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# **Risk assessment of furan in commercially jarred baby foods and insights into furan occurrence and formation in freshly home-cooked foods for infants and young children**

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**Risk assessment of furan in commercially jarred baby foods and insights into furan occurrence and formation in freshly home-cooked foods for infants and young children**

|                               |  |
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|                               |  |

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5 1 **Risk assessment of furan in commercially jarred baby foods,**  
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8 2 **insights into furan occurrence and formation in freshly home-**  
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11 3 **cooked foods for infants and young children**  
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16  
17 5 **Abstract**  
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20 6 Furan is a possible human carcinogen (IARC group 2B) with widespread occurrence in  
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22 7 many types of foods. In this study, a survey of furan contamination in 230  
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24 8 commercially-jarred ready-to-eat infant food products was conducted using headspace  
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26 9 sampling in combination with gas chromatography and mass spectrometry (HS-GC/MS)  
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28 10 with a detection limit of  $0.2 \mu\text{g kg}^{-1}$ . The incidence of furan contamination in jarred  
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30 11 infant beverages, cereals and fruits was relatively low, with average concentrations  
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32 12 below  $10 \mu\text{g kg}^{-1}$ . Significantly higher concentrations were found in pasta ( $34.8 \pm 14.5$   
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34 13  $\mu\text{g kg}^{-1}$ ), meals containing meat ( $28.2 \pm 15.0 \mu\text{g kg}^{-1}$ ), and meals containing vegetables  
35  
36 14 ( $31.2 \pm 17.3 \mu\text{g kg}^{-1}$ ). The average exposure of 6-month old infants to furan was  
37  
38 15 estimated to be  $0.2 \mu\text{g}$  per kg bodyweight per day. The margin of exposure calculated  
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40 16 using the T25 dose descriptor would be 2692, which points to a possible public health risk. In  
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42 17 contrast to commercially jarred food products, none of 20 freshly home-prepared baby foods  
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44 18 contained furan above the limit of detection. Only after re-heating in closed vessels was furan  
45  
46 19 found to have formed. Furan was especially prevalent in reheated foods containing potatoes,  
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48 20 with values ranging between  $2.3$  and  $29.2 \mu\text{g kg}^{-1}$ . The formation of furan in potato-  
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50 21 containing baby foods was increased by addition of ascorbic acid, by longer heating  
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52 22 times above 1 h and by temperatures above  $50^\circ\text{C}$ . Research regarding reduction of  
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54 23 furan in commercial baby foods should be conducted, with a priority aimed at reducing  
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5 24 this heat-induced contaminant without concomitantly increasing the microbiological  
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7 25 risk.

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11 27 **Keywords:** Furan, carcinogens, gas chromatography, mass spectrometry, food  
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14 28 contamination, food analysis, baby food, infant food, risk assessment  
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5 29 Introduction  
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7 30 Furan ( $C_4H_4O$ ), a very volatile and colourless liquid, has been classified by the  
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10 31 International Agency for Research on Cancer (IARC 1995) as a possible human  
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12 32 carcinogen (group 2B). However, it is still a matter of debate whether the carcinogenic  
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14 33 effects are caused by a genotoxic mechanism (Durling et al. 2007). Other chronic effects  
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17 34 in humans may include hepatotoxicity (Jun et al. 2008). Due to its widespread  
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19 35 occurrence in many types of food products, concerns have been raised that furan might  
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21 36 become a serious problem, similar to that seen for acrylamide (Yaylayan 2006).  
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26  
27 38 Furan generation in food is multi-factorial (Yaylayan 2006). A number of model tests  
28  
29 39 have shown that furan is produced through heating of reducing carbohydrates through  
30  
31 40 the Maillard reaction (Maga 1979; Perez Locas and Yaylayan 2004). Furan generation  
32  
33 41 has also been determined in the presence of ascorbic acid (Fan 2005; Becalski and  
34  
35 42 Seaman 2005) or certain amino acids (Perez Locas and Yaylayan 2004; Märk et al.  
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37 43 2006; Limacher et al. 2008). The pathway from ascorbic acid is of special importance as  
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39 44 many foods are fortified with vitamin C as part of processing. Possible intermediates in  
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41 45 the formation from ascorbic acid are 2-deoxyaldotetroses, 2-furoic acid and 2-  
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43 46 furaldehyde (Limacher et al. 2007). The oxidation of poly-unsaturated fatty acids may  
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45 47 also represent a means of furan generation (Becalski and Seaman 2005; Senyuva and  
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47 48 Gökmen 2007).  
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56 50 There are currently a large number of analytical methods for the determination of furan  
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58 51 in foods, developed over the past few years, and the analytical problems first reported  
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5 52 for furan appear to have been resolved (Senyuva and Gökmen 2005; Crews et al. 2007;  
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7 53 Wenzl et al. 2007; Crews and Castle 2007b).

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9 54 In our current study, we have focused on furan in foods intended to be consumed by  
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11 55 infants, because they are the most susceptible consumer group (Suk et al. 2003) and  
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13 56 because relatively high amounts of furan were previously detected in commercial baby  
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15 57 foods. Heppner and Schlatter (2007) summarized the data from a number of sources  
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17 58 (including data from the US FDA) and found that the concentration of furan in baby  
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19 59 foods ranged from non-detectable to as much as 112  $\mu\text{g kg}^{-1}$ . Taking into consideration  
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21 60 a consumption of 234 g per day of canned baby food (Kersting et al. 1998), Heppner and  
22  
23 61 Schlatter (2007) assumed an exposure range of <0.03-3.5  $\mu\text{g}$  per kg body weight (bw)  
24  
25 62 per day, assuming a body weight of 7.5 kg for a 6-month-old baby. Yoshida et al. (2007)  
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27 63 reported levels of furan in a similar range of 1.4 to 90  $\mu\text{g kg}^{-1}$  in 15 baby foods from the  
28  
29 64 Japanese market. Most recently, the US FDA reported furan in ready-to-eat baby foods  
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31 65 from the USA in ranges between 2.5 and 112  $\mu\text{g kg}^{-1}$  were found (Morehouse et al.  
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33 66 2008).

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43 68 The European Food Safety Authority's (EFSA) Scientific Panel on Contaminants in the  
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45 69 Food Chain noted an absence of information on freshly prepared foods in home cooking  
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47 70 and catering in general (Heppner and Schlatter 2007). A first indication of the effect of  
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49 71 consumer cooking on furan in convenience food showed that the levels decreased in  
50  
51 72 most canned and jarred foods after heating due to simple evaporation (Roberts et al.  
52  
53 73 2008). In contrast, other researchers found furan to be relatively persistent in food  
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55 74 (Crews and Castle 2007a) and that it is not lost to a very significant extent when the  
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57 75 foods are simply warmed to be ready to eat (Hasnip et al. 2006). At this point in time,

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4 76 only one study has researched furan in home-prepared baby foods and it showed that all  
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7 77 seven preparations examined had significantly lower levels of furan in comparison with  
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10 78 commercial baby foods (Bianchi et al. 2006). However, the results were described to be  
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12 79 insufficient to make a definite conclusion regarding furan content and home cooking.

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14 80 In the context of EFSA's open call for scientific data on furan in food and beverages  
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16 81 (EFSA 2006), we have analyzed a large collection of commercial jarred baby food  
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18 82 products from the German market and have evaluated the influence of domestic heating  
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20 83 procedures on the furan content of the jars. In addition, we have analyzed freshly  
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22 84 prepared baby foods prepared according to typical baby food recipes using fresh fruits  
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24 85 and vegetables. Finally, we provide some insight into the pathway of formation of furan  
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26 86 in baby foods.  
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## 32 33 88 **Materials and Methods**

### 34 35 89 *Samples*

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38 90 The survey of commercial ready-to-eat baby foods included 230 products sampled and  
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40 91 analyzed between 2004 and 2007. As part of official food control in the German federal  
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42 92 state of Baden-Württemberg, our institute covers the district of Karlsruhe in North  
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44 93 Baden (Germany) with a population of approximately 2.7 million. The sampling was  
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46 94 carried out by local authorities directly at the food producers or at retail trade  
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48 95 establishments including pharmacies and organic food stores. The samples were  
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50 96 randomly selected and collected by government food inspectors. Only products intended  
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52 97 for use as foods specifically for infants and young children, in the sense of Commission  
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54 98 Directive 2006/125/EC, were included in the survey (European Commission 2006).  
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4 100 The ingredients for home preparation of baby foods were purchased in May and June  
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7 101 2008 at local farmer's markets and organic food stores. In the initial experiment  
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10 102 concerning different product groups, only ingredients classifiable as organic according  
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12 103 to Council Regulation (EEC) No 2092/91 were chosen (European Council 2001). The  
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14 104 second experiment, which focused on potato-based baby foods, was conducted with  
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16 105 organic as well as conventionally produced ingredients.  
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21 107 *Quantitative determination of furan*  
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24 108 For the survey, a headspace-gas chromatography-mass spectrometry (HS-GC/MS)  
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26 109 method with deuterated furan as internal standard and standard addition for  
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29 110 quantification was used, which was based on a FDA method (FDA, 2004). The HS-  
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31 111 GC/MS method was previously described in detail (Kuballa et al. 2005; Kuballa 2007).  
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34 112  
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37 113 The HS-GC/MS method was validated for the determination of baby foods and  
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39 114 accredited to ISO 17025. The precision of the method never exceeded 6.4% (relative  
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42 115 standard deviation, n=5) and the average recovery was 105% (n=8). Determined  
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44 116 according to DIN 32645, the limit of detection (LOD) was 0.20  $\mu\text{g kg}^{-1}$  and the limit of  
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46 117 quantification (LOQ) was 0.60  $\mu\text{g kg}^{-1}$ .  
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52 119 Because of the extremely high time effort of the HS-GC/MS method due to standard  
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54 120 addition, the home preparation and formation experiments were evaluated using purge-  
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57 121 and-trap-GC/MS procedure. Deuterated furan was used as internal standard, but the  
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59 122 quantification was conducted using a more efficient external calibration.  
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7 124 The purge-and-trap system used for analysis was an Eclipse 4660 Purge-and-Trap  
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9 125 Sample Concentrator in combination with a model 4552 water/soil autosampler (OI  
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11 126 Analytical, College Station, TX, USA). The trap was #10 (8 cm, tenax, silica gel, carbon  
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13 127 molecular sieve) provided by the manufacturer. The sample temperature was 40°C. The  
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15 128 sample was purged for 5 min. The desorption was conducted for 4 min at 190°C,  
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17 129 followed by a bake time of 20 min at 210°C to avoid carry over.  
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25 131 The purge-and-trap system was combined with an Agilent model 6890 Series Plus gas  
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27 132 chromatograph and an Agilent 5973N mass selective detector (Agilent, Waldbronn,  
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29 133 Germany). Data acquisition and analysis were performed using standard software  
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31 134 supplied by the manufacturer. Substances were separated on a fused silica capillary  
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33 135 column (HP Plot Q, 30 m x 0.32 mm I.D., film thickness 0.25 µm). Temperature  
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35 136 program: 90°C hold for 1 min, 10°C min<sup>-1</sup> up to 225°C, hold for 15 min. The  
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37 137 temperatures for the ion source, quadrupole and interface were set at 230°C, 150°C, and  
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39 138 225°C, respectively. Helium with a constant flow rate of 1.5 ml min<sup>-1</sup> as carrier gas was  
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41 139 used. For quantification, the mass fragments *m/z* 68 and *m/z* 72 were used for furan and  
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43 140 furan-d<sub>4</sub>, respectively.  
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52 142 The purge-and-trap method was validated similar to the HS-GC/MS method. The  
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54 143 precision of the purge-and-trap method never exceeded 3.7% (relative standard  
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56 144 deviation, n=8) and the average recovery was 106 % (n=8). The LOD was 0.15 µg kg<sup>-1</sup>  
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58 145 and the LOQ was 0.44 µg kg<sup>-1</sup>. No artifactual furan formation was observed during the  
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5 146 purge-and-trap step, as e.g. proven by results below LOD in unheated samples  
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7 147 containing furan precursors.  
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12 149 *Experiments for home preparation of baby foods*

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14 150 The home preparation experiments were aimed to simulate typical home cooking as  
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16 151 closely as possible. We used only standard kitchen equipment, e.g. a kitchen stove and a  
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18 152 household blender. The recipes were taken from a cookbook intended for parents  
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20 153 preparing foods for babies between five and 10 months of age, i.e. the time period of  
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22 154 adjustment from breast feeding to normal solid foods (von Mandelsloh 2007). These  
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24 155 foods are generally prepared as a puree (so-called 'Babybrei' in German) using hand or  
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26 156 table-top blenders to achieve a consistency that allows easy ingestion by the babies. In  
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28 157 Germany, potatoes are typical ingredients, alone or in combination with carrots and  
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30 158 other vegetables or meat. In general, we cooked the ingredients in boiling water until  
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32 159 done, then the ingredients were blended, with addition of water to adjust the consistency  
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34 160 to correspond with that of typical commercial baby foods. No other additives were used.  
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36 161 The food groups under investigation are shown in Table 1. Besides the direct analysis of  
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38 162 the freshly prepared food, we have stored the foods overnight at 8°C, followed by a re-  
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40 163 heating in closed vessels for 1 h in a water bath at 70°C. Finally, we have added 2-furan  
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42 164 carboxylic acid (80 mg kg<sup>-1</sup>, purity 98%) and re-heated similarly.  
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53 166 As it became evident in the first experiment that potatoes, in particular, appeared to  
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55 167 have the capacity to form furan, we conducted a second experiment with potato purees  
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57 168 specifically. Potatoes of different origins and agricultural production methods were used  
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5 169 (Table 2). In this experiment, we also performed additional tests involving the addition  
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7 170 of ascorbic acid (500 mg kg<sup>-1</sup>) to the ingredients.  
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12 172 ***Preparation experiments involving commercial baby foods***

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14 173 To assess possible changes in furan content during normal home preparation of  
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16 174 commercial baby foods, we chose 10 products of which we had more than one jar of the  
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18 175 same production lot, and analyzed them as opened, as well as following heating with a  
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20 176 baby food warmer. The warmer was a PTC baby food warmer type 702 by Reer-  
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22 177 Kindersicherheit, Leonberg, Germany. The baby food jar is placed into the device,  
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24 178 which is then filled with water, so that the jar is indirectly heated by the water. To assess  
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26 179 the maximal furan formation capacity, we have used extreme conditions for the heating,  
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28 180 including a maximum temperature setting of the device (80°C water temperature, own  
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30 181 measurement), a 1 h heating time, and closed jars. In two cases, we had three jars of one  
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32 182 lot, so we were also able to assess the effect of heating in an open jar, with regular  
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34 183 stirring during the heating process.  
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43 185 ***Experiment on influences on furan formation in potato puree baby foods***

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45 186 In order to evaluate possible furan formation mechanisms in potato puree baby foods,  
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47 187 with a minimum number of experiments, the information gleaned from each experiment  
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49 188 and the relationships between the experiments have to be fully exploited. This was done  
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51 189 using a D-optimal design type (Box et al. 2005; Montgomery 2005). The D-optimal  
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53 190 algorithm was used because it chooses an ideal subset of all possible combinations and  
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55 191 significantly reduces the number of required experiments when compared to standard  
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57 192 design types.  
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7 194 The potato puree used in this experiment was freshly prepared from organic potatoes  
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9 195 (Nicola from Egypt) using the same methods described above for the home preparation  
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11 196 of baby foods. The preparations were then re-heated using the following conditions. The  
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13 197 heating temperature and heating time were studied at two levels (50°C, 100°C; 1 h, 2 h)  
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15 198 whereas the ascorbic acid concentration was assessed as numeric factor between 0 and  
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17 199 1000 mg kg<sup>-1</sup>.

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24 201 ***Approach for risk assessment***

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26 202 Risk assessment was conducted according to the harmonised approach of the European  
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28 203 Food Safety Authority (EFSA) for the risk assessment of substances which are  
29  
30 204 genotoxic and carcinogenic (EFSA 2005). The EFSA has developed and recommends  
31  
32 205 an approach known as the margin of exposure (MOE). This approach uses the value of  
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34 206 doses of substances that have been observed to cause low but measurably harmful  
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36 207 responses in animals as a reference point, which is then compared with relevant  
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38 208 substance-specific dietary intake estimates in humans, taking into account differences in  
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40 209 consumption patterns. For this case of commercial ready-to-eat baby foods, we used the  
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42 210 consumption data provided by Kersting et al. (1998).

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50 212 To obtain the MOE, the Benchmark Dose Lower Confidence Limit (BMDL) of 10%  
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52 213 was suggested. In cases where the data are unsuitable for obtaining a BMDL, the EFSA  
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54 214 recommends the use of the T25 calculation, wherein the dose corresponding to a 25%  
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56 215 incidence of tumours, after correction for spontaneous incidence, is represented. Since  
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58 216 the dose-response modelling of a BMDL would have gone beyond the scope of this  
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4 217 article, we therefore chose the T25 of  $1.4 \text{ mg kg bw}^{-1} \text{ day}^{-1}$ , as tabulated by Sanner et al.  
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7 218 (2001), to provide a preliminary risk assessment.  
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## 12 *Statistics*

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14 221 The experimental designs and calculations were done using the Software Package  
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16 222 Design Expert v7 (Stat-Ease Inc., Minneapolis, MN, USA). The experiments were  
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18 223 evaluated using Analysis of Variance (ANOVA) to find the significance of variables and  
19  
20 224 their interactions in the models. The models were checked for consistency by looking at  
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22 225 the lack of fit and possible outliers.  
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26 226 The survey data were evaluated using Origin Pro v7.5 (OriginLab Corporation,  
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28 227 Northampton, MA, USA). Statistical significance was assumed at below the 0.05  
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30 228 probability level. Groups of two cases were compared using t-tests. One-way ANOVA  
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32 229 was used to test whether three or more cases had the same mean, including the  
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34 230 Bonferroni post hoc means comparison. Pearson's test was used to evaluate the  
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36 231 significance of linear relations. Box and whisker plots were used for visualization of  
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38 232 data (box 25<sup>th</sup> - 75<sup>th</sup> percentile, line in the box: median, whiskers: minimum and  
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40 233 maximum (max. 1.5 times the length of the inner quartiles), data points outside are  
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42 234 outliers).  
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51 236 To assess the influence of ingredients in commercial jarred baby foods on furan content,  
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53 237 the 230 products in the survey were categorized according to their ingredients lists as to  
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55 238 whether they contained potatoes, carrots, other vegetables, meats, fruits or cereals. A  
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57 239 data matrix was compiled containing the binary classification (0 if the ingredient was  
58  
59 240 not contained, and 1 if it was contained) as well as the furan content of the product. A  
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5 241 partial least squares (PLS) analysis was conducted using the binary classifications as x-  
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7 242 variables and the furan content as y-variable, with the aim of visualizing correlation  
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9 243 between the variables. A multivariate PLS analysis was conducted using the software  
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12 244 Unscrambler v9.7 (CAMO Process AS, Oslo, Norway).  
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## 245 **Results and Discussion**

### 246 *Furan in freshly homeprepared baby foods*

247 A major finding of our study is the fact that self-prepared baby food does not contain  
248 furan. Furan was below the limit of detection in all of the ten different foods prepared  
249 (Table 1). Our results are in agreement with those of Bianchi et al. (2006) who detected  
250 none or only very low concentrations in seven home-made baby foods. We think that the  
251 available literature now conclusively supports the assumption of a very low risk of furan  
252 in home prepared baby foods.

253  
254 In our study, only after storage and re-heating was furan detectable, in three cases in  
255 concentrations between 4.5 and 10.0  $\mu\text{g kg}^{-1}$  (Table 1). However, it must be stressed that  
256 our re-heating conditions (70°C, 1 h, closed vessel) were extreme compared to normal  
257 household conditions. Furan was formed in five cases, at concentrations between 1.8  
258 and 51.8  $\mu\text{g kg}^{-1}$ , after the addition of 2-furan carboxylic acid, a possible precursor of  
259 furan (Yaylayan 2006; Limacher et al. 2007). As the formation capability appears to  
260 have been highest in samples containing potatoes, we have studied potato baby foods in  
261 more detail (Table 2). Again, furan was below the limit of detection in all freshly  
262 prepared samples. After re-heating, amounts between 2.3 and 29.2  $\mu\text{g kg}^{-1}$  were formed.  
263 No significant differences could be detected between organically and conventionally  
264 produced potatoes ( $p=0.1306$ ) or between potatoes with origins in Germany and Egypt  
265 ( $p=0.8600$ ). If ascorbic acid was added to the potato baby foods, the furan content  
266 increased in every case, ranging between 8.3 and 58.3  $\mu\text{g kg}^{-1}$ . The furan contents of the  
267 re-heated samples before and after ascorbic acid addition show a significant linear

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5 268 relation ( $y=5.7+1.8x$ ;  $p=0.0001$ ), which proves that other factors besides ascorbic acid  
6  
7 269 are involved in the formation mechanism. Otherwise, the same amount should have  
8  
9 270 been formed in every sample, had ascorbic acid been the only factor involved. This  
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11 271 finding is in agreement with Limacher et al. (2007), who also suggested that other  
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14 272 compounds must be functioning as precursors and who deduced that transformation of  
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16 273 these into furan is being accelerated by the presence of ascorbic acid.  
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21 275 A more detailed insight into the furan formation in potato baby foods is provided by our  
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23 276 formation experiment (Figure 1). The ANOVA for the response surface two factor  
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25 277 interaction model implies that the model is highly significant ( $p<0.0001$ ). Significant  
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27 278 influences on furan formation were temperature ( $p<0.0001$ ), ascorbic acid content  
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29 279 ( $p<0.0001$ ) and heating time ( $p=0.0093$ ). Significant interactions occurred between  
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31 280 ascorbic acid and temperature ( $p<0.0001$ ) and between temperature and heating time  
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33 281 ( $p=0.0212$ ). Figure 1 shows that, at 50°C, the furan content stays almost constant and  
34  
35 282 there are no differences between 1 and 2 h heating nor between the different ascorbic  
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37 283 acid additions. The picture changes at 100°C, when furan shows a linear increase with  
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39 284 rising ascorbic acid concentrations, and higher concentrations were found at 2 hours of  
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41 285 heating than at 1 hour.  
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51 287 We conclude from our results that furan content in freshly home-cooked baby foods is  
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53 288 not an issue. The problem may only arise if self-prepared foods are stored and then re-  
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55 289 heated. Especially when they contain potatoes, baby foods should only be mildly  
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57 290 reheated to avoid furan formation. The experiments also show that ascorbic acid, a  
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59 291 common ingredient and additive in foods, has the potential to increase furan formation  
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4 292 or act itself as a precursor. We can only stress the warning of Limacher et al. (2007)  
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6 293 who concluded that it is not recommended to fortify canned and jarred food products  
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9 294 with vitamin C before thermal treatment.  
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14 296 ***Behaviour of furan during heating of commercial baby food jars***

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16 297 The heating of commercial baby food jars in a typical baby food warmer showed no  
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18 298 consistent trend (Table 3). Only two products containing potatoes (potato-carrot puree,  
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20 299 cream potatoes) again showed increases in furan, at 7.4 and 6.1  $\mu\text{g kg}^{-1}$ . The eight other  
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22 300 products showed no significant increase or decrease due to heating, but results were  
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24 301 identical within the method uncertainty. Heating of opened jars with stirring also  
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26 302 showed no consistent trend. In the case of a potato-carrot-puree, a slight decrease of 4.9  
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28 303  $\mu\text{g kg}^{-1}$  was detectable, and in the case of a vegetable puree a slight, but not significant,  
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30 304 increase of 0.7  $\mu\text{g kg}^{-1}$  was noted. Further research is required to evaluate the influence  
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32 305 of stirring and other influences during heating, with the aim of determining the best  
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34 306 methodology for reducing furan during household preparation of baby foods.  
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38  
39 308 There is still an ongoing discussion concerning to what extent consumer cooking may  
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41 309 influence the furan levels in foods. Some researchers have found that furan persists  
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43 310 during the normal heating practices that precede consumption (Hasnip et al. 2006),  
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45 311 whereas other studies reported losses of 29-55% in vegetable purees during different  
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47 312 warming procedures in microwave ovens (Zoller et al. 2007). Losses of up to 85% were  
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49 313 reported during heating of opened jars over a period of 5.5 h in boiling water, and a  
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51 314 reduction of ca. 50% if the baby food jar was opened but not heated (Goldmann et al.  
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4 315 2005). However, such significant furan losses were not evident at more moderate  
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7 316 heating or storage conditions.

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9 317 Our results are in agreement with those of Crews et al. (2007a), which indicate that the  
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11 318 removal of furan is not as easy as has been sometimes assumed on the basis of its  
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13 319 volatility. Furan appears to be well dissolved within the matrix of the baby food and  
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15 320 opening of the jars exposes only a relatively small surface area. Therefore, despite its  
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17 321 volatility, the evaporation of furan appears to be hindered due to its apparently slow  
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19 322 diffusion inside the food matrix. The same observations were made by Roberts et al.  
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21 323 (2008), who demonstrated larger declines of furan in baby foods heated in a saucepan  
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23 324 under stirring. A preliminary recommendation could therefore be to transfer the baby  
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25 325 foods into a larger pan or bowl to increase the surface area for furan evaporation.  
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27 326 However, due to the unknown conditions of household preparation, we currently cannot  
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29 327 assume a significant reduction of risk due to evaporation. We agree with Crews et al.  
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31 328 (2007a) that these initial thoughts proved to be naïve, and our results show, in  
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33 329 accordance with Hasnip et al. (2006), that there is even the possibility of additional  
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35 330 formation, which could balance the potential evaporative losses.  
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#### 44 332 *Survey of commercial ready-to-eat baby foods*

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47 333 Table 4 shows the results of our survey of 230 jarred baby foods, which is so far the  
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49 334 largest overview of furan in this food group in Germany. We have classified the baby  
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51 335 foods into five broad groups and ANOVA shows that the groups have highly significant  
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53 336 differences in furan content ( $p < 0.0001$ ), as shown in the distribution patterns in  
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55 337 Figure 2. The highest average content was found in pasta products (i.e. spaghetti or  
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57 338 other pasta meals), followed by vegetable meals and meals with meat. Lower  
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5 339 concentrations were found in beverages and in meals that were comprised of cereals.  
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7 340 Preparations containing only fruits had the lowest furan content and the majority of  
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9 341 samples in this group were below the detection limit. Our results correspond well to the  
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11 342 ranges reported in previous surveys in Europe (Heppner and Schlatter 2007), Japan  
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13 343 (Yoshida et al. 2007), Switzerland (Zoller et al. 2007), and the USA (Morehouse et al.  
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15 344 2008).

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19 345 As the classification of the foods into the five broad groups only allows limited  
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21 346 conclusions regarding the ingredients attributable to furan formation (e.g. most meals  
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23 347 with meat also contain vegetables and potatoes), we have also separately evaluated the  
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25 348 ingredients lists of all products as to whether they contain fruits, cereals, carrots,  
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27 349 potatoes, meat or other vegetables. The PLS correlation loadings plot in Figure 3 shows  
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29 350 that furan is closely correlated with the presence of carrots, potatoes, meat and other  
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31 351 vegetables, while cereals and fruits appear to have no such influence. As our PLS  
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33 352 evaluation is based only on qualitative data (we had no information regarding the  
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35 353 quantity of each ingredient in each jar), this result can only be interpreted as  
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37 354 preliminary, but it does allow the setting of a research focus and of possible preventive  
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39 355 measures on foods containing these suspect ingredients. Currently, we cannot point  
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41 356 specifically to other vegetables besides potatoes and possibly carrots, because the  
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43 357 sample size for each vegetable was too low to acquire statistically significant  
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45 358 information. This type of analysis would also be confounded by the multi-component  
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47 359 vegetable mixtures that occur in commercial baby foods. Further research, with the aim  
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49 360 of studying each vegetable type separately, possibly in a realistic pilot plant setting,  
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51 361 would be required to identify vegetable groups that may be especially prone to furan  
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53 362 formation.  
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364 *Preliminary risk assessment of furan in baby foods*

365 The EFSA (2005) recommends that risk assessments provide different exposure  
366 scenarios (e.g. for entire, or specific groups of populations) along with their inherent  
367 uncertainties. Other than the mean and median, intakes from highly exposed individuals  
368 (due to high consumption or to average consumption of highly contaminated foods)  
369 should be considered as represented by the 90<sup>th</sup>, 95<sup>th</sup>, 97.5<sup>th</sup> and 99<sup>th</sup> percentiles.

370 The intake of commercial food products intended for infants in Germany is available  
371 from the DONALD (Dortmund Nutritional and Anthropometrical Longitudinally  
372 Designed) study (Kersting et al. 1998). The DONALD study also provided separate data  
373 for ready-to-eat or -drink baby foods (without consideration of infant formulas, follow-  
374 on formulas and dry cereal-based foods), so we can directly take the DONALD intake  
375 data to evaluate our commercial ready-to-eat baby foods. We selected four different  
376 exposure scenarios (3 months, 6 months, 9 months and 12 months). Because of their  
377 lower body weights, we chose the data for girls from the DONALD study. The four  
378 scenarios, corresponding body weights, and intake of ready-to-eat baby foods are shown  
379 in Table 5. This table also shows the calculated exposures to furan for mean and median  
380 concentrations and the percentiles. The statistical data for this exposure evaluation were  
381 calculated from all 230 commercial baby foods investigated in our study.

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383 The exposure data from Table 5 were then used to characterize risk using the margin of  
384 exposure (MOE) calculated from T25 (table 6). MOEs can be used by risk managers for  
385 setting priority, with a small MOE representing a higher risk than a larger one.

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4 386 In our case of furan in baby foods, the MOEs were below 10,000 in all cases, a finding  
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7 387 which signifies a potential public health concern for this contaminant (EFSA, 2005).  
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9 388 These values would still be below this threshold even if we were to assume a 30%  
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11 389 evaporation during food preparation. In addition, an additional safety factor of 10 for  
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13 390 exposures to children between 0 and 2 years of age could be required (Barton et al.  
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15 391 2005) because the MOE threshold of 10,000 was deduced for adults.  
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21 393 Uncertainties in the evaluation include the T25 as reference point, as it is calculated  
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23 394 from only one data point in an animal experiment, and there is no clear information of  
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25 395 the raw data (i.e. study type, animal species, exposure route, endpoint) from which the  
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28 396 T25 of furan was derived in the Sanner et al. (2001) study. Nonetheless, we believe that  
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30 397 our preliminary MOEs more than justify priority research with the aim of finding  
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32 398 measures to reduce furan in baby foods. This would be required anyway, according to  
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34 399 the ALARA-principle ("As low as reasonably achievable"), introduced into the *Codex*  
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36 400 *Alimentarius* standards for dealing with contaminants and toxins (Codex alimentarius  
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38 401 1997) and the corresponding EU legislation (Council of the European Communities  
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40 402 1993). The European baby food directive also demands that baby foods shall not contain  
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42 403 any substance in such quantity as to endanger the health of infants and young children  
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44 404 (European Commission 2006). As the EFSA is still in the process of toxicological  
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46 405 evaluation of furan, we cannot finally decide at the present time if the levels detected in  
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48 406 our baby foods endanger the health of the children. In our view, baby foods from other  
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50 407 European countries should be included as priority food group in the data collection of  
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52 408 EFSA mentioned in the introduction, in order to provide exposure data for a final risk  
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54 409 assessment of foods available to this vulnerable consumer group.  
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7 **411 Conclusion**

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10 412 The current recommendation for consumers can only be to include freshly cooked foods  
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12 413 in the diet of their babies. As furan formation is a heat-induced process, we cannot give  
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14 414 recommendations for the industry at this stage because a reduction in temperature would  
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16 415 possibly increase the microbiological risk of the products, which might far outweigh the  
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18 416 risk of furan toxicity. For the same reason, at this stage of data gathering, the  
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20 417 governmental food control agencies currently can only inform the producers and give  
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22 418 recommendations. In our view, any measures to reduce furan in baby food must include  
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24 419 a weighing of the risks presented by the chemical versus the microbiological factors –  
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26 420 and possibly also nutritional factors. The baby food industry should advance this type of  
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28 421 research with priority. We hope that our paper will stimulate industry, other member  
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30 422 states and other research groups to further the research into furan in baby foods.  
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39 **424 Acknowledgments**

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41 425 H. Mann is thanked for excellent technical assistance.  
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47 **427 References**

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5 532 **Figure captions**  
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7 533 *Figure 1. Influence of ascorbic acid concentration, heating temperature and time on the*  
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10 534 *furan content in potato puree baby food.*  
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14 536 *Figure 2. Box-plots for the furan concentrations in different types of commercial ready-*  
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17 537 *to-eat babyfoods (analyzed as bought without prior heating).*  
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22 539 *Figure 3. PLS correlation loadings plot of a dataset of 230 commercial baby food*  
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24 540 *products analyzed for furan content. Furan is predominantly found in products*  
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27 541 *containing carrots, potatoes, other vegetables or meat.*  
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- 1 Table 1. Furan in freshly homeprepared vegetable, cereal, and fruit-based baby foods  
2 (all ingredients from organic production).

| Product               | Furan [ $\mu\text{g kg}^{-1}$ ]     |   |   |
|-----------------------|-------------------------------------|---|---|
|                       | Freshly prepared, directly analysed | Re-heated (1 h, 70°C) in closed jar after storage over night at 8°C | Re-heated (1 h, 70°C) in closed jar after storage over night at 8°C and addition of 2-furan carboxylic acid (60 $\text{mg kg}^{-1}$ ) |
| 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.  |

- 3 n.d. not detectable ( $< 0.15 \mu\text{g kg}^{-1}$ )

4 Table 2. Furan in freshly homeprepared potato puree baby foods.

| Potato variety                  | Potato origin | Method of agricultural production * | Furan [ $\mu\text{g kg}^{-1}$ ]     |   |  |
|---------------------------------|---------------|-------------------------------------|-------------------------------------|---|--|
|                                 |               |                                     | Freshly prepared, directly analysed | Re-heated (1 h, 70°C) in closed jar after storage over night at 8°C | Re-heated (1 h, 70°C) in closed jar after storage over night at 8°C and addition of ascorbic acid (500 mg $\text{kg}^{-1}$ ) |
| Rosetta                         | Egypt         | organic                             | n.d.                                | 4.1   | 11.6   |
| Nicola                          | Italy         | organic                             | n.d.                                | 6.0   | 19.7   |
| Nicola                          | Egypt         | organic                             | n.d.                                | 6.2   | 32.1   |
| Astoria                         | Germany       | organic                             | n.d.                                | 8.6   | 15.8   |
| Nicola                          | Egypt         | organic                             | n.d.                                | 10.1  | 17.3   |
| Christa                         | Germany       | organic                             | n.d.                                | 11.9  | 21.7   |
| Gloria                          | Germany       | organic                             | n.d.                                | 16.1  | 40.0   |
| Nicola                          | Egypt         | organic                             | n.d.                                | 29.2  | 58.3   |
| Nicola                          | Egypt         | conventional                        | n.d.                                | 2.3   | 10.6   |
| Princess                        | Egypt         | conventional                        | n.d.                                | 2.8   | 8.3  |
| Princess                        | Germany       | conventional                        | n.d.                                | 4.6   | 14.2   |
| Berber                          | Germany       | conventional                        | n.d.                                | 6.2   | 19.3   |
| Marabel                         | Israel        | conventional                        | n.d.                                | 7.0   | 16.4   |
| Atlas                           | Egypt         | conventional                        | n.d.                                | 7.2   | 19.3   |
| Annabelle                       | Cyprus        | conventional                        | n.d.                                | 7.6   | 15.9   |
| Monalisa                        | Germany       | conventional                        | n.d.                                | 7.9   | 15.1   |
| Berber                          | Germany       | conventional                        | n.d.                                | 16.8  | 37.2   |
| Convenience pre-boiled potatoes | (unknown)     | conventional                        | n.d.                                | 6.5   | 18.4   |

5 \* According to label. Organic production was assumed when labelling requirements  
6 were in accordance with Council Regulation (EEC) No 2092/91 (European Council  
7 2001). Conventional production was assumed when no information on production  
8 method was provided on the label.

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

| Product                                  | Furan [ $\mu\text{g kg}^{-1}$ ] |  |   |
|--|---------------------------------|--|---|
|  | 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   | -   |

11 *\* experiment not conducted*

13 Table 4. Incidence of occurrence of furan in commercial ready-to-eat babyfoods

14 (analyzed as bought without prior heating)

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

15 <sup>a</sup> Samples below LOD were calculated as zero

16 *Table 5.* Exposure with furan from commercial ready-to-eat baby foods. The exposure  
 17 scenarios were derived using the mean, median and percentiles of the furan  
 18 concentrations in all ready-to-eat baby foods and beverages in our survey (n=230)

| Intake scenarios <sup>a</sup> |                  |  | Exposure scenarios for different furan concentrations in the foods<br>[ $\mu\text{g kg bw}^{-1} \text{ day}^{-1}$ ] |                                     |  |  |  |
|-------------------------------|------------------|--|---|-------------------------------------|--|--|--|
| Age (months)                  | Body weight (kg) | Intake of baby foods ( $\text{g day}^{-1}$ ) | Mean ( $20 \mu\text{g kg}^{-1}$ )   | Median ( $18 \mu\text{g kg}^{-1}$ ) | 90th percentile ( $44 \mu\text{g kg}^{-1}$ ) | 95th percentile ( $54 \mu\text{g kg}^{-1}$ ) | 99th percentile ( $68 \mu\text{g kg}^{-1}$ ) |
| 3                             | 5.8              | 67   | 0.2   | 0.2                                 | 0.5  | 0.6  | 0.8  |
| 6                             | 7.5              | 195  | 0.5   | 0.5                                 | 1.1  | 1.4  | 1.8  |
| 9                             | 8.6              | 234  | 0.5   | 0.5                                 | 1.2  | 1.5  | 1.9  |
| 12                            | 9.4              | 208  | 0.4   | 0.4                                 | 1.0  | 1.2  | 1.5  |

19 <sup>a</sup> Data from Kersting et al. (1998). Only ready-to-eat baby foods and beverages were  
 20 included in the consumption estimate (dry infant formulae and dry processed cereal-  
 21 based foods were not included in this evaluation)

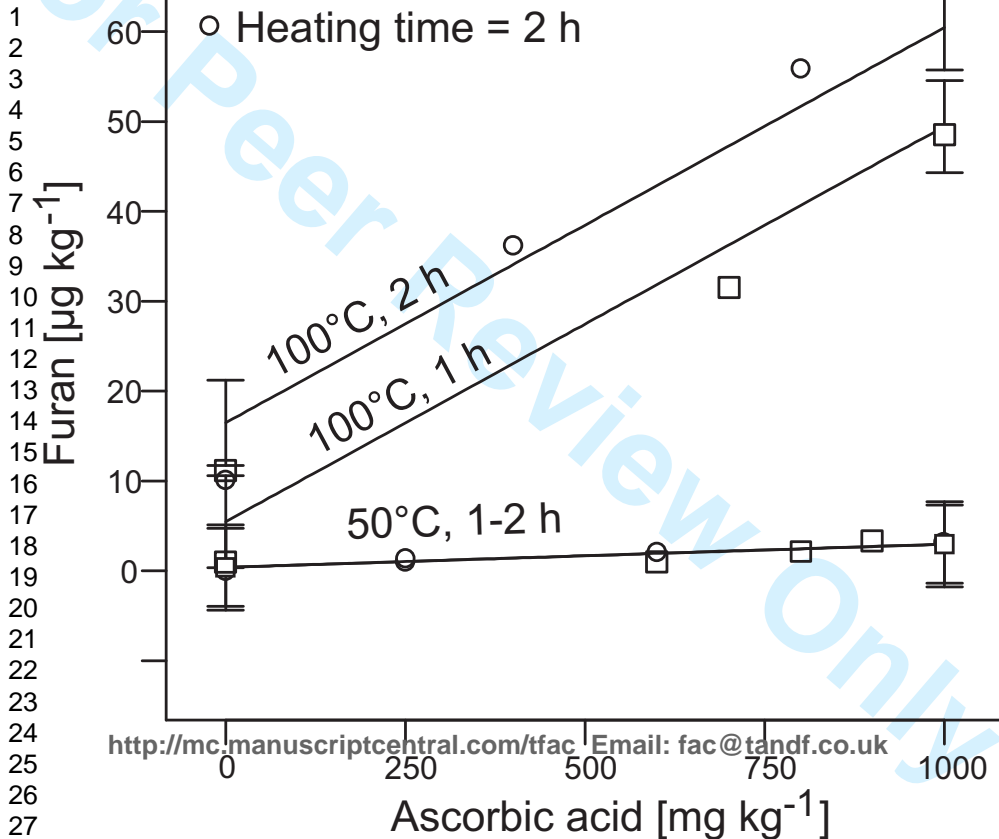
23 *Table 6.* Margin of Exposure (MOE) for furan in the different exposure scenarios (MOE  
 24 = T25 / Exposure). Calculated with T25 of  $1.4 \text{ mg kg bw}^{-1} \text{ day}^{-1}$  from Sanner et al.  
 25 (2001).

| Age (months) | MOE for different exposure scenarios |                                     |  |  |  |
|--------------|--------------------------------------|-------------------------------------|--|--|--|
|              | Mean ( $20 \mu\text{g kg}^{-1}$ )    | Median ( $18 \mu\text{g kg}^{-1}$ ) | 90th percentile ( $44 \mu\text{g kg}^{-1}$ ) | 95th percentile ( $54 \mu\text{g kg}^{-1}$ ) | 99th percentile ( $68 \mu\text{g kg}^{-1}$ ) |
| 3            | 6060                                 | 6733                                | 2754   | 2244   | 1782   |
| 6            | 2692                                 | 2991                                | 1224   | 997  | 792  |
| 9            | 2573                                 | 2858                                | 1169   | 953  | 757  |
| 12           | 3163                                 | 3515                                | 1438   | 1172   | 930  |

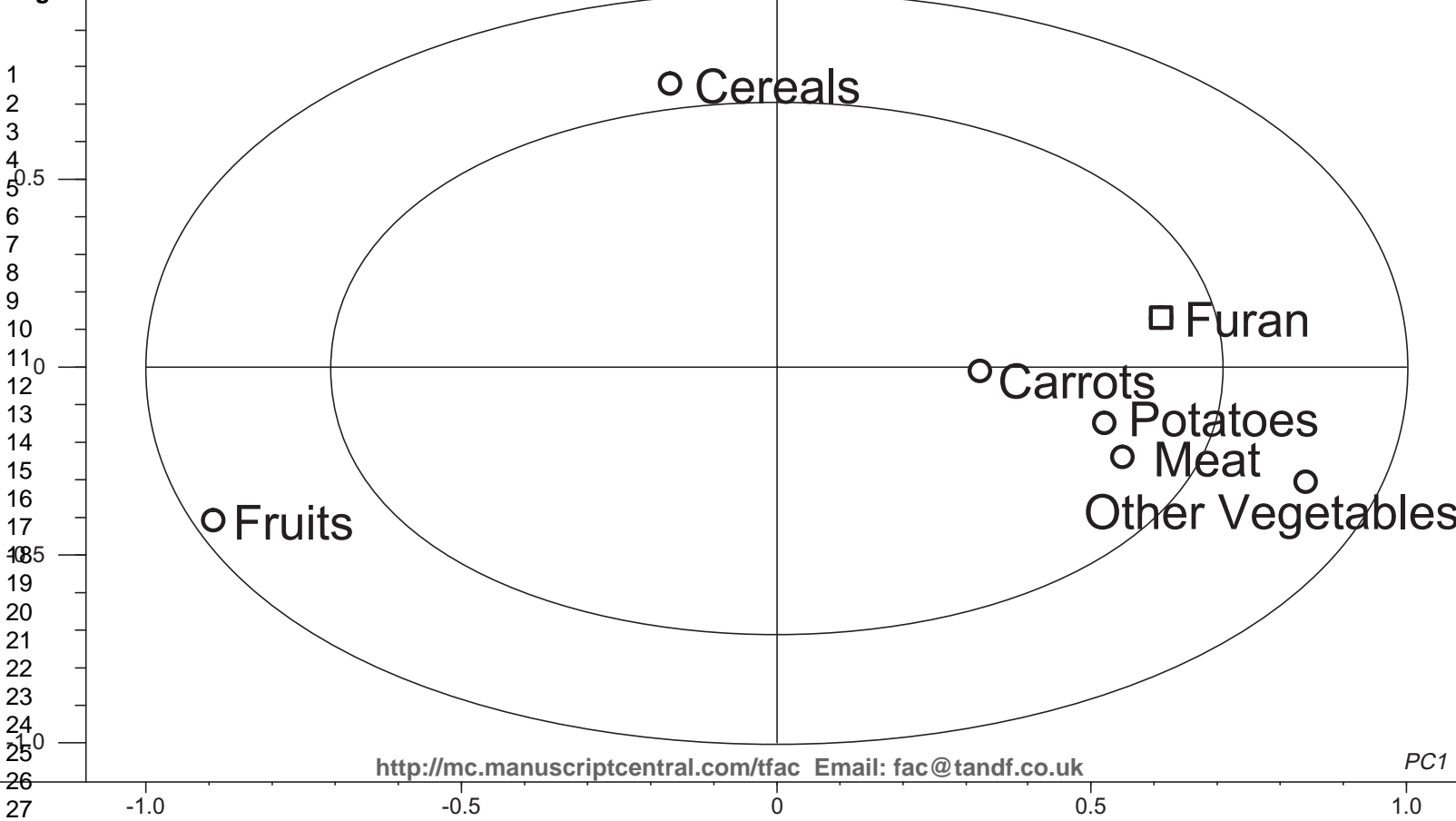
26

□ Heating time = 1 h

○ Heating time = 2 h



Food Additives and Contaminants



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