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About Fungi, Mycotoxins and Food Safety

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Abstract: *The alimentation is considered a basic necessity for humanity. However, to meet this need, foods can be carriers of various components physical, chemical or biological harmful to health. As biological components are bacteria, viruses, parasites, fungi or substances result of their metabolism, capable of generating diseases when ingested. Fungi are cosmopolitan organisms with the ability to grow on various substrates including food intended for human and animal consumption, thus generating different substances called mycotoxins the most highly harmful effects (carcinogenic, immunomodulatory, nephrotoxic, necrotic, estrogenic among others) to health when consumed; so these toxins are classified as a topic of great interest in areas of food safety, public health, animal health and productivity in the livestock industry and agriculture. The present document it is focused on providing an overview about foodborne diseases, mycotoxins and producing organisms, their impact on human and animal health when consumed, control measures and prevention of food contamination with these toxins, permissible limits as well as their detection and quantification analysis in the laboratory.*
Keywords:*Food safety, foodborne illnesses, fungi, mycotoxins, mycotoxicosis.*

I. Introduction

1.1. Foods and diseases

The alimentation is considered both a fundamental worry and a necessity of the human being [1]. The foods are the products, natural or processed, which are consumed by the living beings that provide to an organism of nutritional substances and the vital energy for its growth and maintenance [2]. However, the foods can be carries of several diseases due to its ingestion when those are contaminated with different causal agents (physical, chemical or biological), affecting them individual or collectively. The foods' contamination can take place in any stage of the food chain, from the production, transportation, storage, distribution, and to its consumption[3,4,5]. The food transmission diseases are classified by: 1.-Poisoning generated by the ingestion of toxins developed in vegetal or animal tissues, or by microorganisms' metabolic products (Bacteria or fungus) in foods or chemical substances that are added by intentional, incidental or accidental manner in the production or in its consumption. 2.-Infections caused by the consumption of biological contaminated foods or water (Bacteria, viruses, fungus and parasites) which can multiply inside the intestines and produce toxins or can invade the intestinal wall and, afterwards, reach other organs[4].

The foodborne illnesses (FIS) are considered an important threat to the public health around the world due to its incidence, the emergence of new transmission ways, the appearance of vulnerable population groups, a rising in the pathogens' resistance to antimicrobial compounds and the socio-economic impact that they generate [3,6]. The World Health Organization (WHO) points that, in developing countries, the FIS are the main cause of sicknesses and deaths, associated to a heavy socio-economic charge. Meanwhile, in the developed countries, FIS generate high levels of reduction in productivity, costs associated to health services, and the implementation and tracking of policies of safety in foods. Only in the USA, it's estimated that around 76 million of persons every year get sick of any FIS, from those, 325,000 are hospitalized and 5,000 die, resulting such in expensive costs in the health field [7]. Most of the FIS are associated with acute gastrointestinal symptoms, such as diarrhea, vomit, septic shock, headaches, fever, double vision, among others, being those a severe and deadly problem, especially in kids, unchaining other chronic diseases [3,6]. The incidence of the aforementioned diseases is a direct indicator of the sanitary-hygienic quality of the foods. The FIS microorganisms' control, like the detection or the research of the outbreaks, constitute a challenge for the Public Health System, since it requires the obtainment, in an opportune and efficient fashion, of medical information (personal data, symptoms, etc.) and foods laboratory analysis' methods, raw materials used in its making, and even, the personnel involved in the manipulation of the food [3].

The present document it is focused on providing an overview about foodborne diseases, mycotoxins and producing organisms, their impact on human and animal health when consumed, control measures and prevention of food contamination with these toxins, permissible limits as well as their detection and quantification analysis in the laboratory. All the previous is in favor of the importance about the knowledge and control of these kinds of toxins and its relation with the food safety.

1.2 Fungus and its generalities

The fungus are microorganisms widely spread in the nature, they are considered eukaryotes, heterotrophs, generally multicellular, aerobics and mesophilic; they can grow in an ample range of temperature (5-45°C); its cells form a branched, filamentous mass (hypha), called mycelium, that forms part of the main body of the fungus, its nutrition can be saprophyte (decomposers) or parasites (pathogens), generating diseases to plants, animals and the human; they possess a cellular wall but they don't possess chlorophyll, therefore, they don't execute photosynthesis; they can tolerate high concentrations of solutes, as well as pH extreme conditions (2 to 8), and its reproduction can be either sexual or asexual, through the generation of spores [8,9,10]. Since those organisms are saprophytes, they contribute to the decomposition of the organic matter, as well as the fertility of soils, but also they are responsible for the deterioration of the foods by generating mycotoxins, which give rise to negative effects for the health through intoxications, called mycotoxicosis, when foods contaminated by fungus are eaten [8,11]. However, in like manner, these fungal organisms intervene in the production of different foods (beer, cheese, bread, wine, etc.), and other products of economic and health importance, that's the reason of the importance of the studies around those organisms.

1.3 Mycotoxins and mycotoxicosis

The mycotoxins are secondary metabolites of low molecular weight generated by fungus during the stationary phase of growth, and are frequently associated with the differentiation and the sporulation; these compounds are located in the fodder, ingredients, raw materials and/or finished foods in their conjugated, soluble or incorporated to macro-cells forms (united mycotoxins). When ingested, inhaled or absorbed via cutaneous and metabolized by P450 cytochrome enzymes (CYP450), belonging to the family of enzymes related to the biotransformation of endogenous products and xenobiotics, provoke different alterations and non-infectious pathologic or contagious diseases in the human or the animals known a*s* mycotoxicosis[12,13,14,15,16,17,18]. The mycotoxicosis can be present in three ways: 1) The acute primary, occurring when moderated or enormous amount of mycotoxins are consumed, showing specific symptoms of toxicity; 2) The chronic primary, generated by the low or moderated consumption of mycotoxins, having a decreasing in the gain of weight and the efficiency of the reproduction, and 3) The secondary diseases by mycotoxicosis as a result of low consumption of mycotoxins that, even though the aforementioned don't cause a mycotoxicosis, they favor infectious diseases due to the decreasing of the immune efficiency [16].

It's important to mention that the function of the toxins generated by fungus has been labeled as defensive (bactericides and fungicides), since they maintain the environment of the fungus free of competitors, securing the viability of new generations of spores, maintaining ideal habitats for reproduction. Besides, it has been proved that not all the mycotoxins are dangerous; some of them are beneficial for the human and animals, being the base of the anti-biotherapy[17].

Those compounds generated by the fungus establish a worldwide public health problem, due to its incidence and frequency in foods destined to the human and the animal consumption [19]. Therefore, the warranty of food safety is consider a challenge for the producers and marketers, as well as a big responsibility in matters of health by the corresponding authorities, the contamination by mycotoxins in foods. Besides the repercussions in the health, it also affects, negatively, in the farming and the livestock economies, harming the availability of products and commercialization [14, 20]. The group of mycotoxins is enormous. It contains more than 300 different types. However, among the ones with the most toxicity, that are associated to health problems in humans and animals, are: aflatoxins, ochratoxins, fumonisins, trichothecenes and zearalenones, produced mainly by the species of the genres *Aspergillus, Penicillium*and *Fusarium*. Those colony and poison substrates like: corn, wheat, barley, rice, sesame seed, peanut, and some other destined to the feeding(Table 1). In fact, it's estimated that 25% of the world production of cereals is contaminated, as well as spices, herbs for teas, fruit, nuts, seeds and their derivate[12, 14,17,19,21,22].

The contamination by fungus and the generation of mycotoxins in foods can occur in the different stages of the chain food, since the crop fields, when harvesting, transporting, storing until favorable conditions or in the processing of the food, because since the mycotoxins are thermos-tolerant, they persist in processes such as grinding and/or washing [20,23].

These toxic compounds have isolated from some foods or raw materials and are considered one of the main foods' pollutants, either for human or animal consumption. In animals, the signs of toxicity are so diverse as the species of producer fungus, but it's worth to mention that its toxicity, acute or chronic, will depend on some factors like: the amount of ingested toxins, time of ingestion, type and race of the animal, age, gender or sanitary estate, and even another parameters as the density of animals, another diseases or temperature. So, the mycotoxins are one of the main causes of important economic losses in farms due to its reduction in productivity, increasing in the cases of illnesses, chronic damage in vital organs and reduction of reproductive efficiency [17].

Among the susceptible foods to contamination and accumulation of fungal toxins, the ones with the highest frequency are: cereals, products derivate of cereals, legumes, andgreen, fibrous aliments (Grass, silage, hay, and straw) destined to animal feeding.Related to the green aliments, we have to consider the indirect human contact through products derived from animals, such as: meat, eggs and milk, being this (Milk) the most sensitive to a mycotoxins contamination, specifically aflatoxins, which represents a danger, especially among the children population; therefore, the animals producers of milk shouldn't eat from contaminated fodders, and it is necessary a sanitary quality control in fodders' factories. On the other hand, different products for human consumption that have registered cases of fungal contamination and cases of mycotoxins are: dry fruits, fruits and vegetables, coffee, wine, cereal flakes, bread, confectionery, and bakery. Those present an inadequate preservation or long periods of storage [14,17,23].

The production of mycotoxins in foods depends on some factors, as the number or producer strains can variate in relation with the mycotoxin. The production of these secondary metabolites in food will depend, not only on the genotype of the strain, but also on environmental factors, such as: humidity, water activity, temperature, aeration, pH, mechanical damages, insects and mites, storage time, genome of the host plant, and the competitive microbiota; all of them will influence in the growth and the metabolism of the producer strain [12, 14, 17, 24]. The fungal toxins have been classified according to their affinity with certain cellular organelles, defining their toxicological features and metabolic transformations as follows: a) Inhibitors of the production of energy: It acts by stopping the activity of the ATPase, and also stopping the cell oxidative phosphorylation; b) Inhibitors of the synthesis of proteins: It stops, either the beginning of the synthesis or the elongation and end of the protein, and others stop, in a competitive fashion, the activity of the Phenylalanyl-tRNAsynthetase; c) Modifiers of the cytoskeleton, that changes the functions of the microfilaments and the cell microtubules; d) Estrogenic, which generate responses of mass growth inside the utero and alterations of surrounding levels of hormones; e) Generators of tremors (tremorgens), acting in the central nervous system, leading to general tremors; f) Cancerous, that provoke a development of tumors in the liver and the renal cortex [25].

Table 1.- Fungi producing major mycotoxins of interest in food and health

Mycotoxins	Fungus	Organ attack and effects on health	Foodsource	Biologicalactivity
Aflatoxins B1,B2,G1,G2	*Aspergillus flavus* *Aspergillus parasiticus* *Aspergillus nonius* *Aspergillus niger* *Aspergillus ruber* *Aspergillus fumigatus* *Aspergillus terreus* *Aspergillus candidus* *Penicilliumfrecuentans* *Penicillium variable* *Penicilliumpuberulum*	Liver Carcinogenic Immunosuppression	Peanut Pistachio Nuts Corn Cotton seed Cereals	Inhibition of protein synthesis carbohydrate and lipid metabolism Induction of lipid peroxidation Formation of glucuronates
Trichothecenes Toxin T-2 Toxin HT-2 Diacetoxicirpenol (DAS) Nivalelol (NIV) Deoxynivalenol (DON) Fusarenon-X	*Fusarium avenaceum* *Fusarium tricinctum* *Fusarium poe* *Fusarium culmorum* *Fusarium equiseti* *Fusarium acuminatum* *Fusarium sporotrichioides* *Fusarium roseum* *Fusarium cerealis* *Fusarium nivale* *Fusarium moniliforme* *Gilerellazeac*	Multipleorgans Skin Hepatotoxic Immunosuppression Neurotoxic Necrosis Reduction in nutrientabsorption	Barley Oats Rice Rye Sorghum Saffron Mixed food Brewersgrains Wheat Corn	Inhibition of the synthesis of ceramide synthetase. Disruption of lipid metabolism and accumulation of the natural substrates sphingin, sphingosine and its equilibrium forms. Cellcyclealteration
Ochratoxin A,B,C,α y β	*Aspergillus ochraceus* *Aspergillus alliaceus* *Aspergillus melleus* *Aspergillus ostianus* *Aspergillus petrakii* *Aspergillus sclerotiorum* *Aspergillus sulphureus* *Aspergillus albertensis*	Kidney Nephropathy Immunosuppression Renal and hepatic carcinogenesis	Vegetables Cereals Coffee	Inhibition of protein synthesis and ATP

	Aspergillus auricomus *Aspergillus circumdati* *Penicilliumaurantiogriseu m* *Penicilliumcyclopium* *Penicilliumchrysogenum* *Penicilliumexpansum* *Penicilliumvariabile* *Penicilliumpurpurescens* *Penicilliumverrucosum* *Penicilliumviridicatum*			
Fumonisins B1, B2,B3	*Fusarium verticilliioides* *Fusarium proliferatum* *Fusarium anthophillum* *Fusarium globosum* *Fusarium liseola*	Esophaguscancer Livercancer Neurotóxic	Corn Sorghum Rice Asparagus Beer Beans Garlic	Inhibition of celular enzymes
Zearalenone	*Fusarium graminearum* *Fusarium culmorum* *Fusarium sporotrichioides* *Fusarium equiseti* *Fusarium cerealis* *Fusarium verticiilloides*	17-β-estradiol receptor organs Early puberty Enlargement of reproductive organs Fertility impairment	Corn Wheat Oats Sorghum Sesame seed Hay Silage	Binding to estrogen receptors Bioactivation of reductases
Cyclopiazonicacid	*Aspergillus flavus,* *Aspergillus oryzae* *Aspergillus caelatus* *Penicilliumgriseofulvum* *PenicilliumchrysogenumPenicilliumviridicatumPenicillium commune*	Precursor and synergistic toxin with aflatoxins	Corn Peanuts	Inhibition of intracellular calcium transport through the enzyme ATPase-Ca +
Citrinin	*Aspergillus terreus* *Penicilliumcitrinum* *Penicilliumexpansum* *Penicilliumverrucosum*	Nervous system Neurotoxic Nephrotoxic Renal degeneration Carcinogenic	Rice Cereals Fruits	Alterations of mitochondrial function decreased ATP
Patulin	*Penicilliumexpansum* *Penicilliumclaviforme* *Penicilliumpatulum* *Penicilliumvulpinum* *Aspergillus clavatus* *Aspergillus terreus*	Neurotoxic Mutagenic	Apples Juices Grapes Other fruits	DNA and protein synthesis inhibition, Plasma membrane disruption, Inhibition of urease
Moniliformina	*Fusarium moniliforme* *Fusarium acuminatum* *Fusarium avenaceum* *Fusarium oxysporum*	Heart Cardiotoxic Degeneration of muscle fibers	Corn Rice Wheat	Carbohydrate metabolism, Inhibition of oxidative decarboxylation of pyruvate
Penicillinacid	*Aspergillus ochraceus* *Penicilliumpuberulum,* *Penicilliummartensi* *Penicilliumpalitans* *Penicilliumcyclopium*	Subcutaneous tissue Subcutaneous sarcoma Cytotoxic Hepatotoxic Carcinogenic	Wheat Corn Meat Flour Orange juice	Alteration in nucleic acid synthesis Enzymatic Inhibition
Tenuazonicacid	*Penicilliumgriseum* *Penicilliumexigua* *Penicilliumsorghina* *Alternariaalternata* *Alternariacitri* *Alternaría japonica*	Hemorrhages in various organs Hematologic disorders	Olives Apples Citric fruits Tomato Sorghum Seeds of oilseeds	Inhibition of proteinbiosynthesis
Ergotalkaloids Ergotamine Ergonovine Metisergida Pergolide Bromocriptine Ergocristine, amongothers	*Claviceps purpurea* *Claviceps africana*	Nervous system Seizures Headache Vomiting Tremors Hypotension Gangrenas	Rye Wheat Barley Rice Corn Sorghum Oats	Agonism and antagonism of alpha adrenergic receptors, dopaminergic and serotonergic; Direct action on receptors of smooth muscle, including

				myometrium
Alternariol Alternariolmonomethylether	*Alternariaalternata* *Alternatasolani* *Alternariacitri*	CarcinogenicMutagenic Citotóxic	Melons Apples Blackberries Strawberries Raspberries Grapes Raisins Oranges Lemons Mandarins Nuts Olive Oats Feed Seeds of oilseeds	Estrogenic potency and inhibitor of cell proliferation in vitro
Esteringocystine	*Aspergillus versicolor* *Aspergillus flavus* *Aspergillus sydowi* *Aspergillus nidulans* *Penicillium luteum*	Subcutaneoustissue Hepatotoxic Hepatocarcinogenic	Rice Barley Wheat Cereals for breakfast Coffee Corn Cheese Soy	Precursor of aflatoxins

[11,12,13,17,19,21,22,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39].

In general terms, the risk of acute poisoning by mycotoxins in a human body is low or moderate, compared to those toxins of microbiological origin or chemical contaminants. However, high levels of consumption of mycotoxins on a diet can cause adverse, chronic and acute effects in a human's health and also in a great variety of animal species [13]. Experimental tests made with fungal toxins, and performed individually, allow the researchers to know the pathological panorama specific for each mycotoxin; however, in natural conditions, the mycotoxicosis are generated by two or more toxins and many of the symptoms and injuries are mixed, due to different toxins establishing relations of synergy and antagonism that favor or weaken the pathogenic effects. The adverse effects may affect several organs, or systems, with a special emphasis in the liver, kidney, nervous system, neurologic system, endocrine system and immune system. We can generalize a series of common symptoms for the proper identification of any outbreak in animals, and those are: rejection of the fodder or food, a delay or stop in the growth, a decreasing in the gain of weight, a bad rating of transformation, a deficient feathering, uneven packs or herds, a reduction in the productions of meat, eggs and milk, fertility problems, abortions, hatchability problems, disturbances in the quality of the eggshells, effects in gastroenteritis, immunity, paralysis, paresis, convulsions and mortality [13,17].

1.4 Mycotoxins in foods around the world

According to the FAO, approximately, 25% of the worldwide production of foods is contaminated, in one grade or another, with mycotoxins, being the agricultural and livestock sectors the ones that present the highest economic impact; however, the incidence of their contamination and their concentration are variable, depending on the season of the year and the geographic area [16,40].

Due to the meaningful and toxic character of the mycotoxins and to its incidence in foods, regulations have been established around the world, being Latin America, with the 91% of the population in the region, the part with specific regulations in the matter of mycotoxins [41]. On the other hand, Europe has more detailed and more extensive regulations in the topic of mycotoxins in foods, therefore, Europe has more harmonized regulations for aflatoxins in a wider variety of foods [41]. So, the European commission has established maximum limits that are gathered in different regulations released, such as: the 1881/2006, from December 19th, 2006 (http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2006R1881:20100701:ES:PDF), [42]. the1126/2007, from September 28th, 2007 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:255:0014:0017:ES:PDF), [43]. the 165/2010, from February 26th, 2010 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:050:0008:0012:ES:PDF), and the 105/2010, from February 5th, 2010 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:035:0007:0008:ES:PDF) published in the Official Journal of the European Union, and in which the maximum contents of some foods are displayed (Table 2)[21,23]. Nevertheless, there are different mycotoxins that don't have legislated levels yet, like those produced by the genre *Alternariaspp*; it's from herethat the medical interest become relevant and the importance of the researches about this and some other types of mycotoxins is great [21]. In some countries, it has been made a tracking in the content of mycotoxins in foods destined to the human and animal consumption. In Europe, countries like Serbia have carried out researches in harvested corn from the main crop areas in 2012, showing a frequency of contamination with aflatoxins equivalent to a 29.5%, with intervals of concentrations from 50 to 90 µg/Kg [44]. In Asia, countries like China holder of both an ancient tradition and a high production of cereals like the rice, has conducted to tests, in the period from 2009 to 2011, to discover mycotoxins, aflatoxins and ochratoxins, in six (6) provinces in the southern part of the Asian country, showing a content of aflatoxins in an interval from 0.030 to 21 µg/Kg, and for the ochratoxin, an interval from 0.30 to 3.2 µg/Kg [45]. In Latin American countries, like Peru, studies have been carried out to quantify the level of mycotoxins in foods, as well as in foods' ingredients intended for animals feeding, especially in birds; those studies showed that 66.2% of the corn samples, and 71.9% of soy cake samples were contaminated with ochratoxin, being the highest values 7.78 and 5.59 parts per billion (ppb), respectively [11]. Likewise, 67.4% of corn samples and 88.9% of soy cake samples possessed certain levels of contamination with T2 toxin (Trichothecenes), being the highest values 79.41 and 47.33 ppb, respectively [11]. On the other hand [46] reported that the mycotoxins with a major relevance for the poultry production in Brazil are aflatoxins, deoxynivalenol and fumonisins. For these three mycotoxins, the positivity in the samples analysis is higher than 40% and the concentration average found in those are 11.8 ppb, 233.7 ppb, and 1073 ppb, respectively; it means that almost half of the analyzed foods present contamination by mycotoxins. It's important to point out that the presence of mycotoxins in supplied foods to the birds or other animals may have repercussions in significant losses in the economic and productive sectors in livestock.

In Mexico, the incidence data and the levels of contamination by mycotoxins in foods are limited due to various factors, among which are the available resources for researching, ease in the laboratories to perform the analysis, adequate procedures when gathering the samples, and sensitivity to the used quantification methods. In the variety of mycotoxins, six (6) are consider important, from the food point of view: Ochratoxin A, zearalenone, patulin, deoxynivalenol, fumonisins and aflatoxins [31]. Some studies conducted in Mexico have been made in cereals such as the corn (*Zea mays L.*), consider as a native plant, and also, as the most important crop nowadays destined to the human and livestock feeding, and industrial use [37,47]. However, this cereal is affected in the fields and during storage by fungus producers of mycotoxins like the *Aspergillus spp.*, *Fusarium spp. AndPenicilliumspp*. [47]. Studies carried out in the detection and quantification of mycotoxins in diverse geographic areas, like Monterrey city, showed that some corn sampled gathered in different distribution points contained aflatoxin B1, in a range from 5.03 to 465.31 ng/g, and aflatoxin G1, in concentrations from 1.59 to 57.1 ng/g, where from 41 analyzed samples, 87.8% were contaminated with aflatoxins, and 58.5% contained levels above of those permitted levels [37].

Another study carried out by Arrua and associates in 2012 [47] was about the pollution by fungus potentially toxicogenic (*Aspergillus flavus*, *Aspergillus parasiticus*, *Fusarium spp. AndPenicillium spp*.) in corn grains of fourteen (14) different geographic zones in Mexico, and through samples of 1Kg of white, yellow and colored types of corn, randomly collected from the field, silos and leftovers of crops from different points in the states of Sonora, Coahuila, Nuevo León, Tamaulipas, Zacatecas, Jalisco, Nayarit, Michoacán, Hidalgo, Guanajuato, Veracruz, Chiapas, Quintana Roo and Oaxaca, and from the northern, central and southern parts of the country. It reported that the potentially toxicogenic funguses are widely spread in the analyzed samples. *Fusarium* was present in the 76.99% of the aforementioned samples, *Aspergillus flavus*, 11.72%;*Aspergillus parasiticus*, 0.57% and *Penicillum spp.*, 0.53%. The highest incidence of fungus potentially toxicogenic was obtained in samples collected in Guanajuato and Quintana Roo, showing *Fusarium* genre micro-organisms having an incidence of 100% in tasted grains. Meanwhile, *Penicillum spp.*, presented a higher incidence in the samples collected in Chiapas, *Aspergillus* presented a higher incidence in Hidalgo, and the lowest incidence was present in the samples from Sonora. The conclusion of such study determined that the fungus potentially toxicogenic, from the genres *Aspergillus spp.*, *Fusarium spp.*, and*Penicilliumspp*., are widely spread in corn grains coming from different places in Mexico. However, it's important to point out that the aforementioned incidences are not necessarily related to the production of fungal toxins. Besides, the potential effect of those toxics is accumulative inside the biological, exposed systems or the consumers of contaminated grains, whereby it gains a great importance the development of regular tracking in the fields and storage with the purpose of reducing the risk when consuming contaminated corn, specifically in strati economically disadvantaged, in where the consumption of corn is basic [47].

Table 2.-Mycotoxins present in certain foods and maximum permissible contents according to the regulations of the European Commission

Mycotoxins	Maximum permissible contentsμg/Kg	Foodsource
Total Aflatoxins B1,B2,G1,G2	15	Peanuts, almonds, pistachios, hazelnuts and oilseeds
	10	Raisins, soluble coffee, apple juice
	4	All cereals and cereal products
	10	Maize and rice that are going to undergo a process of Selection or other physical treatment prior to direct human consumption or its use as ingredients of foodstuffs
Deoxynivalenol (DON)	1750	Unprocessed durum wheat and oats
	500	Bread (including small bakery products), cakes, biscuits, cereal snacks and breakfast cereals
OchratoxinA	5	Roasted coffee beans and ground roasted coffee, excluding soluble coffee
	2	Grape juice, reconstituted concentrated grape juice, grape must, grape must and reconstituted concentrated grape must, intended for direct human consumption.
Total fumonisins B1, B2	800	Corn-based breakfast cereals and corn snacks
Zearalenone	100	Maize intended for direct human consumption, corn snacks and cereals for breakfast based on corn.
Patulin	50	Fruit juices, reconstituted concentrated fruit juices and fruit nectars

[42,43]

In matters of sanity regulations, Mexico has developed a series of normativities to regulate the incidence of mycotoxins (aflatoxins) in cereals indicating the specs y test methods in the laboratory for the mycotoxin analysis in different raw materials and food products, like the NOM-247-SSA1-2008 corresponding to products and services, cereals and their products, cereals, cereal flours, grits or semolina, or their mixings, bread making products, sanitary and nutrimental dispositions and specs and tests methods. The normativity also points the cereals must not exceed 20 μg/kg of the total amount of aflatoxins. The Mexican official normativity NOM-187-SSA1-2002 is focused on products and services related to mass, tortillas, tostadas, prepared flours ready to be elaborated and establishments where it's processed, sanitary specs, commercial information, tests methods, and also provides a maximum limit to the aflatoxins of 12 and 20 μg/kg in the nixtamalized corn tortillas and wheat tortillas, respectively. And the normativity NOM-186-SSA1/SCFI-2013 focuses on the cocoa, chocolate and similar products and derivate, sanitary specs, and commercial designation, indicating a maximum of 20 μg/kg in the number of aflatoxins.

However, there are still no regulations for the aflatoxins as there are for mycotoxins like fumosins andochratoxins, which can be found frequently in agricultural products, and even, specific aflatoxins like the B1, or the M1 in dairy products. It is essential an implementation of studies to generate an appropriate knowledge about these and other mycotoxins, and also be able to develop and validate actions for handling these harmful substances in various foods, along with the proper regulator legislation [37] . Before this, it's important to consider various comments released by some researchers in the matter of the legislation about mycotoxins; they mention it might be difficult to accomplish such target due to a series of factors, like the availability of toxicological data, incidence of mycotoxins in various foods, homogeneity of mycotoxins in food samples, availability of analytic methods to control the minimum detectable concentrations of mycotoxins, proper legislation in countries with commercial nexuses, and the need of enough supply in some countries in the matter of foods [48].

1.5 Mycotoxins in laboratory analysis

The detection and quantification of mycotoxins in foods destined to human and livestock consumption is made by thin-layer chromatographic methods (TLC), due to its high accuracy and sensitivity, which has been very popular to perform quantitative or semi-quantitative determinations, its high performance in the number of samples that can be processed, its low operative cost, ease of compounds' identification (ultraviolet or visible light), high performance liquid chromatography (HPLC) which consists on using different columns (normal and reserve phases) depending on the physical and chemical structure of mycotoxins for separation and purification. The most commonly found detection methods are: fluorescence or UV detectors depending on the presence of a chromophore inside the molecules, having as a result: high performance liquid chromatography with fluorescence (HPLC-FL), with a detector of diodes' arrangement (HPLC-DAD), with a detector of masses spectrometry (HPLC-EM), and the methods using gas, used to identify and quantify the presence of mycotoxins in foods and cereals of livestock usage. This chromatography is generally associated with the EM, the flame ionization detector (FID) o the electrons capturing detector (ECD). Mostly of mycotoxins are not volatile, so they have to be derivative previously (Silylation or polyfluoroacylation reactions) for the obtaining of volatile compounds. These methods are combined with extraction and pre-purification in phases solid-liquid, liquid-liquid, supercritical fluids, liquid-liquid dispersive, liquid-liquid dispersive with ionic liquids, solid dispersive, microwave assisted extraction, or immune-affinity columns. To eliminate interferences, there are immunoenzymatic methods, like the Enzyme-Linked Immunosorbent Assays (ELISA), based on the capacity of a specific antibody to distinguish the tridimensional structure of a determined mycotoxin, and which can be performed without purification, but they have to be reinforced with one of the aforementioned methods [13, 14, 18, 22, 49].

Besides, it has to be considered a new sampling program with the following recommendations: the distribution of the concentration of mycotoxins is an important factor to take into account when adopting mandatory sampling criteria for products. In such fashion, the distribution can be very heterogenic in some of them and, if the appropriate cares are not taken the concentration in the inspected batches can be mistakenly estimated [22, 29, 46, 49].

In order to improve the efficiency and the representativeness of the analysis results, recommendations can be taken during the sampling, per example: 1. Sampling with a greater weight and a greater number of points of sampling; 2. Sub-sampling with an increase in size (weight) of the sub-sample, or by the reduction of particles due to grinding processes; 3. An analysis of a bigger number of samples; 4. The sample should be taken as close as possible from the place where the poisoned animal was fed (feeders); 5. The obtainment of blood samples and organs tests ease a retrospective analysis of some contaminations, mainly in situations where availability of foods is involved; for example, mycotoxicosis by ochratoxinA is visible inside the blood until 35 days after the ingestion; 6. Identification of the compound (or compounds) in the contaminated food in which mycotoxins are detected in the balanced food; finally, when the sampling is over, the sending to the lab must be as soon as possible and the material should be placed in a resistant packing. When the precedence of the samples are from far geographic zones, it is recommendable the use of air transportation. It’s important to point out the time of transportation shouldn’t exceed the 48 hours [46].

1.6 Foresight and control

The contamination in foods destined to human and animal consumption by mycotoxins is mainly because of the contamination in vegetable origin products due to the growth of toxicogenic fungus. The mycotoxins are very stable compounds (They are not destroyed by fire) hard to eliminate from the foods once they have been generated [14]. The methods to control these harmful molecules of fungal origin can be classified into two main categories: 1. the foresight of contamination and fungal growth and 2. The detox or decontamination of the harmful compounds produced by the fungus[29].

The prevention of the fungal growth and contamination by mycotoxins include: 1. At field level, the good agricultural practices consisting on crop rotation, proper suitable of soils, insects and plague control, irrigation and use of in a variety of resistant plants to the fungus’ invasion. During the harvest, the products must be gathered in a state of optimal maturity to avoid mechanical damages. In the season post-harvest, like in the storage, it must exist a control in the environmental temperature, humidity and aeration; those factors affect the fungal metabolism and its capacity for growth and production of its metabolites [14, 29, 46]. The contamination in the crops may be prevented on decreased using acids such as the benzoic, sorbic, propionic, formic and acetic, as long as it’s taken into account the concentration of the acid, the pH of the product, the amount of water inside the product, uniformity of distribution of the acid, since it can generate the opposite effect and risk of increasing the toxicogenic capacity of particular fungus[29]; 2. Good practices in fabrication, which are adequate of hygiene and manipulation during the packing, storage, transportation and production of the food and contaminated fooders, with the purpose of reducing, as much as possible, the level of mycotoxins in the food [23]. Some of these measurements are: Tracking of humidity and mycotoxins in ingredients with a high rate of risk, dry and aeration of the cereals and vegetables sub-products during the bulk storage, rejection of ingredients with evident signals of fungus invasion, handling of inventory of ingredients under the “first in- first out” concept, addition of inhibitors of fungus inside the aliment [25]; 3. The implementation of a Hazard Analysis and Critical Control Points (HACCP) system which can identify the most sensitive stages in the contamination by mycotoxins process of food and fodders, adopting control measurements to reduce and/or avoid the contamination [23,50]; 4. Genetic Engineering, where the genome of the plants plays a determinant factor on the fungal contaminations and later biosynthesis of the mycotoxins.That’s the very interest for developing new varieties capable of resisting the fungal attack and/or inhibits the production of toxins [29]; 5. A proper handling of the food used at farm level through some actions like: proper protection of the food against environmental factors, especially the humidity, a rapid rotation of the received food, establishment of a cleanse program and decontamination in the storage warehouses [25].

The most effective way to control the control the contamination by mycotoxins is prevention. However, when the food is used and it presents such contamination, it becomes imperative it's decreasing/elimination [29]. Among the decontamination or detox methods are: 1. Physical methods, involving procedures like selection and elimination of contaminated food, searching by fluorescence of mycotoxins produced by different fungus, especially the *Aspergillus flavus* type; radiations (microwave, gamma, UV and X rays), and heat (very inefficient if used alone); 2. Chemicals (allowed in animal feeding only) like organic solvents, acids, alkalis oxidizing agents (ozone, peroxide of hydrogen), reductive agents (bisulfites), chlorinated agents, formaldehyde that degrades or biotransforms the mycotoxins, and finally the adsorbent agents, substances with a great molecular weight capable of joining the mycotoxins found in foods, avoiding its dissociation; either by physical adsorption, easily reversible due to weak van der Waals interactions and hydrogen links, or chemical adsorption, or irreversible chemisorption due to strong interactions through covalent or ionic links, the mycotoxin-adsorbent complex goes through the intestinal tract of the animal and it's eliminated via the feces (activated carbon, diatomaceous earth, polymers of polyvinylpyrrolidone, clays, synthetic silicates, fibers of plants, extracts of cell walls from yeast and bacteria); in livestock, the usage of silicates with absorbent features mixed with the food is a very spread method to block mycotoxins [14,16,29,40,51] and 3. Microbiologic, where bacteria, fungus, yeast, and even enzymes, such as *Flavobacterium aurantiacum, Corynebacterium rubrum, Aspergillus níger, Trichoderma viride, Mucorambigús, Trichosporonmycotoxinivorans*, proteaseA of *A. niger* and swine pancreatin, can metabolize and biotransform those harmful compounds with the modify of the structure of aflatoxins B1, ochratoxins, zearalenone, among other, although this phenomenon is slow and minimally efficient [29,40,51].

1.7 Ecologic alternatives of prevention and control

The most efficient way to control the contamination by mycotoxins in foods is minimize, as max as possible, the presence of fungus in products. This control has been carried out with the application of chemical substances with a fungal nature; however, during the last few years, its application has been limited due to environmental, human and animal health. All of the aforementioned is in correlation with the emergence of fungicide-resistant strains of wide spectrum [52].

Due to that, the research and development of new control methods of toxigenic fungus has become a priority in order to secure mycotoxins-free foods. Among the control methods are: the use of antioxidant natural compounds (curcumin) and the use of extracts of plants such as the lavender (*Lavandulalatifolia*) and the Spanish sage (*Salvia lavandulifolia*), capable of controlling the growth of some toxicogenic fungus species and, in some cases, they also interfere with their ability of producing mycotoxins like *A. steynii* and *A. westerdijkiae*. The biological control, which is the usage of antagonist microorganisms against plants' pathogens, is considered a potential alternative to the use of fungicides to prevent the formation of mycotoxins. Before this, some species of yeasts have been selected for their capacity of inhibiting the growth of toxicogenic fungus, turning them into perfect candidates for biological control, like the *Debaryomyceshansenii* CYC 1244 against *A. westerdijkiae*, that interferes in the biosynthetic route of theochratoxin, and also against the *A. parasiticus* and *A. flavus*, producers of aflatoxins [52]. In fact, a strategy that has proven to be effective in the reduction of contamination by mycotoxins is the "pre" and "post" operations in the corn harvesting by using atoxicogenic races (Those who cannot produce toxins) of *A. flavus*, the same as, by competition for the same substrates for the growth and development, displace the populations of toxicogenic fungus. This measure was used in the southern part of the United States in corn, cotton, peanut and pistachio crops, where the incidence of aflatoxins was reduced from 70% to 90% [37]. The use of modified atmospheres to avoid or reduce the growth of toxicogenic fungus is another action to have a natural conservation of foods, taking into account that the contaminant fungal organisms are strictly aerobics. It's important also to point out that the minimal concentration of oxygen to allow the growth of fungus can be close or inferior to the 1%. The implementation of controlled or modified atmospheres (replacing the surrounding atmosphere during packing) has been used, mainly, in the conservation of fruits. However, its success not only depends on the mixture of gases, (CO_2 & N_2) but also the storage temperature, packing equipment and packing material. Thus, the inhibition of patulin caused by *P. expansum*, in apples, is almost complete using different modified atmospheres of CO_2& N_2 and using polyethylene containers. Meanwhile, the formation of B1 & B2 aflatoxins, C-Roquefortina, and cyclopiazonic acid has been reduced in inoculated cheeses with toxicogenic species when packed under modified atmospheres [13].

II. Conclusions

The mycotoxins in foods, either for human or for animal consumption, represent an important challenge in public health, livestock, and agriculture matters due to their incidence in contamination, their multiple affections in the consumers' health, the economy and productivity, mainly in countries with a developing process. Because of that, it's necessary to deepen in the people's awareness about these toxic compounds of fungal nature that are present in foods, apart from developing greater studios to obtain more information about their incidence, effects in health, contaminated foods, analysis methods in the laboratory, control methods, reduction and prevention of contamination in foods that lead to establish bigger regulations to a bigger amount of mycotoxins in order to avoid, or minimize, their consequences in the matters of human and animal health, and also in the economy and availability in the livestock and agriculture industries.

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