea bass fed AFB1, suggesting a significant risk for transmission of AFB1 to the human consumer, since the US Food and Drug Administration has set a 20 ppb limit for AFB1 in human foods.

It can be assessed in Table 3, in which studies with identification of mycotoxin levels in organs and tissues of fish are presented, that it is necessary to standardize the analysis techniques. It is indispensable to detect the different mycotoxins in fish tissues and organs, as well as to estimate the risk to public health, determining the safe level of each type of mycotoxins in the different tissues for several species of fish.
6. Legislation for safety level of mycotoxins in human food, animal feed and animal feed ingredients

According to FAO, Food And Agriculture Organization of the United Nations (2014) micronutrient deficiencies affect hundreds of millions of people, particularly women and children in the developing world. More than 200 million children worldwide are at risk of vitamin A deficiency, goiter or are iron deficient. Rural diets in many countries may not be particularly diverse and, thus, it is vital to have good food sources that can provide all essential nutrients in people's diets. Individuals have never consumed so much fish or depended so greatly on the fishery and aquaculture sector for their nutrition as they do today. But, the demand for fish is growing and there are still huge numbers of hungry and malnourished citizens in the world. Aquaculture plays an essential role in meeting these challenges.

However, to do so sustainably, it needs to become less dependent on completely wild fish for feeds and to modify culture species and practices, which, in turn, will require influencing the consumer predilections. Foods from the aquatic environment are a unique source of the essential long-chain omega-3 fatty acids, which are important for optimal brain and neurodevelopment in children (docosahexaenoic acid — DHA) and vascular health (eicosapentaenoic acid — EPA). Sufficient intake of omega-3 fatty acids is particularly important during pregnancy and the first two years of life. Fish consumption among adults lowers the risk of coronary heart disease mortality by up to 36% owing to a combination of EPA and DHA effects (FAO, Food and Agriculture Organization of the United Nations, 2014).

It must be considered that contaminated food becomes threats to global health, endangering everyone, including infants, children, pregnant women, the elderly and those with an underlying disease that are particularly vulnerable. Hence, it is extremely important that the safe levels of mycotoxins present in fish are known, as well as standardized extraction technique of mycotoxins from different animal tissues, being validated by governmental responsible for determining those regulations.

All regulations are primarily made on the basis of known toxic effects in animals or humans and in addition to information about toxicity exposure assessment is another main ingredient of the risk assessment. Reliable data on the occurrence of mycotoxins in various commodities and data on food intake are needed to prepare exposure assessment. Despite the dilemmas, mycotoxin regulations have been established during the past decades in many countries, and newer regulations are still being drafted. According to Fig. 1, can be observed the countries that have some kind of legislation for foodstuffs and animal feedstuffs.

In Table 5, it can be observed the maximum limits allowed in the various countries of the world for some mycotoxins and for grains, animal feed and some products (European Commission, EC, 2006; FAO, Food and Agriculture Organization of the United Nations, 1997; FAO, Food And Agriculture Organization of the United Nations.
Nevertheless, there are still no values permissible limits of mycotoxins for the consumer in relation to the final product. In addition, for the most part still missing regulations for safety values in food to vulnerable people, namely, lactating women, children, elderly or sick.

7. Reduction of mycotoxins in fish feed

Food can be contaminated at any point of production and distribution, and the primary responsibility lies with food producers. Mycotoxins is a group of undesirable substances in food production and its control, it is often overlooked. Mycotoxins can be produced throughout the growing cycle, but predominately after the crop has matured in the field, through the harvest and storage periods. Anyway, there is no approved or sanctioned method for detoxifying most grains, there is only expected for cotton.

Control of mycotoxin contamination must start on rural property, i.e., where the grains are produced, but it is essential to conceive a special attention to the pre and post-harvest and storage of these grains. Mycotoxins are not visible to the eye, and often the grains do not

Fig. 1. Countries that have some kind of legislation for foodstuffs and animal feedstuffs. In accordance to FDA Mycotoxin Regulatory Guidance (2011a,b) and CODEX, there is the action level for AFs and there are advisory levels for two mycotoxins that may be present in human food and animal feed ingredients: DON (vomitoxin) and FBs. The action level for AFs present in human food is 20 ppb; animal feed and animal feed ingredients 20–300 ppb; and advisory levels for DON present in human food is 1 ppm; animal feed and animal feed ingredients 5–10 ppm and for FBs present in human food is 2–4 ppm.
show signs of mold infection, but may be contaminated with mycotoxins (FAO, Food and Agriculture Organization of the United Nations, 2004, 2007).

Action to take before harvest to reduce the risk of mold contamination and mycotoxin production should be based on the use of certified seed or ensure that seed is free from fungal, bacterial or viral infection; avoid drought stress — irrigate if possible; sow seed as early as possible so that crop matures early; if practicing minimum or zero tillage remove crop residues; control insect, mammal, bird and virus pests; rotate crops; avoid nutrient stress (FAO, Food and Agriculture Organization of the United Nations, 2007).

Action to take during harvest to reduce the risk of mold contamination and mycotoxin production should be based on harvest as quickly as possible; avoid field drying; transport the crop to the homestead as soon as possible; dry on platforms raised above ground; bundles of stover should also be placed on platforms to dry and not left to lie on the soil (FAO, Food and Agriculture Organization of the United Nations, 2004, 2007).

Action to take after harvest to reduce the risk of mold contamination and mycotoxin production should be based on drying (crop should be spread on a polythene sheet, tarpaulin or empty sacks laid on the ground or on a concrete plinth; unhreshed crop can be laid on a platform or in a ventilated crib to dry; cobs can also be tied in pairs and suspended from a vertical frame to dry; in wet or humid conditions crop should be artificially dried in a solar dryer), threshing, shellimg, winnowing (handle crop carefully to avoid broken or damaged grain; avoid beating the crop with sticks as this creates lots of damage leading to mold development unless the grain is to be used quickly and not stored) and storage (store grain in a suitable container which is raised above ground level or to do a suitable waterproof barrier; protectant ingredients. 

Permissible limits of mycotoxins in food for humans, animal feed and animal feed ingredients and processed animal protein are suitable alternative feed-stuffs for fish feeds in aquaculture practice. According Guan et al. (2009), the discovery of the mycotoxin-transforming microorganisms may provide new opportunities for managing mycotoxin problems in aquaculture.

8. Conclusion

Mycotoxins can be considered among the most potent causes of cancer. Ingestion through the diet can pose chronic health risks that may result in liver and kidney disease and a suppression of the immune system. This review shows that in spite of inevitable and widespread, the presence of mycotoxins in feeds of fish cannot be neglected, as revealed by the sight of many researches, field outbreaks reports and pathologies related to mycotoxins, mainly because toxic effects and safety levels of mycotoxins in the different species of fish, are known on the surface.

It's necessary to keep a standard to perform the tests in relation to duration of the experiment, because the toxic effect of mycotoxins may be dependent of the type and quantity of mycotoxin content in the feed, but also depends on the duration of exposure, animal species, sex and age.

An approach on the occurrence of mycotoxin-contaminated animal feed, as well as toxic effects that mycotoxins may produce in fish and their residues in meat and organs are outlined in this review. The mycotoxins of most concern from a food safety in products of animal origin in perspective include the aflatoxins (B1, B2, G1, G2 and M1), ochratoxin A and toxins produced by Fusarium molds (FB1, FB2, and FB3); trichothe- cenes like deoxynivalenol, T-2 and HT-2 toxin and ZEN), but in studies with different species of fish, the mycotoxin most studied is the AFBs. The consequences of mycotoxin contamination in fish feeding does not differ from other animal species intended for human consumption and it is directly related to losses in production, especially in reduced weight gain and feed conversion, but also, immune impairment and organ lesions are found; therefore, it is necessary to be extremely careful in concern to the production and storage of animal feed. Further studies should evaluate the effects of foodborne mycotoxins on health and productivity of economically important or not fish species, with the goal of elucidating the public health risks.

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References


