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SCIENTIFIC REPORT OF EFSA

Results on the monitoring of furan levels in food[1]

A report of the Data Collection and Exposure Unit in Response to a request from the European Commission

(Question No EFSA-Q-2009-00607)

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SUMMARY

Furan that is formed during commercial or domestic heat treatment of food and contributes to the sensory properties of the product has been shown to be carcinogenic in animal experiments. In order to monitor the presence of furan in food, the Commission Recommendation 2007/196/EC (OJ L 88, 29.3.2007, p. 56) requested that Member States collect data on heat treated commercial food products, particularly during 2007 and 2008 and subsequently on a routine basis, to allow for a more comprehensive exposure assessment than has been previously possible.

In response, a total of fourteen Member States submitted analytical results for furan content in food to the European Food Safety Authority (EFSA). A total of 2,908 complete results were reported for foods sampled between 2004 and 2009 from 20 different food categories. The arithmetic mean of furan content ranged from 6 µg/kg for beer and fruit juice to 2,272 µg/kg for roasted coffee beans. The highest 95th percentile furan content was observed in roasted coffee beans at 4,895 µg/kg and in coffee not further specified at 6,500 µg/kg. The furan content was lower in ground coffee with an average of 1,114 µg/kg and in instant coffee with an average of 589 µg/kg.

Maximum values in excess of 100 µg/kg were found in cereal products, meat products, soups, sauces and other products although the average furan content in those food categories was much lower. The highest amounts in cereal products were reported for toasted bread and salted crackers.

Jarred baby food and infant formulae are of particular interest as they may form the sole diet of many infants and furan has been found in such products. In the present survey, the average furan content in infant formulae was 8 µg/kg, while commercial jarred baby food had an average of 25 µg/kg and a maximum of 210 µg/kg.

A conservative assessment of adult food consumption in Europe showed a tentative median furan exposure of up to 0.78 µg/kg b.w. per day with the mid-range for the 95th percentile at 1.75 µg/kg b.w. per day. An attempt to correct for an overestimation of coffee consumption resulted in a reduced median exposure of between 0.53 and 0.66 µg/kg b.w. per day and a mid-range 95th percentile of between 1.19 and 1.47 µg/kg b.w. per day. A further decrease of the estimated furan exposure can be expected should more detailed information be available for amounts consumed of individual foods analysed in the survey and now representing a whole aggregated food category and for the effects of domestic food preparation on the furan content since furan might dissipate during heating in an open sauce pan.

The average furan exposure for infants 3-12 months of age in Europe was estimated to be between 0.27 and 1.01 µg/kg b.w. per day with the highest at 6 and 9 months of age. Simulated high furan exposure for 6-9 months old infants resulted in an estimate of between 1.14 and 1.34 µg/kg b.w. per day.

It can be concluded that furan is formed in a variety of heat-treated foods. However, further research is needed on the effect of domestic cooking on the furan content in the different food categories prior to consumption and the impact of food handling past preparation.

Results from the EU-funded project on furan in the 6th framework program as well as from two projects funded by EFSA covering research on furan produced under different cooking conditions and furan inhalation during cooking are expected to assist in refining the exposure assessment process. Future testing of furan by Member States should preferably target food products belonging to food categories where limited results are available to potentially improve the accuracy of the overall prediction of furan exposure.

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BACKGROUND

At the end of 2004, a group of scientific experts of the Scientific Panel on Contaminants in the Food Chain (CONTAM) at the European Food Safety Authority (EFSA) as an urgent self-tasking activity established a Working Group to investigate further the presence of furan in heat-treated foodstuffs. In December 2004 the "Report of the Scientific Panel on Contaminants in the Food Chain on provisional findings on furan in food" was adopted by the CONTAM Panel (EFSA, 2004). Subsequently, a joint workshop on furan in food was organised in May 2006 by DG Health and Consumers, EFSA and the European Commission Joint Research Centre in order to gather information on the status of analytical methods for furan and on data needs for risk assessment. In order to collect more occurrence data for a furan risk assessment, EFSA issued a call for scientific data in December 2006 (EFSA, 2006). In parallel, the Commission, via Recommendation 2007/196/EC[2] on the monitoring of the presence of furan in foodstuffs, recommended Member States to collect data on commercial foodstuffs that underwent heat treatment, with particular focus on year 2007 and 2008.

TERMS OF REFERENCES

In order to give the Commission an overview of the data collected by the Member States with a particular focus on 2007 and 2008, EFSA was asked by the European Commission on 13 May 2009 to compile these data in an occurrence report. Reporting on furan results by the Member States will continue on a regular basis and EFSA is asked to issue an updated report on a yearly basis.

ACKNOWLEDGEMENTS

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EFSA further wishes to acknowledge the contribution of Drs Wegener, Fürst and Wenzl in relation to the analytical methods used and Drs Kuballa and Heppner for reviewing the overall document.

[2] OJ L 88, 29.3.2007, p. 56

REPORT

1. Introduction

Furan is a colourless chemical (C_4H_4O) with low molecular weight and high volatility and lipophilicity. Furan and its derivatives have long been known to occur in heat-treated foods and to contribute to the sensory properties of food (Merrit *et al*., 1963; Maga, 1979). Animal studies have shown that furan is carcinogenic to rats and mice, showing a dose-dependant increase in hepatocellular adenomas and carcinomas in both genders (NTP, 1993). Furan has been classified as possibly carcinogenic for humans (IARC, 1995)

In 2004, the US Food and Drug Administration (US FDA) published a report on the occurrence of furan in thermally treated food commodities (US FDA, 2004). It revealed the occurrence of furan in a number of foods that undergo heat treatment such as canned and jarred foods with levels ranging from non detectable to 174 µg/kg.

Shortly after the publication of the US FDA results, the mechanism of furan formation, which is believed to follow several different routes, was the object of increasing interest. Still, there is only limited information on the mechanism of furan formation under conditions simulating industrial food processing or domestic cooking. Most published data are based on model studies aiming at identifying potential precursors and elucidating the various formation mechanisms. The formation of furan under pyrolytic conditions has been studied in simple model systems revealing a list of major precursors, such as amino acids and reducing sugars forming Maillard reaction products, lipid oxidation of unsaturated fatty acids or triglycerides, carotenoids and ascorbic acid (Perez and Yayalayan 2004; Yayalayan 2005; Limacher *et al*., 2007). In their study on the formation of furan under roasting condition, Maerk *et al*. (2006) found ascorbic acid and polyunsaturated lipids (such as linoleic and linolenic acid) as the most effective precursors. Furthermore, Limacher *et al*. (2007) proposed that the efficiency of the ascorbic acid derivatives to form furan depended very much on the reaction system involved. Interestingly, the highest furan levels were obtained in pure ascorbic acid systems. The furan amounts dropped drastically in the presence of additional compounds, such as sugars, amino acids and lipids. Moreover, Maerk *et al*. (2006) found that combinations of potential furan precursors lead to reduced furan formation.

For the initial CONTAM Panel report issued in December 2004 on provisional findings on furan in food, only limited furan occurrence results were available for a narrow set of foods. Thus, ranges of furan exposure rather than average exposures were presented. The report issued by the CONTAM Panel highlighted the limitation of exposure assessment calculations due to the limited availability of furan occurrence data at that time. In addition, the Panel envisaged the need for future analyses and collection of occurrence data on furan in a wider spectrum of food commodities including beverages (EFSA, 2004; Heppner and Schlatter, 2007).

A call for scientific data on furan in food and beverages was issued in December 2006 (EFSA, 2006) in conjunction with a Commission Recommendation published in March 2007 on the monitoring of the presence of furan in foodstuffs. Member States were requested to collect furan data during 2007 and 2008 for commercial food products after initial heat treatment during manufacturing and after further heating during domestic food preparation. After that, data collection was to continue on a regular basis (Commission Recommendation 2007/196/EC).

1.1. Objective

The purpose of this report is to present the data collected in response to the Commission Recommendation in a form that can be used for a more comprehensive furan exposure assessment in food and possible risk management measures. An initial exposure assessment is also provided.

2. Materials and Methods

2.1. Sampling procedure

Recommendation 2007/196/EC recommended that the Member States monitor the presence of furan in foodstuffs that have undergone heat treatment. The monitoring should include two different kinds of commercial foodstuffs. First, Member States were asked to sample commercial food, which were analysed without any preparation of the purchased foodstuff, *e.g.* coffee powder, juices, jars and cans not heated before consumption. Second, commercial foodstuffs, which were analysed after further preparation as if consumed in the laboratory, e.g. brewed coffee, canned and jarred products heated before consumption. Foods prepared at home on the basis of fresh ingredients were not subject of the monitoring program. It was recommended to follow the sampling procedures as laid down in Part B of the Annex to regulation (EC) No. 333/2007 in order to ensure that samples were representative for the sampled lot. Sample preparation before analysis should be carried out with the necessary care to ensure that the furan content of the sample is not altered.

2.2. Analytical method

The monitoring recommendation laid down that the analysis of samples should be carried out in accordance with points 1 and 2 of the Annex III to Regulation (EC) No. 882/2004.

A guidance document setting criteria for the required accuracy and sensitivity of the analytical methods used for furan analysis was agreed with Member States before commencing the monitoring exercise.

Analytical methods used included static headspace extraction/gas chromatography/mass spectrometry (HS-GC/MS) and head space/solid phase micro extraction/gas chromatography/mass spectrometry (HS-SPME/GC-MS). There are no indications in the Commission Recommendation on a specific analytical procedure to be used.

The collaborating Member States provided the information for the limit of detection (LOD), limit of quantification (LOQ) and the measurement uncertainty for each commodity tested.

2.3. Data handling

A total of 2,918 furan results were reported to EFSA of which 2,908 contained sufficient details to be retained for statistical analysis. The collected data were classified into 20 different food categories in accordance with previously reported results (EFSA, 2004; Crews and Castle, 2007; Zoller *et al.*, 2007; Kuballa, 2007; Morehouse *et al.*, 2008).

The Commission Recommendation required that Member States sample food items, with a particular focus on year 2007 and 2008. However, EFSA received data covering the period 2004 to 2009. It was decided to retain data from the full set since it covered the period after the EFSA opinion published in 2004.

Two scenarios were assumed for handling non-quantified results. First, according to a lower-bound scenario, values below the LOD and values between the LOD and the LOQ) were set to zero. Second, according to an upper-bound scenario values below LOD and values between LOD and LOQ were set to the LOD or the LOQ value, respectively. Both lower bound and upper bound scenarios were used to report descriptive statistics for the characteristics of the data distribution.

Furan occurrence values in the EFSA database were split into data collected in 2004 to 2006 and 2007 to 2009 and compared to data previously collected by EFSA and US FDA before 2004 as published by Crews and Castle (2007).

To determine the proportion of furan content variability attributable to variation between countries compared to overall furan variability in food (sum of between- and within-country variability), the interclass correlation coefficient (ICC) was calculated for each food category. Variance components were estimated in a mixed model (Dunn, 1989).

To calculate exposure, for adults, food consumption information was derived from the EFSA Concise European Food Consumption Database (EFSA, 2008b), which has a lower degree of detail compared to the food categories present in the furan database. For sake of consistency, some of the food categories in the furan occurrence database were merged in order to match the food categories in the consumption database. Thus, “baked beans” were merged with “vegetables” to form the vegetables category, “other products” were merged with “soy sauce” and “sauces” to form the miscellaneous category and the coffee products were merged and used as a proxy for the coffee, tea, cocoa (expressed as liquid) category. A standard dilution factor of 18 was used to convert dry to liquid coffee as consumed. The lower and upper bound means of the furan contents for each food category were combined with consumption information at individual level and individual body weight to express furan exposure in µg/kg b.w. per day.

To calculate exposure for infants, food consumption information was derived from Kersting *et al*. (1998). The mean furan exposure was calculated for infants by combining the exposure result for “baby food” and “infant formula” at 3, 6, 9 and 12 months, respectively, assuming that no exposure resulted from maternal milk. As the ratio of food intake to body weight is highest at age 6 and 9 months, two high exposure scenarios were calculated for each using the 95^{th} percentile consumption of jarred baby food and a mean consumption of infant formulae or mean consumption of jarred baby food and 95^{th} percentile consumption of infant formula, respectively.

3. Results

3.1. Data reported by Member States

Table 1 summarises the country of origin for 2,908 samples reported to EFSA for the years 2004 to 2009 sorted into 20 food categories.

Table 1: Number of samples collected by Member States (indicated by ISO country code) between 2004 and 2009 for the analysis of furan content in food.

Food group	AT	BE	CY	FI	DE	GB	GR	IE	IT	LT	NL	PL	SK	SI	Total
Coffee instant[1]	0	20	0	0	20	0	0	5	2	1	0	0	0	0	48
Coffee roast bean[1]	0	0	0	0	0	3	0	0	0	0	0	0	4	2	9
Coffee roast ground[1]	16	0	5	0	0	7	12	4	1	0	0	0	16	5	66
Coffee non specified[1]	0	18	6	1	245	0	0	1	4	0	0	0	0	0	275
Baby food	12	36	10	20	619	10	13	133	17	0	10	100	0	5	985
Infant formula	11	0	0	0	19	0	0	1	3	0	1	0	0	0	35
Baked beans	2	0	0	1	0	6	2	30	0	0	0	0	1	0	42
Beer	3	0	0	0	67	0	5	0	0	0	7	0	4	0	86
Cereal product	40	0	0	1	38	0	0	18	1	1	0	0	0	0	99
Fish	2	0	0	0	0	0	4	1	0	0	2	0	0	0	9
Fruit juice	0	0	0	34	131	0	5	8	8	1	13	0	3	0	203
Fruits	2	18	0	3	30	0	1	5	9	1	10	0	5	0	84
Meat product	26	0	0	0	15	4	1	9	0	0	0	0	0	10	65
Milk product	0	0	0	0	9	0	0	0	0	0	11	0	0	0	20
Sauces	4	42	4	3	105	5	5	24	2	1	2	0	3	7	207
Soups	4	1	5	0	136	0	0	20	0	0	16	0	12	4	198
Soy sauce	0	46	0	0	2	3	0	0	0	0	0	0	0	0	51
Vegetable juice	0	17	0	0	25	0	0	0	0	0	0	0	3	0	45
Vegetables	0	31	0	2	13	7	0	5	9	1	9	0	16	2	95
Other products	2	0	0	0	272	0	0	0	2	0	7	0	3	0	286
Total	124	229	30	65	1746	45	48	264	58	6	88	100	70	35	2908

[1] Most coffee results were reported as solid coffee or unspecified but 10% were reported as the ready-to-consume beverage.

It can be observed from Table 1 that 60% of all data were from Germany, followed by Ireland, Belgium and Austria (9, 8 and 4%, respectively). The other 10 remaining countries together accounted for 19% of all data.

The number of samples per food category varied between 9 for "fish" to 985 for "baby food". Table 1 shows that the number of samples was not evenly distributed across the different Member States. For the following food categories at least 8 Member States out of the 14 had submitted samples: "coffee roasted ground", "baby food", "vegetables", "fruits", "fruit juice", "soups" and "sauces".

Even if the Commission Recommendation required that Member States focus sampling particularly in 2007 and 2008, EFSA received samples also from previous years, as detailed in Table 2. Samples in 2007 and 2008 represent only half of the whole information in the EFSA dataset and because of the sparse results it was decided to keep the full data set covering the years 2004 to 2009.

Table 2: Number of samples per year.

Sampling year	Number of samples	Sampling year	Number of samples	Total
2004	328	2007	758	
2005	514	2008	672	
2006	605	2009	31	
Total number	**1447**		**1461**	**2,908**

Only 16 % of the results in the EFSA database were obtained after preparation of the sample as consumed before the analysis. In addition, detailed information on the method used to prepare the food for consumption was not consistently reported. The vast majority of results (84%) were obtained excluding any further sample preparation before analysis.

3.2. Reported LOD and LOQ

Eleven countries reported the use of static headspace extraction/gas chromatography/mass spectrometry (HS-GC/MS) method for the analysis of furan. One country did not report at all on the method used and two countries reported using a head space/solid phase micro extraction/gas chromatography/mass spectrometry (HS-SPME/GC-MS) method. Two countries did not report the method used for the furan analysis for every food category.

In Table 3 the number of samples below the limit of detection (LOD) and limit of quantification (LOQ) are reported, as well as the minimum and maximum values for the LOD and the LOQ for each food category.

Table 3: Number of samples in relation to measurement limits (shaded) and range of the reported LOD and LOQ in µg/kg per food category.

Product Category	>LOQ	≤LOD	Min µg/kg	Max µg/kg	≤LOQ	Min µg/kg	Max µg/kg
Coffee instant	41	0	0.10	7.0	7	0.30	28
Coffee roast beans	8	0	0.07	5.0	1	0.20	10
Coffee roast ground	50	0	0.07	40	16	0.20	100
Coffee non specified	270	1	0.10	7.0	4	0.10	28
Baby food	778	59	0.03	5.0	148	0.04	10
Infant formula	27	3	0.20	5.0	5	0.30	10
Baked beans	32	2	0.07	5.0	8	0.20	10
Beer	36	17	0.50	2.7	33	1.0	9.1
Cereal products	37	44	0.10	16	18	0.30	40
Fish	6	2	0.50	5.0	1	1.0	10
Fruit juice	69	32	0.05	5.0	102	0.10	10
Fruits	22	7	0.10	5.0	55	0.60	10
Meat product	36	15	0.07	8.0	14	0.20	20
Milk products	14	0	0.50	0.50	6	1.0	10
Sauces	100	19	0.07	5.0	88	0.20	10
Soups	158	15	0.10	5.0	25	0.30	10
Soy sauce	42	0	0.07	1.0	9	0.20	10
Vegetable juice	7	10	1.0	5.0	28	5.0	10
Vegetables	28	7	0.07	5.0	60	0.20	10
Other products	213	27	0.10	8.0	46	0.30	20

It can be observed in Table 3 that the minimum and maximum values reported for LOD and LOQ ranged from 0.1 to 40 and from 0.2 to 100 µg/kg, respectively. The highest LOD and LOQ were reported for “coffee” and “cereal products”.

One country out of the 14 participating Member States did not report the LOD for the method, but only the LOQ. A total of 558 samples exceeded a suggested maximum LOD of 2 µg/kg while 794 samples exceeded a suggested maximum LOQ of 5 µg/kg (listed in the agreed criteria guidelines) making a total of 819 samples that exceeded either or both limits. Of these samples, 333 or 41% had a quantified value reported and at least 406 or close to 50% were sampled before the issuing of the EFSA call and agreement of the criteria guidelines.

To better illustrate the percentages of numerical values above the LOQ and censored values below the LOD or between the LOD and the LOQ, the respective frequencies shown in Table 3 have been plotted in Figure 1.

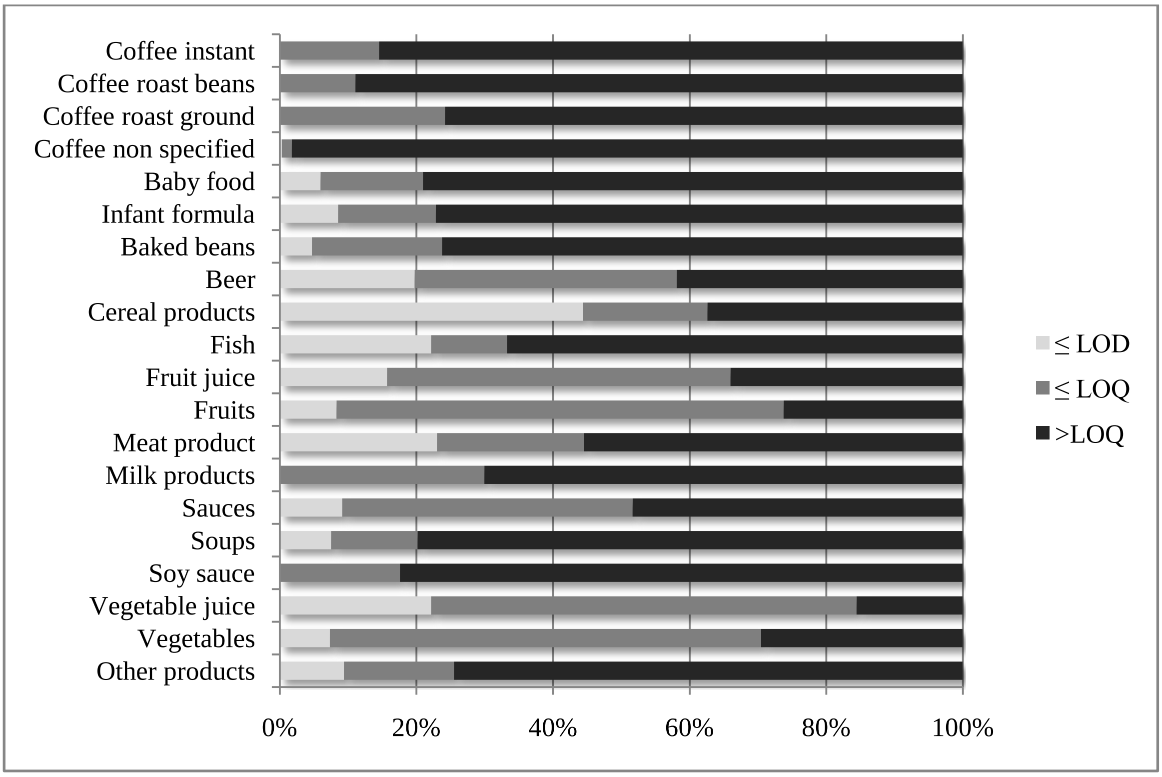

Figure 1: Percentage of values below LOD, between LOD and LOQ, and above the LOQ per food category for the pooled data from all Member States.

The product categories “soy sauce”, “coffee non specified”, “coffee instant” and “coffee roast beans” had more than 80% of quantified values, while the groups “baby food”, “baked beans”, “coffee roast ground”, “fish”, “infant formula”, “milk products”, “other products” and “soups” showed quantified values ranging from 60% to 80%. The food categories “cereal product”, “fruit juice”, “fruits”, “vegetable juice” and “vegetables” showed percentages of quantified values lower than 40%.

3.3 Reported measurement uncertainty

The calculation of measurement uncertainty is described in realtion to EU legislation (EC, 2004). The measurement uncertainty for the HS/GC-MS method is shown per food category in Table 4.

Table 4: Minimum and maximum value for the measurement uncertainty (MU) in percentage per food category for the GC-MS method as reported by the Member States.

Food group	Min MU%	Max MU%	Food group	Min MU%	Max MU%
Coffee non specified	11,6	20	Fruit juice	18	44
Coffee instant	18,3	30	Fruits	6	44
Coffee roast bean	22	*	Meat products	6	22
Coffee roast ground	6	30	Milk products	**	**
Baby food	11,6	44	Sauces	6	44
Infant formula	6	30	Soups	6	18,3
Baked beans	6	22	Soy sauce	22	*
Beer	20	*	Vegetable juice	10	10
Cereal product	6	44	Vegetables	18,3	30
Fish	6	20	Other products	20	44

* No range of MU was reported
** No information on MU was reported

The reported measurement uncertainty varied between 6 and 44%. Concerning the HS-SPME/GC-MS method the reported measurement uncertainty of furan measurements ranged from 10% to 20% in all food categories.

3.4. Statistical descriptors of the reported furan content

In Table 5 the minimum value, the 5th percentile (P05), the median, the arithmetic mean, the standard deviation (SD), the 95th percentile (P95), and the maximum value are presented for each of the food categories for the collected furan data.

With the exception of the maximum value, a range is provided when there was a difference between the estimated lower and upper bound furan concentration values as calculated from the data reported by the Member States.

Table 5: Furan content in food per food category with a range illustrating any difference between the lower and upper bounds as calculated from the data reported by the Member States.

Product category	Furan content µg/kg						
	Minimum	**P05**	**Median**	**Mean**	**SD**	**P95**	**Maximum**
Coffee, non specified[1]	0-2	11	1700	1691	1452	4597	6500
Coffee, instant[1]	0-8	0-10	256	588-589	711	2118	2200
Coffee, roast bean[1]	0-5	0-5	3395	2271-2272	1997	4895	4895
Coffee, roast ground[1]	0-5	0-5	422	1112-1114	1327	3306	5749
Baby food	0-0.03	0-2	18	24-25	27	74	215
Infant formula	0-2	0-3	15	18-19	16	47	56
Baked beans	0-4	0-5	23	25-27	20	57	80
Beer	0-1	0-2	0-3	4-6	6	13	28
Cereal product	0-0.2	0-0.2	0-9	10-14	22	49	168
Fish	0-4	0-4	8	8-10	7	24	24
Fruit juice	0-0.5	0-1	0-2	4-6	32	8-10	420
Fruits	0-0.6	0-2	0-5	2-7	5	11	27
Meat products	0-2	0-4	6-10	19-22	28	85	115
Milk products	0-1	0-3	9-10	13-15	18	55	80
Sauces	0-0.1	0-2	0-10	8-12	15	32	120
Soups	0-0.7	0-1	17	23-24	28	73	225
Soy sauce	0-10	0-10	19	23-25	18	55	78
Vegetable juice	0-1	0-1	0-9	2-7	5	14	20
Vegetables	0-1	0-2	0-10	7-12	16	46	74
Others	0-1	0-2	16	22-23	24	71	164

[1] Coffee samples are a mixture of 304 samples analysed as purchased, 37 samples as consumed and 57 samples without information on the preparation state. Because of the low sample numbers when split into the four different coffee categories the state of the product is not shown separately.

The four coffee categories show the highest furan content in comparison to the other food groups, with upper bound mean values equal to 589 µg/kg for instant coffee, 1,114 µg/kg for roast ground coffee, 1,691 µg/kg for non specified coffee, and 2,272 for roast bean coffee. The maximum values ranged from 20 µg/kg for vegetable juice to 6,500 µg/kg for non specified coffee. In most cases the coffee samples would be diluted before consumption except in the few cases analysed as consumed (for further detail see discussion).

In Figure 2 the information in Table 5 is expanded in a box and whisker plot showing the 5th, 25th, 50th, 75th, and 95th percentiles of furan content across the different food categories. The plot is clearly illustrating the much higher values for coffee compared to any other food category with the highest level in the coffee group for roast bean coffee and the lowest for instant coffee.

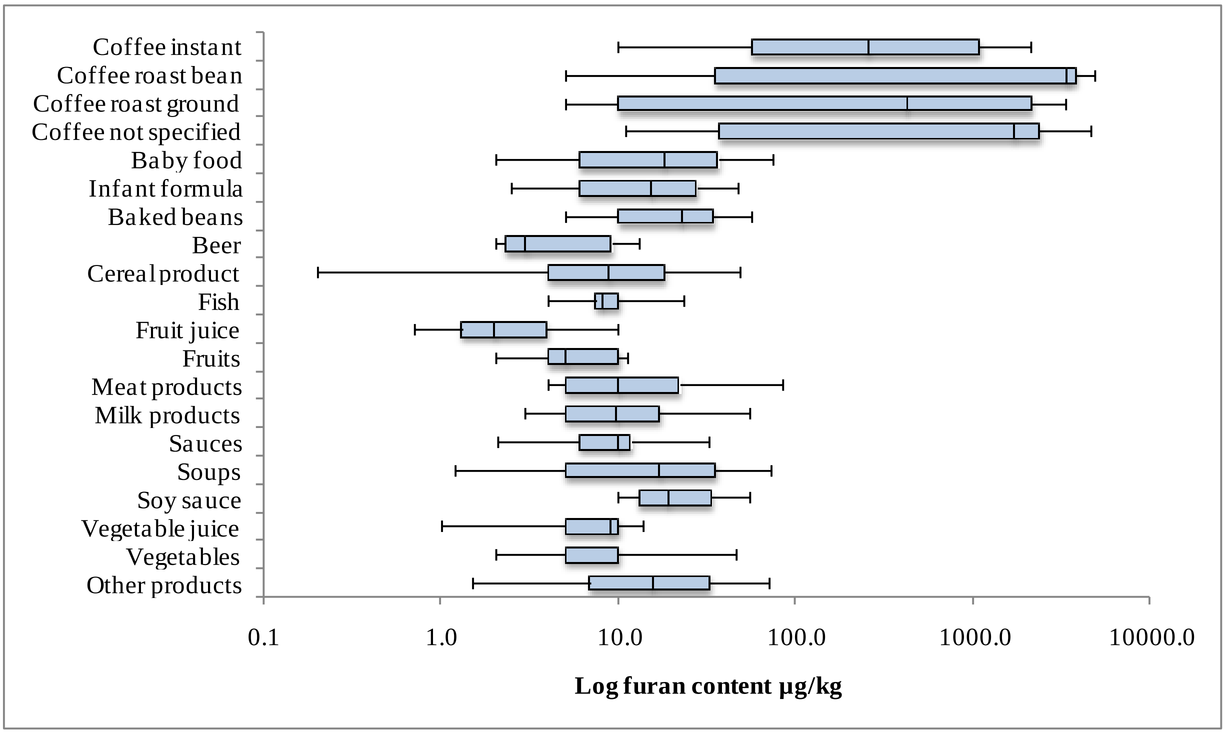

Figure 2: Box and whisker plot for food category-specific upper-bound 5th, 25th, 50th, 75th, and 95th percentiles of furan content (note the logarithmic scale).

In Table 6, levels of furan collected before 2004 and reported by EFSA and US FDA are compared to levels of furan for the data collected in 2004 to 2006 and in 2007 to 2009.

Table 6: Sample size (N), and furan mean content as influenced by year of sampling across the different food categories.

Food Category	Member States				EFSA and FDA*	
	2007-2009		2004-2006		<2004	
	N	Mean µg/kg	N	Mean µg/kg	N	Mean µg/kg
Coffee instant	33	437	15	925	**	**
Coffee roast bean	9	2272	**	**	**	**
Coffee roast ground	66	1114	**	**	**	**
Coffee non specified	152	2384	123	836	19	1500
Baby food	447	24.2	538	26.4	273	28.0
Infant formula	28	21.2	7	9.49	42	12.0
Baked beans	18	24.1	24	28.3	26	59.0
Beer	19	8.34	67	4.90	14	6.00
Cereal products	54	15.0	45	13.7	13	30.0
Fish	8	9.46	1	10.0	9	6.00
Fruit juice	137	2.91	66	13.6	51	5.00
Fruits	52	6.53	32	7.35	28	4.00
Meat products	44	26.0	21	13.6	15	18.0
Milk products	11	13.3	9	16.6	*	*
Sauces	94	7.81	113	16.0	41	11.0
Soups	54	24.6	144	24.1	58	32.0
Soy sauce	49	25.0	2	29.6	12	50.0
Vegetable juice	22	5.81	23	9.07	8	10.0
Vegetables	81	11.1	14	20.0	50	9.00
Other products	83	22.7	203	23.1	**	**

* Data taken from Crews and Castle (2007) initially given as a range only because of the low number of results

** No comparison possible for those food categories

There is no clear trend in the furan content in food as influenced by year of sampling. Initial testing focussed on baby food and coffee and for baby food there is a decrease in the furan content over time. This can also be seen in instant coffee, although sample numbers are small. Other food categories should be interpreted with care since only few samples have been tested or the food category is not well defined and different products could have been tested in different years. This could explain the marked increase in the furan content for coffee not specified.

Interclass correlation coefficients (ICC) are presented for the individual food categories reported by the Member States in Table 7. A low coefficient indicates little between-country variability while a high coefficient indicates large such variability. However, results should be interpreted with care since different product selection between countries could bias results.

Table 7: Number of Member States for each food-category, specific sample size (N) and interclass correlation coefficient (ICC).

Food Category	Member States	N	ICC	Food Category	Member States	N	ICC
Baby food	12	985	0.081	Fruit juice	8	203	0.316
Infant formula	5	35	0.565	Fruits	10	84	0.236
Baked beans	6	42	0.745	Meat products	6	65	<0.001
Beer	5	86	0.185	Milk products	2	20	<0.001
Cereal product	6	99	0.334	Other products	5	286	0.014
Coffee non specified	6	275	0.599	Sauces	13	207	<0.001
Coffee instant	5	48	0.661	Soups	8	198	0.266
Coffee roast bean	3	9	0.133	Soy sauce	3	51	<0.001
Coffee roast ground	8	66	0.280	Vegetable juice	3	45	0.247
Fish	4	9	0.422	Vegetables	10	95	0.283

In Table 7 it can be observed that the proportion of variance attributable to between-country variability compared to the total variability ranges from <0.1% for “meat products”, “milk products”, “sauce” and “soy sauce” to 74% for “baked beans”.

3.5. Dietary exposure estimations

In Table 8 the mean values of the furan occurrence results are shown per food category re-classified according to the EFSA Concise European Food Consumption Database to match available food consumption information (EFSA, 2008b).

Table 8: Upper bound mean furan content according to the food categories in the EFSA Concise European Food Consumption Database.

EFSA Food Category	N	Mean (µg/kg)
Cereals & cereal products	99	14
Vegetable soups	198	24
Vegetables, nuts, pulses other	344	14
Fruits	84	7
Fruit and vegetable juices	248	7
Coffee, tea, cocoa (as liquid)	398	80
Beer and substitutes	86	6
Meat and meat products, offal	65	22
Fish and seafood	9	10
Milk and dairy based drinks	20	15
Dairy based products	20	15
Miscellaneous	337	23

In Tables 9 and 10 the specific mean and 95th percentile food consumption (g/day) by aggregated food category are shown by Member State. In table 11 the resulting mean and 95th percentile exposure estimates to furan are shown by Member State. This is a theoretical estimate assuming that the tested products comprise the whole respective food category.

Table 9: Mean food consumption (g/day) in adult population as recorded in EFSA's Concise food consumption database

EFSA Food Category	BE	BG	CZ	DE	DK	FI	FR	GB	HU	IE	IS	IT	NL	NO	PL	SE	SK
Cereals & cereal products	245	257	274	287	217	153	317	249	252	227	276	271	220	192	312	291	345
Vegetable soups	82	1	(a)	(a)	(a)	(a)	65	24	(a)	6	10	(a)	11	(a)	(a)	(a)	140
Vegetables, nuts, pulses other	146	209	131	252	(a)	(a)	146	138	191	238	115	249	182	(a)	295	(a)	52
Fruits	113	70	122	190	150	121	132	95	180	106	71	203	107	119	282	119	116
Fruit and vegetable juices	71	42	34	141	73	(a)	57	48	47	34	87	18	70	86	35	87	33
Coffee, tea, cocoa (as liquid)	432	120	559	691	836	580	282	724	176	714	429	124	887	604	692	575	461
Beer and substitutes	136	86	373	184	187	120	34	257	52	299	85	33	161	101	62	141	97
Meat and meat products, offal	123	114	187	167	135	286	202	161	186	148	110	137	152	109	259	150	156
Fish and seafood	25	20	19	19	18	127	37	31	9	24	37	43	13	63	19	34	9
Milk and dairy based drinks	100	132	100	177	313	(a)	119	210	188	263	294	124	251	438	121	(a)	47
Dairy based products	64	6	58	94	44	(a)	106	31	64	29	109	33	104	48	22	(a)	47
'Miscellaneous	1	13	14	7	(a)	(a)	(a)	17	17	13	19	5	5	10	7	(a)	4

(a): no food consumption data available for that specific food category

Table 10: 95th percentile of food consumption (g/day) in adult population as recorded in EFSA's Concise food consumption database

EFSA Food Category	BE	BG	CZ	DE	DK	FI	FR	GB	HU	IE	IS	IT	NL	NO	PL	SE	SK
Cereals & cereal products	503	560	551	490	359	283	546	466	400	395	613	427	393	337	636	503	730
Vegetable soups	381	(a)	(a)	(a)	(a)	(a)	286	117	(a)	39	(a)	(a)	96	(a)	(a)	(a)	400
Vegetables, nuts, pulses other	339	532	309	504	(a)	(a)	297	306	356	539	316	460	384	(a)	711	(a)	250
Fruits	347	355	355	492	431	362	383	302	468	335	285	459	332	333	840	313	450
Fruit and vegetable juices	350	250	250	579	283	(a)	239	216	267	150	500	114	345	304	250	343	250
Coffee, tea, cocoa (as liquid)	1225	400	1150	1661	1943	1210	815	1625	550	1383	1350	329	1745	1360	1250	1150	1300
Beer and substitutes	750	500	1750	857	770	(a)	179	1207	333	1511	500	165	900	448	500	514	500
Meat and meat products, offal	296	333	421	341	258	286	376	324	343	288	343	264	305	209	680	269	500
Fish and seafood	121	150	113	53	54	127	106	96	67	80	195	122	90	153	150	91	100
Milk and dairy based drinks	386	500	358	652	842	(a)	350	498	520	620	1000	315	705	1080	500	(a)	300
Dairy based products	225	45	211	268	175	(a)	258	120	200	104	410	125	296	165	100	(a)	225
'Miscellaneous	5	31	33	16	(a)	(a)	3	54	35	47	98	13	17	18	17	(a)	19

(a): no food consumption data available for that specific food category

Table 11: Theoretical lower (LB) and upper (UB) bound estimated mean and high percentile (95^{th}) adult exposure to furan (µg/kg b.w. per day) in the different Member States.

Member State	Mean exposure µg/kg b.w. per day		95^{th} percentile exposure µg/kg b.w. per day	
	LB	**UB**	**LB**	**UB**
AT	0.73	0.80	1.77	1.83
BE	0.67	0.72	1.56	1.69
BG	0.29	0.34	0.65	0.73
CZ	0.79	0.85	1.54	1.6
DE	0.95	1.02	2.10	2.19
FR	0.57	0.63	1.23	1.30
GB	0.98	1.04	2.00	2.05
HU	0.38	0.44	0.86	0.92
IE	0.99	1.06	1.85	1.93
IS	0.63	0.68	1.61	1.67
IT	0.32	0.39	0.60	0.69
NL	1.17	1.23	2.22	2.27
PL	1.01	1.08	1.85	1.93
SK	0.70	0.75	1.75	1.81
Minimum	0.29	0.34	0.60	0.69
Median	0.72	0.78	1.68	1.75
Maximum	1.17	1.23	2.22	2.27

Mean exposure in the different countries varied from 0.29 to 1.17 µg/kg b.w. per day with a median of 0.72 µg/kg b.w. per day for the lower bound and from 0.34 to 1.23 µg/kg b.w. per day with a median of 0.78 µg/kg b.w. per day for the upper bound. High exposure at the 95^{th} percentile varied from 0.60 to 2.22 µg/kg b.w. per day with a median of 1.68 µg/kg b.w. per day for the lower bound and from 0.69 to 2.27 µg/kg b.w. per day with a median of 1.75 µg/kg b.w. per day for the upper bound. Furan exposure could not be calculated for four countries (Finland, Denmark, Norway and Slovenia) because food consumption data were missing for more than one food category.

In Table 12 the food-specific contributions in percentage of the overall total mean exposure by country are shown. Major contributors were "Coffee, tea, cocoa (expressed as liquid)", "Meat and meat products, offal" and "Cereals & cereal products".

Table 12: Food category-specific contribution in percentage of the total mean furan exposure by country.

EFSA Food Category	Contribution of respective food category to overall furan exposure (%)												
	BE	**BG**	**CZ**	**DE**	**FR**	**GB**	**HU**	**IE**	**IS**	**IT**	**NL**	**PL**	**SK**
Cereals & cereal products	8.53	8.72	15.64	5.27	6.07	5.72	10.76	11.26	4.31	4.13	7.77	14.97	3.43
Vegetable soups	1.17	4.46	0.10	0.00	0.00	0.00	3.81	0.00	0.77	0.18	0.41	0.02	0.29
Vegetables, nuts, pulses other	4.85	4.82	12.68	4.69	2.96	5.34	5.01	8.57	2.48	4.38	3.20	13.87	2.85
Fruits	2.62	1.89	2.19	1.87	1.42	2.64	2.27	4.09	0.89	0.97	1.01	5.65	0.84
Fruit and vegetable juices	1.86	1.52	1.36	1.36	0.42	0.34	1.00	1.12	0.45	0.31	1.27	0.50	0.56
Coffee, tea, cocoa (as liquid)	68.1	63.4	43.8	75.0	74.7	74.9	56.7	47.4	79.5	77.2	67.2	40.7	81.1
Beer and substitutes	0.85	1.52	2.11	1.26	3.30	0.44	0.47	0.92	1.78	2.22	0.99	0.75	1.02
Meat and meat products, offal	7.21	6.36	10.96	4.74	6.43	7.29	10.72	12.94	4.27	4.15	4.66	11.85	3.68
Fish and seafood	0.31	0.54	0.92	0.25	0.30	0.23	0.90	0.28	0.39	0.31	0.70	1.72	0.15
Milk and dairy based drinks	1.77	4.55	8.58	3.42	2.42	2.45	4.46	9.02	4.11	5.15	8.70	7.46	4.20
Dairy based products	2.28	2.22	0.40	1.90	1.45	0.45	3.92	3.17	0.59	0.58	3.27	2.04	1.74
Miscellaneous	0.48	0.05	1.25	0.21	0.52	0.21	0.02	1.24	0.48	0.39	0.85	0.49	0.12
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100

In Tables 13 and 14 mean and 95th percentile exposure estimations of furan for infants are shown, respectively.

Table 13: Estimated upper bound mean exposure of infants to furan from 3 to 12 months.

Age (months)	Weight* (kg)	Food consumption g/kg b.w. per day**			Exposure µg/kg b.w. per day		
		Total	Dry infant formula	Jarred food	Infant formula	Jarred food	Total
3	6.4	133	7.4***	5.3	0.14	0.13	0.27
6	8.1	117	4.6	33.9	0.09	0.85	0.93
9	9.3	117	2.8	38.6	0.05	0.97	1.01
12	10.3	110	1.7	26.4	0.03	0.66	0.69

* Boys
** Intake data are taken from Kersting et al. (1998)
*** Conversion factor from wet to dry infant formula of 0.119 was used

Mean infant exposure to furan is highest at age 6 months (0.93 µg/kg b.w.) and 9 months (1.01 µg/kg b.w.).

Table 14 summarises four different exposure scenarios for 95th percentile upper bound exposure to furan for infants at age 6 and 9 months. Scenarios 1 and 3 combine the sum of the 95th percentile consumption of infant formula and the mean consumption of jarred baby food with the upper bound mean furan content for infants at 6 and 9 months of age, respectively. Scenarios 2 and 4 combine the sum of the 95th percentile consumption of baby food and the mean consumption of infant formula with the upper bound mean furan content at 6 and 9 months of age, respectively.

Table 14: Estimated upper bound 95th percentile exposure scenarios for infants to furan at age 6 and 9 months.

Scenario	Age (months)	Weight* (kg)	Food consumption g/kg b.w. per day**				Exposure µg/kg b.w. per day		
			Mean		95th percentile				
			Dry infant formula	Jarred food	Dry infant formula	Jarred food	Infant formula	Jarred food	Total
1	6	8.1	-	33.9	15.4	-	0.29	0.85	1.14
2	6	8.1	4.6***	-	-	50.3	0.09	1.26	1.34
3	9	9.3	-	38.6	9.7	-	0.18	0.96	1.15
4	9	9.3	2.8	-	-	49.9	0.01	1.25	1.26

* Boys
** Intake data are taken from Kersting et al. (1998)
*** Conversion factor from wet to dry infant formula of 0.119 was used

The 95th percentile exposure to furan of infants is highest at age 6 months with 1.34 µg/kg b.w. per day when consuming jarred foods at the high percentile level.

4. Discussion

In response to a request from the Commission for more information on the presence of furan in food, EU Member States analysed food products as purchased or after further preparation for consumption to allow for a more comprehensive exposure assessment than has been previously possible. In reviewing the results it is important to note that 84% of the newly collected furan results were derived from samples analysed as purchased and that the effect of cooking practices at home is not reflected in these results for the most part.

Roberts *et al*. (2008) examined the effect of some domestic cooking procedures on the furan content in food. In general, furan levels did not decrease as much when foods were heated in a microwave oven, as compared to the same food heated in a sauce pan. Furan levels decreased in most canned or jarred foods after heating in a saucepan. Furan decreased slightly in foods on standing before consumption, and did so more rapidly on stirring. The levels also decreased slightly when foods were left to stand on plates.

It is also important to note that in the tentative exposure assessment presented in this report it was assumed that the products tested comprised the only products consumed in the respective food category.

It is expected that both those factors will lead to a very conservative overestimation of furan exposure that will be discussed below.

4.1. Coffee

Among all the products tested, the highest furan content was reported in roasted coffee beans with an average of 3,400 µg/kg when including only samples indicating that they had been analysed as purchased (the average in Table 5 is for all types of sample). This is at the lower end of the average values reported by Kuballa *et al*. (2005) for furan in roasted coffee beans although includes very few samples. Furan and furan derivatives have long been known as intrinsic components of coffee flavours. Green coffee beans contain only traces of furan. The high levels of furan found in roasted coffee beans are probably due to the roasting process at high temperatures. The furan content was lower in ground coffee with an average of 1,114 µg/kg. This is consistent with the results reported previously by Kuballa *et al.* (2005) and Hasnip *et al*. (2005). Unpublished data from the European Coffee Federation showed that grinding of the roasted coffee beans reduces furan levels from 10 to 60% depending on grind size and that degassing reduces furan levels up to 10% in 2 hours (personal communication). The lowest furan content was found in instant coffee with an average of 589 µg/kg, which is consistent with reported data from Kuballa *et al*. (2007), Hasnip *et al*. (2006) and Zoller *et al*. (2007).

In order to accurately estimate the daily exposure to furan from coffee it is important to know the levels in the final ready-to-drink beverage. Several publications reported substantial reductions of the furan content after brewing by expression, filtration, and also in the preparation of instant coffee (Kuballa *et al*., 2005, 2007; Hasnip *et al.*, 2006; Zoller *et al.*, 2007). Automatic coffee machines produce brews with higher levels of furan, because a higher ratio of coffee powder to water is used giving a lower dilution factor, and because of the closed system favouring retention of furan. Much lower levels were produced by standard home coffee-making machines and by manual brewing. Furan will also dissipate from the serving cup, with higher losses at the beginning diminishing over time as the coffee cools down (Goldmann *et al*., 2005; Zoller *et al*., 2007). A preliminary comparison of sample results submitted by the Member States showed levels about two orders of magnitude lower in the beverage samples prepared for consumption compared to samples analysed as purchased. However, little detail was provided about sample preparation conditions and the number of samples prepared for consumption was low.

4.2. Infant food

Jarred baby food and infant formulae are of particular interest as they may form the sole diet of many infants and furan has been reported in those products. In the present survey, the average furan content in infant formulae was 8 µg/kg, which was lower than average results previously reported of 12 µg/kg (Crews and Castle, 2007). However, the furan content of commercial jarred baby food with an average content of 25 µg/kg and a maximum value of 210 µg/kg was similar to previously reported data (Crews and Castle, 2007).

Zoller *et al*. (2007) reported different mean values for jarred and canned baby food depending on the composition of the food. Baby food samples containing mainly fruits and those containing mainly meat showed both a mean furan content of 4 µg/kg, whereas baby food samples containing mainly vegetables (with potatoes included) showed an average furan content of 40 µg/kg.

4.3. Other food

Maximum values in excess of 100 µg/kg were found in cereal products, meat products, soups, sauces and others products. While the mean furan content for baked beans and soy sauce were lower than previously reported, meat products and sauces were higher (Crews and Castle, 2007; Zoller *et al*., 2007). The mean furan content for meat products was nearly twice as high as previously reported by Crews and Castle (2007), but since the number of samples was low, more information would be necessary to draw any firm conclusions.

The highest amounts in cereal products were reported for toasted bread and salted crackers. Similar results were found by Zoller *et al.* (2007). According to their results furan is concentrated in the crust of the bread. The crust always contained more furan than the entire bread, with a 3- to 20-fold difference depending on the surface-to-volume ratio.

4.4. Adult exposure

The median furan exposure for adults in Europe was estimated to be up to 0.78 µg/kg b.w. per day with the mid-range for the 95th percentile at 1.75 µg/kg b.w. per day. Morehouse *et al*. (2008) estimated the daily mean exposure to furan for the average US consumer at about 0.2 µg/kg b.w. per day based on 300 food samples from a limited range of products. Dinovi *et al*. (2007) estimated the 90th percentile exposure at about 0.6 µg/kg b.w. per day.

Brewed coffee was identified by Morehouse *et al*. (2008) and in the present survey as the major contributor to adult consumer exposure. Since no individual information for coffee consumption across the EU Member States was available, the combined consumption of coffee, tea and cocoa was used as a proxy. Although this might be true for a part of the population, for the general population EFSA has previously estimated coffee consumption to broadly comprise 60% of this food category. Applying this proportion and since coffee contributes to between 40 and 80% of the total furan exposure, the estimated median exposure to furan would be reduced to between 0.53 and 0.66 µg/kg b.w. per day and the mid-range 95th percentile to between 1.19 and 1.47 µg/kg b.w. per day. Equally a further decrease of the estimated furan exposure is expected should more detailed information be available for individual foods in other food categories and measurements of the impact of further processing and storage of the food prior to consumption. Results from the EU funded project on furan in the 6th framework program (Universität Würzburg, 2006) as well as two projects funded by EFSA covering research on furan produced under different cooking conditions and furan inhalation during cooking (EFSA, 2008a) are expected to assist in refining the risk assessment process.

4.5. Infant exposure

The average furan exposure for infants 3-12 months of age in Europe was estimated to be between 0.27 and 1.01 µg/kg b.w. per day with the highest at 6 and 9 months of age. Simulated high exposure for 6-9 months old infants was estimated at between 1.14 and 1.34 µg/kg b.w. per day. In 2004, EFSA estimated that the furan exposure of 6 months old infants ranged from less then 0.03 to 3.5 µg/kg b.w. per day using minimum and maximum reported values found in jarred baby food. Dinovi *et al.* (2007) reported furan exposure of infants in the USA from age 0 to 1 year of age to be 0.41 µg/kg b.w. per day and 0.99 µg/kg b.w. per day for the mean and the 90th percentile, respectively.

5. Conclusions and Recommendations

It can be concluded that furan is present in a variety of heat-treated foods and that coffee is the major contributor to furan exposure for adults and jarred baby food for infants. However, further research is needed on the effects of domestic cooking on the furan content in the different food categories prior to consumption and the impact of food handling past preparation.

Results from the EU funded project on furan in the 6th framework program as well as two projects funded by EFSA covering research on furan produced under different cooking conditions and furan inhalation during cooking are expected to assist in refining the exposure assessment process.

Future testing of furan by Member States should preferably target food products belonging to food categories where limited results are available to, if possible, improve the accuracy of the overall prediction of furan exposure.

Reduction of furan formation in food seems to be more challenging compared to other process contaminants, such as acrylamide, particularly since furan formation is intrinsic to the development of desired organoleptic properties of the food. However, before considering remediation recommendations, there is a need not only for more detailed exposure assessment data, but also for better toxicological information on which to base a comprehensive risk assessment.

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