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Dietary exposure to mycotoxins in the French infant total diet study

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Abstract

The present study evaluated the exposure of children aged from one to 36 months to seven groups of mycotoxins, in the context of the infant French Total Diet Study (iTDS).Exposure was then compared to the health-based guidance values (HBGVs) for each mycotoxin. The value of the 90th percentile of exposure to nivalenol, patulin, fumonisins and zearalenone was less than 40% of the HBGV considered relevant for children. On the other hand, a risk could not be excluded for ochratoxin A and aflatoxins as exposure was close to the HBGV for ochratoxin A and the margin of exposure was much lower than the critical margin of 10,000 for aflatoxins. The HBGVs for toxins T2 and HT2, and for deoxynivalenol (DON) and its acetylated compounds were exceeded. Five percent to 10% of the children aged 5 to 12 months exceeded the HBGV considering the lower bound hypothesis for toxins T2 and HT2 and 7.5% to 27% of the children aged 5 months and above exceeded the HBGV for DON. Consequently, the exposure of young children raises safety concerns for T2/HT2 and DON. Efforts should therefore be pursued to decrease their exposure to these molecules.

Keywords

Total diet study; Children; Mycotoxin; Dietary exposure; Risk assessment

1. INTRODUCTION

Mycotoxins are secondary metabolites produced by the toxinogenic strains of several fungal species belonging in particular to the *Aspergillus*, *Penicillium*, *Fusarium* and *Byssochlamys* genera. The toxicity of mycotoxins in humans and animals varies depending on the type of toxin and species. Mycotoxin production in plants, before harvest and during storage, depends on the strain, substrate, temperature and humidity conditions. Damage to the substrate favours infestation or development of the mould strain on the substrate. Mycotoxins are generally thermostable. During the processing of contaminated plants, they persist more or less partially depending on the type of process. As some plant species likely to be contaminated are used in animal feed, chronic animal exposure to certain mycotoxins can cause disorders such as decreased zootechnical performance (particularly reduced weight gain), and due to their transfer and/or metabolisation, can result in the contamination of certain animal products such as milk and offal. Based on data from around 500,000 analyses for 2010-2015 from the European Food Safety Authority (EFSA) and a major global survey on aflatoxins, fumonisins, deoxynivalenol, toxins T2 and HT2, zearalenone and ochratoxin A in cereals and nuts, the prevalence for the detected mycotoxins was found to be 60% to 80% (Eskola et al., 2019).

Mycotoxins can trigger acute or chronic toxicity. Chronic toxicity is the main concern due to the immunotoxic, endocrine-disrupting and carcinogenic properties of some mycotoxins. Mycotoxin carcinogenicity has been evaluated and classified by the International Agency for Research on Cancer, founded by the World Health Organization (IARC, 1993, 2002). In humans, dietary exposure to some mycotoxins may pose a problem depending on dietary habits. Aflatoxins are produced both during storage and in the field by toxinogenic strains belonging to the *Aspergillus* genus (EFSA, 2007a). Several chemically-related aflatoxins exist, the main one being Aflatoxin B1. This mycotoxin can be present in dry fruits (mainly figs), oilseeds and cereals. *Alternaria* toxins (altenariol mainly), produced by fungal species belonging to the *Alternaria* genus, can be present in fruit (apples, citrus fruits) but also in olives and sunflower seeds (EFSA, 2016). Fumonisins are produced by fungal species belonging to the *Fusarium* genus and can be present in cereals, mainly corn. Ochratoxins A, B and C are produced by toxinogenic fungal species belonging to the *Aspergillus* and *Penicillium* genera (EFSA, 2006, 2010). Ochratoxin A, the most prevalent ochratoxin in Europe, is produced in the field or during storage. Corn, wheat, barley, rice and coffee can be contaminated. Patulin is produced by fungal species belonging to the *Aspergillus*,

Penicillium and *Byssochlamys* genera and can be present in fruit, mainly apples. Trichotecens are mycotoxins also produced by fungal species belonging to the *Fusarium* genus. These toxins develop on cereals (corn, wheat, rice, barley) and also dry fruits in the field or during storage (EFSA, 2007b). Depending on their chemical structure, trichothecenes are classified in four different groups (A, B, C and D). The zearalenone mycotoxin is produced in the field or during storage by toxinogenic species belonging to the *Fusarium* (mainly) and *Aspergillus* genera. These toxins can be present on cereals but also in food of animal origin due to the contamination of feed (EFSA, 2011a).

The literature rarely reports the infant population's exposure to these molecules despite the fact that it is a population that tends to consume cereals in great quantity. This paper reports the results of the occurrence of mycotoxins in the diet of French children aged 1 to 36 months, their exposure and the assessment of the associated health risk to this population in the context of a total diet study (TDS).

2. MATERIALS & METHOD

2.1. Principles of Total Diet Studies

The aim of a total diet study (TDS) is to provide representative and realistic data on the food contamination and exposure levels of relevant populations. It entails selecting and gathering food items that are representative of the diet of the studied population. The food items are processed as consumers usually process them (washing, peeling, cooking) and the prepared samples (described henceforth as "prepared as consumed") are pooled into representative food groups; the food in each group is then homogenised prior to analysis. The main principles of TDSs are described in guidelines established in 2011 by the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO) and the European Food Safety Authority (EFSA) (EFSA_FAO_WHO, 2011). This TDS method limits uncertainties in exposure assessment by standardised sampling methods and by analysing food prepared as at home, especially as production processes can affect the concentration of mycotoxins (Bol et al., 2016; Mousavi Khaneghah et al., 2018; Vidal et al., 2018).

2.2. Consumption data

Consumption data came from the cross-sectional survey on individual dietary consumption in children under 3 years old that was conducted by the Syndicat Français des Aliments de l'Enfance et de la Nutrition Clinique "Etude SOFRES 2005 / Université de Bourgogne – Pr M.Fantino pour le Syndicat Français des Aliments de l'Enfance" (Fantino and Gourmet, 2008). This study was conducted between January and March 2005 and focused on a representative sample of 705 infants and young children aged from 1 to 36 months. Each child's caregiver indicated the details of all the food consumed by the child each day in a food diary covering three consecutive days (including a weekend day). Portion sizes were determined using scales or information available on the food packaging. The children's body weight was collected from their health booklet. The children recruited for this study were divided up into four age groups corresponding to the different stages of food diversification: 1-4 months (124 individuals), 5-6 months (127 individuals), 7-12 months (195 individuals), and 13-36 months (259 individuals) (Hulin et al., 2019; PNNS, 2004). Partially or exclusively breastfed children were excluded from this study.

2.3. Sampling plan

Both infant specific food (i.e. food specifically intended for infants and young children) and common food (i.e. food intended for the general population but also commonly consumed by children) was sampled and analysed. In order to reduce the number of samples to be analysed, samples with similar nutritional content that were therefore expected to have comparable levels of contamination were pooled (in accordance with the general principles of TDS), and foods already analysed during the second French TDS on the general population (Sirot et al., 2013) were not sampled. The study's sampling plan included 457 composite samples corresponding to 5,484 food products purchased and prepared as consumed. The sampling phase took place between July 2011 and July 2012, and has already been described (Hulin et al., 2014). Home-cooking practices were reproduced on the basis of a specific survey carried out in 429 households with young children (Hulin et al., 2014), in order to have food samples representative of what children really eat.

2.4. Analytical procedures

The mycotoxins studied were aflatoxins (AFB1, AFB2, AFG1, AFG2, AFM1 and the sum of aflatoxins), *Alternaria* toxins such as alternariol (AOH), alternariol monomethyl ether (AME) and tenuazonic acid (TA), fumonisins (FB1, FB2 and the sum of FB1 and FB2), ochratoxin A (OTA), patulin, trichothecenes (toxins T2, HT2 and the sum of T2 and HT2, deoxynivalenol (DON) and its acetylated compounds (3-acetyldeoxynivanenol 3Ac-DON and 15-acetyldeoxynivanenol 15Ac-DON) and the sum of DON+3Ac-DON+15Ac-DON and nivalenol), and zearalenone.

Priority was given to analysing foods likely to contain the target mycotoxin only (i.e. cereals, fruits or nuts in the case of most of the mycotoxins). The children's whole dietary intake was therefore not analysed as it is clearly established that certain foods do not contain mycotoxins. Between 117 and 192 composite samples were thus analysed depending on the mycotoxin being investigated. The sampling plan therefore covered between 15% and 64% of the total diet of children aged 0 to 3 years (i.e. quantity of food analysed divided by the quantity of food consumed by each child). When considering only the food items contributing to exposure (foods that can contain the mycotoxin investigated), the coverage varies from 57% to 94% (i.e. quantity of food analysed divided by the quantity of food containing mycotoxins consumed by each child) (Table S1).

Mycotoxins were extracted from samples using a solid-liquid (if solid sample) or liquid-liquid (if liquid sample) procedure followed by purification on an immunoaffinity support. Depending on the group of mycotoxins being considered, the compounds were then detected using either liquid chromatography with fluorescence detection (LC-FLD) or liquid chromatography with tandem mass spectrometry (LC-MS/MS). In LC-FLD, only the retention time was used to identify the analytes. In LC-MS/MS, two distinct transitions were used to confirm the presence of a toxin in the event of doubt.

The limits of detection (LOD) were determined in the matrix by considering the signal-to-noise ratio. The limits of quantification (LOQ) were deduced from the detection limits: LOQ = 3*LOD.

The LC-FLD method detection limit (MDL) ranged from 0.002 to 0.05 $ng.g^{-1}$ (ppb) and the LC-MS/MS MDL ranged from 0.05 to 20 $ng.g^{-1}$ (ppb) (Table S2).

2.5. Contamination data management

Contamination data from the previous second French TDS were included for exposure assessment to complete the results on common foods (defined previously as food intended for the general population but also commonly consumed by children) (Sirot et al., 2013). Contamination data on non-alcoholic beverages, milk, eggs and egg products were all obtained during this study. Data on offal, delicatessen meats, breakfast cereals, dried fruits, nuts and seeds, vegetables (excluding potatoes), pizzas, quiches and savoury pastries, mixed dishes, and pastries and cakes were from the second French TDS. The other food categories were analysed during both the second French TDS and this study.

The detection rate was calculated by dividing the number of results above the LOD by the total number of samples analysed. A high detection rate reveals that the mycotoxin was detected in the majority of samples.

For censored data, two calculation hypothesis were made in order to estimate the lowest (lower bound hypothesis - LB) and the highest (upper bound hypothesis - UB) possible contamination level: results below the LOD were replaced by zero under LB and by the LOD under UB. Results below the LOQ were replaced by the LOD under LB and by the LOQ under UB (GEMS/Food-EURO, 2013).

2.6. Exposure calculation

Exposure to each mycotoxin was calculated for each child with the following equation:

$$E_i = \sum_{k=1}^{n} \frac{C_{i,k} \times L_k}{BW_i}$$

where E_i was the daily exposure of an individual i (ng.kg body weight^{-1}.day^{-1}), $C_{i,k}$ was the daily consumption of food k by individual i (g.day^{-1}), L_k was the level of contamination in food k (ng.g^{-1}), BW_i was the body weight of individual i (kg), and n was the total number of foods consumed by individual i.

According to the HBGVs selected for the risk assessment (see paragraph below), most of the mycotoxins were evaluated individually, but some were added up e.g. aflatoxins (AFB1+AFB2+AFG1+AFG2+ 1/10 AFM1), fumonisins (FB1+FB2) and some trichothecenes (DON+3Ac-DON+15Ac-DON, T2+HT2). For the sum of

aflatoxins, a 1/10 factor was considered for AFM1 since its toxic potential was evaluated as being ten times less than that of the other aflatoxins (AFM1 is primarily considered a detoxification product of AFB1, with only 10% of mutagenicity compared to its precursor, as AFM1 is a poorer substrate for epoxidation (Wogan and Paglialunga, 1974)). Moreover, it has been reported that cytochrome P450 activation is not required for AFM1 to exert cytotoxic effects (Marchese et al., 2018).

Depending on the mycotoxin exposure results, exposure data were presented with only the UB hypothesis (when the difference between LB and UB was lower than 10% and when the UB hypothesis was at least ten times lower than the HBGV) or with both the LB and the UB hypotheses, in accordance with WHO recommendations (GEMS/Food-EURO, 2013). The arithmetic mean with the standard deviation, the median and the P90 (90^{th} percentile) were calculated for each mycotoxin.

When the number of food items containing the mycotoxin was limited or when the contaminated foods were consumed by a low percentage of the iTDS population, the exposure was not only calculated for all the children (including those not consuming the food items containing the mycotoxin and therefore not exposed to it) but also for only those children who were exposed (exposure calculated on the basis of the children consuming contaminated food items).

The main contributors to exposure were identified when the detection rate was considered sufficient (at least 60%).

2.7. Risk assessment

The exposure data were compared to the HBGV when available for the considered mycotoxins. The percentage (and confidence interval, 95%CI) of children exceeding the HBGV was calculated for each age group. If fewer than five children exceeded the HBGV, they were considered non-representative. In this case, the exceedance percentage was not calculated. For some mycotoxins with a benchmark dose limit (BMDL), a margin of exposure (MOE) was calculated as the ratio between exposure and the BMDL. This ratio was then compared to a critical MOE in order to assess the risk to the population. For aflatoxin B1, the $BMDL_{10}$ set by the European Food Safety Authority (EFSA) in 2007 was selected (EFSA, 2007a). This value, 170 ng.kg bw^{-1} d^{-1}, is based on

carcinogenicity studies performed on rats exposed to aflatoxin B1. In the absence of HBGVs for the other aflatoxins measured and to take a safety margin, the potential toxicity of all aflatoxins was considered equal to that of aflatoxin B1 (IARC, 1993, 2002). However, experimental data show that the carcinogenic potential of AFM1 is considered to be ten times lower than that of AFB1 (IARC, 1993, 2002; Marchese et al., 2018). Therefore, the sum of aflatoxins considered for risk assessment is AFB1+AFB2+AFG1+AFG2+ 1/10AFM1. For fumonisins, the TDI of 1000 ng.kg $bw^{-1}.d^{-1}$ set by the EFSA panel on contaminants in the food chain in 2018 was selected. This value is based on the increased incidence of megalocytic hepatocytes found in a chronic study with mice (EFSA, 2018). For OTA, we chose the provisional weekly tolerable intake of 120 ng.kg $bw^{-1}.w^{-1}$ set by EFSA in 2006 and based on nephrotoxicity effects observed in pigs (EFSA, 2006). However, considering the paucity of studies focusing on the toxin's effects on human development and reproduction, uncertainty remained as regards the applicability of this value to children. For patulin, the provisional maximum daily dose set by JECFA in 1995 was selected. This value is based on a decrease in body weight gain at 400 ng.kg $bw^{-1}.d^{-1}$ (JECFA, 1995). For toxins T2 and HT2, the provisional tolerable maximum daily intake (PMTDI) of 60 ng.kg $bw^{-1}.d^{-1}$ set by JECFA in 2001 on the basis of immunotoxic and hematotoxic effectswas selected (EFSA, 2011c; JECFA, 2001). For nivalenol, the tolerable daily intake of 1200 ng.kg $bw^{-1}.d^{-1}$ set by EFSA in 2013 on the basis of immunotoxic and hematotoxic effects was selected (EFSA, 2013a). For deoxynivalenol and its metabolites (3Ac-DON, 15Ac-DON and DON-3-glucoside), JECFA and the SCF both set the tolerable daily intake at 1000 ng.kg $bw^{-1}.d^{-1}$ (EFSA, 2017; SCF, 2002) based on a decreased body weight gain reported in a 2-year feeding study in mice. However, in the absence of epidemiological data providing specific quantitative data on a juvenile population that would allow us to accurately extrapolate from adult to children, and considering the sensitivity of children (especially because of the immaturity of metabolism in newborns), the ANSES expert panel on chemical contaminants in food considered that an additional safety factor of three was needed. Consequently, the HBGV used was set at 300 ng.kg $bw^{-1}.d^{-1}$ in the present study.

For zearalenone and metabolites (α- and β-zearalenol, zearalenone and α- and β-zearalenol and their glucosides, sulphates and glucuronides), the TDI of 250 ng.kg $bw^{-1}.d^{-1}$ established by EFSA in 2011 was selected (EFSA 2011a). This TDI was based on effects observed in sow ovaries and uterus. It was considered appropriate for risk assessment in children since it is based on a toxicity study focusing on human reproduction and development.

For *Altenaria* toxins, no HBGV was available at the time of the study.

2.8. Collective appraisal

The ANSES expert panel conducted the collective assessment of the risk linked to human exposure to mycotoxins.

3. RESULTS AND DISCUSSION

3.1. Contamination levels of foods

Contamination data are presented in Table S3, except for aflatoxins and *Alternaria* toxins (data not shown).

Aflatoxins were never detected in any food (infant specific foods or common foods) analysed in the present iTDS. In common food analysed for the second French TDS (Sirot et al., 2013), the detection rate was also very low:. Other publications have reported mean contamination levels for AFB1 of 0.09 $ng.g^{-1}$ in infant cereals in Spain (Hernández-Martínez and Navarro-Blasco, 2010), 0.036 $ng.g^{-1}$ in breakfast cereals (Assunção et al., 2018) and 0.009 $ng.g^{-1}$ in infant specific food (Alvito et al., 2010) in Portugal, 0.115 $ng.g^{-1}$ in cakes and pastries and 0.275 $ng.g^{-1}$ in bread in Lebanon (Raad et al., 2014), 1.32 $ng.g^{-1}$ in filled cakes and 2 $ng.g^{-1}$ in jams in Serbia (Škrbić et al., 2017a), between 2.1 and 3 $ng.g^{-1}$ in dried fruits in Iran (Heshmati et al., 2017), and between 1 $ng.g^{-1}$ and 4.08 $ng.g^{-1}$ in various foodstuffs prepared as consumed (Huong et al., 2016). Detection and quantification rates (proportion of samples above LOD and LOQ values) were much higher in these publications than in the current study.

Alternariol monomethyl ether (AME) and tenuazonic acid (TA) were only detected in three and two food items respectively. Altenariol (AOH) was not found in either infant specific food or common food items (data not shown).EFSA reported levels of 3.0, 6.1 and 26.3 $ng.g^{-1}$ of AME, AOH and TA respectively in breakfast cereals, and 1.1 and 28 $ng.g^{-1}$ of AME and TA in bread (EFSA, 2016). Similar results were observed by Zhao (1.07 $ng.g^{-1}$ for AME and 11.7 $ng.g^{-1}$ for TA in bread) (Zhao et al., 2015).

Detection rates ranged from 0 to 50% in infant specific foods for DON, with a maximum observed in milk-based beverages. Acetylated compounds of DON were rarely detected (Figure 2, Table S3). The highest concentration

of DON was found in a fruit-based dessert containing rice (135 ng.g^{-1}). Detection rates were also highly variable for common foods. DON was detected in all the samples analysed among bread, croissant-like pastries, and pasta, a finding in line with the results of the second French TDS (Sirot et al., 2013). Similar results have been observed for infant cereals (102 ng.g^{-1} (Juan et al., 2014)), bread and biscuits (190 and 148 ng.g^{-1} (Stanciu et al., 2018), breakfast cereals and infant specific foods (96-210 and 112-133 ng.g^{-1} (Zhang et al., 2018)). In its report on DON, EFSA found contamination levels of 81.8 ng.g^{-1} in breakfast cereals, 79.8 ng.g^{-1} in bread and 85.7 ng.g^{-1} in bakery products (EFSA, 2013b). These results are in line with the current study.

Detection rates for FB1 and FB2 in infant specific foods ranged between 7% and 18%, and 9 and 12%, respectively, with highest % of detection in cereal-based foods in both cases. (Figure1, Table S3). In common food in the second French TDS (Sirot et al., 2013), fumonisins were detected in biscuits, breakfast cereals, bread and non-alcoholic beverages (detection rates between 6 and 100%). Assunção et al. found 13 ng.g^{-1} for FB1 and 3 ng.g^{-1} for FB2 in bread (Assunção et al., 2018), and Cano-Sancho et al. a total between 36.4 ng.g^{-1} (infant specific food) and 119 ng.g^{-1} (corn snack) (Cano-Sancho et al., 2012b). These levels are higher than those observed in the current study, especially for infant food.

Detection rate for nivalenol in infant specific food ranged from 0 to 33% depending on the food category (Figure 1, Table S3). The highest concentration was observed in a sample of fruit puree containing rice (65 ng.g^{-1}). For common foods, detection rates also depended on the food category, with a maximum rate observed in wheat-based products. In the literature, Assunção et al. reported 6 ng.g^{-1} of nivalenol in breakfast cereals (Assunção et al., 2015) and Juan 19.9 ng.g^{-1} in infant cereals (Juan et al., 2014), levels that are comparable with the results obtained in this study.

OTA was only detected in cereal-based infant specific food (Figure1, Table S3). For common foods, the maximum detection rate was observed in bread and pasta during the second French TDS (Sirot et al., 2013): OTA was found at 0.023 to 0.12 ng.g^{-1} in infant formula (Kabak, 2012). Juan et al. found 0.06 ng.g^{-1} (Juan et al., 2014) in infant cereals, whereas Kolakowski et al. found 0.59 ng.g^{-1} (Kolakowski et al., 2016) and Mitchell et al. found the much higher level of 14.4 ng.g^{-1} (Mitchell et al., 2017). Coronel et al. found 0.23 ng.g^{-1} in other infant specific foods (Coronel et al., 2012), while Alvito et al. reported values between 0.034 and 0.212 ng.g^{-1} in various infant specific foods (Alvito et al., 2010). Levels between 0.47 and 0.75 ng.g^{-1} have been reported for

breakfast cereals, with a maximum of 26 ng.g^{-1} (Assunção et al., 2015; Coronel et al., 2012; Kabak, 2009; Kolakowski et al., 2016; Mitchell et al., 2017). Škrbić et al. found 4.1 ng.g^{-1} of OTA in biscuits and 17.7 ng.g^{-1} in jams (Škrbić et al., 2017a), and Golge et al. 0.16 ng.g^{-1} in bread (Golge and Kabak, 2016). Cappozzo et al. confirmed that OTA could not be found in any infant formula, but found between 3.7 and 5.5 ng.g^{-1} of OTA in infant cereals (Cappozzo et al., 2017). OTA was also found in dried fruits at 1.2 to 3.03 ng.g^{-1} by Heshmati et al. (Heshmati et al., 2017) and up to 15.3 ng.g^{-1} by Mitchell et al. (Mitchell et al., 2017) and in different food products prepared as consumed by Huong et al. (from 1.9 ng.g^{-1} in cereal products to 4.08 ng.g^{-1} in beans) (Huong et al., 2016). The values observed in the literature are very variable but are generally much higher than those presented in this article.

Detection rate for patulin in infant specific food ranged from 16 to 80% depending on the food category, except in milk-based desserts and fruit juices in which it was not detected (Figure 1). The presence of patulin (which was found in fruits but not in milk) in milk-based beverages was explained by the fact that this kind of product contained fruit juice puree (Table S3). Piqué et al. (Piqué et al., 2013) reported contamination levels for apple juice and apple puree between 5.5 ng.g^{-1} and 3.8 ng.g^{-1} while Barreira et al. (Barreira et al., 2010) reported levels between 1.2 and 42 ng.g^{-1}. Guo et al. reported contamination between 7.21 and 9.07 ng.g^{-1} in apple juice (Guo et al., 2013). These levels are comparable to those obtained in the present study, except the maximum value of 42 ng.g^{-1} observed by Barreira.

Toxins T2 and HT2 toxins were detected at variable levels in infant specific foods. T2 toxin was found in fruit purees, meat-based ready-to-eat meals and follow-on formula (highest % of detection in fruit purees). HT2 toxin was detected in milk-based beverages, cereal-based food, fruit purees, meat based ready-to-eat meals and follow-on formula (highest % of detection in milk-based beverages) (Figure 1, Supplement 3). The highest concentrations were found in an infant follow-on formula (9.5 and 9.3 ng.g-1 for T2 and HT2, respectively) and a fruit puree-based dessert containing rice (4.9 and 8.7 ng.g-1 16 for T2 and HT2, respectively). For common foods, toxins were only detected in one sample of semolina where HT2 was detected.. These results are similar to those observed during the second French TDS (Sirot et al., 2013), where detection rates varied from 0 to 100% depending on the food. The concentrations of the present study were thus lower than levels reported in the literature, in which values varying from 4.37 ng.g^{-1} in jams (Škrbić et al., 2017a) to 19 ng.g^{-1} in cereal products (De Boevre et al., 2013) have been reported for the T2 toxin. The contamination of cereal products by

HT2 has been reported at 13 $ng.g^{-1}$ (De Boevre et al., 2013) and 17.4 $ng.g^{-1}$ (Carballo et al., 2018), with 12.6 $ng.g^{-1}$ reported for infant cereals (Juan et al., 2014), all of which are similar to the results of the current study.

Zearalenone was not detected in any infant specific food (Table S3). Detection rates were very variable for common food in the second French TDS (Sirot et al., 2013): Some metabolites of zearalenone were analysed (α-ZOL and β-ZOL) but not detected in either food intended for babies or common food. The contamination levels of previous studies were recorded as 2.64 $ng.g^{-1}$ in biscuits (Škrbić et al., 2017a), 0.19-7.56 and 17 $ng.g^{-1}$ in cereal products (De Boevre et al., 2013; Yau et al., 2016) and 27-905 $ng.g^{-1}$ in bread (Saladino et al., 2017). The results obtained by Saladino et al. are surprisingly high compared to other results obtained in the literature or in the current study.

3.2. Exposure of children

The exposure results for the mycotoxins raising safety concerns are presented in Tables 1, 2 and 3. Other exposure results are presented in the supplementary material.

The mean exposure to the sum of aflatoxins (AFB1+AFB2+AFG1+AFG2+1/10 AFM1) was zero under LB for the first three age groups and equal to 0.005 $ng.kg\ bw^{-1}.d^{-1}$ for the children aged 13 to 36 months (Table 1). The value of P90 under LB was zero for the first three age groups and equal to 0.005 $ng.kg\ bw^{-1}.d^{-1}$ for the children aged 13 to 36 months. Under the UB hypothesis, the mean exposure was between 2.57 $ng.kg\ bw^{-1}.d^{-1}$ (13 to 36 months) and 4.46 $ng.kg\ bw^{-1}.d^{-1}$ (1 to 4 months) and the value of P90 between 4.12 $ng.kg\ bw^{-1}.d^{-1}$ and 8.28 $ng.kg\ bw^{-1}.d^{-1}$.

The exposure to aflatoxins was equal to 0.0012 $ng.kg\ bw^{-1}.d^{-1}$ under LB and 2.12 $ng.kg\ bw^{-1}.d^{-1}$ under UB in the last French TDS for children aged between 3 and 6 years, which is comparable to the exposure of children aged 13 to 36 months in the current study (Sirot et al., 2013). The mean exposure for aflatoxin M1 alone was between 0 (LB) and 0.093 $ng.kg\ bw^{-1}.d^{-1}$ (UB) in the second French TDS (Sirot et al., 2013), a lower value than that of the present study. This can be explained by the fact that all infant specific foods containing milk, even with a very low percentage, were analysed in this study. Thereby even though aflatoxin M1 was never detected in our study, the contamination level was considered to be at the LOD under UB for all samples, so the mean UB exposure may have been artificially increased. The exposure of children to the sum of aflatoxins was found

by Hernández-Martínez (Hernández-Martínez and Navarro-Blasco, 2010) to lie between 0.08 ng.kg $bw^{-1}.d^{-1}$ and 0.94 ng.kg $bw^{-1}.d^{-1}$ (infant cereals only) , and by Cano-Sancho et al. to lie between 0.033 ng.kg $bw^{-1}.d^{-1}$ and 0.105 ng.kg $bw^{-1}.d^{-1}$ (Cano-Sancho et al., 2013). Exposure to individual aflatoxins has also been assessed in several studies: values for exposure to AFB1 have been reported as between 0.07 and 0.12 ng.kg $bw^{-1}.d^{-1}$ (Villa and Markaki, 2009), 0.011 ng.kg $bw^{-1}.d^{-1}$ (Assunção et al., 2018) and 0.09 ng.kg $bw^{-1}.d^{-1}$ (Škrbić et al., 2017b). Exposure to AFM1 through milk has been reported as 0.30 ng.kg $bw^{-1}.d^{-1}$ for children aged between 1 and 5 years (Kos et al., 2014). The reason for higher levels in the current study than those reported by Villa et al. (2009), Cano-Sancho et al. (2013) and Assunção et al. (2018) is probably also due to the fact that, like for AFM1, all food containing milk was analysed.

The mean UB exposure to AOH was between 17.0 ng.kg $bw^{-1}.d^{-1}$ (infants aged 1 to 4 months) and 192 ng.kg $bw^{-1}.d^{-1}$ (infants aged 7 to 12 months) (Table S4). Mean UB exposure to AME was between 1.30 and 16.8 ng.kg $bw^{-1}.d^{-1}$ and exposure to TA was between 12.2 and 170 ng.kg $bw^{-1}.d^{-1}$ respectively. The value of P90 varied between 41.1 and 385 ng.kg $bw^{-1}.d^{-1}$ for AOH, between 4.04 and 34.2 ng.kg $bw^{-1}.d^{-1}$ for AME, and between 42.4 and 302 ng.kg $bw^{-1}.d^{-1}$ for TA. The exposure of infants aged 1 to 4 months was very low as they consumed almost exclusively infant preparations not containing any A*lternaria* toxins. However, for infants aged 1 to 4 months with early food diversification including in particular products containing fruit, the mean exposure reached 104 ng.kg $bw^{-1}.d^{-1}$ for AOH, 7.98 ng.kg $bw^{-1}.d^{-1}$ for AME and 74.9 ng.kg $bw^{-1}.d^{-1}$ for TA (EFSA, 2019) (Table S5). The maximum exposure level observed for AOH among infants aged 5 to 6 months (1396 ng.kg $bw^{-1}.d^{-1}$) corresponded to a child consuming high quantities of a particular food item (carrot soup) during the consumption survey. For AME, a maximum exposure of 161 ng.kg $bw^{-1}.d^{-1}$ was observed for a child who had consumed a large quantity of a beverage containing milk and fruit juice. The maximum exposure for TA was observed among two children aged from 7 to 12 months who had consumed in one case a large quantity of beverages for infants, and in the other, a large quantity of fruit puree.

In 2016, the values for mean exposure to AOH obtained by EFSA were between 18.7 and 34.9 ng.kg $bw^{-1}.d^{-1}$ for infants (<12 months) under the UB hypothesis, and between 16.7 and 71.6 ng.kg $bw^{-1}.d^{-1}$ for toddlers (12-36 months) (EFSA, 2016). Exposure to AME was between 12.2 and 21.8 ng.kg $bw^{-1}.d^{-1}$ for infants and between 19.2 and 38.8 ng.kg $bw^{-1}.d^{-1}$ for toddlers. Exposure to TA was between 74 and 1490 ng.kg $bw^{-1}.d^{-1}$ for infants and between 215 and 1614 ng.kg $bw^{-1}.d^{-1}$ for toddlers. These EFSA levels are similar to those reported by Zhao et al.

in 2015: 39.1 ng.kg $bw^{-1}.d^{-1}$ for AOH, 10.2 ng.kg $bw^{-1}.d^{-1}$ for AME and 292 ng.kg $bw^{-1}.d^{-1}$ for TA among children aged from 2 to 6 years (Zhao et al., 2015) but are higher than those obtained in the present study, probably due to higher levels of contamination of vegetables and cereals in particular.

The UB exposure to the sum of DON and its acetylated compounds was between 59.5 ng.kg $bw^{-1}.d^{-1}$ (infants aged 1 to4 months) and 648 ng.kg $bw^{-1}.d^{-1}$ (7 to12 months), and between 2.87 and 216 ng.kg $bw^{-1}.d^{-1}$ under LB (Table 3). The value of P90 (90^{th} percentile of exposure) was zero for infants aged 1 to 4 months but 518 ng.kg $bw^{-1}.d^{-1}$ for children aged13 to 36 months under LB. It ranged from 187 to 1198 ng.kg $bw^{-1}.d^{-1}$ under UB.

Three children aged 5 to 6 months had a higher exposure level than the other children of their age group (>2100 ng.kg $bw^{-1}.d^{-1}$) because they consumed large quantities (85 to 120 $g.d^{-1}$) of a fruit puree containing rice that was highly contaminated by DON. For infants aged 1 to 4 months, exposure was mainly due to consumption of milk-based drinks, especially those containing cereals. For infants aged 5 to 6 months and 7 to 12 months, the main contributors were fruit purees, vegetable-based ready-to-eat meals and meat/fish-based ready-to-eat meals. For children aged 13 to36 months, biscuits and bread were the major contributors to exposure (Table S6).

In 2011, JECFA assessed the exposure to DON alone of children of different age groups above 3 years old. The values obtained were between 140 and 660 ng.kg $bw^{-1}.d^{-1}$, a range comparable to the values obtained in the present study (JECFA, 2011). The mean exposure to DON of children aged from 3 to 6 years was 667 ng.kg $bw^{-1}.d^{-1}$ under LB and 686 ng.kg $bw^{-1}.d^{-1}$ under UB in the second French TDS (Sirot et al., 2013). EFSA also assessed the exposure to DON of young children in 2013 and 2017, obtaining values in 2013 between 160 ng.kg $bw^{-1}.d^{-1}$ and 730 ng.kg $bw^{-1}.d^{-1}$ for infants, and between 480 ng.kg $bw^{-1}.d^{-1}$ and 1020 ng.kg $bw^{-1}.d^{-1}$ for toddlers. In 2017, exposure lay between 600 ng.kg $bw^{-1}.d^{-1}$ and 2000 ng.kg $bw^{-1}.d^{-1}$ for infants, and between 1100 ng.kg $bw^{-1}.d^{-1}$ and 1700 ng.kg $bw^{-1}.d^{-1}$ for toddlers (EFSA, 2013b, 2017). Kim et al. found that exposure of children between 3 and 6 years old ranged between 10 ng.kg $bw^{-1}.d^{-1}$ and 144 ng.kg $bw^{-1}.d^{-1}$ (Kim et al., 2009). Škrbić and Assunção obtained much lower results: Škrbić et al. found 2.33 ng.kg $bw^{-1}.d^{-1}$ and Assunção et al. 24.83 ng.kg $bw^{-1}.d^{-1}$ in their first study then 54.79 ng.kg $bw^{-1}.d^{-1}$ (Assunção et al., 2015; Assunção et al., 2018; Škrbić et al., 2017a), but the difference may be due to the fact that these studies analysed a limited number of foods (cereals and dried fruits) and did not take into account any other contributors.

The mean UB exposure to the sum of FB1 and FB2 was between 3.74 ng.kg $bw^{-1}.d^{-1}$ for infants aged 1 to 4 months and 69.2 ng.kg $bw^{-1}.d^{-1}$ for children aged 13 to 36 months. Exposure to fumonisin B1 represents half of the exposure to (FB1 + FB2). Under the UB hypothesis, P90 was equal to 9.59 ng.kg $bw^{-1}.d^{-1}$ for infants aged 1 to 4 months and 140 ng.kg $bw^{-1}.d^{-1}$ for the oldest age group (Table S4). The exposure of infants aged 1 to 4 months was very low as they consumed almost exclusively infant preparations, which do not contain fumonisins. For infants aged 1 to 4 months with early food diversification including in particular fruit purees, the mean UB exposure reached 16.5 ng.kg $bw^{-1}.d^{-1}$ for (FB1 +FB2) (Table S5).

Among the children aged 13 to 36 months, the highest exposure value was 840 ng.kg $bw^{-1}.d^{-1}$, corresponding to a child with a high daily consumption of savoury snacks during the survey that were particularly contaminated (215 $ng.g^{-1}$).

In the last French TDS, the exposure of children aged 3 to 6 years was found to be 58.2 ng.kg $bw^{-1}.d^{-1}$ for fumonisin B1 and 41.7 ng.kg $bw^{-1}.d^{-1}$ for fumonisin B2 (Sirot et al., 2013). These results are comparable to the results obtained for the present study for children aged 13 to 36 months. In 2015, Assunção et al. reported a mean exposure under the UB hypothesis of 5.46 ng.kg $bw^{-1}.d^{-1}$ for FB1 and 1.033 ng.kg $bw^{-1}.d^{-1}$ for FB2 among children aged 1 to 3 years (Assunção et al., 2015), then 5.6 ng.kg $bw^{-1}.d^{-1}$ (FB1) and 0.8 ng.kg $bw^{-1}.d^{-1}$ (FB2) in 2018 (Assunção et al., 2018). Cano-Sancho et al. found that exposure to (FB1+FB2) was 195.2 ng.kg $bw^{-1}.d^{-1}$ for infants and 85.3 ng.kg $bw^{-1}.d^{-1}$ for children (Cano-Sancho et al., 2012b), which is higher than the results of the present study, probably due to higher contamination levels.

The mean UB exposure to nivalenol was between 2.76 ng.kg $bw^{-1}.d^{-1}$ (infants aged 1 to 4 months) and 54.1 ng.kg $bw^{-1}.d^{-1}$ (5 to 6 months) (Table S4). The exposure P90 was 8.79 ng.kg $bw^{-1}.d^{-1}$ for infants aged 1 to 4 months and 84.4 ng.kg $bw^{-1}.d^{-1}$ for infants aged 7-12 months.

Three infants aged between 5 and 6 months had a high level of exposure, between 752 and 1015 ng.kg $bw^{-1}.d^{-1}$, because during the survey they had consumed a large quantity of a fruit puree containing rice that was highly contaminated by nivalenol.

The main contributors to exposure were cereal-based foods for infants aged 1 to 4 months, fruit purees for those aged 5 to 6 months, and fruit purees, meat-based ready-to-eat meals and cereal-based foods for those aged 7 to 12 months. For children aged 13 to 36 months, exposure was mainly due to cereal-based foods, meat-based ready-to-eat meals and mixed dishes (Table S6).

The mean exposure of children aged 3 to 6 years to nivalenol in the second French TDS was 40.7 ng.kg $bw^{-1}.d^{-1}$ under LB and 80.5 ng.kg $bw^{-1}.d^{-1}$ under UB (Sirot et al., 2013), which is similar to the results of the present study. Assunção obtained 2.68 ng.kg $bw^{-1}.d^{-1}$ in 2015 and 0.44 ng.kg $bw^{-1}.d^{-1}$ in 2018 under UB, which is much lower.

Mean exposure to OTA was between 0.005 ng.kg $bw^{-1}.d^{-1}$ (infants aged 1 to 4 months) and 0.144 ng.kg $bw^{-1}.d^{-1}$ (13 to 36 months) under LB, and between 1.12 ng.kg $bw^{-1}.d^{-1}$ and 3.07 ng.kg $bw^{-1}.d^{-1}$ under UB (Table S4). The value of P90 was zero for infants aged 1 to 4 months and 0.407 ng.kg $bw^{-1}.d^{-1}$ for children aged 13-36 months under LB, and varied from 2.04 ng.kg $bw^{-1}.d^{-1}$ to 5.01 ng.kg $bw^{-1}.d^{-1}$ under UB.
The mean UB exposure to OTA of French children aged 3 to 6 years was 3.87 ng.kg $bw^{-1}.d^{-1}$ (Sirot et al., 2013), which is comparable to exposure under UB for children aged 13 to 36 months in the present study. Similar or lower levels have been observed in previous studies: 2.34 ng.kg $bw^{-1}.d^{-1}$ for infants and 0.37 ng.kg $bw^{-1}.d^{-1}$ for children (4-9 years) (Coronel et al., 2012), 0.07-0.12 ng.kg $bw^{-1}.d^{-1}$ for children, on the basis of their consumption of cereal products (Villa and Markaki, 2009), 0.124 ng.kg $bw^{-1}.d^{-1}$ for children aged 1 to 3 years under UB (Assunção et al., 2018), and 0.41 ng.kg $bw^{-1}.d^{-1}$ for children aged 6 to 9 years under UB (Škrbić et al., 2017a).

Mean exposure to patulin was between 1.83 ng.kg $bw^{-1}.d^{-1}$ (infants aged 1 to 4 months) and 5.83 ng.kg $bw^{-1}.d^{-1}$ (infants aged 7-12 months) under LB, and between 4.21 ng.kg $bw^{-1}.d^{-1}$ (infants aged 1 to 4 months) and 58.2 ng.kg $bw^{-1}.d^{-1}$ (children aged 13 to 36 months) under UB (Table S4).
The exposure of the youngest infants (aged 1 to 4 months) was very low due to the fact that they consumed almost exclusively infant preparations that did not contain patulin, which is found only in fruit and vegetables. Exposure was higher for infants with early food diversification: 25.8 ng.kg $bw^{-1}.d^{-1}$ under UB (Table S5).
The exposure P90 was 0.72 ng.kg $bw^{-1}.d^{-1}$ for infants aged 1 to 4 months and 17.1 ng.kg $bw^{-1}.d^{-1}$ for children aged 13 to 36 months under LB. It varied from 2.67 to 125 ng.kg $bw^{-1}.d^{-1}$ under UB.
Two children aged 1 to 4 months had a much higher value of exposure than the other infants of their age group (137 and 232 ng.kg $bw^{-1}.d^{-1}$). These two children were consumers of apple puree not prepared specifically for babies, and highly contaminated by patulin.

The main contributors to exposure for all age groups except children aged from 5 to 6 months were common purees and cooked fruits (i.e. not specifically prepared for infants). Fruit purees formulated for babies were also a key contributor to exposure of infants aged 1 to 12 months, as was fruit for infants aged 5 to 6 months and children aged 13 to 36 months (Table S6).

The mean exposure to patulin for French children aged 3 to 6 years old was found in the second French TDS to be 61.7 ng.kg $bw^{-1}.d^{-1}$ (Sirot et al., 2013) , which is comparable to the exposure of children aged 13 to 36 months in the present study. Piqué et al. found that the exposure of children aged 0 to 3 years, calculated on the basis of their consumption of apple juice or apple puree only, was between 1.9 and 12.7 ng.kg $bw^{-1}.d^{-1}$ (apple puree) and between 4 and 15.5 ng.kg $bw^{-1}.d^{-1}$ (apple juice) (Piqué et al., 2013), which is also generally in the same range as our own study results.

Exposure to the sum of T2+HT2 was between 0.83 ng.kg $bw^{-1}.d^{-1}$ (infants aged 1 to 4 months) and 52.6 ng.kg $bw^{-1}.d^{-1}$ (5-6 months) under LB and between 53.9 ng.kg $bw^{-1}.d^{-1}$ (children aged 13 to 36 months) and 169 ng.kg $bw^{-1}.d^{-1}$ (infants aged 5 to 6 months) under UB (Table 2). The exposure P90 ranged from 0 for infants aged 1 to 4 months to 60.4 ng.kg $bw^{-1}.d^{-1}$ for those aged 5 to 6 months under LB, and from 92.5 ng.kg $bw^{-1}.d^{-1}$ to 235 ng.kg $bw^{-1}.d^{-1}$ respectively under UB.

Two children aged between 5 and 6 months were more exposed to toxins T2 and HT2 than the rest of their age group: 1170 and 1427 ng.kg $bw^{-1}.d^{-1}$ for T2 and 1146 and 1397 ng.kg $bw^{-1}.d^{-1}$ for HT2 under LB and UB respectively. These children were high consumers of highly-contaminated infant formula (9.5 and 9.3 $ng.kg^{-1}$ for T2 and HT2 respectively). EFSA (EFSA, 2011b) evaluated exposure to the sum of T2 and HT2 in 2011, reporting values between 5.9 (LB) and 12 (UB) ng.kg $bw^{-1}.d^{-1}$ for infants aged under 12 months and between 12 (LB) and 43 (UB) ng.kg $bw^{-1}.d^{-1}$ for children aged 13 to 36 months. These values are comparable to those obtained in the present study for the oldest children, but the exposure of the youngest ones is much higher in the infant TDS, probably because of the two outlier children previously mentioned. The mean exposure of children aged 3 to 6 years was between 5.61 (LB) and 52.8 (UB) ng.kg $bw^{-1}.d^{-1}$ for T2 and between 13.1 (LB) and 70.2 (UB) ng.kg $bw^{-1}.d^{-1}$ for HT2 during the second French TDS (Sirot et al., 2013), which is slightly higher than the exposure of children aged 13 to 36 months found in the present study. Škrbić obtained lower results for children aged from 6 to 9 years, with 0.42 ng.kg $bw^{-1}.d^{-1}$ for HT2 and 0.68 ng.kg $bw^{-1}.d^{-1}$ for T2 (Škrbić et al., 2017a).

The mean exposure to zearalenone was between 0.26 ng.kg $bw^{-1}.d^{-1}$ (infants aged 5 to 6 months) and 13.4 ng.kg $bw^{-1}.d^{-1}$ (children aged 13 to 36 months) under LB, and between 2.21 ng.kg $bw^{-1}.d^{-1}$ (infants aged 1 to 4 months) and 57.6 ng.kg $bw^{-1}.d^{-1}$ (children aged 13 to 36 months) under UB (Table S4). The exposure of infants aged 1 to 4 months was very low due to the almost exclusive consumption of infant formula, which did not contain zearalenone. For babies with early food diversification including biscuits among other things, exposure reached 9.56 ng.kg $bw^{-1}.d^{-1}$ under UB (Table S5).

The exposure P90 was equal to 0 for infants aged 1 to 4 months and 25.3 ng.kg $bw^{-1}.d^{-1}$ for children aged 13 to 36 months under LB. The respective values under UB ranged from 5.02 ng.kg $bw^{-1}.d^{-1}$ to 98.2 ng.kg $bw^{-1}.d^{-1}$.

Purees and cooked fruits were the main mycotoxin contributors for all age groups. For children aged 13 to 36 months, dairy-based desserts and pasta were also key contributors to exposure (Table S6).

EFSA in 2011 (EFSA, 2011a) reported exposure between 88 ng.kg $bw^{-1}.d^{-1}$ for children aged under 1 year and 100 ng.kg $bw^{-1}.d^{-1}$ for children aged between 1 and 3 years, which is slightly higher than the results obtained in this study. This difference can be explained by the fact that zearalenone was detected in some of the infant specific foods analysed in the EFSA study, which was not the case in our own study, despite lower detection limits.

The mean exposure of children aged 3 to 6 years was 65.9 ng.kg $bw^{-1}.d^{-1}$ in the second French TDS, which is similar to the exposure of children aged 13 to 36 months in the present study (Sirot et al., 2013). The exposure to zearalenone reported by Cano-Sancho in 2012 (Cano-Sancho et al., 2012a) was 17.9 ng.kg $bw^{-1}.d^{-1}$. Like for nivalenol, Assunção and Škrbić both obtained much lower results (0.69 ng.kg $bw^{-1}.d^{-1}$ and 0.30 ng.kg $bw^{-1}.d^{-1}$ respectively) but these studies did not analyse all the foods consumed by children (Assunção et al., 2018; Škrbić et al., 2017a).

3.3. Risk assessment

The exposure levels for T2 and HT2, as well as for DON and its derivatives, raise safety concerns. For T2 and HT2, the cases where the PMTDI of 60 ng.kg $bw^{-1}.d^{-1}$ proposed by JECFA in 2001 was exceeded under the LB affects over 10% of children aged 5 to 6 months, and 5% of children aged 7 to 12 months. In infants aged under 4 months, the PMTDI was also exceeded by a limited number of children, but it was difficult to estimate the proportion of the whole population in the light of the limited number of children concerned. The limits were

exceeded in children consuming either fruit puree containing rice with especially high mycotoxin levels, or higher-than-average quantities of infant formula in which T2 and HT2 were detected or quantified. Efforts to reduce exposure should therefore be pursued, especially by strengthening the monitoring of infant formulas and associated control measures. Concerning the other food products, efforts should be pursued to lower the analytical limits in order to refine the estimation of concentration levels and thus exposure.

For DON and its acetyl derivatives, and taking into account the benchmark value of 300 ng.kg $bw^{-1}.d^{-1}$ proposed by the ANSES expert panel, he proportion of children exceeding this limits under LB varied between 7.5 and 27% from the age of 7 months. When considering JECFA's TDI of 1000 ng.kg $bw^{-1}.d^{-1}$, a limited number of children (<5) exceeded the TDI under LB in every age group, but once again, it was difficult to estimate the actual proportion in the whole population because of the limited number of children concerned. Dietary exposure to DON and its acetyl derivatives raises safety concerns. Efforts to reduce exposure should therefore be continued, especially via the main contributors: infant milk drinks — especially those containing cereals — fruit purees, vegetable purees with or without meat, biscuits and bread. Additional toxicological studies are also necessary to confirm the HBGVs for young children. Like for toxins T2 and HT2, efforts should be pursued to lower the analytical limits in order to obtain more precise concentration data so as to be able to refine the estimation of exposure.

Aflatoxins were not detected in infant foods and only rarely detected in the common food commodities. However, considering the estimated exposures (UB hypothesis), the margin of exposure is much lower than 10,000 (between 38 and 66 depending on the age group), so a health risk cannot be excluded. In order to refine the exposure calculation and consequently evaluate the risk more precisely, the analytical limits should also be lowered.

For the other mycotoxins studied, the health risk linked to the dietary exposure could be excluded for the infants and young children. Ninetieth percentile (P90) exposure to fumonisins B1 or B2 represents only 14% of the HBGV when considering the upper bound hypothesis, revealing that exposure to these mycotoxins is of no health concern for the infant population.

Neither patulin nor zearalenone exceeded their respective HBGV, even in the 90^{th} percentile and considering the UB hypothesis. A health risk is therefore excluded for these two mycotoxins.

Concerning OTA, the HBGV was never exceeded in this study, but this value—defined on nephrotoxic effects—does not appear to be specific to the infant population. Studies on reproduction and development would be necessary to define a specific HBGV for infants and precisely evaluate their risk.

It was not possible to reach any conclusions as to the health risk associated with *Alternaria* toxins as no HBGV was available at the time of the study. Toxicity studies for establishing HBGVs applicable to the general and infant populations should therefore be conducted. These studies should in particular focus on alternariol and alternariol monomethyl ether, given their genotoxic nature demonstrated *in vitro*.

4. CONCLUSION

In conclusion, the exposure of children aged from 1 to 36 months to the mycotoxins studied raises no health concern for fumonisins, patulin and zearalenone, but raises health concern for aflatoxins, T2 and HT2 toxins, DON and its acetyl derivatives. However, this analysis was conducted on individual mycotoxins and does not take into account any "mixture effect". Complementary studies should be conducted to estimate the impact of combinations of mycotoxins, especially those having a similar effect on health.

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Table

Table 1: Dietary exposure to the sum of aflatoxins (AFB1+AFB2+AFG1+AFG2+1/10 AFM1) of children under 3 years (ng.kg $bw^{-1}.d^{-1}$) and margins of exposure on the basis of the $BMDL_{10}$ of 170 ng.kg $bw^{-1}.d^{-1}$

	Dietary exposure to the sum of aflatoxins (AFB1+AFB2+AFG1+AFG2+1/10 AFM1) ng.kg $bw^{-1}.d^{-1}$				**Margin of exposure**			
Age group (months)	**Mean ± standard deviation**		**P90**		**mean exposure**		**P90 of exposure**	
	LB	**UB**	**LB**	**UB**	**LB**	**UB**	**LB**	**UB**
1-4	0	4.46±3.37	0	8.28	NA*	38	NA*	21
5-6	0	3.70±2.15	0	6.41	NA*	46	NA*	27
7-12	0	3.74±1.78	0	5.85	NA*	45	NA*	29
13-36	0.005±0.02	2.57±1.23	0.005	4.12	35 000	66	32 000	41

LB: lower bound hypothesis; UB: upper bound hypothesis

NA*: not applicable (exposure null)

Table 2: Dietary exposure to the sum of T2 and HT2 toxins of children under 3 years (ng.kg $bw^{-1}.d^{-1}$) and percentage of exceedance of the HBGV of 60 ng.kg $bw^{-1}.d^{-1}$

Mycotoxin	**Age group (months)**	**Dietary exposure to the sum of toxins T2 and HT2 ng.kg $bw^{-1}.d^{-1}$**				**% of exceedance [95% CI]**	
		Mean ± standard deviation		**P90**			
		LB	**UB**	**LB**	**UB**	**LB**	**UB**
T2 toxin	1-4	0.422 ±3.56	79.1 ±24.5	0	104	0%	89.1% [82 ; 96]
	5-6	25.7 ±157	78.0 ±153	25.5	99.8	5.2% [0 ; 12]	42.4% [27 ; 58]
	7-12	5.92 ±33.4	42.0 ±37.6	16.3	62.9	NC*	11.8% [5,9 ; 18]
	13-36	1.97 ±3.87	23.3 ±14.6	5.73	41.5	0%	2.7% [1,3 ; 4,2]
HT2 toxin	1-4	0.405 ±3.23	80.1 ±23.5	0	104	0%	90.4% [84 ; 97]
	5-6	27 ±155	90.6 ±151	38.7	158	6.7% [0 ; 14]	57.5% [42 ; 73]
	7-12	6.8 ±33.5	57.2 ±41.6	16.3	92.2	NC*	38.2% [29 ; 47]
	13-36	2.51 ±4.13	30.6 ±17.7	6.41	54.6	0%	7.0% [4,6 ; 9,2]
Sum of T2+HT2 toxins	1-4	0.827 ±6.54	159 ±47.9	0	208	NC*	95.2% [91 ; 100]
	5-6	52.6 ±312	169 ±303	60.4	235	10.7% [1,1 ; 20]	87.8% [78 ; 98]
	7-12	12.7 ±66.7	99.2 ±77.8	33.2	164	4.9% [0,98 ; 8,8]	75.8% [68 ; 84]
	13-36	4.48 ±7.08	53.9 ±31.6	11.7	92.5	0%	36.6% [33 ; 41]

LB: lower bound hypothesis; UB: upper bound hypothesis

NC*: not calculated because of low number of children exceeding the HBGV (<5)

CI: confidence interval

Table 3: Dietary exposure to the sum of deoxynivalenol and its acetylated compounds of children under 3 years (ng.kg $bw^{-1}.d^{-1}$) and percentage of exceedance of the HBGV of 300 ng.kg $bw^{-1}.d^{-1}$

Age group (months)	**Dietary exposure to the sum of deoxynivalenol and its acetylated compounds (ng.kg $bw^{-1}.d^{-1}$**				**% of exceedance [95% CI]**	
	Mean ± standard deviation		**P90**			
	LB	**UB**	**LB**	**UB**	**LB**	**UB**
1-4	2.87 ± 27.4	59.5 ± 173	0	187	NC*	5.8% [0,6 ; 8,5]
5-6	101 ± 304	455 ± 508	254	1171	8.5% [0 ; 17]	49.4% [34 ; 65]
7-12	98.4 ± 165	648 ± 441	248	1198	7.5% [2,7 ; 12]	76.1% [68 ; 84]
13-36	216 ± 196	553 ± 317	518	954	27% [23 ; 31]	76.8% [73 ; 81]

LB: lower bound hypothesis; UB: upper bound hypothesis

NC*: not calculated because of low number of children exceeding the HBGV (<5)

CI: confidence interval

Figure

Figure 1: Mean concentration of mycotoxins in food groups for which mycotoxins were detected in at least one sample ($ng.g^{-1}$)

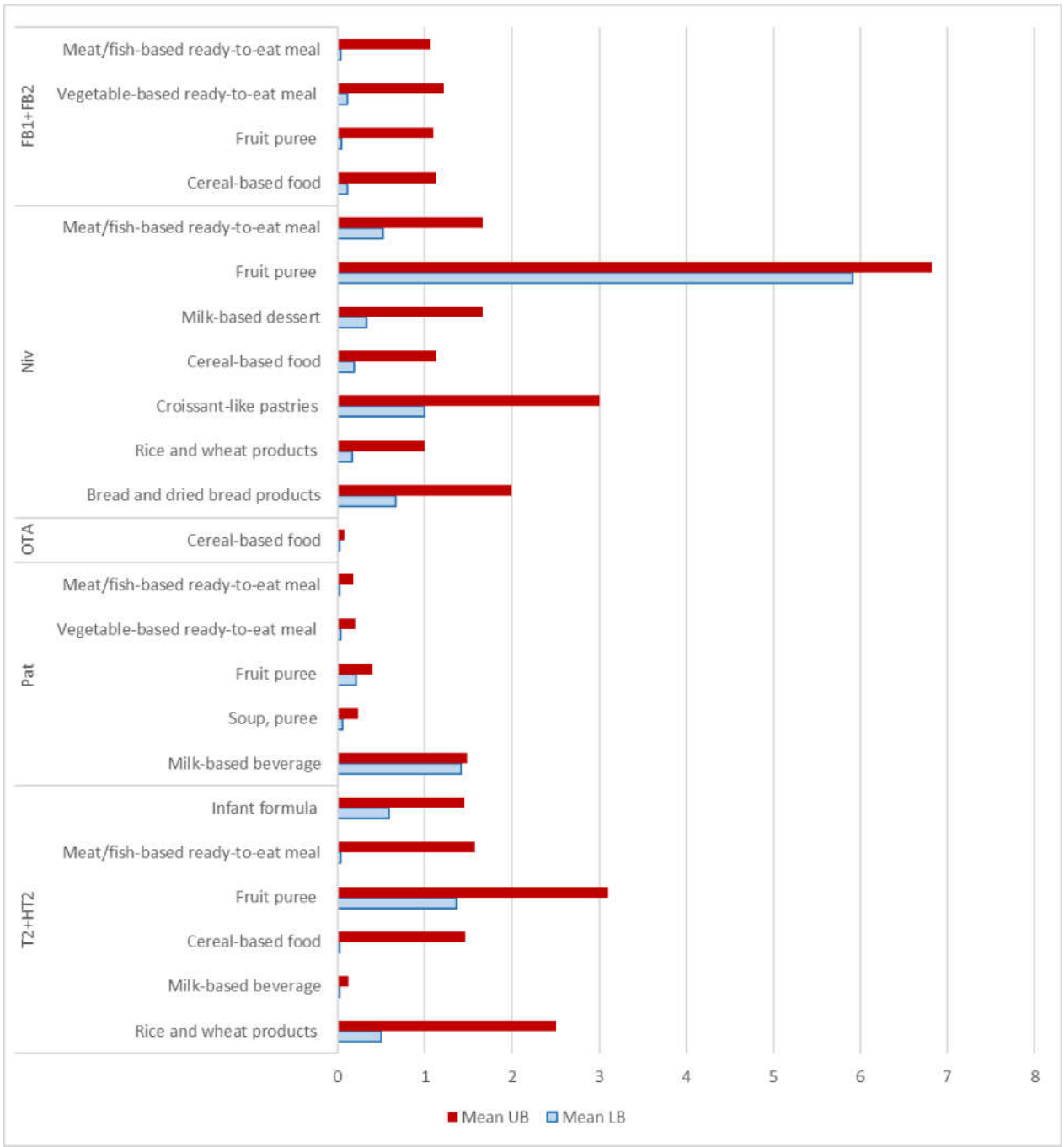


Figure 2: Mean concentration of deoxynivalenol and its acetylated compounds (sum) in food groups for which mycotoxins were detected in at least one sample ($ng.g^{-1}$)

