Food and Chemical Toxicology 177 (2023) 113843

Contents lists available at ScienceDirect

Food and Chemical Toxicology

journal homepage: www.elsevier.com/locate/foodchemtox

Development of a food composition database of different food contaminants CONT11 and estimation of dietary exposure in children of southern Spain

Daniel Hinojosa-Nogueira [a,b], José J. Muros [c], Beatriz Navajas-Porras [a,b], Adriana Delgado-Osorio [a,b], Sergio Pérez-Burillo [a,b], Silvia Pastoriza [a,b], José Á. Rufián-Henares [a,b,*]

[a] Department of Nutrition and Food Science, Institute of Nutrition and Food Technology, Biomedical Research Centre, University of Granada, 18071, Granada, Spain
[b] Instituto de Investigación Biosanitaria ibs. GRANADA, Universidad de Granada, Granada, Spain
[c] Department of Didactics of Corporal Expression, University of Granada, 18071, Granada, Spain

ARTICLE INFO

Handling Editor: Dr. Bryan Delaney

Keywords:
Food contaminants
Dietary exposure
Food composition database
Children

ABSTRACT

Increasing food security is one of the Sustainable Development Goals. One of the main risks in food is the increase in food contaminants. Processing methods, such as the addition of additives or heat treatment, influence contaminant generation and increase their levels in food. The aim of the present study was to create a database using a methodology similar to that of food composition databases but with a focus on potential food contaminants. CONT11 collects information on 11 contaminants: hydroxymethyl-2-furfural, pyrraline, Amadori compounds, furosine, acrylamide, furan, polycyclic aromatic hydrocarbons, benzopyrene, nitrates, nitrites and nitrosamines. This is collected for more than 220 foods obtained from 35 different data sources. A food frequency questionnaire validated for use with children was used to validate the database. Contaminant intake and exposure in 114 children aged 10–11 years were estimated. Outcomes were within the range of values described by other studies, confirming the usefulness of CONT11. This database will allow nutrition researchers to go a step further in assessing dietary exposure to some food components and the association of this with disease, whilst also informing strategies to reduce exposure.

1. Introduction

Increasing food security was one of the Sustainable Development Goals (SDGs) proposed by the Food and Agriculture Organization of the United Nations (FAO) (Lillford and Hermansson, 2021). Food security is about ensuring the availability and safety of food. Nevertheless, through diet, humans are exposed to a large range of substances that can induce adverse health effects (Sirot et al., 2019). Contaminants are among the most potentially harmful substances. Some are present in high concentrations in food. These contaminants can be generated during or after processing, especially during heating, handling and storage (Mesías et al., 2019; Rufián-Henares et al., 2004; Sirot et al., 2019). In this context, contaminants from food preservation and processing are of great relevance, due to growing trends towards following diets high in processed foodstuffs (Lauria et al., 2021; Mielech et al., 2021; Monteiro et al., 2019).

During thermal processing, such as drying, smoking, grilling, frying or baking, different chemical reactions take place within food components which give rise to new substances (Delgado-Andrade et al., 2007; Hulin et al., 2014; Kwon et al., 2021; Rufián-Henares et al., 2006). Some of these reactions are the degradation of ascorbic acid, caramelisation or the Maillard reaction, which generate a large amount of contaminants (Cotterill et al., 2008; Delgado-Andrade et al., 2007; Hinojosa-Nogueira et al., 2020; Mesías et al., 2019; Sirot et al., 2019). Such contaminants include 5-Hydroxymethyl-2-Furfural (HMF), pyrraline, Amadori compounds, furosine, acrylamide, furan and total polycyclic aromatic hydrocarbons (PAHs), among which benzopyrene stands out (Rufián-Henares et al., 2002, 2008). On the other hand, inorganic

* Corresponding author. Department of Nutrition and Food Science, Institute of Nutrition and Food Technology, Biomedical Research Centre, University of Granada, 18071, Granada, Spain.

E-mail addresses: dhinojosa@ugr.es (D. Hinojosa-Nogueira), jjmuros@ugr.es (J.J. Muros), beatriznavajas@ugr.es (B. Navajas-Porras), adrianadelgado@ugr.es (A. Delgado-Osorio), spburillo@ugr.es (S. Pérez-Burillo), spdelacueva@ugr.es (S. Pastoriza), jarufian@ugr.es (J.Á. Rufián-Henares).

https://doi.org/10.1016/j.fct.2023.113843
Received 12 January 2023; Received in revised form 27 February 2023; Accepted 13 May 2023
Available online 23 May 2023

nitrates (NO_3) and nitrites (NO_2) are compounds present in both natural and industrially processed foods (Hsu et al., 2009; Kalaycıoğlu and Erim, 2019; Karwowska and Kononiuk, 2020; Keller et al., 2020). Green leafy vegetables and drinking water are the main sources of NO_3 in the diet (Ward et al., 2018; Zhong et al., 2022a). Further, the highest dietary intake of NO_2 usually comes from processed meat due to the use of nitrite salts as food additives (Hsu et al., 2009; Zhong et al., 2022b). Concern is increased by the endogenous conversion of these contaminants into the highly toxic compound nitrosamines (Kotopoulou et al., 2022; Moazeni et al., 2020; Thomas et al., 2021).

Organisations such FAO, or the European Food Safety Authority (EFSA), are developing databases and tools to help assess dietary exposure to different contaminants in global populations (Kovarich et al., 2022; Talari et al., 2021). The aim of such tools includes helping to protect the most vulnerable populations, such as children, due to their specific physiological characteristics, such as lower weight or greater development of new tissues (Mielech et al., 2021; Sirot et al., 2019). Estimates of exposure to contaminants can be calculated using the tools provided by these organisations. However, dietary exposure to contaminants could be better assessed by estimating food intake and contaminant concentrations with more specific tools (Mielech et al., 2021). In order to determine intake levels of contaminants, food intake data provided by dietary records and adequate food composition data are required. In contrast to other nutrients and food components, few databases include food composition and food contaminants. Instead, specific and independent databases for each contaminant or family of contaminants tend to be used for this purpose (Durazzo et al., 2018; Jakszyn et al., 2004; Marconi et al., 2018; Zhong et al., 2022a; Zhong et al., 2022b).

The aim of the present study was to describe the elaboration of a food composition database (FCDB), developed in line with food classification systems outlined for the elaboration of nutritional FCDB and used for dietary pattern analysis. In this way, the intake of 11 contaminants potentially present in food could be estimated by collecting information from different sources such as publications and databases. In addition, the usability and validity of this FCDB was tested by estimating intake in a population of Spanish children.

2. Materials and methods

2.1. Selection of contaminants and source of information

Many contaminants are potentially present in food. 11 compounds were selected for database development. Of these, nitrates, nitrites and nitrosamides may be present in food or added as additives (Hsu et al., 2009; Kalaycıoğlu and Erim, 2019; Karwowska and Kononiuk, 2020; Keller et al., 2020). The remaining food contaminants, HMF, pyrraline, Amadori compounds, furosine, acrylamide, furan, PAH and benzopyrene come from the thermal processing of foods or appear during storage or aging (Cotterill et al., 2008; Hinojosa-Nogueira et al., 2020; Mesías et al., 2019; Sirot et al., 2019). We have selected these contaminants since thermal food processing is the most prevalent method of industrial and domestic food processing, representing more than 80% of the foods consumed (Chan-Hon-Tong et al., 2013; Hulin et al., 2014). On the other hand, the use of additives is always in the spotlight; in this sense we have focused on nitrates and nitrites because of their wide use as additives in the food industry and their naturally presence in foods or water (Kotopoulou et al., 2022; Mielech et al., 2021). The FCDB created with these 11 compounds was named CONT11. Each contaminant was assigned a label to which a unit of measurement was associated in line with protocols described by FAO (Charrondiere et al., 2016a; Klensin et al., 1989). These contaminants are presented in Table 1.

A working team consisting of a coordinator and several data gatherers, all of whom were researchers or dietitians and nutritionists, was established for to develop the CONT11 FCDB. Protocols for the standardisation and harmonisation of data were based on the same procedures used in the development of the FCDB S4H and suggested by the FAO (Charrondiere et al., 2016a; Charrondiere et al., 2016b; Hinojosa-Nogueira et al., 2021).

Table 1
Contaminants included in the CONT11 FCDB, labels, units and sources of information pertaining to food concentrations.

Contaminant	Label	Unit	Source of information
5-Hydroxymethyl-2-Furfural	HMF5	mg	Arribas-Lorenzo and Morales (2010); Capuano and Fogliano (2011); Delgado-Andrade et al. (2010); Mesías et al. (2019); Rufian-Henares and De la Cueva, 2008; Shapla et al. (2018); *TUD - AGE* Database (2022)
Pyrraline	PYRR	mg	Förster et al. (2005); Hellwig et al. (2018); Scheijen et al. (2016); *TUD - AGE* Database (2022)
Amadori compounds	AMCOMP	mg	(2005); Yang et al. (2020)
Furosine	FUROS	mg	Mesías et al. (2019); *TUD - AGE* Database (2022)
Acrylamide	ACRYL	µg	Bermudo et al. (2008); Boletín Boletín Oficial del Estado (2003); Capuano and Fogliano (2011); Cressey et al. (2012); EFSA Panel on Contaminants in the Food Chain (CONTAM), 2015; Food Safety Commission of Japan (2016); Hamlet et al. (2014); Hulin et al. (2014); Jakszyn et al., 2004; World Health Organization (2012)
Furan	FURAN	µg	European Food Safety Authority (EFSA), 2011; Hamlet et al. (2014); Hulin et al. (2014); Jakszyn et al., 2004; Mesías et al. (2012); Seok et al. (2015); Sijia et al. (2014)
Nitrates	NITRA	mg	Blekkenhorst et al. (2017); Boletín Boletín Oficial del Estado (2003); Griesenbeck et al. (2009); Hord et al. (2009); Jakszyn et al. (2004); Kalaycıoğlu and Erim (2019); World Health Organization (2012); Zhong et al., 2022a; Zhong et al., 2022b
Nitrites	NITRI	mg	Blekkenhorst et al. (2017); Boletín Boletín Oficial del Estado (2003); Griesenbeck et al. (2009); Hord et al. (2009); Jakszyn et al. (2004); Kalaycıoğlu and Erim (2019); World Health Organization (2012); Zhong et al., 2022a; Zhong et al., 2022b
Nitrosamines	NITRN	µg	Griesenbeck et al. (2009); Jakszyn et al. (2004)
Benzopyrene	B(A)P	µg	Boletín Boletín Oficial del Estado (2003); Ekhator et al. (2018); European Food Safety Authority (EFSA), 2008; Hulin et al. (2014); Jakszyn et al. (2004); Martorell et al. (2010); Veyrand et al. (2013); World Health Organization (2012)
Total Polycyclic aromatic hydrocarbon	TPAHC	µg	Boletín Boletín Oficial del Estado (2003); Ekhator et al. (2018); European Food Safety Authority (EFSA), 2008; Hulin et al. (2014); Jakszyn et al. (2004); Martorell et al. (2010); Veyrand et al. (2013); World Health Organization (2012)

Briefly, the process for the development of CONT11 started with a review of relevant literature and possible sources of information, such as databases belonging to research centres or reports by different organisations, such as EFSA or the World Health Organization (WHO) European Food Safety Authority (EFSA), 2008; *TUD- AGE* Database, 2022; World Health Organization, 2012; Zhong et al., 2022a). All selected studi es and databases had to have been published following the year 2000 in order to get as much information as possible. A total of 35 information sources from studies and repositories that could potentially be useful for constructing a FCDB of contaminants were identified and are shown in Table 1. Each information source varied in terms of quality and quantity of food. Nonetheless, the approach adopted was to try to obtain the maximum amount of data possible.

In addition, with regards to water contaminant levels, maximum values stipulated by Spanish legislation were used and are identical to the maximum values permitted in the European Union (Boletín Boletín Oficial del Estado, 2003). This data establishes sanitary criteria for water quality for human consumption and maximum values for nitrates, nitrites, acrylamide, benzopyrene and PAHs. All data were extracted and compiled manually in a spreadsheet.

2.2. Development and validation of the CONT11 FCDB

From each data source, information on all foods that could be clearly identified and concentrations of the 11 selected contaminants was collected. In parallel, original data were preserved and coded according to the information source. This process was performed to ensure traceability and allow for later verifications or corrections. All foods were identified and classified according to the ontology proposed by EFSA FoodEx2 (European Food Safety Authority, 2015), which guaranteed that food-to-food comparisons were consistent.

Certain foods, such as infant formula or foods that could not be adequately classified, were excluded. Foods with values below the limits of quantification or with 0 values were also excluded. Cooking methods were included as an additional data element. Possible methods included boiling, frying, baking, grilling or roasting. In cases where several values were possible for a given cooking method, with the only variation being cooking temperature, values were correlated. In cases where cooking methods varied, the method was coded by associating it with a similar cooking method. Preservation methods such as salting, smoking, or dehydrating were also coded. Methodology for this coding was based on that used for the creation of the S4H FCDB (Hinojosa-Nogueira et al., 2021).

In order to optimise standardisation, all contaminants were considered as if they were nutrients. Thus, contaminant concentrations were standardised in line with units provided on food labels per 100 g or millilitres of foodstuff. When measurements were expressed in terms of grams of protein, they were converted to grams of food using protein values extracted from the S4H FCDB (Hinojosa-Nogueira et al., 2021). In cases where several contaminant values were present for the same foodstuff within the same data source, means were used as preferred values. In order to create a single FCDB, data were organised in a uniform structure, which involved food items being linked according to the FoodEx2 identification code. For each food, several values were sought so that different information sources provided data on the same foodstuff and the same contaminant. In these cases, median values were estimated for each compound whenever a foodstuff had the same code. Data unification permitted unique values for each contaminant to be input into the FCDB for each food. In this way, contaminant intakes could be estimated in the same way as nutrient intake. All changes were made manually or semi-automatically in spreadsheets. A HACCP system similar to the one developed for S4H was employed for data control and validation (Hinojosa-Nogueira et al., 2021). Detected errors were verified and rectified by traceability of the data back to the original sources of information.

CONT 11 was used to estimate contaminant intake and exposure in a population of children in Granada, Spain. Outcomes were compared with those reported by other studies in order to validate the developed database.

2.3. Population used to test the usefulness of the tool and analysis of the data obtained

CONT11 was validated within a population of children in order to estimate intake of the contaminants under study in a vulnerable population. All children were recruited from different schools with the same socio-economic status and located in a similar rural environment in the region of Granada, Spain. The study involved 228 children aged 10–11 years. For test the usefulness of CONT11, data were randomly extracted from 114 children of which half were girls and half were boys. The study collected information on food consumption through different dietary records including a previously validated (de la Fuente-Arrillaga et al., 2010) food frequency questionnaire (FFQ). The FFQ included 136 items and collected information on different food groups. Different anthropometric parameters such as height, weight and BMI were also recorded.

Means and standard deviations (SD) were estimated for all variables. The Mann-Whitney *U* test was used to conduct gender differentiated analysis. Correlations were performed using the Spearman test. Significance was set at $p = 0.05$. Data were analysed using IBM SPSS 24 statistical software.

2.4. Estimation of intake and exposure

Different spreadsheets were used to estimate contaminant intake and exposure. Food intake data were obtained from the FFQ. FFQ usually indicates the amount of raw food making adaptation necessary. For this purpose, the method adopted by other studies was followed, using the weighted averages pertaining to different cooking methods (Kotemori et al., 2018).

In order to calculate food intake, the portion consumed in grams was multiplied by the reported frequency per day. Subsequently, contaminant intakes were estimated through the weighted concentrations for each item.

Individual dietary exposure was calculated according to the daily intake of each contaminant divided by the body weight of each subject. Data were expressed as mg or μg of contaminant/day per kg body weight. Mean exposure for each contaminant for the overall population was estimated from individual exposure values. Foods were grouped into 12 food groups and the percentage of intake in each food group for the different contaminants was calculated to assess the contribution of each food group to the total intake.

3. Results

After selecting and analysing the different information sources, CONT11 included 220 foods, of which 45 associations were found with regards to cooking method. All foods were classified into 20 different food groups.

Different foods and food groups can contribute to contaminant intake. In this way, the foods and food groups most likely to be main sources of exposure to food contaminants were examined. Fig. 1 shows the percentage contribution of the food groups listed in the CONT11 FCDB to contaminant intake based on the absolute amount of each contaminant.

Turning attention to each individual contaminant, it can be seen that in HMF foods such as coffee or processed products, sweets, grains and alcoholic beverages are the main contributors to the intake of this compound. In the case of pyrraline, grains and their derivatives are the main contributors to intake. For Amadori compounds and furosine, dairy products were the group with the highest exposure to these compounds, followed by grains. For furan and acrylamide, the main food groups contributing most to exposure are processed foods such as sweets, snacks, coffee, grains and tubers. For PAHs, especially benzopyrene, fats, fish, meat and meat products and grains are the main contributors to exposure. Finally, a large difference is seen between food groups in the intake of nitrates, nitrites and nitrosamines. While vegetables and spices are mainly accountable for nitrate intake, fish, meat and meat products are mainly responsible for dietary exposure to nitrosamines. For nitrites, two large groups emerged, namely, vegetables and nuts and meat. The former contain these compounds due to its

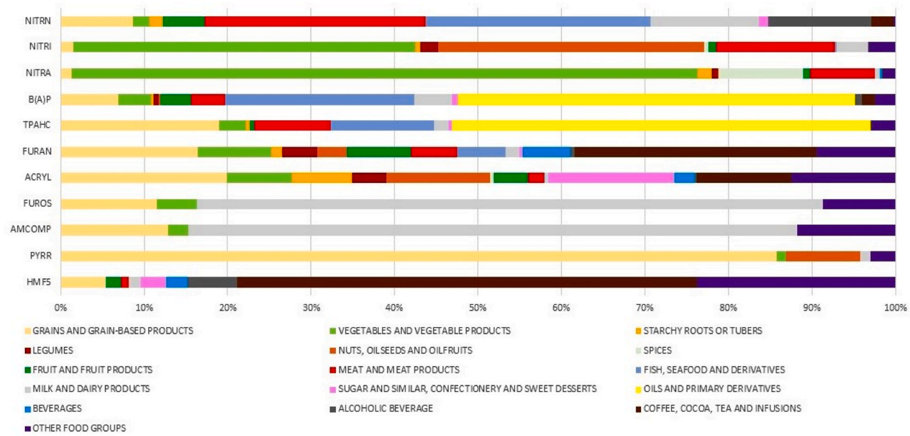

Fig. 1. Percentage contribution of CONT11 FCDB food groups to contaminant intake.

absorption from irrigation water and soil, whilst the latter has nitrites added as additives.

Using a validated FFQ adapted to CONT11, total and individual contaminant intake in schoolchildren was estimated according to gender. As shown in Table 2, significant differences according to gender were not found for any contaminant.

The main food groups implicated in contaminant intake in school children can be seen in Fig. 2 with grains, dairy products, processed foods and beverages, specifically juices, being the main sources of exposure to some contaminants, such as HMF, pyrraline, furosine and Amadori compounds. In terms of acrylamide intake, tubers (more specifically fried potatoes and other processed foods) are the main contributors to intake. In the case of furan, furan intake is widely distributed between food groups, such as beverages, processed foods and meat and meat products, whilst PAHs and benzopyrene intake is modulated by the consumption of foods of animal origin, although fats and oils also contribute to intake. As for nitrates, products of plant origin have the highest concentrations, while nuts and meats mainly contribute to nitrite consumption. Finally, nitrosamines intake is influenced by the consumption of meat and dairy products.

Anthropometric data were used to estimate exposure to each contaminant. Mean weight was 41 ± 8 kg and mean BMI was 19.7. Table 3 shows mean exposure to each contaminant according to gender. No significant differences in contaminant exposure were observed between boys and girls. Further, no significant correlations were found between contaminant intake and the anthropometric parameters of the school children.

Finally, Fig. 3 compares outcomes pertaining to the intake of the different contaminants found in the school children examined in the present study and those reported in previously conducted scientific literature (Arribas-Lorenzo and Morales, 2010; Blekkenhorst et al., 2017; Cressey et al., 2012; Delgado-Andrade et al., 2010; Delgado-Andrade et al., 2007; Domingo and Nadal, 2015; EFSA Panel on Contaminants in the Food Chain (CONTAM), 2015; Ekhator et al., 2018; Förster et al., 2005; Hellwig and Henle, 2012; Hord et al., 2009; Hsu et al., 2009; Hulin et al., 2014; Keller et al., 2020; Mariotti et al., 2013; Mesías et al., 2012, 2019; Pastoriza de la Cueva et al., 2017; Pysz et al., 2016; Rufian-Henares and De la Cueva, 2008; Santonicola and Mercogliano, 2016; Sijia et al., 2014; Thomas et al., 2021; Timmermann et al., 2021; Ward et al., 2018). Values were logarithmically transformed in order to plot them on the same graph. The intake of some contaminants presented considerable variability in the literature and all data estimated from the child population of the present study were within or below the ranges described in other research.

Table 2
Contaminant intakes of 114 school children according to gender.

Contaminant intake	Mean ± SD	Girls	Boys
HMF5 (mg/day)	13.5 ± 4.6	13.8	13.3
PYRR (mg/day)	21.7 ± 8.1	21.2	22.1
AMCOMP (mg/day)	140 ± 79.7	130	150
FUROS (mg/day)	51.0 ± 26	47.8	54.2
ACRYL (μg/day)	85.3 ± 21.2	83.8	86.8
FURAN (μg/day)	19.9 ± 6.4	20.1	19.7
NITRA (mg/day)	101 ± 39.4	101	101
NITRI (mg/day)	10.7 ± 3.7	10.3	11.1
NITRN (μg/day)	7.9 ± 2.3	7.8	8.1
B(A)P (μg/day)	1.1 ± 0.4	1.1	1.1
TPAHC (μg/day)	7.3 ± 1.6	7.1	7.5

4. Discussion

4.1. CONT11 as a database

Food composition databases available at a national level do not commonly assess food contaminants. Agencies such as WHO and EFSA are working to develop tools to estimate contaminant intake and exposure in food (Ioannidou et al., 2021; Kovarich et al., 2022; Talari et al., 2021). Although different information sources are available on the concentrations of contaminants in food, few use an approach similar to that used by FCDB. One example comes from the nitrate and nitrite databases developed by Zhong et al. (Zhong et al., 2022a; Zhong et al., 2022b). These databases classify foods using the Foodex2 ontology and adopt similar guidelines to the FCDB. The use of an ontology enables better food classification, in addition to offering greater versatility and adaptability than dietary registers such as FFQ or 24 h recall (Charrondiere et al., 2016a; Charrondiere et al., 2016b; European Food Safety Authority (EFSA), 2015; Hinojosa-Nogueira et al., 2021).

For this reason, CONT11 was developed using the standard models for the development of FCDB (Charrondiere et al., 2016a; Charrondiere et al., 2016b). This approach permits traceability of information and standardisation of contaminant concentrations pertaining to a given foodstuff as measured by different sources. In addition, information can be used more accurately and, as with nutrients, intake and exposure may be more easily estimated in epidemiological studies (Charrondiere et al., 2016a; Charrondiere et al., 2016b; Hinojosa-Nogueira et al., 2021; Jakszyn et al., 2004; Kwon et al., 2021; Mielech et al., 2021; Sirot et al., 2019).

Contaminant concentrations in food may differ considerably according to geographical region, food source, environmental conditions and food production. Also cooking or preservation methods have a high impact on such concentrations (Ekhator et al., 2018; Shapla et al., 2018). For this reason, CONT11 was elaborated by collecting data from official sources such WHO or EFSA and scientific literature, thus guaranteeing a

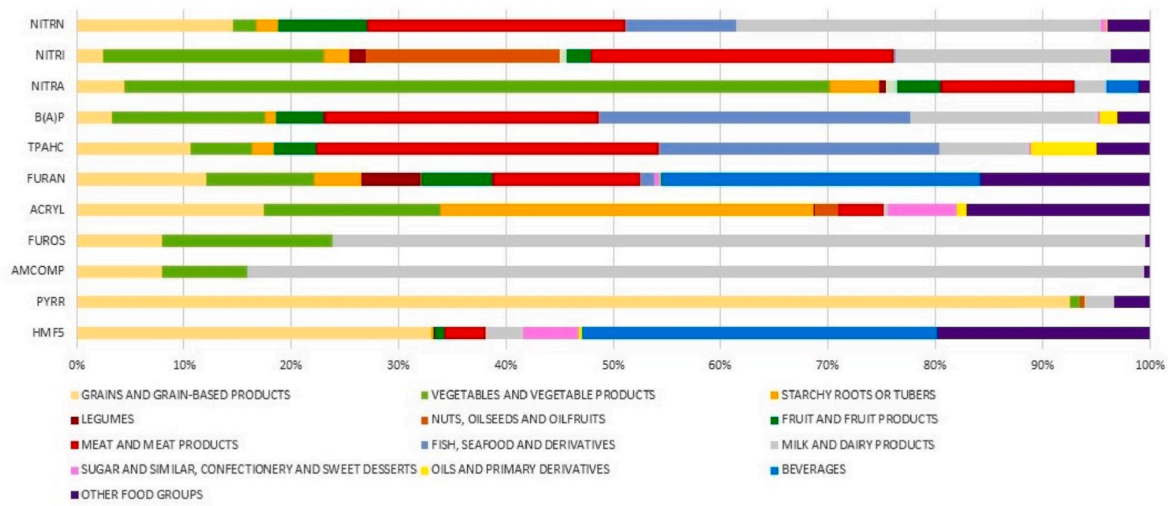

Fig. 2. Percentage of contaminants according to food group with respect to children's food intake.

Table 3
Contaminant exposure according to gender.

Contaminant exposure	Mean ± SD	Girls	Boys
HMF5 (mg/kg body weight/day)	0.34 ± 0.15	0.36	0.33
PYRR (mg/kg body weight/day)	0.54 ± 0.23	0.55	0.54
AMCOMP (mg/kg body weight/day)	3.50 ± 1.98	3.32	3.68
FUROS (mg/kg body weight/day)	1.28 ± 0.65	1.22	1.33
ACRYL (μg/kg body weight/day)	2.16 ± 0.75	2.16	2.16
FURAN (μg/kg body weight/day)	0.50 ± 0.20	0.51	0.49
NITRA (mg/kg body weight/day)	2.57 ± 1.22	2.58	2.56
NITRI (mg/kg body weight/day)	0.27 ± 0.12	0.27	0.28
NITRN (μg/kg body weight/day)	0.20 ± 0.07	0.20	0.20
B(A)P (μg/kg body weight/day)	0.03 ± 0.01	0.03	0.03
TPAHC (μg/kg body weight/day)	0.18 ± 0.05	0.18	0.18

greater amount and validity of included information. In this context, the year of publication of included articles was limited in order to make the search more precise and focus on more recent information. Despite the diverse values obtained due to the different information sources, standardisation and unification processes made it possible to obtain reference values. In the future, database accuracy could be improved by adding more information sources. The traceability system also means that values can be corrected or updated. Currently, CONT11 is able to obtain values for different contaminants for a large number of different foods at a detailed level.

Moreover, CONT11 data shown in Fig. 1 are consistent with those described by other studies. For example, cereals and coffee are mainly responsible for HMF consumption (Arribas-Lorenzo and Morales, 2010; Husøy et al., 2008; Rufian-Henares and De la Cueva, 2008). In the case of pyrraline, grains are the foods with the highest concentrations (Hellwig et al., 2018). Dairy products have high concentrations of Amadori compounds and furosine (Delgado-Andrade et al., 2007; Mesías et al., 2019). For furans and acrylamide, as described in other studies, fried and processed foods have the highest levels of these contaminants (EFSA Panel on Contaminants in the Food Chain (CONTAM), 2015; Food Safety Commission of Japan, 2016); Santonicola and Mercogliano, 2016; Sijia et al., 2014). CONT11 agrees that fats, fish, meat and meat products are the main foods containing both benzopyrene and PAHs (Domingo and Nadal, 2015; Polachova et al., 2020). Finally, the concentrations of nitrates, nitrites and nitrosamines are largely dependent on the food source. While nitrate concentrations may appear to be present in food naturally (Moazeni et al., 2020; Thomas et al., 2021; Zhong et al., 2022a; Zhong et al., 2022b), nitrites and nitrosamines are mainly found in foods that contain additives. In this sense, products such as meat products stand out, with nuts, in contrast, having high concentrations of nitrates (EFSA Panel on Food Additives and Nutrient Sources added to Food (ANS) et al., 2017; Kalaycıoğlu and Erim, 2019).

Although seen in the general overview of the included food groups, some specific foods contain high levels of specific contaminants, such as HMF in coffee. It should be noted that their effect on exposure decreases

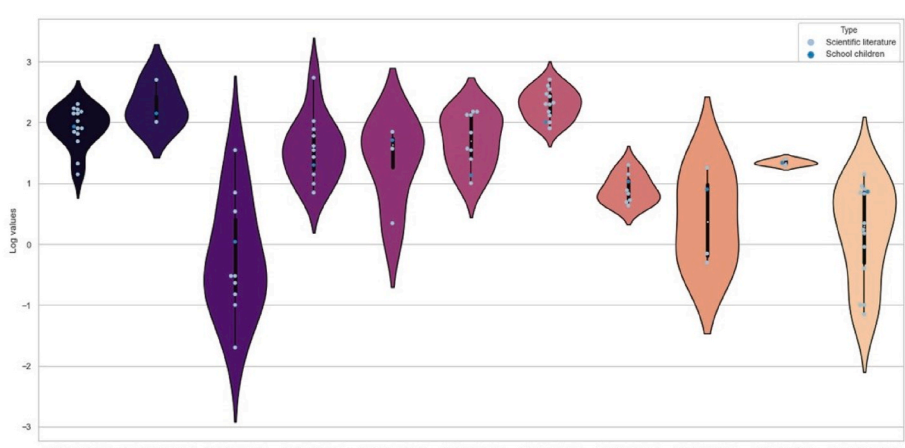

Fig. 3. Differences between the intake of the 11 contaminants under study in school children in the present study and that reported by other studies.

when the whole group is taken into account, such as in the case of fried or smoked fish, chips or fried nuts. Some foods were also found to have high concentrations but be consumed in low intakes, for example some spices and alcoholic beverages (Anese et al., 2013; Capuano and Fogliano, 2011; Rannou et al., 2016). The cooking method can also have a major impact, a clear example of this being fast food and street food whose higher exposure to flames and fumes and the higher temperatures used or overheating of oil means higher exposure to these contaminants (Ekhator et al., 2018).

The development of CONT11 offers the opportunity to see what possible actions can be taken to mitigate and reduce contaminant production, intake and exposure. Organisations such EFSA are currently working to reduce the levels of some of these contaminants, such as acrylamide (Anese et al., 2013; EFSA Panel on Contaminants in the Food Chain (CONTAM), 2015; European Food Safety Authority EFSA, 2011). Actions that can be taken to mitigate intake and exposure to most contaminants include replacing cooking oils frequently, using lower cooking temperatures, using other less heat-aggressive cooking methods, cooking with spices or additives such as sulphite salts, modifying parameters during food production such as water activity or pH, using new sterilisation methods and reducing the consumption of ultra-processed foods or foods that have been highly aggressively heat processed (Anese et al., 2013; Capuano and Fogliano, 2011; Karwowska and Kononiuk, 2020; Mesías et al., 2019; Przygodzka et al., 2015; Rannou et al., 2016; Seok et al., 2015). These actions have been evaluated by scientific committees and different organisations, which are increasing pressure on the food industry to adopt a compromise for the reduction of these compounds because of the risk they pose for health (EFSA Panel on Contaminants in the Food Chain (CONTAM), 2015; EFSA Panel on Food Additives and Nutrient Sources added to Food (ANS) et al., 2017; European Food Safety Authority EFSA, 2011; European Food Safety Authority (EFSA), 2008; Food Safety Commission of Japan, 2016); World Health Organization, 2012).

4.2. CONT11 FCDB utility

CONT11 provides information on 11 contaminants that may be present in food. It is especially important to be able to estimate some of these contaminants, such as acrylamide or benzopyrene, given that they are classified by the International Agency for Research on Cancer (IARC) as carcinogenic or probably carcinogenic (Domingo and Nadal, 2015; EFSA Panel on Contaminants in the Food Chain (CONTAM), 2015; Hulin et al., 2014; Kwon et al., 2021, 2021; Rannou et al., 2016; Sirot et al., 2019). Thus, the ability to estimate contaminant intake and exposure, especially in vulnerable populations, represents an important step towards taking measures to reduce their potential adverse effects. Children are one of the most vulnerable populations exposed to food contaminant intake and exposure due to their physiological conditions and lower weight (Mielech et al., 2021). CONT11 makes it possible to assess intake and exposure to 11 contaminants using a validated FFQ in Spanish school children (de la Fuente-Arrillaga et al., 2010).

Contaminant intake estimations using FFQ could overestimate exposure. Moreover, weighting to control for food cooking methods is necessary (Kotemori et al., 2018). Nevertheless, the use of FFQ as a dietary record of contaminants is one of the most widely used methods, along with 24 h recall (Blekkenhorst et al., 2017; Förster et al., 2005; Griesenbeck et al., 2009; Husøy et al., 2008; Kotemori et al., 2018). In the future, it may be necessary to create more concrete dietary records in order to estimate contaminant intake in a more accurate way (Chan--Hon-Tong et al., 2013; Hulin et al., 2014). For example, HMF levels may be lower than those described for adults, this is due to a null consumption of coffee, one of the main exponents of this contaminant (Arribas-Lorenzo and Morales, 2010; Rufian-Henares and De la Cueva, 2008). Unlike other populations, records are not available for this population on the consumption of alcoholic beverages or coffee, given that such foodstuffs should not be consumed by these populations.

Based on the results described above, no significant differences are found in relation to contaminant intake and exposure according to gender (Tables 2 and 3). Furthermore, no association was found with BMI, although some studies suggest an association between high exposure to some contaminants and obesity, for example acrylamide or PAHs (Kadawathagedara et al., 2018; Li et al., 2021; Timmermann et al., 2021).

Fig. 2 shows that grains and dairy products were mainly responsible for high intakes of most of the examined contaminants. Meat and meat products, fish and processed foods are also relevant for the intake of these contaminants. Tuber intake, particularly in the form of fried potatoes, and beverage consumption, in particular juices, are the main contributors to acrylamide and HMF levels, respectively. These findings agree with those reported in existing literature conducted with children, which found juices and fried foods, such as potatoes, to contribute to these levels (Nagata et al., 2018; Rufian-Henares and De la Cueva, 2008). Reducing the consumption of these contaminants may be a challenge in this population, especially when it comes to reducing the consumption of cereals and dairy products. A main focus should be to decrease the consumption of ultra-processed foods, substituting fried foods and breakfast cereals for other alternatives (Anese et al., 2013; EFSA Panel on Contaminants in the Food Chain (CONTAM), 2015; European Food Safety Authority (EFSA), 2008; Förster et al., 2005; Jakszyn et al., 2004).

Present findings agreed with those described in other studies conducted in children's populations, showing reasonable concordance in the exposure to certain contaminants such as HMF, acrylamide or Amadori compounds (Delgado-Andrade et al., 2007; Mielech et al., 2021; Pastoriza de la Cueva et al., 2017). The other contaminants were compared with intakes in the adult population due to the absence of information for children. Thus, findings supported the range of exposure reported by other studies (Hord et al., 2009; Lou et al., 2019; Polachova et al., 2020).

Fig. 3 shows the considerable variability found in existing literature, which may be due to the type of dietary records used or information source from which contaminant concentrations were obtained. Present findings were in the range described by other studies (Arribas-Lorenzo and Morales, 2010; Blekkenhorst et al., 2017; Cressey et al., 2012; Delgado-Andrade et al., 2010; Delgado-Andrade et al., 2007; Domingo and Nadal, 2015; EFSA Panel on Contaminants in the Food Chain (CONTAM), 2015; Ekhator et al., 2018; Förster et al., 2005; Hellwig and Henle, 2012; Hord et al., 2009; Hsu et al., 2009; Hulin et al., 2014; Keller et al., 2020; Mariotti et al., 2013; Mesías et al., 2012, 2019; Pastoriza de la Cueva et al., 2017; Pysz et al., 2016; Rufian-Henares and De la Cueva, 2008; Santonicola and Mercogliano, 2016; Sijia et al., 2014; Thomas et al., 2021; Timmermann et al., 2021; Ward et al., 2018).

Variability can also be due to food consumption. For example, nitrate values are related to vegetables consumption as shown in Fig. 1. If vegetables consumption decreases, the values of this contaminant are expected to be affected. Therefore, we can see that the variability in the studies does not only depends on the database or the dietary tools used, at the same time it also depends on the dietary pattern of the population (Anese et al., 2013; Capuano and Fogliano, 2011; Rannou et al., 2016).

5. Conclusions

CONT11 is proposed as a reliable and representative FCDB for the estimation of intakes of several contaminants. This database, although tested on children, could be useful for other populations. A better understanding of contaminant intake and the foods involved will allow better strategies to be adopted to reduce intake and exposure. CONT 11 will provide a useful starting point for investigating possible relationships between these compounds and the risk of different diseases in epidemiological and nutritional studies. In this way, dietary information can be added to environmental or occupational exposures.

Ethical approval

The study received ethical approval from the bioethical committee of the University of Granada for human research approved the study under reference SA/11/AYU/246.

Informed consent

All participants were involved voluntarily and in agreement with the Declaration of Helsinki on Ethical Research. Informed consent was also obtained from all parents or legal guardians of participating children.

CRediT authorship contribution statement

Daniel Hinojosa-Nogueira: Methodology, Formal analysis, Investigation, Writing – original draft, while the other authors revised that draft. **José J. Muros:** Methodology, Formal analysis, Writing – original draft, Investigation. **Beatriz Navajas-Porras:** Methodology, Formal analysis, Writing – original draft, Investigation. **Adriana Delgado-Osorio:** Methodology, Formal analysis, Investigation. **Sergio Pérez-Burillo:** Methodology, Formal analysis, Investigation. **Silvia Pastoriza:** Methodology, Formal analysis, Investigation. **José Á. Rufián-Henares:** Methodology, Formal analysis, Investigation, coordinated the work and obtaining funding to perform the study.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

This work was supported by the "Plan propio de Investigación y Transferencia" of the University of Granada under the program "Intensificación de la Investigación, modalidad B″ granted to José A. Rufián-Henares. This work is part of the doctoral thesis of Daniel Hinojosa-Nogueira conducted within the context of the "Program of Nutrition and Food Sciences" at the University of Granada.

References

Anese, M., Manzocco, L., Calligaris, S., Nicoli, M.C., 2013. Industrially applicable strategies for mitigating acrylamide, furan, and 5-hydroxymethylfurfural in food. J. Agric. Food Chem. 61 (43), 10209–10214.

Arribas-Lorenzo, G., Morales, F.J., 2010. Estimation of dietary intake of 5-hydroxymethylfurfural and related substances from coffee to Spanish population. Food Chem. Toxicol. 48 (2), 644–649.

Bermudo, E., Moyano, E., Puignou, L., Galceran, M., 2008. Liquid chromatography coupled to tandem mass spectrometry for the analysis of acrylamide in typical Spanish products. Talanta 76 (2), 389–394.

Blekkenhorst, L.C., Prince, R.L., Ward, N.C., Croft, K.D., Lewis, J.R., Devine, A., Shinde, S., Woodman, R.J., Hodgson, J.M., Bondonno, C.P., 2017. Development of a reference database for assessing dietary nitrate in vegetables. Mol. Nutr. Food Res. 61 (8), 1600982.

Boletín Oficial del Estado, 2003. Real Decreto 140/2003, de 7 de febrero, por el que se establecen los criterios sanitarios de la calidad del agua de consumo humano. BOE 45, 7228–7245.

Capuano, E., Fogliano, V., 2011. Acrylamide and 5-hydroxymethylfurfural (HMF): a review on metabolism, toxicity, occurrence in food and mitigation strategies. LWT–Food Sci. Technol. 44 (4), 793–810.

Chan-Hon-Tong, A., Charles, M.-A., Forhan, A., Heude, B., Sirot, V., 2013. Exposure to food contaminants during pregnancy. Sci. Total Environ. 458, 27–35.

Charrondiere, U.R., Rittenschober, D., Nowak, V., Nicodemi, C., Bruggeling, P., Petracchi, C., 2016a. Fao/infoods e-learning course on food composition data. Food Chem. 193, 6–11.

Charrondiere, U.R., Rittenschober, D., Nowak, V., Stadlmayr, B., Wijesinha-Bettoni, R., Haytowitz, D., 2016b. Improving food composition data quality: three new FAO/INFOODS guidelines on conversions, data evaluation and food matching. Food Chem. 193, 75–81.

Cotterill, J., Chaudhry, M., Matthews, W., Watkins, R., 2008. In silico assessment of toxicity of heat-generated food contaminants. Food Chem. Toxicol. 46 (6), 1905–1918.

Cressey, P., Thomson, B., Ashworth, M., Grounds, P., McGill, E., 2012. Acrylamide in New Zealand Food and Updated Exposure Assessment. Ministry of Agriculture and Forestry, Wellington, New Zealand.

TUD - AGE Database, 2022. https://lemchem.file3.wcms.tu-dresden.de/.

de la Fuente-Arrillaga, C., Ruiz, Z.V., Bes-Rastrollo, M., Sampson, L., Martinez-Gonzalez, M.A., 2010. Reproducibility of an FFQ validated in Spain. Publ. Health Nutr. 13 (9), 1364–1372.

Delgado-Andrade, C., Rufián-Henares, J.A., Morales, F.J., 2007. Lysine availability is diminished in commercial fibre-enriched breakfast cereals. Food Chem. 100, 725–731.

Delgado-Andrade, C., Morales, F.J., Seiquer, I., Navarro, M.P., 2010. Maillard reaction products profile and intake from Spanish typical dishes. Food Res. Int. 43 (5), 1304–1311.

Delgado-Andrade, C., Seiquer, I., Navarro, M.P., Morales, F.J., 2007. Maillard reaction indicators in diets usually consumed by adolescent population. Mol. Nutr. Food Res. 51 (3), 341–351.

Domingo, J.L., Nadal, M., 2015. Human dietary exposure to polycyclic aromatic hydrocarbons: a review of the scientific literature. Food Chem. Toxicol. 86, 144–153.

Durazzo, A., Camilli, E., D'Addezio, L., Le Donne, C., Ferrari, M., Marconi, S., Marletta, L., Mistura, L., Piccinelli, R., Scalvedi, M.L., Sette, S., Turrini, A., 2018. Food groups and individual foods: nutritional attributes and dietary importance. In: Reference Module in Food Science (P. B9780081005965214000). Elsevier. https://doi.org/10.1016/B978-0-08-100596-5.21337-1.

EFSA Panel on Contaminants in the Food Chain (CONTAM), 2015. Scientific opinion on acrylamide in food. EFSA J. 13 (6), 4104.

Ekhator, O.C., Udowelle, N.A., Igbiri, S., Asomugha, R.N., Frazzoli, C., Orisakwe, O.E., 2018. Street foods exacerbate effects of the environmental burden of polycyclic aromatic hydrocarbons (PAHs) in Nigeria. Environ. Sci. Pollut. Control Ser. 25 (6), 5529–5538.

European Food Safety Authority (EFSA), 2008. Polycyclic aromatic hydrocarbons in food-scientific opinion of the Panel on contaminants in the food Chain. EFSA J. 6 (8), 724.

European Food Safety Authority (EFSA), 2011. Update on furan levels in food from monitoring years 2004–2010 and exposure assessment. EFSA J. 9 (9), 2347.

European Food Safety Authority (EFSA), 2015. *The Food Classification and Description System FoodEx 2 (Revision 2)* (No. 2397–8325). Wiley Online Library.

Food Safety Commission of Japan, 2016. Acrylamide in foods generated through heating. Food Safety 4 (3), 74–88. https://doi.org/10.14252/foodsafetyfscj.2016013s.

Förster, A., KüHNE, Y., Henle, T.O., 2005. Studies on absorption and elimination of dietary maillard reaction products. Ann. N. Y. Acad. Sci. 1043 (1), 474–481.

Griesenbeck, J.S., Steck, M.D., Huber, J.C., Sharkey, J.R., Rene, A.A., Brender, J.D., 2009. Development of estimates of dietary nitrates, nitrites, and nitrosamines for use with the Short Willet Food Frequency Questionnaire. Nutr. J. 8 (1), 1–9.

Hamlet, C.G., Asuncion, L., Liang, L., 2014. Survey of acrylamide and furan in UK retail products: summary report for samples purchased between November 2011 and Dec 2013. Food Standards Agency C 30, 1–74.

Hellwig, M., Henle, T., 2012. Quantification of the Maillard reaction product 6-(2-formyl-1-pyrrolyl)-l-norleucine (formyline) in food. Eur. Food Res. Technol. 235 (1), 99–106.

Hellwig, M., Kühn, L., Henle, T., 2018. Individual Maillard reaction products as indicators of heat treatment of pasta—a survey of commercial products. J. Food Compos. Anal. 72, 83–92.

Hinojosa-Nogueira, D., Pérez-Burillo, S., Rufián-Henares, J.Á., de la Cueva, S.P., 2020. Characterization of rums sold in Spain through their absorption spectra, furans, phenolic compounds and total antioxidant capacity. Food Chem. 323, 126829.

Hinojosa-Nogueira, D., Pérez-Burillo, S., Navajas-Porras, B., Ortiz-Viso, B., de la Cueva, S.P., Lauria, F., Fatouros, A., Priftis, K.N., González-Vigil, V., Rufián-Henares, J.Á., 2021. Development of an unified food composition database for the European project "Stance4Health.". Nutrients 13 (12), 4206.

Hord, N.G., Tang, Y., Bryan, N.S., 2009. Food sources of nitrates and nitrites: the physiologic context for potential health benefits. Am. J. Clin. Nutr. 90 (1), 1–10.

Hsu, J., Arcot, J., Lee, N.A., 2009. Nitrate and nitrite quantification from cured meat and vegetables and their estimated dietary intake in Australians. Food Chem. 115 (1), 334–339.

Hulin, M., Bemrah, N., Nougadère, A., Volatier, J., Sirot, V., Leblanc, J., 2014. Assessment of infant exposure to food chemicals: the French Total Diet Study design. Food Addit. Contam. 31 (7), 1226–1239.

Husøy, T., Haugen, M., Murkovic, M., Jöbstl, D., Stølen, L., Bjellaas, T., Rønningborg, C., Glatt, H., Alexander, J., 2008. Dietary exposure to 5-hydroxymethylfurfural from Norwegian food and correlations with urine metabolites of short-term exposure. Food Chem. Toxicol. 46 (12), 3697–3702.

Ioannidou, S., Cascio, C., Gilsenan, M.B., 2021. European Food Safety Authority open access tools to estimate dietary exposure to food chemicals. Environ. Int. 149, 106357.

Jakszyn, P., Agudo, A., Ibáñez, R., García-Closas, R., Pera, G., Amiano, P., González, C.A., 2004. Development of a food database of nitrosamines, heterocyclic amines, and polycyclic aromatic hydrocarbons. J. Nutr. 134 (8), 2011–2014.

Kadawathagedara, M., Botton, J., de Lauzon-Guillain, B., Meltzer, H.M., Alexander, J., Brantsaeter, A.L., Haugen, M., Papadopoulou, E., 2018. Dietary acrylamide intake during pregnancy and postnatal growth and obesity: results from the Norwegian Mother and Child Cohort Study (MoBa). Environ. Int. 113, 325–334.

Kalaycıoğlu, Z., Erim, F.B., 2019. Nitrate and nitrites in foods: worldwide regional distribution in view of their risks and benefits. J. Agric. Food Chem. 67 (26), 7205–7222.
Karwowska, M., Kononiuk, A., 2020. Nitrates/nitrites in food—risk for nitrosative stress and benefits. Antioxidants 9 (3), 241.
Keller, R.M., Beaver, L., Prater, M.C., Hord, N.G., 2020. Dietary nitrate and nitrite concentrations in food patterns and dietary supplements. Nutr. Today 55 (5), 218–226.
Klensin, J.C., Feskanich, D., Lin, V., Truswell, A.S., Southgate, D.A., 1989. Identification of Food Components for INFOODS Data Interchange. United Nations University Tokyo.
Kotemori, A., Ishihara, J., Nakadate, M., Sawada, N., Iwasaki, M., Sobue, T., Tsugane, S., 2018. Validity of a self-administered food frequency questionnaire for the estimation of acrylamide intake in the Japanese population: the JPHC FFQ Validation Study. J. Epidemiol. 28 (12), 482–487.
Kotopoulou, S., Zampelas, A., Magriplis, E., 2022. Dietary nitrate and nitrite and human health: a narrative review by intake source. Nutr. Rev. 80 (4), 762–773.
Kovarich, Simona, Ciacci, Andrea, Baldin, Rossella, Roncaglioni, Alessandra, Mostrag, Aleksandra, Tarkhov, Aleksey, Carnesecchi, Edoardo, Gibin, Davide, Di Piazza, Giulio, Pasinato, Luca, Sartori, Luca, Benfenati, Emilio, Yang, Chihae, Richardson, Jane, Dorne Jean Lou, C.M., 2022. OpenFoodTox: EFSA's Chemical Hazards Database. Zenodo. https://doi.org/10.5281/ZENODO.5076033 (Version 5) [Data set].
Kwon, K., Jo, C.-H., Choi, J.-D., 2021. Korea total diet study-based risk assessment on contaminants formed during manufacture, preparation and storage of food. Journal of Food Hygiene and Safety 36 (3), 213–219.
Lauria, F., Russo, M.D., Formisano, A., De Henauw, S., Hebestreit, A., Hunsberger, M., Krogh, V., Intemann, T., Lissner, L., Molnar, D., 2021. Ultra-processed foods consumption and diet quality of European children, adolescents and adults: results from the I. Family study. Nutr. Metabol. Cardiovasc. Dis. 31 (11), 3031–3043.
Li, K., Yin, R., Wang, Y., Zhao, D., 2021. Associations between exposure to polycyclic aromatic hydrocarbons and metabolic syndrome in US adolescents: cross-sectional results from the National Health and Nutrition Examination Survey (2003–2016) data. Environ. Res. 202, 111747.
Lillford, P., Hermansson, A.-M., 2021. Global missions and the critical needs of food science and technology. Trends Food Sci. Technol. 111, 800–811.
Lou, X.-Y., Wu, P.-R., Guo, Y., 2019. Urinary metabolites of polycyclic aromatic hydrocarbons in pregnant women and their association with a biomarker of oxidative stress. Environ. Sci. Pollut. Control Ser. 26 (26), 27281–27290.
Marconi, S., Durazzo, A., Camilli, E., Lisciani, S., Gabrielli, P., Aguzzi, A., Gambelli, L., Lucarini, M., Marletta, L., 2018. Food composition databases: considerations about complex food matrices. Foods 7 (1), 2.
Mariotti, M.S., Toledo, C., Hevia, K., Gomez, J.P., Fromberg, A., Granby, K., Rosowski, J., Castillo, O., Pedreschi, F., 2013. Are Chileans exposed to dietary furan? Food Addit. Contam. 30 (10), 1715–1721.
Martorell, I., Perelló, G., Martí-Cid, R., Castell, V., Llobet, J.M., Domingo, J.L., 2010. Polycyclic aromatic hydrocarbons (PAH) in foods and estimated PAH intake by the population of Catalonia, Spain: temporal trend. Environ. Int. 36 (5), 424–432.
Mesías, M., Guerra-Hernández, E., García-Villanova, B., 2012. Estimation of exposure to furan in the Spanish population. Int. J. Food Sci. Nutr. 63 (1), 16–22.
Mesías, M., Sáez-Escudero, L., Morales, F.J., Delgado-Andrade, C., 2019. Occurrence of furosine and hydroxymethylfurfural in breakfast cereals. Evolution of the Spanish market from 2006 to 2018. Foods 8 (5), 158.
Mielech, A., Puścion-Jakubik, A., Socha, K., 2021. Assessment of the risk of contamination of food for infants and toddlers. Nutrients 13 (7), 2358.
Moazeni, M., Heidari, Z., Golipour, S., Ghaisari, L., Sillanpää, M., Ebrahimi, A., 2020. Dietary intake and health risk assessment of nitrate, nitrite, and nitrosamines: a Bayesian analysis and Monte Carlo simulation. Environ. Sci. Pollut. Control Ser. 27 (36), 45568–45580.
Monteiro, C.A., Cannon, G., Levy, R.B., Moubarac, J.-C., Louzada, M.L., Rauber, F., Khandpur, N., Cediel, G., Neri, D., Martinez-Steele, E., 2019. Ultra-processed foods: what they are and how to identify them. Publ. Health Nutr. 22 (5), 936–941.
Nagata, C., Konishi, K., Wada, K., Tamura, T., Goto, Y., Koda, S., Mizuta, F., Nishizawa, S., Sukigara, E., Watanabe, K., 2018. Associations of acrylamide intake with urinary sex hormone levels among preschool-age Japanese children. Am. J. Epidemiol. 187 (1), 75–81.
Pastoriza de la Cueva, S., Álvarez, J., Végvári, Á., Montilla-Gómez, J., Cruz-López, O., Delgado-Andrade, C., Rufián-Henares, J.A., 2017. Relationship between HMF intake and SMF formation in vivo: an animal and human study. Mol. Nutr. Food Res. 61 (3), 1600773.
Polachova, A., Gramblicka, T., Parizek, O., Sram, R.J., Stupak, M., Hajslova, J., Pulkrabova, J., 2020. Estimation of human exposure to polycyclic aromatic hydrocarbons (PAHs) based on the dietary and outdoor atmospheric monitoring in the Czech Republic. Environ. Res. 182, 108977.
Przygodzka, M., Zieliński, H., Ciesarová, Z., Kukurová, K., Lamparski, G., 2015. Study on sensory quality, antioxidant properties, and Maillard reaction products formation in rye-buckwheat cakes enhanced with selected spices. J. Chem. 2015.
Pysz, K., Leszczyńska, T., Bieżanowska-Kopeć, R., Kopeć, A., 2016. Chemical assessment of lead, cadmium, nitrate, and nitrite intakes with daily diets of children and adolescents from orphanages in Krakow, Poland. Environ. Sci. Pollut. Control Ser. 23 (24), 25200–25209.
Rannou, C., Laroque, D., Renault, E., Prost, C., Sérot, T., 2016. Mitigation strategies of acrylamide, furans, heterocyclic amines and browning during the Maillard reaction in foods. Food Res. Int. 90, 154–176.
Rufian-Henares, J., De la Cueva, S., 2008. Assessment of hydroxymethylfurfural intake in the Spanish diet. Food Addit. Contam. 25 (11), 1306–1312.
Rufián-Henares, J.A., Guerra-Hernández, E., García-Villanova, B., 2002. Maillard reaction in enteral formula processing: furosine, loss of o-phthaldialdehyde reactivity, and fluorescence. Food Res. Int. 35, 527–533.
Rufián-Henares, J.A., García-Villanova, B., Guerra-Hernández, E., 2004. Generation of furosine and color in infant/enteral formula-resembling systems. J. Agric. Food Chem. 52 (17), 5354–5358.
Rufián-Henares, J.A., Guerra-Hernández, E., García-Villanova, B., 2006. Colour measurement as indicator for controlling the manufacture and storage of enteral formulas. Food Control 17, 489–493.
Rufián-Henares, J.A., García-Villanova, B., Guerra-Hernández, E., 2008. Occurrence of furosine and hydroxymethylfurfural as markers of thermal damage in dehydrated vegetables. Eur. Food Res. Technol. 228, 249–256.
Santonicola, S., Mercogliano, R., 2016. Occurrence and production of furan in commercial foods. Ital. J. Food Sci. 28 (2), 155.
Scheijen, J.L., Clevers, E., Engelen, L., Dagnelie, P.C., Brouns, F., Stehouwer, C.D., Schalkwijk, C.G., 2016. Analysis of advanced glycation endproducts in selected food items by ultra-performance liquid chromatography tandem mass spectrometry: presentation of a dietary AGE database. Food Chem. 190, 1145–1150.
Seok, Y.-J., Her, J.-Y., Kim, Y.-G., Kim, M.Y., Jeong, S.Y., Kim, M.K., Lee, J., Kim, C., Yoon, H.-J., Lee, K.-G., 2015. Furan in thermally processed foods-a review. Toxicol. Res. 31 (3), 241–253.
Shapla, U.M., Solayman, M., Alam, N., Khalil, M., Gan, S.H., 2018. 5-Hydroxymethylfurfural (HMF) levels in honey and other food products: effects on bees and human health. Chem. Cent. J. 12 (1), 1–18.
Sijia, W., Enting, W., Yuan, Y., 2014. Detection of furan levels in select Chinese foods by solid phase microextraction–gas chromatography/mass spectrometry method and dietary exposure estimation of furan in the Chinese population. Food Chem. Toxicol. 64, 34–40.
Sirot, V., Rivière, G., Leconte, S., Vin, K., Traore, T., Jean, J., Carne, G., Gorecki, S., Veyrand, B., Marchand, P., 2019. French infant total diet study: dietary exposure to heat-induced compounds (acrylamide, furan and polycyclic aromatic hydrocarbons) and associated health risks. Food Chem. Toxicol. 130, 308–316.
Talari, G., Cummins, E., McNamara, C., O'Brien, J., 2021. State of the art review of Big Data and web-based Decision Support Systems (DSS) for food safety risk assessment with respect to climate change. Trends Food Sci. Technol.
Thomas, R., Thresher, A., Ponting, D.J., 2021. Utilisation of parametric methods to improve percentile-based estimates for the carcinogenic potency of nitrosamines. Regul. Toxicol. Pharmacol. 121, 104875.
Timmermann, C.A.G., Mølck, S.S., Kadawathagedara, M., Bjerregaard, A.A., Törnqvist, M., Brantsaeter, A.L., Pedersen, M., 2021. A review of dietary intake of acrylamide in humans. Toxics 9 (7), 155.
Veyrand, B., Sirot, V., Durand, S., Pollono, C., Marchand, P., Dervilly-Pinel, G., Tard, A., Leblanc, J.-C., Le Bizec, B., 2013. Human dietary exposure to polycyclic aromatic hydrocarbons: results of the second French Total Diet Study. Environ. Int. 54, 11–17.
Ward, M.H., Jones, R.R., Brender, J.D., De Kok, T.M., Weyer, P.J., Nolan, B.T., Villanueva, C.M., Van Breda, S.G., 2018. Drinking water nitrate and human health: an updated review. Int. J. Environ. Res. Publ. Health 15 (7), 1557.
World Health Organization, 2012. Tracking Contaminants in Food.
Yang, C., Zhang, S., Shi, R., Yu, J., Li, S., Tao, G., Tsao, R., Zhang, J., Zhang, L., 2020. LC-MS/MS for simultaneous detection and quantification of Amadori compounds in tomato products and dry foods and factors affecting the formation and antioxidant activities. J. Food Sci. 85 (4), 1007–1017.
Zhong, L., Blekkenhorst, L.C., Bondonno, N.P., Sim, M., Woodman, R.J., Croft, K.D., Lewis, J.R., Hodgson, J.M., Bondonno, C.P., 2022a. A food composition database for assessing nitrate intake from plant-based foods. Food Chem. 394, 133411.
Zhong, L., Liu, A.H., Blekkenhorst, L.C., Bondonno, N.P., Sim, M., Woodman, R.J., Croft, K.D., Lewis, J.R., Hodgson, J.M., Bondonno, C.P., 2022b. Development of a food composition database for assessing nitrate and nitrite intake from animal-based foods. Mol. Nutr. Food Res. 66 (1), 2100272.