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Risk assessment of Belgian adults for furan contamination through the food chain

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Abstract:	Risk assessment is an interdisciplinary process used to quantify the risk linked to a hazard. In the present paper, it is applied to quantify the risk linked to furan ingestion through the food chain for the Belgian adult population. Two approaches, deterministic and probabilistic, are carried out in parallel. The deterministic method relies on a case-study, whereas the probabilistic approach involves statistical distributions of contamination and consumption data to calculate a statistical distribution of the daily intake. First, the deterministic method revealed a low Estimated Daily Intake (EDI) for the average population ($380 \text{ ng} \cdot (\text{kg} \cdot \text{w} \cdot \text{day})^{-1}$) and a huge contribution of coffee consumption to the EDI (55%). Increasing or decreasing by one cup the daily coffee consumption can affect the EDI by about 22%. Afterwards, the probabilistic approach showed that the average population has a low EDI ($494 \text{ ng} \cdot (\text{kg} \cdot \text{w} \cdot \text{day})^{-1}$), and that high contamination levels were only registered in a small proportion of the population. Finally, a comparison to the RfDchronic-oral showed that less than 10% of the Belgian population presents an EDI above the reference dose proposed by the US-EPA; the majority of the population presents an

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	EDI 20% below the reference dose. The Margin of Exposure (MoE) approach revealed that the level of risk related to furan intake through ingestion is low, with a MoE above 10,000 for more than 10 % of the population and no result below 100.

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Risk assessment of Belgian adults for furan contamination through the food chain

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Abstract

Risk assessment is an interdisciplinary process used to quantify the risk linked to a hazard. In the present paper, it is applied to quantify the risk linked to furan ingestion through the food chain for the Belgian adult population. Two approaches, deterministic and probabilistic, were carried out in parallel. The deterministic method relied on a case-study, whereas the probabilistic approach involved statistical distributions of contamination and consumption data to calculate a statistical distribution of the daily intake. First, the deterministic method revealed a low Estimated Daily Intake (EDI) for the average population ($380 \text{ ng} \cdot (\text{kg}_{\text{b.w.}} \cdot \text{day})^{-1}$) and a huge contribution of coffee consumption to the EDI (55%). Increasing or decreasing by one cup the daily coffee consumption can affect the EDI by about 22%. Afterwards, the probabilistic approach showed that the average population has a low EDI ($494 \text{ ng} \cdot (\text{kg}_{\text{b.w.}} \cdot \text{day})^{-1}$), and that high contamination levels were only registered in a small proportion of the population. Finally, a comparison to the $\text{RfD}_{\text{chronic-oral}}$ showed that less than 10% of the Belgian population had an EDI above the reference dose proposed by the US-EPA; the majority of the population had an EDI 20% below the reference dose. The Margin of Exposure (MoE) approach indicated that the level of risk related to furan intake through ingestion is low, with a MoE above 10,000 for more than 10 % of the population and no result below 100.

Keywords: Furan, Adult, Risk assessment, Food Chain, Belgium

Introduction

Risk assessment is: *‘The estimation of the nature and probability of adverse health effects related to a hazard, e.g., microbiology, chemistry, fire, riots, etc. (US-EPA risk assessment¹;*

¹ <http://epa.gov/riskassessment/index.htm>

Renwick et al., 2004; Feinberg et al., 2006). In the present paper, the risk related to furan ingestion throughout the food chain is discussed for the Belgian adult population.

Furan is a low molecular mass toxicant mainly found in food undergoing heat treatment such as canned, jarred or roasted food (Hasnip et al., 2006; Crews et al., 2007; Roberts et al., 2008; Fromberg et al., 2009; Kim et al., 2009). Maga first reported its occurrence in food in the late 70s (Maga, 1979), but its toxicity was only studied since the 90s (Kedderis et al., 1993; Chen et al., 1995; Peterson et al., 2006; Bakhiya et al. 2010). Consecutively, the American National Toxicology Program (NTP) published a report on its toxicity (NTP, 1993), the American National Academy of Science (NAS) classified it as a narcotic (NAS, 2000), and the International Agency for Research on Cancer (IARC) involved it as possibly carcinogenic to humans (group 2B). Nevertheless, furan has only gained interest since 2004, when the United State Food and Drug Administration published a report about its wide occurrence in food (US-FDA, 2004). Since then, national and international food control authorities started gathering information on furan levels, toxicity and risk for the population (Hepner et al., 2007; Stadler, 2007).

Several contamination assessments have been carried out to date, which led to the implementation of food control plans in some countries (Reinhard et al., 2004; Kim et al., 2009; Liu and Tsai, 2010). The main contamination assessment was recently achieved for the European population by the European Food and Safety Authorities (EFSA, 2009). It was based on a set of contamination data collected from European control plans, and on several independent contamination studies. EFSA combined these contamination data with the results of consumption surveys from several Europeans countries to estimate the furan daily intake. Nevertheless, the risk linked to furan firstly depends on food consumption habits, and secondly on food contamination levels (Feinberg et al., 2006). As consumption habits are related to subpopulations and locations, the present paper describes a risk assessment

targeting the Belgian adult population. The Estimated Daily Intake (EDI) was calculated using the deterministic and probabilistic methodologies. Afterwards, the risk was estimated both by comparing it to a toxicological reference dose (classical way) and also by calculating the Margin of Exposure (MoE).

Materials and methods

Contamination data

The contamination dataset only included products sold in Belgium, which were analysed by a previously described methodology (Scholl et al., 2009). This assessment was performed using 496 items sampled in the whole country (Scholl et al., 2011). Samples were taken all along the food chain, in several food markets. The sampling plan included weighting factors, such as food consumption and already reported contamination levels, to focus on the main food groups. This methodology was also applied to avoid the bias resulting from a similar product sold in several countries, but for which the preparation and/or composition can be different (Wegener and Lopez-Sanchez, 2010).

The assessment relied on a sole methodology to avoid the bias resulting from applying several approaches with different detection capabilities (CC_{β}) (in a first approach equivalent to the limit of quantification (LOQ)), repeatability, precisions, and expanded uncertainties (Scholl et al., 2009). The procedure used is a solid phase micro-extraction (SPME) coupled to a gas chromatography separation followed by a mass spectrometry detection using the isotopic dilution technique for quantification. The analytical approach is very sensitive and provides a response rate of up to 78.2% above the LOQ.

Consumption data

The Belgian Institute of Public Health provided consumption data. In 2004, De Vriese and co-workers carried out a consumption assessment of the Belgian population (De Vriese et al.,

2005). This assessment involved 3,200 people of at least 15 years old from the whole country. The protocol was a recall performed on two non-consecutive days combined to a self-administrated questionnaire on food consumption frequency and a final face-to-face interview. This assessment focused not only on consumption habits, but also on socio-economic data of each participant, providing relevant information to study some subpopulations.

Methodology of risk assessment

Hazard Identification

Furan is a toxic present in the food chain. In 1993, the NTP published a first report on furan toxicity and carcinogenicity based on *in vivo* studies on rat. This report was used in 1995 by the International Agency for Research on Cancer (IARC) to classify it in the group 2B, which means 'possibly carcinogenic to humans'. Five years later, the NAS also classified it as a narcotic. Several independent toxicological studies highlighting the carcinogenic effect of its metabolites have been performed since the 90s, (Kedderis et al., 1993; Chen et al., 1995; Peterson et al., 2000; Peterson et al., 2005; Peterson et al., 2006; Bakhiya et al. 2010; Hamberger et al., 2010). More recent studies revealed that furan toxicity was linked to its major primary metabolite, the *cis*-2-butene-1,4-dial, able to induce tumours through a genotoxic effect on liver cells (Chen et al., 1995; Peterson et al., 2000; Peterson et al., 2005; Peterson et al., 2006). This metabolite results from the first hepatic transformation of furan by cytochrome P-450. To date, toxicity for humans has only been extrapolated from *in vitro* and animals studies.

Hazard characterisation

Hazard characterisation corresponds to a dose-response assessment. It is a toxicological step describing the mechanism of action including dynamic and kinetic aspects. The main intake

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122 pathway of furan into the body is the food chain. The low polarity of furan allows it to easily
123 cross biological membranes. Studies on rats revealed that about 80 % of furan is eliminated
124 within 24 hours: 40 % by respiration, 22 % in faeces and 20 % in urine (Burka et al., 1991).
125 The remaining 18% are rapidly metabolised by hepatic enzymes of the cytochrome P-450 into
126 more than 10 metabolites (Bakhiya et al., 2010). Its major primary metabolite, the *cis*-2-
127 butene-1,4-dial resulting from furan oxidation, is known to induce hepatocellular tumour and
128 mononuclear cell leukaemia in rats. Furan is also known to induce cholangiocarcinomas in rat
129 liver through an oxidative stress mechanism (Hickling et al., 2010a,b)

130 In the late 80s, the US-EPA proposed a Reference Dose for Chronic Oral Exposure
131 (RfD) based on NTP studies (US-EPA Integrated Risk Information System²). This dose was
132 calculated according to a 13 week-study involving rat gavages aiming at inducing hepatic
133 lesions. The Lowest Observed Adverse Effect Level (LOAEL) was then estimated to be 4
134 mg*(kg_{body weight} and day)⁻¹ for rats. The No Observed Adverse Effect Level (NOAEL) was
135 fixed at 2 mg * (kg_{b.w.}*day)⁻¹. The application of several precaution factors allowed the US-
136 EPA to recommend a RfD_{chronic-oral} of 1 µg * (kg_{b.w.}*day)⁻¹ for humans.

137 In addition, based on the NTP and on the Moser and co-workers studies (Moser et al.,
138 2009), a benchmark dose for 10% extra risk (BMD₁₀) of hepatocellular adenomas and
139 carcinoma was established. Subsequently, a 95% lower confidence limit for this benchmark
140 dose (BMDL₁₀) for the same Mode of Action (MoA) was reported to be 0.96 mg *
141 (kg_{b.w.}*day)⁻¹ (Benford et al., 2010; Carthew et al., 2010; Williams et al, 2011).

142 *Exposure Assessment*

143 The exposure assessment aims at estimating the daily intake of a toxic (EDI). When available,
144 the EDI may be combined to the daily out-take to estimate the mean absorption.

² <http://www.epa.gov/iris/subst/0056.htm>

Furan daily intake throughout the food chain is calculated by applying three equations, namely Equation 1, Equation 2 and Equation 3. The first equation means the global EDI equals the sum of individual EDIs (EDI of each food group). The second equation explains that a food group EDI results from multiplying the specific food group relative consumption by the food group contamination. The third equation shows that the relative daily consumption corresponds to the ratio between the daily consumption and the 'population' weight.

Equation 1: Calculation of global EDI

$$EDI_{Global} = \sum_{FoodGroup} EDI_{FoodGroup}$$

Equation 2: calculation of EDI

$$EDI_{FoodGroup} = [Furan]_{FoodGroup} \times (relativeDailyConsumption)_{FoodGroup}$$

Equation 3: Estimation of the relative daily consumption

$$relativeDailyConsumption = \frac{DailyConsumption}{Weight}$$

Two approaches were applied to calculate the EDI: deterministic and probabilistic; both methods are described in the following sections.

1.1.1.1. Deterministic approach

In the deterministic approach, the EDI was calculated for several categories of the population according to selected cases, e.g. mean or worst case. As furan contamination is directly related to food origin and preparation (Crews and Castle, 2007; Wegener and López-Sánchez, 2010), only the results of the previously mentioned Belgian contamination assessment were used (Scholl et al., 2011). Three different approaches are recommended by the WHO to deal with contamination data below the quantification limits (WHO, 2003). These approaches are named Lower Bound (LB), Middle Bound (MB) and Upper Bound (UB), where results below

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the limit of quantification (LOQ) are respectively replaced by 0, half-LOQ and LOQ itself. In the present study, as the proportion of non-quantifiable results was very low (< 12 %), these approaches were expected to provide quite similar results. Consumption depends on the population studied; therefore, only data from the '*First Belgian consumption survey*' (De Vriese et al., 2005) were used. Several categories of population were studied for each food group such as the average consumption, the 2.5th, 25th, 50th, 75th, and 97.5th consumption percentiles. These categories of population are assessable by two ways depending on how unconsumated items are dealt with. On one hand, the statistical analysis is performed by considering only the subpopulation consuming the food group; statistical results of consumption are therefore not representative of the whole population. On the other hand, the whole population is included, and the no-consumption of a food item is characterised by a null-consumption value. The first approach is usually applied in cases of acute toxicity as is more related to a punctual dose, which is the most appropriate for a worst case-study. The second approach is generally applied in case of chronic toxicity as it considers the possibility of not consuming a food item. As furan is known to have a chronic toxicity, only the second procedure was applied in the present paper.

The real weight of each participant to the food consumption survey was used to estimate the EDI more accurately as it was available.

Probabilistic approach

In this approach, raw (consumption and contamination) data are converted into a function of occurrence (Table I) and computed using the @Risk software (version 5.5; Palisade Corporation, New York, USA). Afterwards, functions are combined through Eq.1, Eq.2 and Eq.3 by using a Monte-Carlo simulation with 500,000 iterations to obtain a function of furan EDI.

Functions of contamination occurrence are computed in two steps. The function of each food group is first determined by only including contamination data $>LOQ$ (this function is truncated such as no result $<LOQ$ can be drawn). Thereafter, a function dealing with the probability to have a data $<LOQ$ is added to the occurrence function determined in the first step. The nature of the second function depends on the approach used to deal with data $<LOQ$. In the probabilistic method, the three approaches described in the deterministic section (LB, MB and UB) were also applied. A fourth approach named Uniform and involving a random distribution of data $<LOQ$, was used as well, because it appears more representative of the reality. Practically, in the first three approaches, a discrete function corresponding to, respectively, 0, $LOQ/2$ and LOQ was used, while a uniform distribution between 0 and LOQ was applied in the fourth approach. Four bimodal functions corresponding to the four approaches were calculated for each food group.

The functions of consumption occurrence were also computed in two steps based on raw data of the Belgian consumption survey. First of all, a function was computed for each food group by including only the consuming subpopulation (functions are also truncated to avoid a ≤ 0 consumption draw). Secondly, the subpopulation not consuming the food item was calculated. A discrete function set to 0 was then proportionally added to the function calculated in the first step. Therefore, the resulting function of consumption occurrence resulting is bimodal like the contamination function.

In this approach, the real population weight was also used and represented by a statistical distribution of the population weight reported in the consumption survey.

Risk characterisation

Two risk characterisation approaches are presented in this paper: a classical way and a new method. In the first one, conclusions have been drawn from comparing the EDIs of several proportions of the population to toxicological reference doses. However, as carcinogenic

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effects have no threshold values, a new methodology called Margin of Exposure (MoE) was recently developed (ILSI, 2009). In the MoE approach, a level of concern for the risk linked to a Mode of Action (MoA) is calculated (Eq.4).

Equation 4: MoE calculation for a carcinogenic MoA

$$MoE = \frac{BMDL_{10}}{EDI}$$

Where $BMDL_{10}$ is the 95% lower confidence limit for this benchmark dose for 10% extra risk of hepatocellular adenomas and carcinoma and EDI is the estimated daily intake.

The risk may be considered as negligible if the MoE is >10,000. On the other hand, a MoE <100 is of major concern. Finally, discussions are needed, according to the involved MoA, for a MoE included in a range between 10,000 and 100 (ILSI, 2009).

Results

Deterministic approach

Results of the deterministic risk assessments are summarised in Table II and Figure 1. The three approaches used to deal with values <LOQs gave quite similar results, as shown in Table II. There is a <2 ng * (kg_{b.w.}*day)⁻¹ difference between LB and UB for the average population; it is a consequence of the high proportion of results > LOQs (>78%) in the contamination assessment. In Figure 1, only the MB approach was illustrated for a question of readability.

Average and median population EDIs are close (respectively 380 and 330 ng * (kg_{b.w.}*day)⁻¹). Therefore, the distribution of the 3,200 individual EDIs across the population tends to normality, as illustrated in Figure 2A. The figure also shows that the majority of the population has a low EDI with a mode at 225 ng * (kg_{b.w.}*day)⁻¹ for 9.5% of the studied population. In this approach, the minimal and maximal EDIs were 0.7 and 3,843 ng * (kg_{b.w.}*day)⁻¹, respectively.

Only 2.7% of the population presented an EDI above the $RfD_{\text{chronic-oral}}$. The majority of the population has an EDI equivalent to 22% of the $RfD_{\text{chronic-oral}}$, and the average population EDI is equivalent to 38% of the $RfD_{\text{chronic-oral}}$.

Figure 2A also displays the MoE calculation while the proportion of the population at a given MoE is presented in Figure 2C. About 10% of the population presents a MoE >10,000 and a MoE >1,500 is observed for >90% of the population. The minimal calculated MoE was 404 for 0.02% of the population and no MoE was <100. Finally, the MoE dispersion mode is 4,266 for 9.5% of the population. The main contributors to the EDI are shown in Figure 1. Coffee contributes by 55% to the average EDI, and the other main groups are: soups, prepared meat, pasta and rice and potatoes with an overall contribution of 26% to the EDI (ranging individually from 4 to 9%).

Coffee consumption scenario

Coffee was shown to be the major contributor (55%) to the average EDI. This average EDI was achieved after a daily consumption of three cups. The influence of reducing or increasing by one cup the daily consumption was tested in the proposed scenario, as shown in Figure 3. These variations induced a 21% increase ($460 \text{ ng} \cdot (\text{kg}_{\text{b.w.}} \cdot \text{day})^{-1}$) and a 23% decrease ($294 \text{ ng} \cdot (\text{kg}_{\text{b.w.}} \cdot \text{day})^{-1}$) of the average EDI ($380 \text{ ng} \cdot (\text{kg}_{\text{b.w.}} \cdot \text{day})^{-1}$), corresponding to a 12% reduction (or 8% increase) of the contribution to the EDI when simulating both scenarios.

Probabilistic approach

Results of the probabilistic risk assessment are summarized in Table III and Figure 2B. Figure 2B displays the distribution of EDIs across the population. A uniform distribution for the results <LOQ and a statistical distribution of the body weights were used to estimate the EDIs.

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Differences between the contamination approaches are shown in Table III. A difference of $6 \text{ ng} \cdot (\text{kg}_{\text{b.w.}} \cdot \text{day})^{-1}$ (from 488 to 494) was highlighted for the average population. Consequently, it was decided to show only the results of the uniform distribution approach in the figures. The median EDI represents 43% ($212 \text{ ng} \cdot (\text{kg}_{\text{b.w.}} \cdot \text{day})^{-1}$) of the average EDI and is not a normal distribution as confirmed by Figure 2B. The EDI of the majority of the population is low ($23 \text{ ng} \cdot (\text{kg}_{\text{b.w.}} \cdot \text{day})^{-1}$), corresponding to 5% of the average EDI.

An EDI below the $\text{RfD}_{\text{chronic-oral}}$ was reported for 91.9% of the population. The average EDI and the EDI of the majority of the population represented, about 49% and 0.2% of the $\text{RfD}_{\text{chronic-oral}}$, respectively.

MoEs related to specific EDIs are displayed in Figure 2B, while the proportion of the population relative to a MoE are shown in Figure 2D. A MoE above 10,000 was reported for 30% of the population. Seventeen percent of the population presented a MoE of 38,400 (distribution mode) and 90% of the population had a MoE above 1,164. Calculated MoE decreased until 0.1 for a maximum estimated EDI of $9.2 \text{ mg} \cdot (\text{kg}_{\text{b.w.}} \cdot \text{day})^{-1}$ ($<0.0002\%$ of the population), while only 0.03% of the population displayed a MoE <380 .

Discussion

Consumption data

As previously mentioned, it was decided to use Belgian datasets with the objective to avoid bias linked to consumption habits observed in other countries. Several consumption surveys have been carried out to date in Belgium, but only the Belgian study achieved in 2004 included the whole adult population. This survey was representative of the Belgian population as it included 3,200 people (out of a 10,400,000-global population registered in 2004), from the whole country, and homogeneously distributed according to gender, age, education level,

working field, etc. Nevertheless, data are out-dated as the survey was performed 7 years ago. However, consumption habits have probably not evolved a lot since the end of the survey. Thus, one can assume that differences between current and reported consumption habits are minor. The ideal situation would have been to work on a freshly updated survey involving a constant review of data, but such a tool is not yet available.

Contamination data

The contamination dataset was provided by a survey focusing on local products in order to avoid any bias linked to different preparations and compositions of the same product sold in other countries. In addition, the study relied on a highly sensitive analytical methodology specifically designed to reach low quantification limits. There are two beneficial consequences. Firstly, a high proportion of data >LOQ (up to 78%), characterised by small differences between LB and UB, were observed. Secondly, inter-laboratory analytical biases resulting from applying different methodologies (different LOQs, expanded uncertainties, etc.) were eliminated.

The representativeness of this study comes from its design. It was constructed to avoid a geographical or branding side effect. The dataset is not out-dated as it was compiled only two years ago. But as already mentioned for the consumption study, regular updates are needed to avoid biases related to a modified production and/or distribution scheme. An on-going survey based on a constant re-evaluation through a food control plan would be suitable.

Deterministic vs. probabilistic approach

Deterministic and probabilistic approaches should not be seen as different but rather as complementary methods.

The comparison of average EDIs only displayed few differences. However, comparing EDI distributions and medians or modes displayed important differences, especially for the

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low daily intake. Furthermore, the EDI distribution is narrower and the EDI increases faster in the probabilistic approach compared to the deterministic approach. This is a consequence of a difference of contamination data management. In the deterministic approach, only the average contamination value of each food group was taken into account, whereas in the probabilistic approach, a distribution of values (including 0 and very high levels) was used. Therefore, average EDIs and extreme values are biased, in the deterministic and in the probabilistic approaches respectively.

MoE distributions are very different, but led to similar conclusions. The majority of the population presented a high MoE and a >10,000 MoE was reported for a meaningful percentage of people. Differences were however observed for extreme values: the minimal MoE was 404 in the deterministic approach, while it decreased to 0.1 in the probabilistic method. Such a low MoE value results from very high consumption and contamination values, only encountered in a statistical distribution. Therefore, such a combination is very unlikely and should be ignored.

The same differences were observed in the $RfD_{\text{chronic-oral}}$ approach: the EDI of the majority of the population corresponded to <50 % of the $RfD_{\text{chronic-oral}}$ and few percents had an $EDI > RfD_{\text{chronic-oral}}$. The probabilistic methodology tended to display a higher risk than the deterministic approach. As already observed for the MoE, it finds its explanation in the unlikely extreme EDI values and biased average values in the probabilistic and in the deterministic approaches respectively. Consequently, most results tended to display a low risk level for furan intake. The real situation should fit between both approaches.

Coffee consumption scenario

Coffee consumption was shown to be a critical parameter regarding its impact on furan daily intake. Several straightforward or basic recommendations such as a reduction of the daily

consumption, a thorough mixing of coffee before drinking or even a coffee percolation allows reducing the exposure (Kuballa et al., 2007).

Conclusion

The present study showed that the majority of the population presents a low daily intake; only extreme consumers are really at risk. The major contamination is due to coffee consumption (one of the most contaminated items) and changing consumption habits can strongly impact the EDI.

One must be cautious regarding the conclusions drawn from the risk characterisation. If it is commonly accepted that a MoE >10,000 corresponds to a low risk level, and that a MoE <100 means a high risk, there is no consensus for the results included between 10,000 and 100. In the present survey, 10 to 30% of the population are exposed to a low risk level. Nevertheless, the risk level is not defined for the remaining 70 to 90%. The majority of the population displays a high MoE and therefore a low risk for the selected MoA (hepatocellular adenomas and carcinomas). Similar conclusions drawn when using the classical way (comparison between EDI and the $RfD_{\text{chronic-oral}}$).

Finally, the present study only focused on the adult Belgian population, and a question remains pending about furan exposure of subpopulations at risk, like babies and children. Carrying out a risk assessment targeting these subpopulations would be relevant but remains a great challenge, as few data are available on their consumption habits.

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3 479 **Table and figure caption**

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5 481 **Table I.**
6 482 List of the distributions used for the probabilistic risk assessment (only distributions for
7 483 samples >LOQ and for 'consuming' people are presented) according to the @Risk software
8 484 notations.

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10 485 **Table II.**
11 486 Deterministic EDI ($\text{ng} * (\text{kg}_{\text{b.w.}} * \text{day})^{-1}$) for several contamination approaches.
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13 488 **Table III.**
14 489 Probabilistic EDI ($\text{ng} * (\text{kg}_{\text{b.w.}} * \text{day})^{-1}$) for several contamination approaches.
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17 492 **Figure 1.**
18 493 Title: Deterministic EDI for the average population, including the contribution of the most
19 494 relevant food groups.
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22 497 **Figure 2.**
23 498 Title: (A): Distribution of the EDI across the population in the *deterministic* approach, and
24 499 evolution of the MoE according to the EDI; (B): Same as A but for the *probabilistic*
25 500 approach; (C): Distribution of the MoE across the population in the *deterministic* approach;
26 501 (D): Same as C for the *probabilistic* approach.
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29 504 **Figure 3.**
30 505 Title: Influence of decreasing or increasing the daily coffee consumption by one cup on the
31 506 EDI of the average population, including the contribution of the most relevant food groups.
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Table I. List of the distributions used for the probabilistic risk assessment (only distributions for samples >LOQ and for 'consuming' people are presented) according to the @Risk software notations.

Food group	@Risk Contamination distribution	@Risk Consumption distribution
Vegetables	RiskBetaGeneral(0.21931;0.22834;0.8;30.68)	RiskPearson5(7.9716;1688.8;RiskShift(-75.196))
Fruits	RiskPearson5(0.87353;1.1588;RiskShift(0.13385))	RiskPearson5(6.8822;1997.4;RiskShift(-120.74))
Milk and Milky beverages	RiskLognorm(3.3751;2.9041;RiskShift(-0.5535))	RiskLoglogistic(-54.643;288.93;5.0313)
Dessert cream	RiskNormal(7.358;7.209)	RiskLoglogistic(-16.106;148.06;3.764)
Pasta, Rice, Other Grain	RiskExtvalue(22.516;27.748)	RiskLognorm(203.84;132.09;RiskShift(-27.127))
Breakfast Cereals	RiskLognorm(33.178;32.292;RiskShift(-1.3011))	RiskPearson5(8.3866;564.71;RiskShift(-23.071))
Biscuits	RiskNormal(25.721;19.913)	RiskInvgauss(49.638;67.916;RiskShift(-4.3678))
Raw Meat	RiskBetaGeneral(0.27138;0.35639;0.32;66.93)	RiskInvgauss(101.66;226;RiskShift(-11.664))
Processed meat	RiskInvgauss(4.0861;0.7775;RiskShift(0.17294))	RiskInvgauss(67.906;106.439;RiskShift(-4.1765))
Fish	RiskExpon(23.148;RiskShift(-0.79903))	RiskBetaGeneral(1.4836;5.9922;1.6382;526.32)
Chocolate, Candy Bars, Paste, etc.	RiskUniform(-0.33556;8.9656)	RiskPearson5(3.793;147.04;RiskShift(-11.33))
Confectioner and Non-Chocolate	RiskBetaGeneral(0.18312;0.21331;0.72;8.79)	RiskInvgauss(37.276;33.348;RiskShift(-2.6119))
Cakes	RiskPearson5(1.2746;5.7504;RiskShift(1.4743))	RiskInvgauss(48.025;79.124;RiskShift(-3.4931))
Fruit And Vegetable Juices	RiskLoglogistic(-0.6429;2.0314;5.2505)	RiskLoglogistic(-72.436;278.71;3.2801)
Soft drinks	RiskTriang(-0.018347;0.95;1.6178)	RiskInvgauss(635.46;1093.9;RiskShift(-57.616))
Coffee	RiskBetaGeneral(0.4086;0.47225;1.13;106.23)	RiskPearson5(4.9426;2648.5;RiskShift(-191.14))
Tea	RiskBetaGeneral(0.29271;0.27597;0.37;2.87)	RiskLognorm(338.95;321.83;RiskShift(39.603))
Herbal Tea	RiskBetaGeneral(0.18842;0.20477;0.22;3.68)	RiskPearson5(4.2366;1363.5;RiskShift(-80.915))
Wine	RiskLoglogistic(0.19764;0.30883;2.0584)	RiskLognorm(287.29;189.16;RiskShift(-26.305))
Beer, Cider	RiskInvgauss(3.9075;19.794;RiskShift(-1.2641))	RiskPearson5(3.0816;1457;RiskShift(-129.34))
Tomato Sauces	RiskLogistic(11.2955;2.9182)	RiskInvgauss(73.018;30.148;RiskShift(-0.36396))
Soups	RiskInvgauss(25.542;10.767;RiskShift(-0.5567))	RiskExtvalue(241.22;109.2)
Miscellaneous	RiskPearson5(5.8123;82.114;RiskShift(-7.3599))	RiskLoglogistic(2.7612;71.036;2.4976)
Soya Products	RiskExtvalue(1.3338;1.1449)	RiskInvgauss(135.6;45.027;RiskShift(-4.31))

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Table II. Deterministic EDI (ng * (kg_{b.w.}*day)⁻¹) for several contamination approaches.

	Lower Bound	Middle Bound	Upper Bound
First Quartile	191	192	193
Median	329	330	331
Mean	379	380	381
Third Quartile	500	501	501

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Table III. Probabilistic EDI ($\text{ng} \cdot (\text{kg}_{\text{b.w.}} \cdot \text{day})^{-1}$) for several contamination approaches.

	Lower Bound	Middle Bound	Upper Bound	Uniform
Mode	25	23	27	23
First Quartile	80	80	82	81
Median	211	212	213	212
Mean	494	494	488	494
Third Quartile	492	493	493	493
Proportion of results > RfD_{ora} (%)	8.1	8.1	8.1	8.1

53x35mm (300 x 300 DPI)

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