Risk Assessment of Mycotoxins Intake through the Consumption of Maize, Peanuts, Rice and Cassava in Côte d'Ivoire

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Abstract

Mycotoxins are secondary metabolites of filamentous fungi that colonize a wide range of crops, including cereals and oilseeds, both in the field and after harvest, especially during storage. Several studies carried out on the occurrence of mycotoxins in crops and their derived products such as maize, peanuts, rice and attieke (cassava product), reported substantial levels of Aflatoxins (AFs), Fumonisins (FBs), Ochratoxin A (OTA) and Zearalenone (ZEA). The aim of the present study was to analyze findings available on Aflatoxins, Ochratoxin A and Fusarium toxins occurrence in maize, peanuts, rice and attieke in order to assess the exposure level and cancers risk in the Ivorian population. References and publications related to OTA in Côte d'Ivoire were searched and selected. Medline/PubMed, Elsevier Bibliographic Databases, BioInfoBank Library, DOAJ (Directory of Open Acess Journal), Australian Journal of Basic and Applied Sciences and https://medwelljournals.com/home.php were used as databases. Data available showed Estimated Daily Intake (EDI) of AFs and OTA were above of their Tolerable Daily Intake (TDI) as recommended by the Joint FAO/WHO Experts Committee on Food Additives through rice, maize, peanut and attieke consumption in Côte d'Ivoire. In addition, there is a veritable incidence of cancers with the abundant and frequent consumption of foods maize, rice, peanuts and attieke. However, maize and rice seemed to be sources of FBs and ZEA exposure in the population. In brief, there is a need to improve postharvest practices and to institutional strengthening for foods check.

Keywords

Mycotoxins Exposure, Food Contamination, Cancers Prevalence

1. Introduction

The term of mycotoxins refers to natural products with low molecular weight, produced as secondary metabolites by filamentous fungi that colonize a wide range of crops, including cereals and oilseeds, both in the field and after harvest, especially during storage [1]. Due to their thermal and chemical stability, mycotoxins can also be found in processed foods of plant origin, or by transfer, in food products of animal origin such as milk, eggs, meat and offal from animals consuming contaminated feed [2]. These natural contaminants represent a major concern for human and animal health since they can cause acute or chronic intoxications which are sometimes fatal due to their various toxic effects (carcinogenic, hepatotoxic, nephrotoxic, neurotoxic, genotoxic, immunotoxic, oestrogenic…) [3]. Some mycotoxins have been classified by the World Health Organization (WHO) as human carcinogens. Most mycotoxins currently known are grouped based on their toxic activity under chronic conditions, which are classified into mutagenic, carcinogenic, or teratogenic mycotoxins. For example, Aflatoxins that occur naturally are classified as human carcinogens (Group 1); Ochratoxins and fumonisin are classified as possible human carcinogens (Group 2B), while trichothecenes and Zearalenone are not recognized as human carcinogens (Group 3) [4]. Even today, after the identification of more than 300 mycotoxins, Aflatoxins, Ochratoxin A, Zearalenone and Fumonisins remain those usually found in African countries of only about 20 mycotoxins known to occur in foodstuffs at sufficient levels and frequencies to cause food safety concerns [5]. The most common genus of mycotoxigenic fungi in food and feed are Aspergillus, Fusarium, Penicillium, Claviceps and Alternaria [3] which are classified as species of fungi that can produce one or more mycotoxins. Mycotoxins can be produced by multiple fungal species [1] [6]; for example, Aflatoxins and Ochratoxins are produced by more than one fungal species [7], and this contributes to the year-round presence of mycotoxins. The co-occurrence of different mycotoxins within the same food almost always occurs and may result in greater toxicity to humans due to possible additives or synergistic effects [8] [9] [10]. In general, the effect of mycotoxins on human health can be influenced by age, sex, weight, diet, exposure to infectious agents, the quantity of toxins exposed, the presence of other mycotoxins (synergistic effects) and pharmacologically active substances [11]. For example, in humans, the rate at which exposure to mycotoxins occurs will affect a young person or an infant to a greater degree than an adult [1]; in addition, the quantity of exposure is a major determinant of the degree of toxicity to the consumer. Thus, in order to protect consumer health by reducing mycotoxins exposure, many countries worldwide, and particularly in Europe, have established regulatory limits and guidances values for certain mycotoxins in foodstuffs [1]. In Côte d'Ivoire, as in some African countries, the regulatory control of mycotoxins in retail foods sold on the local markets was rare. However, since the assessment of human mycotoxins exposure was based on the occurrence of mycotoxins or their biomarkers in both food and biological fluids, several studies have been carried out in this field in Côte d'Ivoire [6] [7] [8] [12] [13]. Thus, the occurrence of mycotoxins such

as Aflatoxins (AFs), Ochratoxin A (OTA), Fumonisins (FBs), Zearalenone (ZEA) and Deoxynivalenol (DON) had been evaluated in foods largely consumed by the Ivorian population namely coffee and cocoa [14] [15] [16], cereals (maize, rice, millet) and derived products (maize flour), in oleaginous products (peanut and peanut paste) [6] [7] [8], in spices and cassava products [17] [18]. Recent studies have shown an association between co-exposure of the population to major mycotoxins such as AFs, FBs, OTA through the frequent consumption of peanuts, rice, millet, attieke, maize [8] and the increased risk of developing hepatocellular carcinoma in patients infected with the Hepatitis B Virus (HBV) [18]. This manuscript provides, according to data available, an analysis of the AFs, OTA and Fusarium toxins exposure of the Ivorian population through reported results on both occurrences of the mycotoxin in foodstuffs, as well as reported internal dose assessments. After the review of mycotoxins external and internal doses, the most recent and representative data is used to draw a comparative contribution of each foodstuff to the mycotoxins intake of the Ivorian population. Thus, this study was focused on the risk of mycotoxins exposure in the Ivorian population.

2. Material and Method

The present study is summary of studies focused on Ivorian mycotoxins exposure to date in Côte d'Ivoire. The bibliographic sources consulted are original articles published in databases such as Medline/PubMed, Elsevier Bibliographic Databases, BioInfoBank Library, DOAJ (Directory of Open Access Journal), Australian Journal of Basic and Applied Sciences and https://medwelljournals.com/home.php, but also reports of training courses and studies not yet published or in the process of publication. The present article covers all the research work carried out on mycotoxins in Côte d'Ivoire, including occurrence of mycotoxins in rice, maize, peanuts and Attieke, the assessment of exposure in the general population by biological fluids contamination and by determination of Estimated Daily Intake (EDI). In addition, the cancer risk has been estimated by Threshold of Toxicological Concern (TTC) and Margin of Exposure (MOE) approches for all mycotoxins.

3. Results and Discussion

3.1. Biological Fluids Contamination

In general, bio-monitoring is preferable over the evaluation of food contamination, given that variations in food preparation methods, food intake, contamination level, intestinal absorption, and toxin distribution and excretion lead to individual variations in exposure that are more readily measured with a biomarker [12] [13]. In Côte d'Ivoire, some studies have been carried out about mycotoxins in blood and in urine [8] [19] [20].

The first study concerned blood specimen-derived OTA exposure assessments in Abidjan from two categories of people namely apparently healthy donors (n = 63) and nephropathy patients undergoing dialysis (n = 39) [19]. Among healthy donors, 34.9% show OTA concentrations ranging from 0.01 - 5.81 µg/l with a

mean value of 0.83 µg/l, whereas, among nephropathy patients undergoing dialysis 20.5% are OTA positive in a range of 0.167 - 2.42 µg/l with a mean value of 1.05 µg/l. Although the sex ratio is 0.82 (46 females for 56 males) Ochratoxin A contamination is equally distributed in both sexes. Nephropathy patients undergoing dialysis appear, however, less frequently contaminated than healthy donors (20.5% versus 34.9%) and show higher OTA concentrations (higher mean value, p = 0.01). It is worth mentioning that OTA concentrations found in human blood reflect concentrations previously detected in cereals and peanuts according to the eating habits and diets of people in Côte d'Ivoire. But, the prevalence of Ochratoxin A in blood of nephropathy people undergoing dialysis appears lower than expected from the frequency of OTA contamination in cereals and peanuts. However, statistical analysis of data reported that among OTA-positive individuals renal dialysis and age are important modalities for consideration [19]. Another study focused on the impact of the OTA in the development of bladder tumors in Ivorian patients has been carried out [20]. This was a case study/control involving 120 patients with bladder tumor and 120 healthy as control during the period from 2005 to 2010. The obtained results have shown a relatively high ochratoxicosis level, because 70% to 76.67% of the sera were OTA positive respectively in controls and patients. The average OTA level detected in the control population was 0.79 ± 1.20 µg/l against 1.16 ± 1.85 µg/l in patients (no significant difference, p > 0.01). Urine OTA biomarker had been also used to assess OTA exposure in population living in Côte d'Ivoire in particular at Abidjan and Daloa. The aim of this study was to investigate the mycotoxins exposure of Ivorian population related to the consumption patterns of maize, peanuts, millet, and cassava product (attieke). Urine (n = 99) samples were collected during the period (July-September 2011) from volunteers living in Abidjan and Daloa cities. Biomarkers (AFM1, DON, DON + de-epoxydeoxynivalenol (DOM-1), FB1, α-zearalenol (ZOL), β-ZOL, and OTA) were simultaneously analyzed by reversed-phase liquid chromatography cou- pled with electrospray ionization triple quadrupole mass spectrometry (LC-ESI- MS/MS). As results, AFM1 was detected in 40% of urines samples (0.06 - 14.11 ng/ml), OTA in 37% (0.01 - 0.42 ng/ml), FB1 in 27% (0.07 to 15.31 ng/ml) and, DON was found in 21% of samples at levels up to 10.0 ng/ml. The correlation coefficients (R(2)) obtained by plotting the percentage of biomarker occurrence (positive samples) versus the frequency of food consumption revealed maize, peanuts, millet and attieke were strongly linked to AFB1 and OTA exposure with values of R(2) ranged from 0.462 to 0.956 [8].

Critical analyses of data available suggested a frequent co-exposure to the major mycotoxins such as AFs, OTA, and Fumonisins, which appeared to be related to the frequency of peanuts, maize, millet and attieke consumption. When one compares the results of the healthy Ivorian population studied with population having any pathology such as nephropathy patients or bladder tumors patients, data available could not allow establishing the link between mycotoxins exposure and these pathologies. But, measures must be taken to eliminate the risk of OTA

contamination in most commonly consumed foods because that could be aggravating factor in ethiology of bladder tumors [20]. Surprisingly, the presence of DON biomarker in population urine has been found. Indeed, any study carried out to day on mycotoxins occurrence in food from Côte d'Ivoire reported contamination by trichotecene A or B toxins [6] [7] [8]. However, data available concerned only urban population by not rural population. There is need to investigate in rural areas of Côte d'Ivoire, mainly in regions where the high consumption of foods potentially contaminated by mycotoxins was known. A comprizon of concentrations of urine or blood biomarkers showed that values from Ivorian population were higher than those from European countries. For example, while OTA concentrations in blood were ranged from 0.01 to 5.81 µg/l with a mean value of 0.83 µg/l (or 0.83 ng/mL), the average level, lower mean values were reported in Europe countries such as Zagreb (0.19 ng/mL) [21], Norway (0.18 ng/mL) and Sweden (0.21 ng/mL) [22], Lebanon (0.17 ng/mL) [23] and the Czech Republic (0.28 ng/mL) [24].

3.2. Food Contamination

Our study concerned 4 foods largely consummed in Côte d'Ivoire such as maize, peanuts, rice and cassava derived namely attieke. There is a frequent co-exposure to the major mycotoxins such as AFs, OTA, Fumonisins and Zearalenone, which appeared to be related to the frequency of peanuts, maize, millet and attieke consumption [8]. For example, in recent study, carried out of 238 food samples collected in Côte d'Ivoire, 91% were contaminated with more than one mycotoxin (about 21% between 2 and 4 mycotoxins, 21% between 5 and 7 and 48% with more than 8), 4% with only one mycotoxin (9 rice samples) and 5% (12 rice samples) were not contaminated [6] (Table 1).

3.2.1. Maize Contamination

The major mycotoxins such as AFs, OTA, Fumonisins and Zearalenone (ZEA) have been found in maize with varied concentrations but not trichothecenes namely DON, T-2, and HT-2 toxins [6] [7] [8] [25] [26].

Aflatoxins contamination

For AFs, in a survey carried out on maize flour collected from all markets of 10 communes of Abidjan, AFB1 had been found the most frequently occurring

Table 1. Mycotoxins range levels (µg/kg) in food from Côte d'Ivoire.

Foods	AFB1		OTA		FB1		ZEA	
	Levels (µg/kg)	Authors	Levels (µg/kg)	Authors	Levels (µg/kg)	Authors	Levels (µg/kg)	Authors
Rice	0.45 - 14	[6] [7] [29]	0.16 - 15	[6] [7] [25] [29]	2.7 - 13	[6] [7]	0.25 - 200	[7]
Maize	0.3 - 324	[6] [7] [8] [25] [26]	0.09 - 86	[6] [7] [8] [25] [26] [27]	0.3 - 763	[6] [7] [8]	2.3 - 50	[6] [8]
Attieke	0.01 - 35	[18] [26]	0.06 - 2.78	[18] [26]	-	-	-	-
Peanut	0.6 - 4535	[6] [7] [28]	0.6 - 174	[6] [7] [25] [28]	0.3 - 6	[6] [7]	0 - 200	[6] [7]

AFs (100% of positive samples) with levels up to 324 μg/kg, followed by AFB2 (94% of positive samples) with levels up to 21.6 μg/kg. AFG1 and AFG2 showed lower incidence but levels of AFG1 were up to 49 μg/kg. Total AFs values ranged from 4.5 to 330 μg/kg with mean of 128.7 ± 98.3 μg/kg and median of 101.5 μg/kg [8]. Similarly, in more recent study, AFB1 was recovered in 96%, AFB2 in 67%, AFG1 in 57% and AFG2 in 24% of maize samples, respectively. The highest levels quantified in maize samples were 80 μg/kg for AFB1 (mean 8.6 μg/kg), 84 μg/kg for AFG1 (mean 5.3 μg/kg), 7 μg/kg for AFB2 (mean 1.5 μg/kg), 3.8 μg/kg for AFG2 (mean 0.8 μg/kg) and 173 μg/kg for AFT (mean 13 μg/kg) [6]. Before these two major studies, it had been reported that 100% of maize samples collected from markets in Abidjan were contaminated by AFB1 but with lower levels (up to 20 μg/kg) than those quantified in the two more recent studies probably from period and site of samples collected [7]. Similarly, in one more recent study focused on dried maize samples collected from Abobo, AFB1 levels were ranged from not detected to 10.08 μg/kg with mean of 2.28 μg/kg and 85% (n = 13) of positive samples [26].

Ochratoxin A (OTA) contamination

For OTA, the frequency of its occurrence in maize samples analyzed from studies carried out was mitigated [6] [7] [8] [25]. Indeed, some data available revealed that OTA was found in 13%, 22% of maize samples collected in Côte d'Ivoire [6] [8] but, in another studies OTA had been found in 100% (n = 43) of maize samples [7] [25] and in 69% (n = 13) of maize samples [26] respectively. In addition, low levels of OTA have been reported ranging from 0.09 to 0.86 μg.kg [7] and from not detected to 1.03 μg/kg with mean of 0.48 μg/kg [26] but surprisingly, high levels were also found in maize with mean 37 μg/kg and ranged from 9.8 to 86 μg/kg [25]. More recently, levels of OTA found in maize sample were ranged from not detected to 114 μg/kg with mean of 21 μg/kg [8] and <LOQ to 7.6 μg/kg with mean of 1.9 μg/kg [6]. The apparent controversy of OTA levels could be explained by several factors namely the period of the year and site of samples collecting and agricultural practices of maize producers as revealed about other crops such as cashew nuts [27].

Fusarium toxins contamination

For Fumonisins, FB1 concentrations ranged from 32.3 to 1463.6 μg/kg, and FB2 concentrations from 18.5 to 746.6 μg/kg have been reported from maize flour collected at Abidjan markets [8]. Total Fumonisins levels were ranged from 45.3 to 2210.2 μg/kg with mean of 355.5 ± 368.2 μg/kg and median of 278 μg/kg. It is worth noting that only two samples showed total Fumonisins levels above 1000 μg/kg (*i.e.*, the EC maximum permitted level in maize for human consumption) [8]. Similarly, values of concentrations of FB1 reported in more recent study, were ranged from 10 - 587 μg/kg [6]. But, very low values of concentrations of FB1 (0.3 - 1.5 μg/kg) have been reported [7]. Concerning ZEA, its occurrence in maize appeared low. Indeed, in one study focused on 51 samples of miaze flour, only one sample was contaminated at level above 100 μg/kg (the EC maximum permitted level in maize for human consumption). The other samples showed

low ZEA levels ranging from 2.3 to 28 µg/kg. Mean and median values were 14.0 ± 20.1 and 7.2 µg/kg, respectively [8]. Similar findings have been previously reported with concentrations ranged from 20 to 50 µg/kg [7] and more recently with <LOQ to 7.7 µg/kg [6]. For Trichothecenes (DON, T-2, and HT-2 toxins), any findings in maize have been reported on samples of maize collected from Côte d'Ivoire [6] [8]. Taken together, concentrations of Zearalenone and Fumonisins were low and seemed not cause problems *per se*.

3.2.2. Peanuts Contamination by Mycotoxins

Data available on mycotoxins occurrence in peanuts revealed the presence of Aflatoxins, Ochratoxins and low levels of Fursarium toxins [6] [7] [28].

Aflatoxins contamination

Data of peanut contamination by Aflatoxins available were very few. AFB1 had been found in 100% of peanuts (n = 10) samples collected from markets at Abidjan especially in Adjamé, Abobo and Treichville. These markets represent the significant areas which provide feeds to other markets in Côte d'Ivoire. Values of AFB1 were ranged from 1.5 to 10 µg/kg in peanuts with mean of 4.8 µg/kg [7]. These relative low values were supported by those reported more recently where AFB1 contents varied from 0.23 to 2.49 µg/kg [28]. Suprisingly, alarming values of AFB1, AFG1 and AFTs have been reported in more recent study. AFB1, AFG1 and AFTs have been found in 100% of peanut paste (n = 71) collected in the main markets of Abidjan, Bouaké (Center of Côte d'Ivoire) and Korhogo (North of Côte d'Ivoire). For AFB1 values were ranged from 0.6 to 4535 µg/kg with mean of 260 µg/kg, for AFG1, from 0.7 to 2194 µg/kg with mean of 143 µg/kg and for AFTs, from 1.4 to 8094 µg/kg with mean of 530 µg/kg [6].

OTA contamination

The contamination of peanuts by Ochratoxin A had been reported in some studies focused on peanuts grains or peanut paste. For peanuts grains, OTA levels were ranged from not detected to 0.642 µg/kg with 60% of peanuts samples (n = 10) contaminated by OTA [7]. Similar values of OTA have also been reported (0.53 - 2.23 µg/kg) [28]. Suprisingly, another study reported OTA levels in peanuts ranged from 0.6 to 64 µg/kg with mean of 23 µg/kg and OTA had been found in 100% of peanuts samples [25]. Peanut past contamination by OTA had been recently evaluated [6]. OTA had been found in 65% of peanut past samples at levels ranged from <LOQ to 174 µg/kg with mean of 9.8 µg/kg [6].

Toxins of fusarium

Fumonisins have been found in peanuts from Côte d'Ivoire but the values of their concentrations were low ranged from <0.3 to 6 µg/kg [7] and not detected in 71 samples of peanut paste [6]. But, Zearalenone occurrence appeared questionable because it had been found in 10 peanuts samples from Côte d'Ivoire at levels ranged from 50 to 200 µg/kg [7] but not detected in 71 samples of peanut paste collected from three localities of Côte d'Ivoire such as Abidjan, Bouaké and Korhogo [6].

3.2.3. Rice Contamination

Occurrence of mycotoxins in rice samples collected from Côte d'Ivoire had been also evaluated [6] [7] [25] [29]. Rice samples were obtained from markets in Abidjan, Côte d'Ivoire, especially in Adjamé, Abobo and Treichville, also from markets of Bouaké and Korhogo. These markets represent the significant areas which provide feeds to other markets in Côte d'Ivoire [6] [7] [25] [29].

Aflatoxins contamination

Data available revealed occurrence of AFB1, AFG1 and AFTs in rice samples collected from Côte d'Ivoire. AFB1 had been found in 100% (n = 10) of rice samples at levels ranged from <1.5 to 10 μg/kg [7], from 0.45 to 1.17 with 50% of positive samples [29] and from <LOQ to 14 μg/kg (LOQ = 0.25 μg/kg) with mean of 3.9 μg/kg [6]. Similarly, AFG1 concentrations were ranged from <LOQ to 17 μg/kg (LOQ = 0.25 μg/kg) with mean of 3.3 μg/kg. AFTs were also found in 66% (n = 47) of rice samples with concentrations ranged from <LOQ to 33 μg/kg with mean of 5.8 μg/kg [6] and from 0.65 to 2.01 μg/kg with mean of 1.73 μg/kg in 50% of rice samples [29].

OTA contamination

OTA was found in 100% of rice samples from Côte d'Ivoire but at relative low concentrations ranged from 0.16 to 0.92 [7]. In addition, in more recent study, any OTA has been found in 100% of samples of rice collected (n = 20 and LOQ = 0.4 μg/kg) from Abidjan markets [29]. But relative high levels of OTA have been found in 8% (n = 47) of rice samples collected from Abidjan, Bouaké and Korhogo. Values of OTA concentrations were ranged from <LOQ to 15 μg/kg with mean of 6.3 μg/kg [6]. These high levels of OTA have been previously reported, ranged from 9 to 92 μg/kg [25].

Fusarium toxins

Despite relative high levels of Zearalenone in 100% (n = 10) rice samples from Côte d'Ivoire ranged from 50 to 200 μg/kg [7], toxins of Fusarium levels in rice were low in Côte d'Ivoire. Thus, in more recent study, Zearalenone has been found in only 4% of samples (n = 47) at levels of <LOQ to 7.5 μg/kg (LOQ = 0.25 μg/kg) while Fumonisins (FB1 + FB2) were found in 32% of rice samples (n = 47) at low levels of 2.7 to 13 μg/kg [6].

3.2.4. Cassava Contamination by Mycotoxins

The few data available on mycotoxins in cassava concerned those reported on dried cassava and Attiéké collected from markets from Abidjan namely [18] [26]. Mycotoxins researched and found in cassava product were Aflatoxins and OTA.

Aflatoxins contamination

In dried cassava collected from markets of Abidjan, AFB1 had been found in 94% of samples (n = 16) at levels ranged from not detected to 29.82 μg/kg with mean of 4.17 μg/kg [26]. Similarly, AFTs has been found in 97% of cassava derived namely Attiéké samples (n = 290) at values ranged from 0.01 to 39.85 μg/kg with mean of 13.95 μg/kg [18]. Levels of individual AFTs such as AFB1, AFB2,

AFG1 and AFG2 were relatively critical. Values were ranged from 0.02 to 35.78 µg/kg with mean of 3.44 µg/kg for AFB1, from 0.1 to 23.95 µg/kg with mean of 1.9 µg/kg for AFB2, from 0.56 to 69.32 µg/kg with mean of 8.07 µg/kg for AFG1 and from 0.04 to 13.33 µg/kg with mean of 0.56 µg/kg for AFG2 [18]. AFB1 has been found in 56% of Attieke samples (n = 170), 23% (n = 70) for AFB2, 46% (n = 140) for AFG1 and 40% (n = 120) for AFG2 respectively [18].

OTA contamination

OTA had been found in 63.3% (n = 190) Attieke samples [18] and in 69% (n = 13) dried cassava samples [26]. Values of OTA reported in both studies were ranged from not detected to 2.78 µg/kg with mean of 0.94 µg/kg [26] and from 0.06 to 1.83 µg/kg with mean of 0.42 µg/kg [18].

3.3. Exposure Estimate

Calculation of the Estimated Daily Intake (EDI) was done by using the mean levels of mycotoxins obtained in rice, peanuts, maize and cassava product or Attieke samples, the daily intakes of same samples [30] [31], and the average body weight. The EDI for mean each mycotoxin was calculated according to the following formula and expressed in µg/kg of body weight/day (µg/kg bw/day) [32].

EDI = Daily intake (food) × level of mycotoxin/Average body weight.

The tolerable daily intake (TDI) set by the Joint FAO/WHO Experts Committee on Food Additives were respectively for Aflatoxins <1 µg/kg bw/day, OTA (14.28 ng/kg bw/day), fumonisin B1 (2 µg or 2000 ng/kg bw/day) and Zearalenone (250 ng/kg bw/day) [33] [34]. Especially for OTA, several values of tolerable daily intake (TDI) were recommended by food safety organism such as the European Commission's SCF with 5 ng/kg bw/day, the Joint FAO/WHO Experts Committee on Food Additives, 14.28 ng/kg bw/day and EFSA, 17.14 ng/kg bw/day. But, value of TDI recommended by the Joint FAO/WHO Experts Committee on Food Additives, 14.28 ng/kg bw/day was applied in Côte d'Ivoire and most of African countries. Thus, the consumption of rice, maize, peanut and Attieke could present risk of Aflatoxins exposure above of TDI < 1 ng/kg bw/day. Similarly for OTA, maize, peanut and rice according to our data could present risk of exposue above 14.28 ng/kg bw/day. Despite the EDI of 12.8 ng/kg bw/day for OTA though Attieke was lower than 14.28 ng/kg bw/day, the low difference could pose some concerns. In addition, lower TDI is recommended by European Commission's SCF with 5 ng/kg bw/day. For toxins of Fusarium, maize consumption could present risk of exposure above 2000 ng/kg bw/day while rice could be the food with high exposure of ZEA above of 250 ng/kg bw/day (Table 2).

3.4. Cancers Risk Assessment

The cancer risk has been estimated by Threshold of Toxicological Concern (TTC) method and Margin of Exposure (MOE) according to Table 2.

Cancer risk assessment by TTC

According TTC approch, when the EDI was above of 0.0025 µg or 2.5 ng/kg

bw/day for genotoxic substance [35], there is risk of cancer for the population. Aflatoxin B1 is classified as human carcinogens (Group 1); Ochratoxins and fumonisin are classified as possible human carcinogens (Group 2B), whereas trichothecenes and zearaleone are not recognized as human carcinogens (Group 3). Thus, AFB1 with minimal values of EDI below 2.5 ng/kg bw/day, could not cause ineluctably cancers though the consumption of maize, peanut, attieke and rice (Table 2). That supports the importance of improving postharvest practices by farmers and solders.

HCC and neoplastic effects risk assessment by MOE

This method has been used only for AFs though AFB1 and OTA. The benchmark dose lower confidence limit (BMDL) for a benchmark response of 10% of 0.4 µg/kg body weight (bw) per day for the incidence of HCC in male rats following AFB1 exposure to be used in a margin of exposure (MOE) approach [36]. Similarly, for characterization of neoplastic effects, a BMDL10 of 14.5 µg/kg bw par day was calculated from kidney tumors seen in rats [37] (Table 3).

$$MOE = BMDL10/EDI$$

MOE values for AFB1 exposure were below 10,000 regardless the food concerned. This raises a health concern. The estimated cancer risks in humans following exposure to AFB1 is real though MOE approach for all foods (rice, maize, attieke and peanut). For OTA, all foods could cause neoplastic effects but with extreme values of OTA EDI. In contrast to AFB1, the minimum values of OTA EDI did not pose any concerns.

Table 2. Estimated Daily Intake (EDI) range by food consumption with daily intake estimated at 300 g of food (maize, attieke and rice) and at 22 g for peanut and an average body weight of 65 kg. AFB1 is aflatoxin B 1, the major aflatoxin among total aflatoxins (AFs).

Food	Daily intake (g)	Estimated daily intake (ng/kg bw/day)			
		AFB1	OTA	FB1	ZEA
Rice	300	2 - 65*	0.74 - 69*	12 - 60	1.1 - 923*
Maize	300	1.3 - 1495*	0.4 - 397*	1.3 - 3521*	10.6 - 231
Attieke	300	0.046 - 162*	0.28 - 12.8	-	-
Peanut	22	0.2 - 1534*	0.2 - 58*	0.1 - 2	0 - 67.7

*Values of EDI above Tolerable Daily Intake (TDI) of mycotoxins; TDI for Aflatoxins (<1 ng/kg bw/day), OTA (1.5 - 17.14 ng/kg bw/day), FB1 (2000 ng/kg bw/day) and ZEA (250 ng/kg bw/day).

Table 3. MOE values range though consumption of rice, maize, peanut and attieke.

	Rice	Maize	Attieke	Peanut
MOE of AFB1	6.15 - 200	0.267 - 307.6	2.47 - 8695	0.0003 - 2000
MOE of OTA	19,595 - 210	36,250 - 36.53	51,786 - 1133	72,500 - 250

4. Conclusion

The risk assessment of mycotoxins intake through the consumption of maize, peanuts, rice and cassava in Côte d'Ivoire revealed significant exposure of the population to Aflatoxins and Ochratoxins. These findings were supported by high Estimated Daily Intake (EDI) of aflatoxins namely aflatoxin B1 and ochratoxin A and the high prevalence of their biomarkers in biological fluids. Among mycotoxins, AFs were more critical in Côte d'Ivoire following OTA with a high incidence of cancers as confirmed by Margin of Exposure (MOE) and TTC approaches. The risk of toxins of Fusarium was low but the consumption of rice and maize was abundant and daily could enhance ZEA and FBs exposure respectively. The need to ensure postharvest practices in Côte d'Ivoire is impertive since the contamination of foods by mycotoxins poses some concerns.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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