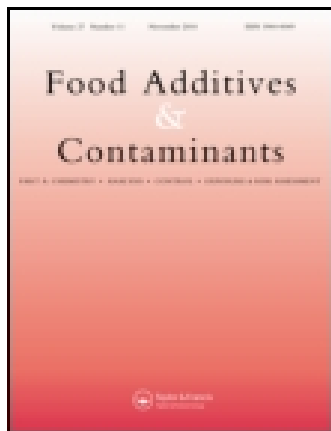


This article was downloaded by: [Ryerson University]

On: 10 October 2014, At: 12:37

Publisher: Taylor & Francis

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Food Additives & Contaminants: Part A

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/tfac20>

Occurrence of furan in commercial processed foods in Brazil

A.P. Ariseto^a, E. Vicente^a, R.P.Z. Furlani^a, M.S. Ueno^a, A.L.D. Pereira^a & M.C.F. Toledo^a

^a Food Science and Quality Center, Institute of Food Technology, Avenida Brasil 2880, C.P. 139, 13070-178 Campinas - SP, Brazil

Accepted author version posted online: 18 Jul 2012. Published online: 21 Aug 2012.

To cite this article: A.P. Ariseto, E. Vicente, R.P.Z. Furlani, M.S. Ueno, A.L.D. Pereira & M.C.F. Toledo (2012) Occurrence of furan in commercial processed foods in Brazil, *Food Additives & Contaminants: Part A*, 29:12, 1832-1839, DOI: [10.1080/19440049.2012.713030](https://doi.org/10.1080/19440049.2012.713030)

To link to this article: <http://dx.doi.org/10.1080/19440049.2012.713030>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>

Occurrence of furan in commercial processed foods in Brazil

A.P. Arisseto*, E. Vicente, R.P.Z. Furlani, M.S. Ueno, A.L.D. Pereira and M.C.F. Toledo

Food Science and Quality Center, Institute of Food Technology, Avenida Brasil 2880, C.P. 139,
13070-178 Campinas – SP, Brazil

(Received 10 May 2012; final version received 12 July 2012)

Selected commercial processed foods available in the Brazilian market (306 samples) were analysed for furan content using a validated gas chromatography-mass spectrometry method preceded by headspace solid phase micro-extraction (HS-SPME-GC/MS). Canned and jarred foods, including vegetable, meat, fruit and sweet products, showed levels up to $32.8 \mu\text{g kg}^{-1}$, with the highest concentrations observed in vegetables and meats. For coffee, furan content ranged from 253.0 to $5021.4 \mu\text{g kg}^{-1}$ in the roasted ground coffee and from not detected to $156.6 \mu\text{g kg}^{-1}$ in the beverage. For sauces, levels up to $138.1 \mu\text{g kg}^{-1}$ were found. In cereal-based products, the highest concentrations (up to $191.3 \mu\text{g kg}^{-1}$) were observed in breakfast cereal (corn flakes), cracker (cream crackers) and biscuit (wafer). In general, these results are comparable with those reported in other countries and will be useful for a preliminary estimate of the furan dietary intake in Brazil.

Keywords: GC/MS; process contaminants; canned foods; coffee; bakery products

Introduction

Furan is a highly volatile and lipophilic organic compound that can be formed in foods as a result of heating or exposure to ionising or ultraviolet radiation (Codex Committee on Contaminants in Foods (CCCF) 2011). The occurrence of furan and its derivatives in heat-treated foods such as coffee, canned meat, bread and cooked chicken has long been recorded (Maga 1979).

Furan represents a potential concern since it was classified as possibly carcinogenic to humans (Group 2B) by the International Agency for Research on Cancer (IARC) (1995), based on the increased incidence of liver tumours and cholangiocarcinomas in rats and mice at high exposure doses (National Toxicology Program (NTP) 1993). It is assumed that *cis*-2-butene-1,4-dial, the reactive metabolite of furan, is the causative agent leading to toxicity and carcinogenicity in experimental animals. However, epidemiological studies investigating a possible association between furan exposure and human cancer have not been reported (Bakhiya and Appel 2010).

In 2004, researchers from the US Food and Drug Administration (USFDA) reported the occurrence of furan in a broad variety of thermally processed foods, indicating significant concentrations in coffee, in foods that underwent a heat treatment in sealed containers including baby foods, as well as in crusty and dry

products such as toasted bread or bread crust (USFDA 2004). These findings were later confirmed by the European Food Safety Authority (EFSA) in a report containing a compilation of available data (EFSA 2004). According to these preliminary results, coffee contained the highest concentrations of furan, up to $5050 \mu\text{g kg}^{-1}$ for roasted beans, while levels up to $112 \mu\text{g kg}^{-1}$ were reported for jarred baby foods.

The presence of furan in an unexpected number of commonly consumed foods caused a worldwide concern regarding the potential risks of this contaminant to human health since preliminary exposure assessments revealed a relative small margin between the estimated intakes and furan doses which induce liver tumours in experimental animals (EFSA 2004). As a consequence, several research studies have been led by scientists and industry on analysis, formation and control, while advice on consumption has been communicated (CCCF 2011).

To date it has been well established that gas chromatography/mass spectrometry (GC/MS) preceded by headspace sampling (HS) or headspace solid phase micro-extraction (HS-SPME) are the most appropriate techniques to determine furan in foods (Becalski et al. 2005; Goldman et al. 2005; Bianchi et al. 2006; Hasnip et al. 2006; USFDA 2006; Altaki et al. 2007; Wenzl 2008). Moreover, several compounds such as carbohydrates, amino acids, polyunsaturated

*Corresponding author. Email: adriana.arisseto@gmail.com

fatty acids and ascorbic acid have already been identified as potential precursors in the generation of this contaminant (Locas and Yaylayan 2004; Becalski and Seaman 2005; Märk et al. 2006; Limacher et al. 2007). On the other hand, more information is still needed regarding the mechanism of furan formation in foods as are practical and consistently effective strategies for decreasing its occurrence levels (CCCF 2011).

In addition, action plans and monitoring programmes were proposed by several countries (USFDA 2005; European Commission 2007). In the United States, the USFDA planned actions mainly on analytical methods, exposure assessment and risk analysis (USFDA 2005). In Europe, data from the European Union member states collected between 2004 and 2010 were organised by EFSA in a public database (EFSA 2011). Independent surveys have also been conducted in several European countries (Zoller et al. 2007; Bononi and Tateo 2009; Jestoi et al. 2009; Wegener and López-Sánchez 2010; Scholl et al. 2012) as well as in Canada (Becalski et al. 2010), Australia (Food Standards Australia New Zealand (FSANZ) 2008), and Asian countries (Kim et al. 2010; Liu and Tsai 2010).

In Brazil, a survey carried out to determine furan levels in commercial baby foods showed results comparable with those obtained in other countries (Arisseto et al. 2010). However, no data for commercially processed foods from Brazil other than baby foods have been published so far. Therefore, the objective of this study was to use a validated HS-SPME-GC/MS method to collect information on furan levels in canned/jarred foods, sauces, coffees and cereal-based products in order to provide a comprehensive database on the occurrence of this contaminant in Brazilian foods.

Materials and methods

Standards and chemicals

Furan and [²H₄] furan (furan-d₄) were obtained from Sigma-Aldrich (Sigma-Aldrich Corp., St. Louis, MO, USA) at purity higher than 98%. Methanol was of HPLC grade (Tedia Company Inc., Fairfield, OH, USA) and water was purified by reverse osmosis (Gehaka, São Paulo, SP, Brazil). Individual stock solutions of both standards at approximately 2 mg ml⁻¹ were prepared by dissolving the compounds in methanol. Intermediate (approximately 20 µg ml⁻¹) and work solutions (approximately 2 and 0.2 µg ml⁻¹) were prepared in water.

Samples

A total of 306 samples of canned/jarred foods, sauces, coffees and cereal-based products were purchased at

supermarkets, restaurants and cafeterias in the city of Campinas, SP, Brazil, between September 2009 and September 2011. The sampling was made considering previous data reported by other countries and included products typically consumed in Brazil, commercially available in metal cans, such as feijoada (a thick stew made from black beans and a variety of salted pork and beef products), doce de leite (a thick, caramel-like sweet made from sugar and milk) and goiabada (a conserve made of guava, sugar and water). For most of the products, three different brands and two different lots of each brand were analysed. The samples were stored at 4°C for at least 4 h before homogenisation, which was carried out as quickly as possible in order to avoid furan losses due to volatilisation.

Determination of furan

Furan was determined by using a HS-SPME-GC/MS method as described previously (Arisseto et al. 2010, 2011). The sample weight, volume and concentration of furan-d₄ working solution, volume of water and extraction temperature were optimised for each group of sample, and are shown in Table 1. The SPME was carried out for 30 min employing a 75 µm carboxen-polydimethylsiloxane (CAR-PDMS) fibre (Supelco, Bellefonte, PA, USA). The GC/MS system consisted of a HP 6890 gas chromatograph (Agilent Technologies, Palo Alto, CA, USA) equipped with a MSD 5973 mass spectrometer (Agilent Technologies) and the chromatographic conditions were as previously described. The mass spectrometer was operated in positive electron impact ionisation mode (+EI) with 70 eV of electron energy. Selected ion monitoring (SIM) was applied by using three characteristic ions for furan (*m/z* 68, 39 and 69) and two characteristic ions for furan-d₄ (*m/z* 72 and 42). The quantification of furan in samples was proceeded by extrapolation from a linear analytical curve using furan-d₄ as an internal standard.

Method validation

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 Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO) (2007). Linearity was evaluated by using at least six calibration points. Selectivity was determined by comparison between curves set on standard solutions and on matrix by applying the *F*-test (Snedecor) and *t*-test (Student). LOD and LOQ were estimated by seven independent replicates of the matrix and calculated as three- and 10-fold the

Table 1. Parameters (sample weight, volume of internal standard (IS), concentration of IS, volume of water and extraction temperature) used in the solid-phase micro-extraction (SPME) for each group of sample.

Sample	Weight (g)	IS volume (μl)	IS concentration ($\mu\text{g ml}^{-1}$)	Water (ml)	Extraction temperature ($^{\circ}\text{C}$)
Canned/jarred foods	1.0	125	0.2	1	25
Coffee (beverage) and sauces	1.0	125	0.2	–	25
Cereal-based products	1.0	125	0.2	5	25
Coffee (powder)	0.25	150	2.0	1	35

Table 2. Validation results.

Matrix	Calibration range ($\mu\text{g kg}^{-1}$)	r^2	Matrix effect	LOD ($\mu\text{g kg}^{-1}$)	LOQ ($\mu\text{g kg}^{-1}$)	R (%)	CV_r (%)	CV_R (%)
Baby food	0–100	0.998	No	0.7	2.4	80–107	5.6–9.4	7.4–12.4
Coffee	0–9600	0.992	No	3.0 ^a	10.0 ^a	76–101	1.7–7.1	6.2–13.8
Soy sauce	0–100	0.998	No	1.3	4.2	83–127	2.8–13.2	17.0–23.6
Bread	0–100	0.998	No	1.4	4.8	92–123	6.7–9.8	10.3–23.3

Notes: ^aLimits estimated for beverages.

r^2 , coefficient of correlation; LOD, limit of detection; LOQ, limit of quantification; R , recovery; CV_r , coefficient of variation under repeatability conditions (same day); and CV_R , coefficient of variation under within-laboratory reproducibility conditions (different days).

standard deviation of the obtained responses, respectively. Recovery, repeatability and within-laboratory reproducibility were evaluated by spiking the matrix with furan at three different levels (seven replicates for each level). The validation procedure was performed for different matrices such as jarred baby food (containing vegetables, beef, rice and pasta), ground roasted coffee, soy sauce and whole bread in order to represent most of the analysed foods. If a blank matrix was not available, a sample with a low contamination level was used in the experiments.

Results and discussion

Method validation

Previous studies (Arisseto et al. 2010, 2011) have described in detail the definition of chromatographic conditions and the optimisation of the SPME procedure for baby food and coffee matrices, which were taken into account in the present work.

The results obtained during the validation experiments are summarised in Table 2. As can be seen, the method is reliable and can be applied to determine furan in several foodstuffs. The method also showed good linearity in the calibration ranges tested as well as high selectivity, since no matrix effects were observed for the evaluated samples. The estimated LOD and LOQ were appropriate to detect low concentrations of

furan. Mean recoveries varied from 76% to 123%, and the coefficients of variation ranged from 1.7% to 13.2% for repeatability and from 6.2% to 23.6% for within-laboratory reproducibility, which are within the tolerances considered acceptable (Horwitz et al. 1980; European Commission 2002).

Occurrence in food

The validated HS-SPME-GC/MS method was used to determine the concentrations of furan in canned/jarred foods, coffees, sauces and cereal-based products available on the Brazilian market. Although the sampling included brands that are probably commercialised in other Brazilian regions, it should be noted that the samples were only collected in the Campinas area and, therefore, may not be representative of the national food supply. However, this study provides a comprehensive database on furan levels in a selected segment of Brazilian food resources.

Canned/jarred foods

The results obtained in relation to the occurrence of furan in canned and jarred foods are presented in Table 3. The concentrations ranged from not detected to $32.8 \mu\text{g kg}^{-1}$. The mean values were calculated at $4.9 \mu\text{g kg}^{-1}$ for vegetable products, $10.9 \mu\text{g kg}^{-1}$ for

Table 3. Furan levels in canned/jarred foods ($N=94$).

Group	Sample	$N/N+$	Furan ($\mu\text{g kg}^{-1}$)	
			Mean	Minimum–maximum
Vegetables	Mixed vegetables	5/1	0.6–1.5	n.d.–3.1
	Tomato puree	6/4	5.3	<2.4–13.1
	Tomato sauce	6/3	6.0	<2.4–15.7
	Olive	6/5	5.0	<2.4–7.5
	Mushroom	6/4	2.8	<2.4–4.0
	Heart of palm	6/4	8.5	<2.4–16.1
	Maize	6/5	6.8	<2.4–13.0
Meats	Pea	4/3	3.4	<2.4–5.5
	Feijoada	5/4	6.7	<2.4–16.5
	Tuna	6/5	5.3	<2.4–9.2
	Sausage	4/4	10.8	4.8–18.8
	Sardine	6/6	9.4	2.7–15.5
Fruits and sweets	Ham pate	3/3	22.5	17.1–32.8
	Peach	6/1	0.9–1.8	n.d.–5.3
	Pineapple	5/4	6.8	<2.4–10.3
	Strawberry jam	6/2	1.9–3.5	<2.4–7.8
	Doce de leite	4/3	3.7	<2.4–5.9
	Goiabada	4/3	2.7	<2.4–3.3

Notes: N , number of samples; $N+$, number of samples above the limit of quantification ($\text{LOQ}=2.4 \mu\text{g kg}^{-1}$); and n.d., values below the limit of detection ($\text{LOD}=0.7 \mu\text{g kg}^{-1}$).

To calculate the mean, values below the LOD and LOQ were treated according to World Health Organization (WHO) (2002). The range indicates different results for the lower and upper bounds for a group of data with fewer than 40% of quantifiable results.

Table 4. Furan levels in coffee ($N=79$).

Group	Sample	$N/N+$	Furan ($\mu\text{g kg}^{-1}$)	
			Mean	Minimum–maximum
Roasted ground coffee (in pillow packs)	Instant	8/8	448.9	253.0–1005.3
	Classic	7/7	1669.7	1139.3–2026.4
	Extra-strong	6/6	1556.1	1262.0–1791.8
Roasted ground coffee (vacuum packed)	Classic	6/6	3472.0	2704.1–5021.4
	Strong	4/4	4164.3	3475.9–5017.8
	Extra-strong	6/6	2445.0	1732.1–4481.7
	Premium	4/4	1789.4	1273.8–2328.5
Beverage	Instant ^a	8/2	3.8–9.6	n.d.–20.6
	Filtered ^b	10/10	25.5	15.4–55.1
	Espresso	14/14	79.8	44.5–156.6
	Cappuccino	6/6	40.7	27.7–74.2

Notes: ^aBeverages prepared in the laboratory by using 2 g of instant coffee to 100 ml water.

^bInclude beverages collected in restaurants and prepared in the laboratory (manually and automatically) by using 10 g of roasted ground coffee to 100 ml water.

N , number of samples; $N+$, number of samples above the limit of quantification ($\text{LOQ}=10 \mu\text{g kg}^{-1}$); and n.d., values below the limit of detection ($\text{LOD}=3 \mu\text{g kg}^{-1}$).

To calculate the mean, values below the LOD and LOQ were treated according to World Health Organization (WHO) (2002). The range indicates different results for the lower and upper bounds for a group of data with fewer than 40% of quantifiable results.

meat products and $3.4 \mu\text{g kg}^{-1}$ for fruits and sweets. The group of meat products presented the higher percentage of positive samples (92%). The results are comparable with those reported in other studies (Zoller et al. 2007; Morehouse et al. 2008; EFSA 2011).

In general, higher concentrations of furan have been found in canned/jarred vegetables and meats. Some authors attributed this trend to the higher pH of vegetables, which could lead to a higher degradation of ascorbic acid and subsequent furan formation (Mesías-García et al. 2010). Other studies demonstrated that the degradation of ascorbic acid can also be enhanced in the presence of lipids, which could constitute an important route for furan formation in foods (Owczarek-Fendor, De Meulenaer, Scholl, Adams, van Lancker, Yogendrarajah, Uytterhoeven, et al. 2010). In addition, other factors such as availability of oxygen and the presence of buffers (phosphate, citrate) can interfere on the concentration of the contaminant in the final product (Owczarek-Fendor, De Meulenaer, Scholl, Adams, van Lancker, Yogendrarajah, Eppe, et al. 2010).

Coffees

Furan levels in coffee samples are presented in Table 4. The concentrations ranged from 253.0 to $5021.4 \mu\text{g kg}^{-1}$ in roasted ground coffee and from not detected to $156.6 \mu\text{g kg}^{-1}$ in the beverage, which is comparable with data reported in the literature (Zoller et al. 2007; Morehouse et al. 2008; Crews et al. 2009; EFSA 2011). With the exception of instant coffee (beverage), all other coffee samples showed 100% of quantifiable results. The mean concentrations observed

were 1224.9 $\mu\text{g kg}^{-1}$ for roasted ground coffee packed in pillow packs, 2967.7 $\mu\text{g kg}^{-1}$ for roasted ground coffee vacuum packed and 38.2 $\mu\text{g kg}^{-1}$ for beverages.

The high levels of furan found in roasted ground coffee may be probably due to the temperatures used in the roasting process, which are generally higher than those employed in most of other thermal treatments. Within these samples instant coffee showed the lowest concentrations of furan, which could be attributed to the volatilisation of the contaminant during the extraction and concentration steps employed to obtain this product. As expected, the highest levels were observed in vacuum-packed roasted ground coffee, since the loss of volatile compounds during the storage is less significant in this type of packaging. The intensity of coffee (classic, strong and extra-strong) could not be correlated with the level of furan, although some studies have suggested that the concentration of the contaminant increases with the roasting degree (Guenther et al. 2010; Arisseto et al. 2011). The composition of the products in relation to species (*C. arabica* and *C. canephora*) could also contribute to the observed differences, since experiments carried out with coffees of light, medium and dark roasting degrees showed higher furan levels for the *C. canephora* species (Arisseto et al. 2011).

In contrast to roasted ground coffee, much lower concentrations were found in coffee beverages, which might be associated to furan volatilisation due to the high temperature of water as well as its solubility in this solvent. The variation on furan content in different beverages depends on the brewing procedure (filtration, percolation, pressure, etc.), on the furan content in roasted ground coffee and on the proportion of powder and water used (Kuballa et al. 2005; Zoller et al. 2007; Arisseto et al. 2011). Espresso coffees have higher furan levels due to the largest amount of powder needed to prepare this beverage, to the closed system of commercial machines that limits losses by volatilisation, to the higher pressure during brewing which increases the extraction of furan from the coffee powder, and to the reduced loss of furan in the cup since this procedure required less time for preparation (Kuballa et al. 2005; Zoller et al. 2007; Altaki et al. 2011).

It has been reported in the literature that brewed coffee is the most important contributor to furan exposure in the adult population (Morehouse et al. 2008; EFSA 2011). The choice of a brewing method that results in lower furan levels could be, in principle, a useful approach to reduce furan exposure from coffee. However, the amount of furan ingested through drinking coffee will depend not only on the final concentration of the contaminant in the beverage, but also on the serving size (Stadler 2011). Thus, it is important to note that although furan concentrations are relatively higher in espresso coffee, the usual

serving size of this beverage is generally smaller in comparison with other types of coffee.

Sauces

Table 5 presents the levels of furan found in soy sauces and related products. As can be noted, all samples showed results above the LOQ, and the concentration of furan varied from 6.0 to 138.1 $\mu\text{g kg}^{-1}$. Similar results were reported in other studies (USFDA 2004; EFSA 2011).

There is no information available in the literature about the possible contamination sources of soy sauce with furan. One hypothesis is that the occurrence of the contaminant be due to the use of roasted grains (such as wheat, maize and rice) in the formulation of these products. The addition of caramel colouring in some brands may also be a potential source of furan. The information available on the labels regarding ingredients and manufacturing process was not sufficient to explain the variation observed in the results and it was not possible to establish a correlation between the brand or type of soy sauce with furan levels.

Cereal-based products

Table 6 shows the results obtained for furan in cereal-based products. Of the 71 analysed samples, 62 presented quantifiable results, with concentrations up to 191.3 $\mu\text{g kg}^{-1}$. The highest levels of the contaminant were found in breakfast cereal (corn flakes), cracker (cream crackers) and biscuit (wafer), while the lowest concentrations were observed in loaf bread and cake. Data reported by Fromberg et al. (2009) showed levels of furan up to 387 $\mu\text{g kg}^{-1}$ in breakfast cereals. Other studies have also confirmed the occurrence of high concentrations of the contaminant in cereal-based

Table 5. Furan levels in soy sauces and related products ($N = 62$).

Soy sauce	$N/N+$	Furan ($\mu\text{g kg}^{-1}$)	
		Mean	Minimum–maximum
Traditional	26/26	27.2	10.5–57.8
Light	7/7	21.9	7.6–37.8
Premium	9/9	26.3	6.0–47.3
Other	4/4	50.2	40.9–65.1
Sauces containing soy sauce ^a	16/16	42.7	7.6–138.1

Notes: ^aYakissoba, shimeji, oriental, tonkatsu and tare sauces.

N , number of samples; and $N+$, number of samples above the limit of quantification (LOQ = 4.2 $\mu\text{g kg}^{-1}$).

Table 6. Furan levels in cereal-based products ($N=71$).

Sample	$N/N+$	Furan ($\mu\text{g kg}^{-1}$)	
		Mean	Minimum–maximum
Granola	6/6	18.8	11.8–23.9
Cereal bar	5/5	13.2	7.6–19.4
Corn flakes	6/6	77.1	36.5–145.0
Loaf bread	6/3	5.9	<4.8–12.0
Whole bread	6/4	12.5	<4.8–29.5
French bread	6/6	26.4	5.9–50.3
Toast	6/6	42.2	24.6–85.2
Cracker (cream cracker)	6/6	95.9	42.4–166.4
Cracker (other)	6/6	22.2	15.6–29.0
Biscuit (wafer)	6/6	105.3	29.5–191.3
Biscuit (milk)	6/6	38.1	23.8–67.2
Cake (orange)	6/2	1.8–5.0	n.d.–5.6

Notes: N , number of samples; $N+$, number of samples above the limit of quantification ($\text{LOQ}=4.8\ \mu\text{g kg}^{-1}$); and n.d., values below the limit of detection ($\text{LOD}=1.4\ \mu\text{g kg}^{-1}$).

To calculate the mean, values below the LOD and LOQ were treated according to World Health Organization (WHO) (2002). The range indicates different results for the lower and upper bounds for a group of data with fewer than 40% of quantifiable results.

products such as biscuits, crackers and crispbread (Hoenicke et al. 2004; EFSA 2011).

There are few studies available on the formation of furan in cereal-based products. Fromberg et al. (2009) reported that the colour of toasted bread is directly proportional to the level of furan, with the highest concentrations of the contaminant obtained for darker toasted bread. It has also been demonstrated that higher levels of furan are found in the bread crust (Zoller et al. 2007).

According to Table 6, a large variation on furan levels was observed between different products and between different brands for the same product. These differences may be related to the ingredients used in the formulation, the type of process employed and the heterogeneity of furan formation in the food (Fromberg et al. 2009; Wegener and López-Sánchez 2010).

Conclusions

This paper reports the results of a survey on furan content in 306 samples collected from the Brazilian market, including canned/jarred foods, coffees, sauces and cereal-based products. Furan was found in quantifiable amounts in most of the samples, in levels that are comparable with those obtained in other countries. Coffee, which has been identified as the most important contributor to furan exposure, presented very high concentrations in the powder, but much lower levels in the beverages. Significant contents were also found in cereal-based products, which can constitute another

important source of furan in the diet taking into account their high and usual consumption. These results will be used for a preliminary estimate of the furan dietary intake in Brazil and it is expected that potential alternatives to reduce furan exposure can be derived from these data, since the scientific literature has indicated that mitigation strategies are mostly targeted at the level of the consumer, rather than production methods.

Acknowledgements

Scholarship and financial support were provided by FAPESP (Proc. 2008/50095-0) and CNPq (Proc. 474267/2008-3 and Proc. 578381/2008-7).

References

- Altaki MS, Santos FJ, Galceran MT. 2007. Analysis of furan in foods by headspace solid-phase microextraction-gas chromatography-ion trap mass spectrometry. *J Chromatogr A*. 1146:103–109.
- Altaki MS, Santos FJ, Galceran MT. 2011. Occurrence of furan in coffee from Spanish market: contribution of brewing and roasting. *Food Chem*. 126:1527–1532.
- Arisseto AP, Vicente E, Toledo MCF. 2010. Determination of furan levels in commercial samples of baby-food from Brazil and estimated exposure. *Food Addit Contam A*. 27(8):1051–1059.
- Arisseto AP, Vicente E, Ueno MS, Tfouni SAV, Toledo MCF. 2011. Furan levels in coffee as influenced by species, roast degree, and brewing procedures. *J Agric Food Chem*. 59:3118–3124.
- Bakhiya N, Appel KE. 2010. Toxicity and carcinogenicity of furan in human diet. *Arch Toxicol*. 84:563–578.
- Becalski A, Forsyth D, Casey V, Lau BPY, Pepper K, Seaman S. 2005. Development and validation of a headspace method for determination of furan in food. *Food Addit Contam*. 22:535–540.
- Becalski A, Hayward S, Krakalovich T, Pelletier L, Roscoe V, Vavasour E. 2010. Development of an analytical method and survey of foods for furan, 2-methylfuran and 3-methylfuran with estimated exposure. *Food Addit Contam A*. 27(6):764–775.
- Becalski A, Seaman S. 2005. Furan precursors in food: a model study and development of a simple headspace method for determination of furan. *J AOAC Int*. 88:102–106.
- Bianchi F, Careri M, Mangia A, Musci M. 2006. Development and validation of a solid phase micro-extraction-gas chromatography-mass spectrometry method for the determination of furan in baby-food. *J Chromatogr A*. 1102:268–272.
- Bononi M, Tateo F. 2009. Determination of furan by headspace solid-phase microextraction-gas chromatography-mass spectrometry in balsamic vinegars of Modena (Italy). *J Food Compos Anal*. 22(1):79–82.
- Codex Committee on Contaminants in Foods (CCCF). 2011. Discussion paper on furan. 5th Session; The Hague, The Netherlands; 21–25 March 2011.

- Crews C, Roberts D, Laurysen S, Kramer G. 2009. Survey of furan in foods and coffees from five European Union countries. *Food Addit Contam B*. 2:95–98.
- European Commission. 2002. Commission Decision 2002/657/EC concerning the performance of analytical methods and the interpretation of results. *Off J Eur Comm*. L221:8–36.
- European Commission. 2007. Commission Recommendation 2007/196/EC, March 28, 2007. Monitoring of the presence of furan in foodstuffs. *Off J Eur Comm*. L85:56–57.
- European Food Safety Authority (EFSA). 2004. Report of the CONTAM Panel on provisional findings on furan in food. *EFSA J* [Internet]. [cited 2012 May 9];137:1–20. Available from: <http://www.efsa.europa.eu/de/efsajournal/doc/137.pdf>
- European Food Safety Authority (EFSA). 2011. Update on furan levels in food from monitoring years 2004–2010 and exposure assessment. *EFSA J* [Internet]. [cited 2012 May 9]; 9(9):2347. Available from: <http://www.efsa.europa.eu/en/efsajournal/doc/2347.pdf>
- Food Standards Australia New Zealand (FSANZ). 2008. Survey of chemical contaminants and residues in espresso, instant and ground coffee [Internet]. [cited 2012 May 9]. Available from: http://www.foodstandards.gov.au/_srcfiles/Survey%20of%20chemical%20contaminants%20and%20residues%20in%20coffee1.pdf
- Fromberg A, Fagt S, Granby K. 2009. Furan in heat processed food products including home cooked food products and ready-to-eat products. Report of the EFSA CFP/EFSA/DATEX/2007/03 Project [Internet]. Søborg (Denmark): The National Food Institute, Technical University of Denmark; [cited 2012 May 9]. Available from: <http://www.efsa.europa.eu/en/supporting/doc/1e.pdf>
- Goldman P, Périsset A, Scanlan F, Stadler RH. 2005. Rapid determination of furan in heated foodstuffs by isotope dilution solid phase micro-extraction-gas chromatography-mass spectrometry (SPME-GC-MS). *Analyst*. 130: 878–883.
- Guenther H, Hoenicke K, Biesterveld S, Gerhard-Rieben E, Lantz I. 2010. Furan in coffee: pilot studies on formation during roasting and losses during production steps and consumer handling. *Food Addit Contam A*. 27:283–290.
- Hasnip S, Crews C, Castle L. 2006. Some factors affecting the formation of furan in heated foods. *Food Addit Contam*. 23:219–227.
- Hoenicke K, Fritz H, Gatermann R, Weidemann S. 2004. Analysis of furan in different foodstuffs using gas chromatography mass spectrometry. *Czech J Food Sci*. 22:357–358.
- Horwitz W, Kamps LR, Boyer KW. 1980. Quality assurance in the analyses of foods for trace constituents. *J Assoc Off Anal Chem*. 63:1344–1354.
- Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO). 2007. Orientação sobre validação de métodos de ensaios químicos DOQ-CGCRE-08. Review 2, June. Available from: http://www.inmetro.gov.br/Sidoq/Arquivos/CGCRE/DOQ/DOQ-CGCRE-8_02.pdf
- International Agency for Research on Cancer (IARC). 1995. Furan. IARC Monographs on the evaluation of carcinogenic risks of chemicals to humans, vol. 63. Lyon (France): IARC.
- Jestoi M, Järvinen T, Järvenpää E, Tapanainen H, Virtanen S, Peltonen K. 2009. Furan in the baby-food samples purchased from the Finnish markets – determination with SPME-GC-MS. *Food Chem*. 117:522–528.
- Kim TK, Kim S, Lee KG. 2010. Analysis of furan in heat-processed foods consumed in Korea using solid phase microextraction-gas chromatography/mass spectrometry (SPME-GC/MS). *Food Chem*. 123(4):1328–1333.
- Kuballa T, Stefan S, Nina S. 2005. Furan concentrations in coffee and coffee beverages. *Deut Lebensm-Rundsch*. 101:229–235.
- Limacher A, Kerler J, Conde-Petit B, Blank I. 2007. Formation of furan and methylfuran from ascorbic acid in model systems and food. *Food Addit Contam*. 24:122–135.
- Liu YT, Tsai SW. 2010. Assessment of dietary furan exposures from heat processed foods in Taiwan. *Chemosphere*. 79:54–59.
- Locas CP, Yaylayan VA. 2004. Origin and mechanistic pathways of formation of the parent furan – a food toxicant. *J Agric Food Chem*. 52:6830–6833.
- Maga JA. 1979. Furans in foods. *Crit Rev Food Sci Nut*. 11:355–400.
- Märk J, Pollien P, Lindinger C, Blank I, Mark T. 2006. Quantitation of furan and methylfuran formed in different precursor systems by proton transfer reaction mass spectrometry. *J Agric Food Chem*. 54:2786–2793.
- Mesías-García M, Guerra-Hernández E, García-Villanova B. 2010. Determination of furan precursors and some thermal damage markers in baby foods: ascorbic acid, dehydroascorbic acid, hydroxymethylfurfural and furfural. *J Agric Food Chem*. 58:6027–6032.
- Morehouse KM, Nyman PJ, McNeal TP, Dinovi MJ, Perfetti GA. 2008. Survey of furan in heat processed foods by headspace gas chromatography/mass spectrometry and estimated adult exposure. *Food Addit Contam A*. 25:259–264.
- National Toxicology Program (NTP). 1993. Toxicology and carcinogenesis studies of furan (CAS No. 110-00-9) in F344 rats and B6C3F1 mice (gavage studies). NTP Technical Report No. 402 [Internet]. [cited 2012 May 9]. Available from: http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/tr402.pdf
- Owczarek-Fendor A, De Meulenaer B, Scholl G, Adams A, van Lancker F, Yogendrarajah P, Eppe G, De Pauw E, Scippo M-L, De Kimpe N. 2010. Furan formation from vitamin C in a starch-based model system: influence of the reaction conditions. *Food Chem*. 121:1163–1170.
- Owczarek-Fendor A, De Meulenaer B, Scholl G, Adams A, van Lancker F, Yogendrarajah P, Uytterhoeven V, Eppe G, De Pauw E, Scippo M-L, et al. 2010. Importance of fat oxidation in starch-based emulsions in the generation of the process contaminant furan. *J Agric Food Chem*. 58:9579–9586.
- Scholl G, Scippo ML, De Pauw E, Eppe G, Saegerman C. 2012. Estimation of furan contamination across the Belgian food chain. *Food Addit Contam A*. 29(2):172–179.
- Stadler RH. 2011. Response to the article ‘Occurrence of furan in coffee from Spanish market: contribution of brewing and roasting’. *Food Chem*. 129:1325–1326.
- US Food and Drug Administration (USFDA). 2004. Exploratory data on furan in food: individual food products [Internet]. [cited 2012 May 9]. Available from: <http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/ChemicalContaminants/Furan/ucm078439.htm/>

- US Food and Drug Administration (USFDA). 2005. FDA action plan for furan in food [Internet]. [cited 2012 May 9]. Available from: <http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/ChemicalContaminants/Furan/ucm078392.htm/>
- US Food and Drug Administration (USFDA). 2006. Determination of furan in foods [Internet]. [cited 2012 May 9]. Available from: <http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/ChemicalContaminants/Furan/ucm078400.htm/>
- Wegener JW, López-Sánchez P. 2010. Furan levels in fruit and vegetables juices, nutrition drinks and bakery products. *Anal Chim Acta*. 672:55–60.
- Wenzl T. 2008. Methods for the determination of furan in food. Outcome of a survey conducted among EU food control laboratories. JRC Scientific and Technical Reports, EUR 23269 EN. Geel: European Communities.
- World Health Organization (WHO). 2002. Instructions for electronic submission of data on chemical contaminants in foods – Appendix 5: evaluation of low level contamination in foods [Internet]. [cited 2012 May 9]. Available from: ftp://ftp.ksph.kz/Chemistry_Food%20Safety/TotalDietStudies/Chemical.pdf/
- Zoller O, Sager F, Reinhard H. 2007. Furan in food: headspace method and product survey. *Food Addit Contam*. 24:91–107.