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Determination of furan levels in commercial samples of baby food from Brazil and preliminary risk assessment

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Commercial baby food samples available on the Brazilian market ($n = 31$) were analysed for furan content using a gas chromatography-mass spectrometry method preceded by solid-phase microextraction. A limit of detection of 0.7 μg kg^{-1}, a limit of quantitation of 2.4 μg kg^{-1}, mean recoveries varying from 80% to 107%, and coefficients of variation ranging from 5.6% to 9.4% for repeatability and from 7.4% to 12.4% for within-laboratory reproducibility were obtained during an in-house validation. The levels of furan found in the samples were from not detected to 95.5 μg kg^{-1}. Samples containing vegetables and meat showed higher furan levels as compared with those containing only fruits. An exposure assessment showed furan intakes up to 2.4 μg kg^{-1} body weight day^{-1} (99th percentile) for babies fed exclusively with commercial baby foods. Margins of exposure obtained from intakes estimated in this work indicated a potential public health concern.

Keywords: gas chromatography-mass spectrometry (GC-MS); solid-phase microextraction (SPME); exposure assessment; process contaminants; baby food

Introduction

An important study reported by American researchers in 2004 showed that furan can be formed during thermal treatment of several foods, especially canned and jarred products (US Food and Drug Administration (USFDA) 2004). Although furan had previously been identified in foods such as coffee, canned meat, baked bread, and cooked chicken (Maga 1979), the discovery by the USFDA raised for the first time a concern about the potential risks of furan to human health due to its occurrence in commonly consumed foods and toxicological properties.

Furan (C_4H_4O) is a highly volatile cyclic ether with an aromatic character classified as a possible human carcinogen (group 2B) by the International Agency for Research on Cancer (IARC) (1995). It is clearly carcinogenic to rats and mice, showing a dose-dependent increase in hepatocellular adenomas and carcinomas in both sexes (National Toxicology Programme (NTP) 1993; Goldsworthy et al. 2001). It has also been demonstrated that furan is cytotoxic to the liver (Wilson et al. 1992). No data are available on reproductive and developmental toxicity, and there are also no human studies.

Several authors have focused their studies on the occurrence of furan in commercial baby foods due to the susceptibility of this consumer group and the relatively high amounts of furan (up to 112 μg kg^{-1}) reported by the USFDA in this food category. Yoshida et al. (2007) reported levels of furan in the range 1.4–90 μg kg^{-1} in 15 baby food samples from the Japanese market. In Switzerland, levels from 1 to 153 μg kg^{-1} were reported in 102 samples by Zoller et al. (2007). In Finland, mean concentrations of furan in 21 different baby food samples varied from 4.7 to 90.3 μg kg^{-1} (Jestoi et al. 2009). A survey of 230 jarred baby foods was conducted in Germany, the results showing furan levels up to 63 μg kg^{-1} (95th percentile) (Lachenmeier et al. 2009). So far, no data on the level of furan in foods from Latin America are available in the literature.

The occurrence of furan in a large variety of foods suggests that there are probably multiple routes for its formation rather than a single mechanism. Furan is formed at high temperature conditions and the pathways proposed to understand its origin in foods are based mainly on the thermal decomposition of ascorbic acid, the thermal degradation of carbohydrates by the Maillard reaction, and the thermal oxidation of polyunsaturated fatty acids. Experiments using simple models systems have shown that ascorbic acid has the highest potential to form furan, followed by

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polyunsaturated fatty acids and sugars (Locas and Yaylayan 2004; Becalski and Seaman 2005; Märk et al. 2006). In binary mixtures, it has been demonstrated that the potential of furan formation from ascorbic acid is decreased in the presence of other precursors, which is likely due to competing reactions in complex systems (Märk et al. 2006; Limacher et al. 2007).

Due to its high volatility (boiling point 31°C), gas-chromatography coupled to mass spectrometry (GC-MS) has been suggested as a technique to analyse the furan content in foods, preceded by headspace sampling (HS) or solid-phase micro-extraction (SPME) (Becalski et al. 2005; Goldman et al. 2005; Ho et al. 2005; Senyuva and Gökmen 2005; Bianchi et al. 2006; USFDA 2006; Hasnip et al. 2006; Altaki et al. 2007; Wenzl et al. 2007). Both HS and SPME approaches are very simple and convenient for volatiles analyses, demand no expensive equipment for sample extraction, and give satisfactory and comparable results (Wenzl 2008). SPME seems to be more advantageous since it allows sample concentration and affords higher sensitivity. To avoid losses of furan during sample preparation, foods need to be chilled (approximately 4°C) before handling and briefly homogenized. Quantification has been based on standard addition or external calibration, both incorporating furan-d_4 as the internal standard (Crews and Castle 2007).

Furan dietary intakes estimated from reported occurrence data and regional patterns of baby food consumption have been shown to vary from 0.1 to 10.6 $\mu g\,kg^{-1}$ body weight (bw) day^{-1} (Bianchi et al. 2006; USFDA 2007; European Food Safety Authority (EFSA) 2009; Jestoi et al. 2009; Lachenmeier et al. 2009). When the present manuscript was under review, the Joint Food and Agricultural Organization/World Health Organization (FAO/WHO) Expert Committee on Food Additives (JECFA) made available the results of a full evaluation of furan carried out during its 72nd Meeting (FAO/WHO 2010). For the purposes of risk characterization, a value of 1 $\mu g\,kg^{-1}\,bw\,day^{-1}$ was taken to represent the mean dietary exposure to furan; and a value of 2 $\mu g\,kg^{-1}\,bw\,day^{-1}$ was taken to represent high dietary exposure. These values were considered to be sufficient to cover potential dietary exposures of infants and children to furan. The Committee considered that margins of exposure (MOEs) obtained from average and high dietary exposures (960 and 480, respectively) indicate a human health concern for a carcinogenic compound that might act via a DNA-reactive genotoxic metabolite.

Considering the potential risks of furan to health as well as the lack of occurrence data in Brazil, the objective of this study was to validate a SPME-GC-MS method to analyse furan in baby foods, determine furan levels in samples available on the Brazilian market, conduct an exposure assessment, and evaluate the risks associated with the consumption of baby foods containing furan.

Materials and methods

Standards

Furan and [$^2H_4$] furan (furan-d_4) were obtained from Sigma-Aldrich at a purity greater than 98%. Individual stock solutions of both standards at approximately 2 $mg\,ml^{-1}$ were prepared by dissolving in methanol. For that, a 5 ml glass vial was filled with methanol and sealed, and the exact weight of methanol was recorded. The headspace in the vials might be kept as small as possible in order to keep partitioning of furan into the gas phase low. About 10 µl of refrigerated standard were injected into the vial through the silicone-polytetrafluoroethylene (PTFE) septum with a syringe, holding the vial in an inverted position. The exact weight of the added standard was recorded and the concentration expressed in $mg\,ml^{-1}$, taking into account the density of methanol. The stock solutions were prepared every 2 weeks and stored at 4°C. The same procedure was used to prepare intermediate standards solutions at approximately 20 $\mu g\,ml^{-1}$, but diluting the stock solutions (about 60 µl) in water. The intermediate solutions were prepared weekly and stored at 4°C. Finally, working solutions of both furan and furan-d_4 (at about 0.2 $\mu g\,ml^{-1}$) were prepared daily by diluting the intermediate solutions (about 60 µl) in water, following the procedure initially described.

Chemicals

Methanol was of HPLC-grade (Tedia Company, Inc.) and water was of ultra-pure quality (Milli-Q system; Millipore Corp.).

Samples

Thirty-one samples of baby food containing meat, vegetables, cereals or fruits (pureed) were purchased at supermarkets in Campinas, SP, Brazil, between July and August 2009. As there is only one company that produces baby food in Brazil, all commercialized products were sampled. The samples were stored at 4°C for at least 4 h before homogenization. Two jars of the same sample and batch were mixed as quickly as possible in a cooled stainless steel vessel immersed in an ice bath in order to avoid furan loss. Sub-samples were homogenized with a Turratec TF-102 (Tecnal) and analysed at the same day, in duplicate. All products were analysed as bought.

Experimental design

To evaluate the effects of temperature of extraction (T), time of extraction (t) and ionic strength (% NaCl) as well as their interactions on the SPME procedure, a 2^3 full-factorial design with three central points and two axial points for each independent variable (rotatable central composite design – RCCD) was employed (Rodrigues and Iemma 2005). The range levels investigated were: T (°C) = 25–45, t (min) = 10–30, and % NaCl = 0–30. All statistical analysis were carried out by using STATISTICA 5.5 software.

SPME procedure

The method used was an optimization of the method described by Bianchi et al. (2006). A portion of 1.0 g of homogeneous sample was weighed in a chilled 40 ml screw-cap glass vial fitted with silicone-PTFE septum containing a 15×5 mm PTFE-coated stir bar. A volume of approximately 875 µl of water and 125 µl of the furan-d_4 water working standard solution were added and the vial immediately closed. The final concentration of furan-d_4 was 25 µg kg^{-1}. A 75 µm carboxen-polydimethylsiloxane (CAR-PDMS) fibre (Supelco), previously conditioned in the GC injector port at 280°C under helium flow for 1.5 h, was exposed to the headspace of the vial by using a manual holder (Supelco) during 30 min at 25°C, under a constant magnetic agitation rate of approximately 1200 rpm. After the extraction, the fibre was removed from the headspace of the vial and immediately inserted into the injector port of the GC-MS system. Thermal desorption was carried out according to the temperature programme of the programmable temperature vaporizing (PTV) injector and the fibre was removed after 6 min to ensure no carryover.

GC-MS analysis

The GC-MS system consisted of a HP 6890 gas chromatography (Agilent Technologies) equipped with MSD 5973 mass spectrometer (Agilent Technologies). Helium was used as the carrier gas at a flow rate of 0.7 ml min^{-1}. The PTV injector was operated in the splitless mode under the following temperature programme: 40°C (held for 0.1 min), 700°C min^{-1} to 230°C (held until the end of the run). The split valve remained closed for 0.7 min. The separation was performed on a $60\,m \times 0.25$ mm, d_f 0.5 µm HP-INNOWAX capillary column (Agilent Technologies) and the oven temperature programme was: 30°C (held for 0.1 min), 2°C min^{-1} to 40°C (held for 3 min), 12°C min^{-1} to 200°C (held for 2 min). The mass spectrometer was operated in positive electron-ionization mode (+EI) with 70 eV of electron energy. The quadrupole and the ionization source were maintained at 150 and 230°C, respectively. Selected ion monitoring (SIM) was used for the detection of furan and furan-d_4, using three characteristic ions for furan (m/z 68 as quantifier, m/z 39 and m/z 69 as qualifier) and two characteristic ions for furan-d_4 (m/z 72 as quantifier and m/z 42 as qualifier).

Identification and quantification

The identification of furan was based on the relative retention time (RRT) and the presence of diagnostic ions. For confirmatory purposes, a comparison with a standard solution was performed using an acceptable deviation of ±0.5% for RRT, ±10% for ionic relative abundance considering m/z 39/68, and ±50% for ionic relative abundance considering m/z 69/68, according to the acceptance criteria as stipulated in European Commission Decision 2002/657 (European Commission 2002). The quantification of furan in samples proceeded by extrapolation from a linear analytical curve (0–100 µg kg^{-1}), using furan-d_4 as the internal standard.

Validation of the method

The method was validated in terms of linearity, selectivity, limit of detection (LOD), limit of quantitation (LOQ), trueness (recovery), and precision (repeatability and within-laboratory reproducibility) according to the guidelines laid down by the Brazilian Institute of Metrology, Standardization and Industrial Quality (INMETRO 2007). Linearity was evaluated over the range zero to 100 µg kg^{-1} (seven calibration points). Selectivity was evaluated by comparison between curves set on standard solutions and on matrix by applying the F-test (Snedecor) and t-test (Student). The LOD was determined by seven independent sample blanks fortified at lowest acceptable concentration measured once each and calculated as three-fold standard deviation of fortified sample blank values. The LOQ was determined by seven independent sample blanks measured once each and calculated as the analyte concentration corresponding to the sample blank value plus a ten-fold standard deviation. Recovery, repeatability, and within-laboratory reproducibility were evaluated by spiking sample blanks with furan at 2.5, 10 and 50 µg kg^{-1} (seven replicates for each concentration level). A home-made baby food containing vegetables (carrot, potato, beans), beef, rice and pasta was used as a blank.

Exposure assessment

The intake of furan was estimated for babies from 6 to 11 months by combining levels of the contaminant determined in the present study with estimates of the

average daily consumption of baby food. Two sources of consumption data were considered. Scenario 1: the guidelines of the Sociedade Brasileira de Pediatria (SBP – Brazilian Society of Pediatrics 2006), which recommend the daily intake of one (for 6 months) or two (for 7–11 months) portions of baby food containing meat and/or vegetables and one portion of baby food containing fruits; and Scenario 2: individual consumption data obtained by a survey conducted in the city of São Paulo (SP, Brazil) between September 1995 and September 1996, using a 24-h recall applied to 718 individuals aged from zero to 60 months, from which 136 were aged from 6 to 11 months (Aquino and Philippi 2002). The first scenario was used to express a 'theoretical' estimate of furan intake by a baby fed exclusively with commercial baby food, while the second one represents the 'real' intake. For each scenario, different situations were simulated, considering different percentiles of furan concentration in the analysed foods. The intakes were estimated separately for baby food containing meat and vegetables and for baby food containing fruits, and they were summed to give the total intake. An average body weight of 8.4 kg was used in calculations (WHO 2006).

For risk assessment purposes, MOEs were calculated considering furan intakes estimated here and the T25 dose of 1.4 mg kg^{-1} bw day^{-1} established by Sanner et al. (2001). The T25 dose is the dose that represents an incidence of 25% of tumours in a studied population, after correction for spontaneous incidence. The use of the T25 dose is recommended when the data are unsuitable to obtain the benchmark dose lower confidence limit (BMDL) (EFSA 2005; Lachenmeier et al. 2009).

Results and discussion

Method development

The first objective of this study was to obtain a reliable and efficient method for the determination of furan in baby food by using SPME. Several procedures described in the literature have shown that this technique can provide enough selectivity and sensitivity for furan analysis (Ho et al. 2005; Goldman et al. 2005; Bianchi et al. 2006; Altaki et al. 2007; Jestoi et al. 2009). Initial tests were carried out with standard solutions and sample (commercial baby food containing beef, rice, beans and vegetables) by applying the method described by Bianchi et al. (2006) in order to set the chromatographic parameters and optimize the SPME conditions. Preliminary results demonstrated a peak of an undesirable co-extractive close to the retention time of furan, indicating a need to make some adjustments in the chromatographic conditions. In order to achieve the separation of the two compounds, a temperature programme in the PTV injector was used and the flow rate and temperature programme of the oven were modified. Best results were obtained with the following conditions: injector, 40°C (held for 0.1 min), 700°C min^{-1} to 230°C; flow rate, 0.7 ml min^{-1}; and oven, 30°C (held for 0.1 min), 2°C min^{-1} to 40°C (held for 3 min), 12°C min^{-1} to 200°C (held for 2 min). The typical retention time of furan was approximately 8 min; the total run time was 23 min.

The next step was the optimization of the SPME procedure in order to improve the performance of the method. As it is well established that headspace extraction, magnetic stirring and the use of 75 μm CAR-PDMS fibres increase sensitivity in furan analysis (Goldman et al. 2005; Bianchi et al. 2006; Altaki et al. 2007), these parameters were not investigated in this study. Instead, we focused on optimizing the amount of the sample, extraction time, extraction temperature and ionic strength. Amounts of 0.5, 1, 2 and 4 g of sample were evaluated in order to determine the saturation of the fibre. As no saturation was observed up to 2 g of sample, the amount of 1 g was then chosen taking into account the variation on furan levels in other samples. Extraction time, extraction temperature, and ionic strength were optimized by applying a rotatable central composite design (RCCD) in order to evaluate the main effects of these variables and their interactions. The ranges evaluated for each parameter were set according to information available in the literature, considering instrumental and operative limits. A negative effect of the temperature and a positive effect of time on the peak area of furan and furan-d_4 were observed, while the addition of NaCl was not significant ($p > 0.05$). Analysis of variance (ANOVA) demonstrated the validity of the model ($F_{calc} = 22.84 > F_{tab} = 3.74$; $R^2 = 0{,}765$) and, by evaluating the response surface (not shown), it was possible to fix the optimized conditions for the SPME: temperature = 25°C and time = 30 min.

As demonstrated in other studies (Bianchi et al. 2006; Altaki et al. 2007), a decrease in the extraction temperature causes an increase on furan peak area. Some authors have attributed this fact to the desorption of furan from the fibre at higher temperatures (Bianchi et al. 2006), whereas others explain it by the increase in the distribution constant of furan between the headspace and the fibre coating since the process is exothermic (Altaki et al. 2007). In relation to ionic strength, many organic molecules show a decrease in aqueous solubility with salt addition, improving the partitioning to the headspace. Some procedures described in the literature for furan analysis use NaCl to increase sensitivity (Goldman et al. 2005; Altaki et al. 2007; Jestoi et al. 2009). According to Crews et al. (2007), salt addition caused a 2.5-fold increase in peak area for both furan and furan-d_4, and the level of furan was the same within experimental error. However, we

decided do not use NaCl since the results of the present study showed no significant effect of salt addition, as observed by other authors (Scholl et al. 2007; La Pera et al. 2009).

After setting the chromatographic conditions and optimizing the SPME, an in-house validation of the proposed method was performed. The furan response was linear over a concentration range of 0–100 $\mu g\,kg^{-1}$, as shown by Mandel's fitting test, with correlation coefficients of 0.998. A comparison between curves set on standard solutions and on the matrix by applying the *F*-test and *t*-test revealed a non-significant matrix effect ($F_{calc} = 1.04 < F_{tab} = 5.82$; $t_{calc} = 0.23 < t_{tab} = 1.78$). The LOD and LOQ were 0.7 and 2.4 $\mu g\,kg^{-1}$, respectively. Mean recoveries ranged from 80% to 107%; coefficients of variation ranged from 5.6% to 9.4% for repeatability and from 7.4% to 12.4% for within-laboratory reproducibility. All results were within the tolerances set by European Commission Decision 2002/657 (European Commission 2002).

A typical chromatogram of a baby food sample is illustrated in Figure 1. It should be mentioned that all samples below the LOD showed a visible signal at the retention time of furan; however, the furan content could not be determined since the confirmation criteria based on ionic relative abundance was not fulfilled below this level.

Furan levels in baby food

The furan levels in samples of baby food available on the Brazilian market were analysed according to the described method, and the results are presented in Table 1. The levels of furan in samples varied from not detected to 95.5 $\mu g\,kg^{-1}$. Furan was found in quantifiable amounts in all samples containing meat and vegetables, whereas only three samples containing fruits showed furan content above the LOQ. Mean concentrations were 31.8 $\mu g\,kg^{-1}$ for meat and vegetable-based baby food and 1.7 $\mu g\,kg^{-1}$ for fruit-based baby food (furan levels below the LOQ were considered as half the LOQ). According to EFSA (2004), which compiled data from the USFDA, Switzerland, and Germany, furan was found in commercial baby food at concentration levels varying from not detected to 112 $\mu g\,kg^{-1}$; however, higher levels up to 215 $\mu g\,kg^{-1}$ were recently reported by the European Union (EFSA 2009). As can be seen, the results obtained in the present study are in accordance with data reported by European and North American countries.

Although it is difficult to deduce which ingredients are involved in furan formation, as the exact mechanism of the reaction is not completely understood, it has been conclusively reported that fruit-based baby foods contain lower amounts of furan than meat and vegetable-based products (Bianchi et al. 2006; Jestoi et al. 2009; Zoller et al. 2007). However, as fruit-based baby foods contain naturally or added ascorbic acid, a potential precursor of furan, it would be expected that higher furan levels are to be found in these products. Moreover, some studies conducted with model systems have indicated that furan formation from ascorbic acid is higher at a lower pH (Fan 2005; Limacher et al. 2007; Fan et al. 2008), and the pH of baby food-containing fruits is usually below 5. It seems that in real samples the formation of furan from ascorbic acid is disfavoured due to competing reactions in complex systems, which confirms the results observed by

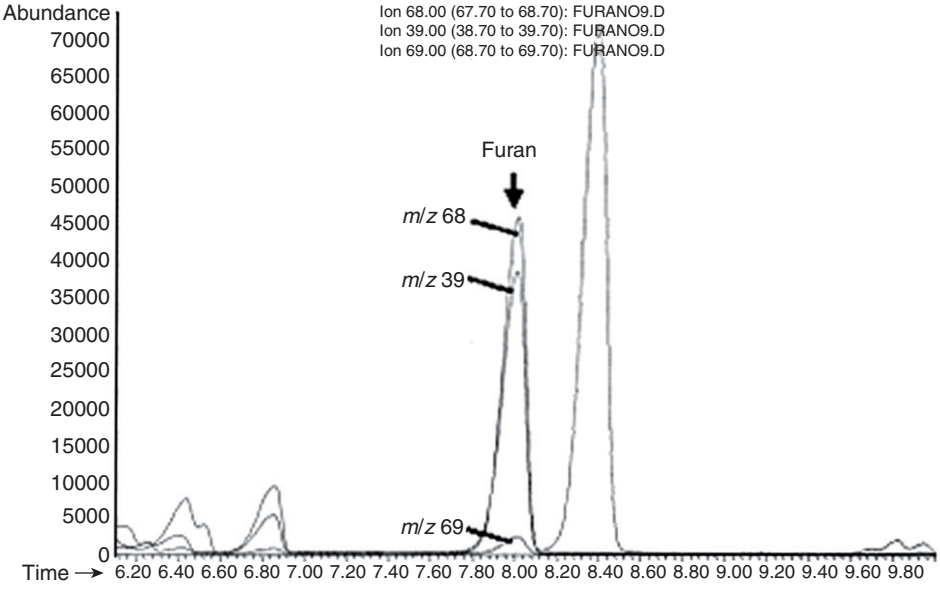

Figure 1. Typical GC/MS SIM chromatogram of a baby food sample (papaya and orange juice) containing 3.0 $\mu g\,kg^{-1}$ of furan.

Table 1. Furan levels in baby food samples.

Sample (main ingredients)	Furan ($\mu g\,kg^{-1}$)
Carrot	23.8
Carrot, potato, beetroot, rice and beans	77.4
Beef, carrot and potato	95.5
Beef, carrot and potato (pieces)	11.7
Beef, carrot, potato and pasta	10.7
Beef, carrot, potato and pasta (pieces)	17.8
Beef, carrot, potato and arracacha root	26.3
Beef, carrot, potato, rice and egg	24.8
Beef, carrot, potato, rice and beans	15.9
Chicken, carrot, potato and pasta	34.5
Chicken, potato, spring greens and spinach	39.2
Chicken, carrot and potato (pieces)	20.0
Turkey, carrot, potato and arracacha root	12.8
Spaghetti with Bolognese sauce	23.9
Beef stroganoff	44.8
Beef stew	28.2
Chicken risotto	32.6
Apple and prune	2.5
Papaya and orange juice	3.0
Banana and oat (pieces)	5.7
Banana and oat	<2.4
Pear	<2.4
Apple and orange juice	<2.4
Apple	n.d.
Apple, papaya and orange juice	n.d.
Apple and banana	n.d.
Apple, papaya, passion fruit, oat flour and barley flour	n.d.
Prune	n.d.
Guava	n.d.
Pear and mango	n.d.
Mango, banana, pineapple and orange juice	n.d.

Notes: Samples were analysed in duplicate.
n.d., Not detected.

Märk et al. (2006) and Limacher et al. (2007) in binary mixtures.

It should be noted that other factors, probably still unknown, might also be involved in the mechanism of furan formation in baby foods, since large differences between samples from the same basic recipe were verified (beef, carrot and potato samples). Studies conducted by the USFDA and other researchers showed that some irradiated foods form furan when heated and still other foods form furan during storage at refrigeration temperatures (USFDA 2008). On the other hand, Lachenmeier et al. (2009) observed that furan was formed in potato-based baby foods after storage overnight at 8°C and reheating in a closed jar (1 h, 70°C). Interestingly, during our validation experiments, it was noted that blank samples containing potato showed quantifiable amounts of furan after 24 h under refrigerated storage and that the amount of furan increased over time, but this should be confirmed in further experiments. Thus, it is very important to investigate other possible routes of furan formation as well as major precursors in real samples.

Estimate of furan intake and risk assessment

The average daily consumption of baby foods for each scenario as well as the levels of furan used in calculations are shown in Table 2. High percentiles of furan content in samples were used in order to obtain the intake for high consumers (due to average consumption of highly contaminated foods).

Estimated furan intakes are shown in Figure 2. The mean total intake was estimated to be 0.82 and $0.46\,\mu g\,kg^{-1}\,bw\,day^{-1}$ for scenarios 1 and 2, respectively. At high percentiles (P99), the furan intake was approximately three-fold higher than the mean for both scenarios (2.40 and $1.34\,\mu g\,kg^{-1}\,bw\,day^{-1}$, respectively). The 'theoretical' intake (scenario 1), which considers that all babies are exclusively fed with commercial baby foods, was almost two-fold higher than the furan intake obtained from individual consumption data (scenario 2) for all percentiles. An assessment of the contribution of each baby food group (based on their ingredients) to furan exposure showed that meat and vegetables-based products were the most important source of furan in the diet of babies, contributing more than 94% of the total average intake.

Few data on the exposure of babies to furan can be found in the literature. In Italy, the maximum exposure of a 6-month-old baby to furan was estimated to be $7\,\mu g\,kg^{-1}\,bw\,day^{-1}$, considering the most contaminated sample (Bianchi et al. 2006). In the United States, intakes from 0.4 to $1.0\,\mu g\,kg^{-1}\,bw\,day^{-1}$ were estimated for babies from zero to 12 months (USFDA 2007). The furan intake by German 6-month-old babies was estimated to be between 0.5 and $1.8\,\mu g\,kg^{-1}\,bw\,day^{-1}$ (Lachenmeier et al. 2009). For Finnish 6-month-old babies, the exposure to furan varied from 0.1 to $2.1\,\mu g\,kg^{-1}\,bw\,day^{-1}$, but intakes up to $10.6\,\mu g\,kg^{-1}\,bw\,day^{-1}$ were estimated in a worst-case scenario (Jestoi et al. 2009). According to EFSA (2009), which reported estimated intakes from occurrence data obtained during the monitoring plan of furan levels in foods, the average exposure for infants aged 3–12 months due to the consumption of jarred baby food was estimated to be between 0.13 and $0.97\,\mu g\,kg^{-1}\,bw\,day^{-1}$. In general, the exposure to furan in Brazil is comparable with results obtained in other countries.

In order to discuss the risks associated to furan, MOEs were calculated by the relation between the T25 dose and the total intakes estimated in the present work (Table 3). MOEs can be used by risk managers for priority setting in relation to the presence of carcinogenic substances in foods. A small MOE

Table 2. Average consumption of baby food and furan levels used to assess the exposure.

Product group (-based baby food)	Consumption ($g\,day^{-1}$)		Furan levels ($\mu g\,kg^{-1}$)				
	Scenario 1[a]	Scenario 2[b]	Mean	Median	P90	P95	P99
Meat and vegetables	211	115	31.8	24.8	57.9	81.1	92.6
Fruits	120	120	1.7	1.2	2.8	3.9	5.3

Notes: [a]Average consumption recommended by the Sociedade Brasileira de Pediatria (SBP) (2006).
[b]Individual consumption data (Aquino and Philippi 2002); average consumption determined for consumers only.

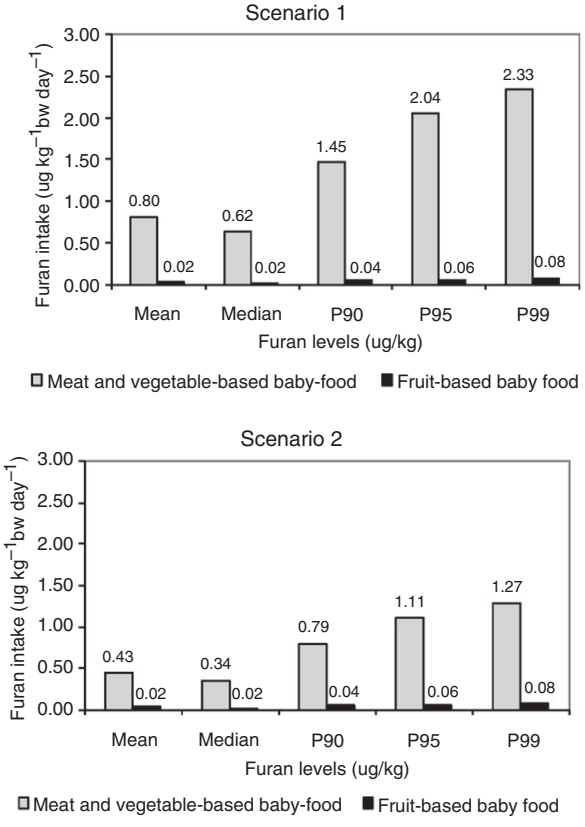

Figure 2. Estimated intakes for different levels of furan.

Table 3. Margins of exposure (MOE).

Furan level	Scenario 1		Scenario 2	
	Total intake ($\mu g\,kg^{-1}$ $bw\,day^{-1}$)	MOE	Total intake ($\mu g\,kg^{-1}$ $bw\,day^{-1}$)	MOE
Mean	0.82	1702	0.46	3046
Median	0.64	2184	0.36	3919
P90	1.49	937	0.86	1682
P95	2.09	669	1.17	1201
P99	2.40	583	1.34	1041

represents a higher risk than a larger MOE. Although the interpretation of its magnitude is still under discussion, it has been suggested that a MOE of 10,000 or higher would be of low concern from a public health point of view and might reasonably be considered as a low priority for risk-management actions (EFSA 2005). According to Table 3, the calculated MOEs ranged from 583 to 2184 in scenario 1 and from 1041 to 3919 in scenario 2, which can be considered low for a possible human carcinogen, indicating a potential public health concern.

Similar results were reported by Lachenmeier et al. (2009) (MOEs from 757 to 6733), whereas Jestoi et al. (2009) obtained MOEs from 7.5 to 750 (the authors used the no observable adverse effect level of $0.08\,mg\,kg^{-1}\,bw\,day^{-1}$ as a toxicological reference value). According to JECFA (FAO/WHO 2010), MOEs of 480 and 960 were obtained for high and average consumers, respectively, by using the recently derived BMDL of $0.96\,mg\,kg^{-1}\,bw\,day^{-1}$ for induction of hepatocellular adenomas and carcinomas in female mice.

It is possible that MOEs calculated in the present study are overestimated by a small amount since the samples were analysed as bought. If it is considered that furan is partially lost during the warming procedures of opened jars, the risks could be reduced. However, this cannot be assumed since available studies on the stability of the contaminant during heating have shown conflicting results. Some authors reported furan losses of 29–85% during warming under different times (Goldman et al. 2005; Zoller et al. 2007), whereas others have found that furan persists during normal heating practices (Hasnip et al. 2006; Lachenmeier et al. 2009).

According to JECFA, there is currently a lack of quantitative data for all foods in relation to the reduction of furan levels through volatilization as well as available information on other mitigation methods (FAO/WHO 2010). As a first initiative to reduce the exposure of consumers to furan, the recommended strategy from this Committee is heating canned or jarred foods under stirring in an open saucepan. Moreover, since some studies have shown none or only very low concentrations of furan in homemade baby foods (Bianchi et al. 2006; Lachenmeier

et al. 2009), an additional advice would be to cook baby meals at home in an open saucepan using fresh ingredients, especially those containing meat and vegetables.

Conclusions

The present study reports the first data on furan occurrence in foods in Brazil. The levels of the contaminant found in commercial samples of baby food as well as the estimated intakes were within those reported from other countries. Margins of exposure indicated a potential public health concern. It is expected that these results will contribute to data accumulation for worldwide health risk assessment and be helpful in the stimulation of researches aimed at lowering furan formation during the processing of commercial baby foods.

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