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Review

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.

Contents

Abbreviations: AFB, aflatoxin B; AFB_1, aflatoxina B_1; AFB_1/G_1, aflatoxins $B_1 + G_1$; AFG_1, aflatoxin G_1; AFG_2, aflatoxin G_2; AFM_1, aflatoxin M_1; AF_S, total aflatoxins; AGA, agaric 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; FB_1, fumonisin B_1; $FB_{1/2}$, fumonisin $B_1 + B_2$; $FB_{1/2/3}$, fumonisin $B_1 + B_2 + B_3$; 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 (Frenich et al., 2014). Therefore, international organizations, like Food and Drugs Administration (FDA, Food and Drugas 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 overage 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