SAFE POSITION PAPER

EFSA MANDATE ON FURAN AND METHYLFURAN IN FOOD

ABOUT SAFE – SAFE FOOD ADVOCACY EUROPE

SAFE's mission is to improve the representation of ordinary citizens in the EU debate concerning the future of EU food regulation.

SAFE – Safe food advocacy Europe is a non-profit independent organisation based in Brussels whose main objective is to ensure consumers' health and concerns remain at the core of the European Union's food legislation.

SAFE members are consumer, food health, vegan and vegetarian associations and individual members such as independent research scientist, doctors and nutritionist spread across Europe. To date our membership collectively represents the voice of over 1.000.000 European consumers.

The core mission of SAFE is to influence the future of European food legislation in favor of European consumers' interest through policy advocacy and outreach.

More information available on www.safefoodadvocacy.eu

CONTEXT

→ Definition

Furan is a food contaminant highly volatile and lipophilic, naturally present in food. Furan formation is the result of the thermal degradation of natural food constituents, more specifically carbohydrates and unsaturated fatty acids. Heating food in a closed container is the main reason for furan appearance. Furan is generated through a chemical reaction, induced by heat at low humidity levels, which transforms sugar and amino acids that are naturally comprised in starchy food products. This reaction, known as the Maillard Reaction, enhances the taste of the cooked item, while being also responsible for the brownish colour it often gives to food. Furan can also be formed by other food compounds such as carotene, organic acids and ascorbic acid.

Furan is mostly found in jarred food – as direct packing after processing impedes its evaporation – and in roasted coffee beans, as well as in home-cooked food at a lesser extent.

It is important to bear in mind that furan volatility helps to find solutions for its mitigation. As soon as food is cooked in an open sauce pan, furan evaporates. In addition to its volatility, furan is also lipophilic, meaning that oil induces furan retention. As a matter of fact, removing oil from cooking process could reduce furan as well.

→ **Population at risk**

Health risks may appear above a certain daily dose of furan consumption. Toddlers (12 to 36 months) and adults (18 to 65 years) are the most concerned with furan exposure.

→ **Health concern**

Since 1995, the World Health Organization's International Agency for Research on Cancer (IARC) qualified furan as "reasonably anticipated to be a human carcinogen based on evidence of malignant tumor formation at multiple tissue sites in multiple species of experimental animals" (Group 2B). Further researches, such as the joint report by the Food Agriculture Organisation (FAO) and the World Health Organisation (WHO) released in 2010, highlighted that average furan exposure level "indicates a human health concern for a carcinogenic compound".

→ **Legal framework**

Up to now, the current European legislation on food contaminant ensures that "it is essential, in order to protect public health, to keep contaminants at levels which do not cause health concerns" (Regulation No. 882/2004). The European Commission goes further with its recommendation 2007/196/EC of 28 March 2007 on the monitoring of furan in foodstuffs, calling for a reassessment of furan regarding "that a reliable risk assessment would need further data on both toxicity and exposure". Hence the need to regulate soon on this issue.

→ **EFSA Mandate**

The European Commission has given the mandate to EFSA in January 2016, asking for a new risk assessment which has to be handed over by December 2017 (Mandate M-2016-0012).

ANSWERS TO EFSA'S QUESTIONS

1. Exposure Assessment

1.1 Mean levels of furan in ground roasted coffee beans are approximately 2 times lower than those observed in whole roasted coffee beans. It is therefore expected that grinding of roasted coffee beans has a significant impact on the levels of furan. What information do you have on the dynamics of furan during this process, in particular when coffee beans are ground just prior to the brewing of coffee (e.g. in a bar)?

On account of its volatility, when roasted beans are grinded, furan is not trapped anymore in beans' husks and can therefore evaporate.

Indeed, depending on the type of coffee and duration of roasting time, furan level fluctuates. Three different coffee samples (instant coffee, ground coffee and mixed coffee) have been analyzed. The results show that the lower furan rate stems from coffee mix, then from instant coffee, while the highest rate comes from ground coffee. Different types of coffee samples may contain different concentrations of furanic compounds, due to the various processing conditions such as temperature, degree of roasting and fineness of grind. Among different coffee samples, the highest level of furan (6320 µg kg-1) was detected in ground coffee, while coffee-mix samples showed the lowest furan concentration (10-226 µg kg-1). No significant difference was found in furan levels between caffeinated and decaffeinated coffee, because the roasting process is responsible for the formation of furanic compounds and decaffeination is performed before this process. Levels in brewed coffees indicated that brewing by an espresso machine caused significant loss of furanic compounds (Chaichi *et al*, 2015).

The aroma profile analyses of espresso coffee and plunger (cafetiere) coffees prepared from different blends (Arabica, Robusta Natural blend, Robusta Torrefacto) allowed the identification of 37 compounds, among which 11 furans. The volatile composition was related more to the botanical species (*C. arabica* or *C. canephora*) rather than to the method of preparation of the sample. The espresso coffee volatiles seem to be higher than those obtained for plunger coffee volatiles. Additionally, studies trying to establish the main sources of variability between different coffees and possible relationships between the botanical varieties, blending technologies, brew modes of preparation, and volatile components, led to identify pyridine as the characteristic component of plunger coffee, whilst 2-methylfuran is the characteristic component of the espresso coffee (Caprioli *et al*, 2015).

Espresso coffee quality is related to the coffee blend, but also to all the parameters set on the espresso machine: temperature, pressure and composition of water, amount and granulometry of coffee powder used, and time of percolation. Studies on the correlation between the final quality of espresso coffee and the extraction temperature used in preparing it investigated the following parameters: influence of the water temperature (88, 92, 96 and 98°C) on the final quality of three types of espresso coffee (Arabica, Robusta Natural blend and Robusta Torrefacto blend), optimal temperature, keeping constant all the other parameters, and pressure at 9 bar. Volatile compounds and sensory flavor profiles appear to be the most relevant parameters for selecting the best water temperature, as they are what consumers are most aware of. Results revealed that 92°C is the optimal water temperature to enounce the chosen parameters for all blends examined (Caprioli *et al*, 2015).

1.2 When assessing the conversion of solid coffee products to coffee brews, EFSA usually applies dilution factors of 63, 18, 18 and 7 for instant, americano, cappuccino and espresso coffee, respectively. Do you have data that would support other dilution factors for these coffee types? Do you have data regarding the effect of dilution when preparing coffee substitute beverages?

No data available.

1.3 During the beverage preparation, in addition to the effect of dilution, concentration of furan may be further reduced due to other losses (e.g. evaporation). Do you have data to support the use of additional factors to account for such losses in the aforementioned coffee types? Would you suggest the same additional factors for all coffee types or do you expect losses of furan to be different depending on the coffee type or brewing method (i.e. steamed vs filtered)?

The brewing method has an impact on furan level. Levels of furanic compounds in ground coffees are reported much higher (range of 1375–6233 µg kg-1) than in other categories of coffee samples. This is supposed to be due to the fact that ground coffees, unlike instant coffees, are not dried and packed after grinding. Nevertheless, boiling ground coffee enables to reduce furan by 87% compared to 47% reduction with the espresso machine. The factors explaining the difference are the openness to the air of boiling ground coffee and the longer time required for preparation (Caprioli et al. 2015).

See also previous answer to Question 1.1

1.4 Food consumption data available in EFSA are in some surveys not sufficiently detailed for an accurate exposure assessment of canned and jarred foods. Do you have any information that would allow for a more refined exposure assessment such as the relative contribution of jarred/canned food to the overall consumption of the following food categories: 'Vegetables and vegetable products', 'Legumes', 'Fruit and fruit products', 'Meat and meat products', 'Composite foods' and 'Fish and fish products'?

The following tables report data on furan in commercial ready-to-eat baby food (Lachenmeier et al. 2008).

Table 3. Furan in commercial baby food jars analyzed without preparation and heating in a typical baby-food warmer.

	Furan [µg kg^{-1}]		
Product	Unprepared	Heated with baby food warmer, closed (1 h, 80°C)	Heated with baby-food warmer, opened jar, periodical stirring
Potato/carrot puree	39.6	47.0	34.7
Mixed vegetable puree	66.8	67.0	67.5
Vegetables with chicken and pasta	28.7	29.7	–*
Muesli	10.0	8.5	–
Cream potatoes with cauliflower and veal	73.5	79.6	–
Rigatoni Napoli	92.0	89.5	–
Vegetables with beef	25.4	27.6	–
Spaghetti Bolognese	44.0	45.9	–
Mixed vegetables with chicken	27.5	28.5	–
Potato-vegetables with pork	47.5	48.0	–

Note: *Experiment not conducted.

Table 4. Occurrence of furan in commercial ready-to-eat babyfoods (analyzed as bought without prior heating).

Sample matrix	Numbers of samples in the range [μg kg^{-1}]								Furan concentrations [μg kg^{-1}][a]		
	<2	2–5	5–10	10–20	20–30	30–40	40–50	>50	Mean ± SD	Median	95th percentile
Baby beverages	7	4	1	0	2	1	1	0	9.6 ± 14.8	2	45
Fruit-only dishes	30	3	15	1	0	0	0	1	3.5 ± 8.4	0.2	9
Meals with cereals	5	9	5	4	1	1	0	0	6.6 ± 7.2	4	20
Pasta	0	0	0	1	3	4	1	2	34.8 ± 14.5	35	63
Meals with meat	0	0	2	15	21	8	6	5	28.2 ± 15.0	26	59
Vegetable meals (without meat)	3	0	1	13	17	18	8	11	31.2 ± 17.3	30	63

Note: [a]Samples below LOD were calculated as zero.

Furthermore, some data on furan content in other types of food are also available (Fromberg et al. 2014).

Table 1. Levels of furan in ready-to-eat products (μg/kg)

Product	n	Mean (μg/kg)	Range (μg/kg)
Chocolate and cookies	9	3.9	< 2.4–11.0
Dried fruit	18	6.5	< 2.4–83
Canned vegetables	18	3.8	< 2.4–12.0
Crisps	9	24.3	< 2.4–91
Dry bakery products	5	35.8	4.9–74
Breakfast cereals	11	57.4	< 2.4–387
Infants food	5	17.8	< 2.4–45

Table 2. Levels of furan, 2-methylfuran, 2-ethylfuran, 2-pentyl, and 2,5-dimethylfuran in canned foods and coffee

Product	Compound	n	Mean (μg/kg)	Range (μg/kg)
Canned food	furan	12	20.5	< LOD – 47
	2-methylfuran	12	4.7	< LOD – 8.0
	2-ethylfuran	12	8.5	< LOD – 17.7
	2-pentylfuran	12	2.7	< LOD – 3.2
	2,5-dimethylfuran	12	67	< LOD – 105
Coffee	furan	15	885	47–2821
	2-methylfuran	15	1328	117–5982
	2-ethylfuran	15	76	< LOD – 98
	2-pentylfuran	15	< LOD	< LOD
	2,5-dimethylfuran	15	217	32–466

1.5 The occurrence data available at EFSA have been collected between 2004 and 2016. EFSA intends to pool the information available in the exposure assessment. Do you have data that would indicate that this pooling would not reflect current occurrence.

No data available.

1.6 Do you have data that explains the variability in the 2-methylfuran/furan ratio in foods and beverages (e.g. ingredients, roasting degrees, seasonality, varieties, origin)?

2-methylfuran and furan are formed by thermal decomposition when precursors are reacting with each others. Four precursors have been distinguished:

- ascorbic acid
- carbohydrates (fructose and other sugars)
- amino acid
- unsaturated fatty acids
- carotene & organic acids

Ascorbic acid is one of the major furan precursors but its formation is very fluctuant, depending on heating temperature (aqueous or dry-heating conditions) or pH level. Indeed, the more heated is the food, the more furan will be formed. Furan is lower at pH=4 than pH=7 (Limacher *et al.* 2007, Mariotti et al, 2013).

Furan and methylfuran formation under roasting conditions in closed systems may yield up to 330 micromol of furan and 260 micromol of 2-methylfuran per mol of precursor. The total furan levels in cooked vegetables may be increased by spiking with hexoses. The presence of certain aminoacids, such as alanine, threonine, or serine, may promote furan formation by the recombination of C(2) fragments, such as acetaldehyde and glycolaldehyde, which may originate from both sugars and amino acids (please also refer to answer 2 "Homecooking").

Pressure-cooking conditions may lead to lower amounts of furan (below 20 micromol/mol). Labeling studies indicated two major formation pathways for both furans: from the intact sugar skeleton and by recombination of reactive C(2) and/or C(3) fragments. Under roasting conditions, in the absence of amino acids, furan formation results mainly from the intact sugar skeleton (Limacher *et al.* 2008).

The 2-methylfuran formation preferably occurs in the presence of amino acids by aldol-type reactions [C(2) and C(3) fragments with lactaldehyde as a key intermediate. Elimination of sodium chloride may prevent Methylfuran formation.

Furthermore, lowering oxygen or pH levels in food before heating could be a solution for mitigating furan in thermally treated plant-based foods. (Palmers *et al,* 2016).

Furan ratio in food decreases when food storage is kept below 4°C, even after simulating reheating at 90°C for normal consumption, furan is evaporated (Palmers *et al.* 2015).

The following table reports data in pH and presence of water in relation to the formation of furan and methylfuran (Limacher et al, 2007):

Table III. Repeatability of the heating procedure under various reaction conditions ($n = 6$).[a]

		Furan		2-Methylfuran	
Condition	Heat treatment	Average (µmol mol^{-1})	RSD (%)	Average (µmol mol^{-1})	RSD (%)
Dry	200°C, 10 min	2050.9	4.5	19.04	20.3
Aqueous, pH 7	121°C, 25 min	3.69	7.8	1.19	24.9

[a]Ascorbic acid (0.1 mmol) was used as an example.
RSD, relative standard deviation.

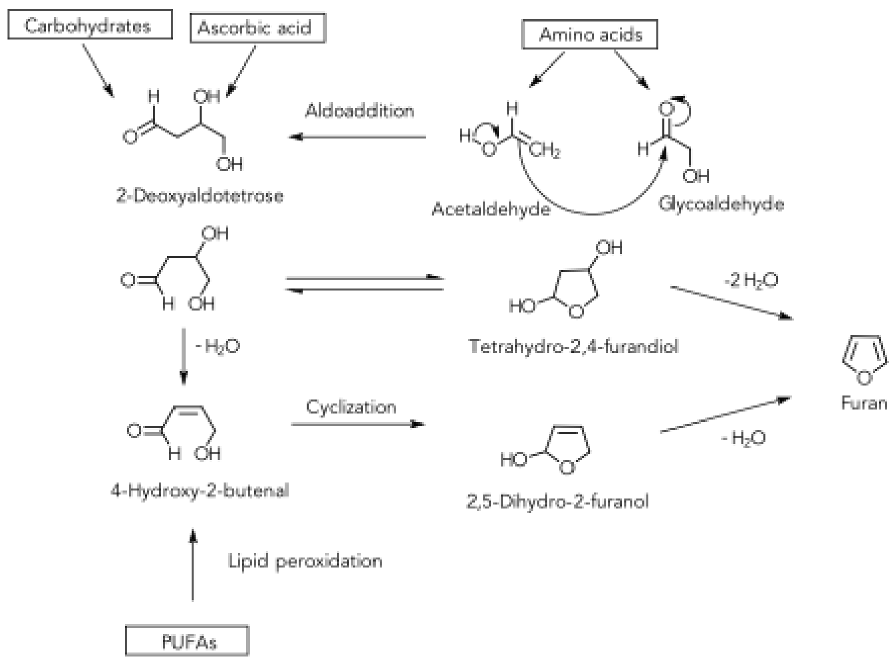
See also previous answer to Question 1.1

2. Home-cooking

Apart from presence in commercially processed foods, furan and methylfurans can be formed during cooking (home and catering). Do you have information regarding the levels of furan and methylfurans formed in food during cooking?

First of all, home or catering cooking generally reduces furan formation. Even though, carbohydrates, ascorbic acid and oil enhance the level of furan in food, as well as the presence of ferric ions (added to food, contained in it or migrated from metal containers used in processing) and NaCl. Furan could also be formed through oxidation of polyunsaturated fatty acids (PUFA) and carotenoids at elevated temperatures. In addition, as furan is highly lipophilic, oil contributes to furan formation and retention in food (Fromberg et al. 2014).

Following table describing possible furan formation routes (Mogol, 2015):



Data on furan levels in freshly home-prepared baby foods are available in the following table (Lachenmeier et al. 2008):

Table 1. Furan in freshly home-prepared vegetable, cereal, and fruit-based baby foods (all ingredients from organic production).

Product	Furan [$\mu g\,kg^{-1}$]		
	Freshly prepared, directly analysed	Re-heated (1 h, 70°C) in closed jar after storage overnight at 8°C	Re-heated (1 h, 70°C) in closed jar after storage overnight at 8°C and addition of 2-furan carboxylic acid (60 $mg\,kg^{-1}$)
Potato puree	n.d.	10.0	51.8
Carrot puree	n.d.	n.d.	n.d.
Potato/carrot puree	n.d.	6.7	3.3
Spinach puree	n.d.	n.d.	n.d.
Broccoli puree	n.d.	4.5	2.5
Spaghetti, mashed	n.d.	n.d.	2.7
Semolina-milk pudding	n.d.	n.d.	n.d.
Rice porridge	n.d.	n.d.	n.d.
Apple puree	n.d.	n.d.	1.8
Chicken puree	n.d.	n.d.	n.d.

Note: n.d., not detectable ($<0.15\,\mu g\,kg^{-1}$).

Also homemade apple pie and apple cake were found to have contents of 4.4 and 23.4 µg/kg, respectively, resulting from the furan content of homemade bread crumbs (133 µg/kg) (Fromberg *et al,* 2014).

3. Toxicity

Has your organisation carried out, or are you aware of toxicity studies (including toxicokinetics) on furan and/or methylfurans that are not available in the public domain and that you are willing to share with EFSA?

No data available.

SAFE POSITION

Firstly, SAFE welcomes the initiative of the European Commission to call for a new risk-assessment of furan.

Indeed, SAFE considers that, in regard to the current legislation on food contaminant, which has the willingness to prevent any health concern for consumers, as well as to the significant results of the different scientific researches that tend to prove the carcinogenic properties of furan, it is a necessity to reduce furan levels in food. European exposure estimates suggest that mean dietary exposure to furan may be as high as 1.23 and 1.01 µg/kg bw/day for adults and 3- to 12-month-old infants, respectively; such levels of exposure to furan may indicate a risk to human health and need for mitigation (Moro *et al*, 2012).

It is therefore suggested to keep furan levels as low as possible, applying the ALARA (As Low As Reasonably Achievable) concept. Indeed, the lack of legally binding benchmark leaves the room to consumers' potential and dangerous exposure to furan.

REFERENCES

Anese M, Manzocco L, Calligaris S, Nicoli MC. (2013). Industrially applicable strategies for mitigating acrylamide, furan, and 5-hydroxymethylfurfural in food. *J Agric Food Chem*, 30;61(43):10209-14.

Caprioli, G., Cortese, M., Sagratini, G., & Vittori, S. (2015). The influence of different types of preparation (espresso and brew) on coffee aroma and main bioactive constituents. *International Journal Of Food Sciences And Nutrition*, *66*(5), 505-513. doi:10.3109/09637486.2015.1064871

Chaichi M, Ghasemzadeh-Mohammadi V, Hashemi M, Mohammadi A. (2015). Furanic compounds and furfural in different coffee products by headspace liquid-phase micro-extraction followed by gas chromatography–mass spectrometry: survey and effect of brewing procedures. *Food Additives & Contaminants: Part B*, 8, 1, 73–80.

EC (European Commission) Regulation No. 882/2004 of the European Parliament and of the Council of 29 April 2004 on official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules. OJ L 191, 28.5.2004, p. 1.

EC (European Commission) Recommendation., 2007. Commission recommendation 2007/196/EC of 28 March 2007 on the monitoring of the presence of furan in foodstuffs. Official Journal of the European Union L 88/56.

Fadel, H. H. M., Abdel Mageed, M. A., & Lotfy, S. N. (2008). Quality and flavour stability of coffee substitute prepared by extrusion of wheat germ and chicory roots. *Amino Acids*, *34*(2), 307-314.

FAO/WHO (Food and Agricultural Organisation/World Health Organization), 2010. Summary and conclusions report of the seventy-second meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA),pp 1-16. Available at: http://www.fao.org/ag/agn/agns/jecfa_output_en.asp

Fromberg, A., Mariotti, M. S., Pedreschi, F., Fagt, S., & Granby, K. (2014). Furan and alkylated furans in heat processed food, including home cooked products. *CZECH JOURNAL OF FOOD SCIENCES*, *32*, 443-448.

Furan. (1995). *IARC Monographs On The Evaluation Of Carcinogenic Risks To Humans*, *63*, 393-407.

Heppner CW, Schlatter JR. (2007). Data requirements for risk assessment of furan in food. *Food Addit Contam*, 24 Suppl 1:114-21.

Lachenmeier DW, Reusch H, & Kuballa T. (2009). Risk assessment of furan in commercially jarred baby foods, including insights into its occurrence and formation in freshly home-cooked foods for infants and young children. *Food Additives & Contaminants. Part A, Chemistry, Analysis, Control, Exposure & Risk Assessment*, *26*(6), 776-85. doi:10.1080/02652030802714018

Limacher, A., Kerler, J., Conde-Petit, B., & Blank, I. (2007). Formation of furan and methylfuran from ascorbic acid in model systems and food. *Food Additives &; Contaminants*, *24*(01), 122-135.

Limacher A, Kerler J, Davidek T, Schmalzried F, Blank I. (2008). Formation of furan and methylfuran by maillard-type reactions in model systems and food. *J Agric Food Chem*, May 28;56(10):3639-47.

Mariotti MS, Granby K, Rozowski J, & Pedreschi F. (2013). Furan: a critical heat induced dietary contaminant. *Food & Function*, *4*(7), 1001-15. doi:10.1039/c3fo30375f

Moro, S., Chipman, J. K., Wegener, J.-W., Hamberger, C., Dekant, W., & Mally, A. (2012). Furan in heat-treated foods: Formation, exposure, toxicity, and aspects of risk assessment. *Molecular Nutrition & Food Research*, *56*(8), 1197-1211. doi:10.1002/mnfr.201200093

Mogol B. A. (2014). Mitigation of thermal process contaminants by alternative technologies (Doctoral Dissertation), DOI: 10.1016/B978-0-12-802832-2.00022-X

Palmers S, Grauwet T, Buvé C, Van de Vondel L, Kebede BT, Hendrickx ME, & Van Loey A. (2015). Furan formation during storage and reheating of sterilised vegetable purées. *Food Additives & Contaminants. Part A, Chemistry, Analysis, Control, Exposure & Risk Assessment*, *32*(2), 161-9. doi:10.1080/19440049.2014.999720

Palmers S, Grauwet T, Vanden Avenne L, Verhaeghe T, Kebede BT, Hendrickx ME, Van Loey A- (2016). Effect of oxygen availability and pH on the furan concentration formed during thermal preservation of plant-based foods. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess*, 33(4):612-22.

Palmers S, Grauwet T, Buvé C, Vanratingen K, Kebede BT, Goos P, Hendrickx ME, Van Loey A. (2016). Relative importance and interactions of furan precursors in sterilised, vegetable-based food systems. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess*, 33(2):193-206.

Petisca, C., Pérez-Palacios, T., Farah, A., Pinho, O., & Ferreira, I. M. P. L. V. O. (2013). Furans and other volatile compounds in ground roasted and espresso coffee using headspace solid-phase microextraction: Effect of roasting speed. *Food And Bioproducts Processing*, *91*(3), 233-241. doi:10.1016/j.fbp.2012.10.003

Perez Locas, C, Yaylayan, VA. (2004). Origin and mechanistic pathways of formation of the parent furan - A food toxicant. *Journal of Agricultural and Food Chemistry*, 52, 6830-6836.

Pérez-Palacios T, Petisca C, Melo A, & Ferreira IM. (2012). Quantification of furanic compounds in coated deep-fried products simulating normal preparation and consumption: optimisation of HS-SPME analytical conditions by response surface methodology. *Food Chemistry*, *135*(3), 1337-43. doi:10.1016/j.foodchem.2012.05.100