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Formaldehyde in cultivated mushrooms: a negligible risk for the consumer

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2 1 **FORMALDEHYDE IN CULTIVATED MUSHROOMS: A NEGLIGIBLE RISK FOR THE**
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4 2 **CONSUMER**
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11 5 Wendie Claeys ¹, Christiane Vleminckx ², Alain Dubois ¹, André Huyghebaert ³, Monica Höfte ³,
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14 Abstract

15 Following the detection of formaldehyde in cultivated mushrooms, an evaluation was carried out
16 to assess whether its presence in food poses a risk to public health. Formaldehyde, a
17 carcinogenic chemical, has a broad range of industrial applications and hence, exposure to
18 formaldehyde is ubiquitous through diverse consumer goods, food, the air, etc. The observed
19 levels of formaldehyde in mushrooms are lower than the levels that are reported for vegetables,
20 fruit, meat, fish and dairy products. On the basis of available data, a rough estimate of the
21 dietary exposure to formaldehyde was performed. The exposure through the consumption of
22 cultivated mushrooms (~ 0.19 µg/kg bw per day on average, consumers only) appeared to be
23 small compared to the total dietary intake of formaldehyde (~ 99.0 µg/kg bw per day, total
24 population). Based on comparison with toxicological safety limits for chronic exposure and given
25 that formaldehyde is carcinogenic only through inhalation and not by ingestion, it can be
26 concluded that the dietary exposure to formaldehyde is not a cause for concern.

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31 **Keywords:** *formaldehyde, food, mushrooms, exposure*

32 Introduction

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34 Formaldehyde (CH₂O, CAS 50-0-0) is a colourless, flammable gas that is commercially
35 available as a 35-40% aqueous solution (formalin), as formol (a mixture of formaldehyde, formic
36 acid and methanol in water) or as the precursor hexamethylenetetramine (a complex of
37 formaldehyde with ammonium). In the solid form formaldehyde is available as the trimer
38 trioxane (1,3,5-trioxane or s-trioxane) or as the polymer paraformaldehyde ((CH₂O)_n with n ≥ 8)
39 (IPCS 1989, 2002).

40 Formaldehyde is classified by the "International Agency on Cancer" (IARC) into Group 1,
41 carcinogenic to humans (IARC 2006). Within the EU formaldehyde is currently classified as a
42 category 3 carcinogen with the risk phrase 'R40, limited evidence of a carcinogenic effect'
43 (Directive 2001/59/EC), but discussions are currently taking place to change this classification to
44 category 1 - 'R49, may cause cancer by inhalation'. Most studies regarding the toxicity of
45 formaldehyde relate to the inhalation of formaldehyde, which is probably the most important
46 route of exposure. The available data on the effects of ingestion or of skin contact with
47 formaldehyde are limited. Since formaldehyde is water soluble, highly reactive with biological
48 macromolecules (formaldehyde induces DNA-protein and protein-protein cross-links) and
49 rapidly metabolized, the effects of exposure are mainly observed in those tissues or organs
50 which come into first contact with formaldehyde, namely the respiratory and gastrointestinal
51 tract, oral and gastro-intestinal mucosa included (erosion, ulceration, inflammation and
52 hyperplasia of stomach and fore-stomach were observed in rats) (IPCS 1989, 2002; BfR 2006 a
53 & b; IARC 2006). There is no evidence that formaldehyde is carcinogenic by the oral route
54 (EFSA 2006). Formaldehyde causes toxicity to the nasal epithelium of rats and mice upon
55 inhalation and induces above certain concentrations dose-related increases in nasal tumours.
56 Epidemiological data have shown that formaldehyde is carcinogenic in human by the inhalation
57 route (nasopharyngeal cancers and sinonasal cancers). While a genotoxic mode of action
58 (MOA) can never be ruled out for a compound that is clearly genotoxic, at least *in vitro* and
59 locally *in vivo*, the MOA would be based on the induction at the site of contact of sustained
60 cytotoxicity and cell proliferation upon long-term exposure (McGregor *et al.* 2006).

1
2 61 Formaldehyde is produced industrially for a large number of applications such as the
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4 62 production of resins that act as adhesives and binders for wood products, pulp, paper, glass
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6 63 wool and rock wool, and the production of some plastics, coatings, paints and varnishes,
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8 64 industrial chemicals and textile finishing. It is also used in packaging, cosmetics and as a
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10 65 disinfectant and preservative. For example, formaldehyde is currently allowed as a preservative
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12 66 under the form of hexamethylene tetramine (E 239) in Provolone cheese at a residual
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14 67 concentration of 25 mg/kg expressed as formaldehyde (Directive 95/2/EC). For materials and
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16 68 articles made of plastic that come into contact with food, a specific migration limit (SML) of 15
17
18 69 mg/kg is set for formaldehyde (Directive 2002/72/EC).

20
21 70 In the context of its monitoring programme, the Belgian Federal Agency for the Safety of the
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23 71 Food Chain (FASFC) analysed formaldehyde in cultivated mushrooms. In Belgium the use of
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25 72 formaldehyde as a disinfectant in the cultivation of mushrooms is not allowed. However, there
26
27 73 are biocides admitted that contain formaldehyde and the regulation provides the possibility of
28
29 74 exemptions for mushroom substrates and fertilisers (Royal Decree of January 7th, 1998 on the
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31 75 trade in fertilizers, soil improvers and growing substrates). Currently, there are no European nor
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33 76 Belgian standards for formaldehyde in mushrooms. The main objective of this paper is to
34
35 77 evaluate if the presence of formaldehyde in cultivated mushrooms poses a risk to consumers
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37 78 and if regular control of formaldehyde in cultivated mushrooms is necessary. To place the
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39 79 potential risk into perspective, the total dietary exposure to formaldehyde is considered as well.
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45 82 **Materials & Methods**

46 83 *Samples*

47 84 A first batch of mushrooms (*Agaricus*, *Pleurotus*) was sampled in the context of the
48
49 85 monitoring programme of the FASFC. Mainly mushrooms of Belgian origin were sampled, but
50
51 86 also imported mushrooms were considered (Table 1). Next, an inquiry was performed at
52
53 87 corresponding Belgian production sites, where a second mushroom sample (ready for
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55 88 harvesting), a sample of the compost bed and a sample of the casing soil were taken. Samples
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57 89 were stored frozen until analysis.
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4 91 *Analysis of formaldehyde*
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6 92 Formaldehyde levels in mushrooms and substrates were analysed after extraction with
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8 93 acetonitrile and derivatization with dinitrophenylhydrazine (DNPH) by HPLC with ultra violet -
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10 94 diode array detection (HPLC-UV-DAD, Varian, USA), according to the method described by
11
12 95 Tomkins *et al.* (1998).
13
14

15 96 For the extraction, fresh mushroom (100 g) was mixed with 1acetonitrile (100 ml) and
16
17 97 placed for 30 min in an ultrasonic bath and for 30 min on an orbital shaker. After filtration, 5 ml
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19 98 DNPH derivatization reagent was added (i.e. 300 mg DNPH dissolved in 50 ml acetonitrile with
20
21 99 0.5 ml H₃PO₄ (85%)). The mixture was further diluted to 200 ml with acetonitrile and placed for 3
22
23 100 h in a thermostatic oven at 40°C. After filtration on a membrane filter (0.45 µm), 20 µl of sample
24
25 101 was injected on a Luna C18 column (250 x 4.6 mm, 5 µm, Phenomenex). Mobile phase A was
26
27 102 acetonitrile, mobile phase B was a 0.02M NaH₂PO₄ solution in acetonitrile at pH 4 (50:50 v/v).
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29 103 Gradient elution started at 0% A, rising after 12 min linearly to 60% A over 2 min, held at 60% A
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31 104 for a further 6 min before returning to the initial conditions. The total injection cycle time was 24
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33 105 min and the flow rate was 1.0 ml/min. The presence of formaldehyde was confirmed by
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35 106 comparison of the samples' retention time (~9.6 min) and characteristic spectrum with a
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37 107 standard sample (formaldehyde solution, > 36.5%, Sigma-Aldrich) at 353 nm. The limit of
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39 108 quantification (LOQ) for 100 g of sample was determined as 0.02 mg/kg.
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45 109 46 110 *Consumption data*

47
48 111 Consumption data were obtained from the Belgian Food Consumption Survey (BFCS)
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50 112 performed in 2004 and coordinated by the Scientific Institute of Public Health (Devriese *et al.*
51
52 113 2005). The survey involved 3,214 participants older than 15 years, which were interviewed twice
53
54 114 about their consumption during the last 24 hours (non-consecutive 24h recall). Participants were
55
56 115 selected by a multistage procedure from the National Register and the fieldwork was spread
57
58 116 over one year to anticipate seasonal effects. The usual food intake was estimated by the Nusser
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60 117 method using C-side software (Dodd 1996).
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2 1193
4 120 **Results & Discussion**5
6 121 *Occurrence of formaldehyde*

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9 122 Formaldehyde is ubiquitous. Possible anthropogenic sources of formaldehyde are
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11 123 combustion (vehicular exhaust, waste, cigarettes, etc.), industrial applications (resins, paints,
12
13 124 etc.) and consumer goods (cosmetics, pesticides, contact materials, etc.).

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15 125 In the atmosphere, formaldehyde is both directly emitted and formed as a result of
16
17 126 photochemical oxidation of reactive organic gases. The concentration of formaldehyde in the air
18
19 127 is generally below 0.001 mg/m³ in rural areas and below 0.020 mg/m³ in urban areas (IARC
20
21 128 2006). The indoor air may contain higher levels of formaldehyde compared to the outdoor air
22
23 129 due to evaporation from furniture, paints and construction materials. Reported levels for indoor
24
25 130 air range between 0.02 and 0.06 mg/m³ (IARC 2006). The formaldehyde level due to
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27 131 occupational exposure (e.g. during the varnishing of furniture and wooden floors, in the finishing
28
29 132 of textiles, in the garment industry, in the treatment of fur and in certain jobs within
30
31 133 manufactured board mills and foundries, ...) is on average 2 mg/kg (Heck & Casanova 2004;
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33 134 IARC 2006). In rainwater, formaldehyde concentrations of 0.1-0.2 mg/l are measured (IPCS
34
35 135 1998). In drinking water, formaldehyde is mainly formed by natural oxidation of humic
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37 136 substances during the ozonation and chlorination of the water or is released into the water from
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39 137 plastic plumbing. Water treated with ozone likely contains less than 50 µg formaldehyde / l
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43 138 (WHO 2005; Owen *et al.* 1990).

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45 139 Formaldehyde is also naturally present in the majority of living organisms. As an
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47 140 intermediary metabolic product formaldehyde is essential for the biosynthesis of certain amino
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49 141 acids. *In vivo* most formaldehyde is probably (reversibly) bound to macromolecules (IPCS
50
51 142 2002). The content of endogenously metabolically formed formaldehyde can range between 3
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53 143 and 12 ng/g tissue (Owen *et al.* 1990). The endogenous concentration of formaldehyde
54
55 144 measured in blood is 2-3 mg/l (IARC 2006). A similar concentration was found in the blood of
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57 145 rats and monkeys (Heck *et al.* 1985; Casanova *et al.* 1988) and a 2 to 4 times higher
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59 146 concentration was observed in the liver and the nasal mucosa of rats (Heck *et al.* 1982).

1
2 147 Additionally, formaldehyde is a natural component of a variety of foodstuffs. Monitoring the
3
4 148 formaldehyde level of food however, has generally been performed sporadically and source-
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6 149 directed and only few data are available to characterize the range and distribution of
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9 150 formaldehyde concentrations in food (IPCS 2002). In the context of the monitoring programme,
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11 151 the FASFC analysed the formaldehyde level of cultivated mushroom samples. The
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13 152 concentration ranged between 0.08 and 0.65 mg/kg ($n = 29$) (Table I). It seems that the
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15 153 formaldehyde concentration of organically cultivated mushrooms (on average 0.34 ± 0.19 mg/kg
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17 154 ($n=5$)), is similar to the concentration measured in conventionally cultivated mushrooms (on
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19 155 average 0.29 ± 0.15 mg/kg ($n = 24$)). (The production of organic food within the EU, as well as
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21 156 the importation of organic food from outside the EU is controlled by EU Regulation 2092/91). No
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23 157 correlation is observed between mushrooms and compost bed or casing soil with respect to the
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25 158 formaldehyde concentration. Moreover, there seems to be no transfer of formaldehyde between
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27 159 substrate treated with formaldehyde and mushrooms (internal communication, data not given).
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30 160 At the production site no indications were found of unauthorized treatment of substrates
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32 161 (compost bed and casing soil) with formaldehyde. Data given in Table I thus concerns
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34 162 endogenously formed formaldehyde.

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37 163 In literature studies considering the presence of formaldehyde in mushrooms are scarce.
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39 164 Existing data concern Shiitake mushrooms, which have a relatively high formaldehyde level. In
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41 165 a study of the British 'Food Safety Agency' (FSA) formaldehyde concentrations in the order of
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43 166 100 to 300 mg/kg were observed in both fresh and partially dried Shiitake mushrooms due to
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45 167 natural production. These formaldehyde concentrations refer however, to a combination of free
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47 168 and 'bound' formaldehyde (i.e. formaldehyde derived from the breakdown of larger molecules by
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49 169 thermal degradation, by acidic and enzymatic hydrolyses, e.g. during analysis). After 6 minutes
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51 170 of cooking, the formaldehyde level was significantly decreased. Preservation for 10 days had no
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53 171 effect on the formaldehyde content of the mushrooms (Mason *et al.* 2004). In an opinion of the
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55 172 French 'Agence Française de Sécurité Sanitaire des Aliments' (AFSSA), it was concluded that
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57 173 a maximum formaldehyde level of 63 mg/kg in fresh Shiitake mushrooms can be considered
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59 174 safe for the consumer (AFSSA 2001). Formaldehyde levels observed in the present study are
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175 well below these values.

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4 177 [Table I]
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8 179 For comparison, literature data regarding the formaldehyde concentration of different
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10 180 foodstuffs are presented in Table II. Formaldehyde levels range between 3 and 60 mg/kg for
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12 181 vegetables and fruits, between < 1 and 34 mg/kg for fish and meat (for crustaceans between 1
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14 182 and 98 mg/kg), and around 1 mg/kg for milk and milk products. For alcoholic beverages, soft
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16 183 drinks and coffee, formaldehyde levels between 0.02 and 16.3 mg/L are reported. It should be
17
18 184 noted however, that literature data are scarce and that data presented in Table II could be
19
20 185 biased (e.g. because they are based on a limited number of samples). Most of the levels
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22 186 reported in Table II are due to the natural occurrence of formaldehyde, but it can not be
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24 187 excluded that some values are a result of processing (e.g. fumigation, the use of formaldehyde-
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26 188 containing food additives, migration from melamine-, phenol- and urea-formaldehyde plastics,
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28 189 addition to feed to improve handling characteristics or as a preservative, etc.). Moreover, the
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30 190 analytical method used to quantify formaldehyde may affect the formaldehyde level measured
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32 191 since there are many potential precursors that can form formaldehyde under certain extraction
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34 192 and derivatization conditions used during analysis (Mason *et al.* 2004).
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41 194 [Table II]
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45 196 *Formaldehyde intake*

46
47 197 Table III presents the intake of formaldehyde through the consumption of cultivated mushrooms
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49 198 based on monitoring data of the FASFC (Table I) and consumption data of the BFCS (IPH
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51 199 2006). The intake was calculated by a deterministic approach multiplying a fixed value for
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53 200 consumption with a fixed value for the formaldehyde level (such as the mean or P97.5), and
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55 201 concerns only consumers of mushrooms and not the whole population. One of the main
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57 202 criticisms of the deterministic approach is its inherent conservatism. Nevertheless, due to its
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59 203 simplicity and its worldwide use and acceptance, this point estimate approach may be used as a
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204 screening tool.

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2 205 On average, the formaldehyde intake due to the consumption of cultivated mushrooms was
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4 206 0.2 µg/kg bw per day. In the (upper) worst case scenario, the intake could amount to 4.0 µg/kg
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6 207 bw per day. In the FSA study cited above, the formaldehyde intake due to consumption of
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8 208 Shiitake mushrooms was estimated to be 0.15-0.16 mg/kg bw. It was concluded that such an
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10 209 intake level poses probably no appreciable risk to public health (Mason *et al.* 2004). The intake
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12 210 determined in the FSA study is two orders of magnitude higher than estimated in the present
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14 211 study. Not only different types of mushrooms were considered in both studies, but also different
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16 212 analytical methods were applied. As mentioned above, the analytical conditions used can affect
17
18 213 the formaldehyde level measured due to the breakdown by thermal degradation, acidic and
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20 214 enzymatic hydrolyses of larger molecules. In the FSA study, formaldehyde levels were
21
22 215 determined after extraction by acid hydrolysis and steam distillation using a spectrophotometric
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24 216 method and LC-MS. Formaldehyde formation and potential routes for its generation in
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26 217 mushrooms by steam distillation under acidic conditions have been described in literature
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28 218 (Tjihak *et al.* 1996 and Yamazaki *et al.* 1980, cited by Mason *et al.* 2004).
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34 220 [Table III]
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39 222 Additionally the total dietary exposure of formaldehyde was estimated deterministically for
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41 223 the whole population (Table IV). Based on the formaldehyde data available in literature, an
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43 224 average formaldehyde intake of approximately 7.5 mg/day (0.10 mg/kg bw per day) was
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45 225 obtained (beverages not included). This is a rough estimate of the actual intake, for one
46
47 226 because it was assumed that each person consumes each day average amounts of fruit,
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49 227 vegetables, meat or fish, milk and dairy products. Also, formaldehyde levels used for
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51 228 calculations were taken arbitrary as the average between the minimum and maximum
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53 229 concentration found in literature and are as such biased (see *supra*). In addition, the effect of
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55 230 *e.g.* cooking before consumption on the formaldehyde content, which can lower the
56
57 231 formaldehyde content of the food by evaporation, was not accounted for. Moreover, the
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59 232 proportion of formaldehyde in foods that is bioavailable and the amount that is in a bound and
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233 unavailable form, is unknown (IPCS 1989, 2002; Health Canada 2001).

1
2 234 A similar exercise was performed by Owen *et al.* (1990), who calculated an annual dietary
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4 235 formaldehyde intake of about 4000 mg/year, equivalent to approximately 11 mg/day. The intake
5
6 236 through drinking water was calculated to be on average less than 40 µg/day. The rough
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8 237 estimate given by the 'International Programme on Chemical Safety' (IPCS 1989) for
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10 238 formaldehyde exposure through food is of the same range, namely between 1.5 to 14 mg/day
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12 239 for an average adult.

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15 240 It is clear that the intake through the consumption of mushrooms is negligible compared to
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17 241 the intake of formaldehyde via the consumption of different food products (only 0.2%).
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21 243 [Table IV]
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26 245 When considering the 'total' exposure to formaldehyde, also other routes of exposure
27
28 246 should be considered such as inhalation and skin absorption by dermal contact (e.g. by use of
29
30 247 cosmetics). The latter route of exposure can be considered negligible (except in certain
31
32 248 workplaces) whereas the first route is probably the most important one. Probabilistic simulations
33
34 249 of Health Canada indicate that through air one of every two persons would be exposed to 24-h
35
36 250 average formaldehyde concentrations of $\geq 20\text{--}24$ µg/l ($24\text{--}29$ µg/m³) and that 1 in 20 persons
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38 251 (i.e. the 95th percentile) would be exposed to 24-h average formaldehyde concentrations in air \geq
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40 252 $67\text{--}78$ µg/l ($80\text{--}94$ µg/m³) (Health Canada 2001). The German 'Bundesinstitut für
41
42 253 Risikobewertung' (BfR) established in a recent toxicological evaluation a tolerable air
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44 254 concentration of 0.1 mg/l formaldehyde, which is in line with the MAC value or 'Maximum
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46 255 Allowable Concentration' of 0.3 mg/l determined to protect workers in the workplace (BfR
47
48 256 2006b).
49
50 257

51 52 258 *Risk Characterization*

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54
55 259 The WHO guideline for drinking water sets a maximum limit of 900 µg formaldehyde/l water
56
57 260 (WHO 2006). The limit was determined on the basis of a TDI ('tolerable daily intake') of 0.15
58
59 261 mg/kg bw per day and assuming that drinking water accounts for 20% of the intake. This TDI
60
262 was established on the basis of a NOAEL ('no observed adverse effect level') of 15 mg/kg bw

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2 263 per day from a 2-year study in rats where irritations of the stomach and papillary hyperplasia
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4 264 were observed at a formaldehyde dose of 82 mg/kg bw per day. Based on the same NOAEL the
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6 265 U.S. Environmental Protection Agency (EPA) determined a chronic reference dose (RfD) of 0.2
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8 266 mg/kg bw per day for oral exposure (U.S. EPA 1990). The formaldehyde intake through
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10 267 consumption of mushrooms estimated in this study is 0.10% of the chronic U.S. EPA RfD and
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12 268 0.13% of the TDI determined by the WHO. As to the total dietary intake, it amounts to more or
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14 269 less 50% and 66% of the U.S. EPA and WHO safety limits respectively.

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16
17 270 The risk associated with the formaldehyde levels measured in food appears thus to be
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19 271 acceptable. Moreover, in an opinion regarding the use of formaldehyde as a preservative in food
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21 272 manufacturing the EFSA AFC Panel ('Panel on food additives, flavourings, processing aids and
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23 273 materials in contact with food') concluded on the basis of recent and past toxicological
24
25 274 evaluations that there is no evidence indicating that formaldehyde is carcinogenic by the oral
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27 275 route (EFSA 2006).

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31 32 277 **Conclusion**

33
34 278 The levels of formaldehyde detected in cultivated mushrooms are generally lower than the
35
36 279 levels reported to occur naturally in vegetables, fruit, meat, fish and dairy products. The
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38 280 consumption of mushrooms results in a formaldehyde intake 1000 times lower than the
39
40 281 toxicological safety limits given by the WHO and the U.S. EPA and contributes only little to the
41
42 282 total formaldehyde intake. Regular control of formaldehyde in cultivated mushrooms is thus not
43
44 283 a priority.

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46
47 284 Due to a lack of data, it is difficult to assess precisely the total dietary intake. Nevertheless,
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49 285 the rough estimate presented in this paper is in line with values reported elsewhere and is 66%
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51 286 of the WHO TDI of 0.15 mg/kg bw per day. Since probably not all formaldehyde is bioavailable
52
53 287 and since there are no indications that formaldehyde is carcinogenic via the oral route, it can be
54
55 288 concluded that the natural occurrence of formaldehyde in food presents no immediate cause for
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57 289 concern.
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3
4 291 **Acknowledgement**

5
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7
8 293 the Safety of the Food Chain for their guidance of this study.
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Table I. Formaldehyde concentration (mg/kg) measured in cultivated mushrooms, compost bed and casing soil.

Mushroom sample 1	Mushroom sample 2	Compost bed	Casing soil	Remarks
0.35	0.40	0.23	0.02	Belgian origin, Conventional farming
0.27	0.08	0.10	< LOQ (0.02)	Belgian origin, Conventional farming
0.31	0.13	0.36	0.02	Belgian origin, Conventional farming
0.30	0.21	0.12	0.05	Belgian origin, Conventional farming
0.21	0.53	0.49	0.06	Belgian origin, Organic farming
	0.56	0.49	0.06	Belgian origin, Organic farming
	0.16	0.28		Belgian origin, Organic farming
0.39	0.38	0.44	0.04	Belgian origin, Conventional farming
0.42				Belgian origin, Conventional farming
0.53	0.18	0.05	0.02	Belgian origin, Conventional farming
0.21				Belgian origin, Conventional farming
	0.18	0.27	0.03	Belgian origin, Conventional farming
	0.30	0.20	0.03	Belgian origin, Conventional farming
0.16	0.07	0.34		Belgian origin, Conventional farming; 5.1 mg formaldehyde / kg was measured in supplementary feeding
0.18	0.09	0.30		Belgian origin, Conventional farming
0.65				Belgian origin, Conventional farming
0.24				Dutch origin, Organic farming
0.28				Polish origin, Conventional farming
0.34				Polish origin, Conventional farming
0.45				Polish origin, Conventional farming

5 **Table II.** Formaldehyde level of different foodstuffs reported in literature .

Food	Concentration mg/kg (litre)	Remarks	Ref.
<i>Fruit & vegetables</i>			
Apples	17.3 (38.7) ^a	Colorimetric determination using chromotropic acid (Schiff 's reagent)	(1)
	6.3-22.3		(2)
Banana	16.3		(2)
Pears	60 (38.7) ^a	Colorimetric determination using chromotropic acid (Schiff 's reagent)	(1)
Cauliflower	4.7 (5.3) ^a	Colorimetric determination using chromotropic acid (Schiff 's reagent)	(1)
	26.9		(2)
Carrots	6.7 (10) ^a	Colorimetric determination using chromotropic acid (Schiff 's reagent)	(1)
Onion	13.3 (26.3) ^a	Colorimetric determination using chromotropic acid (Schiff 's reagent)	(1)
Spinach	3.3 (7.3) ^a	Colorimetric determination using chromotropic acid (Schiff 's reagent)	(1)
Tomatoes	5.7 (7.3) ^a	Colorimetric determination using chromotropic acid (Schiff 's reagent)	(1)
Radish	3.7 (4.4) ^a	Colorimetric determination using chromotropic acid (Schiff 's reagent)	(1)
Shiitake mushrooms	100 - 406 / 6 - 54.4		(2)
	100-320	Colorimetric determination using chromotropic acid and dimedone/ammonium acetate derivative measured by LC-MS/MS	(3)
<i>Meat products</i>			
Beef	0.094 ± 0.044	France	(4)
	0.079 ± 0.051 and	European Member States	(4)
	0.161 ± 0.071		
Poultry	5.7	Colorimetric analysis	(1)
	2.3 - 5.7		(4)
Pork	20	Colorimetric determination using chromotropic acid	(1)
Sheep	8		(1)
Beef, pork, sheep and chicken	2.5 - 20		(2)
<i>Fish products</i>			
Freshwater fish	8.8	Fumigated, colorimetric analysis	(1)
Sea fish	20	Fumigated, colorimetric analysis	(1)
Cod	20	Frozen	(1)
	4.6 – 34		(2)
Crustaceans	1-60	Mediterranean	(1)
	3-98	Ocean	(1)
Shrimp	1	Live, HPLC	(1)
<i>Milk & dairy products</i>			
Milk	0.041 ± 0.045	France	(4)
Goat's milk	1		(1)
Cow's milk	Up to 3.3	Colorimetric analysis	(1)
Fresh milk	0.013-0.057	(mean = 0,027 mg/l)	(5)
Treated milk	0.075-0.255	(mean = 0,164 mg/l)	(5)
Cheese	up to 3.3	Colorimetric analysis	(1)
Dairy products	0.02		(4)
<i>Beverages</i>			
Alcoholic beverages	0.04-1.7	Fluorescence detection after on-line condensation with 4-amino-3-penten-2-one (Japan)	(5)
	0.02-3.8	Spectrofluorimetric determination (Brazil)	(5)

1				
2	Soft drink	7.4-8.7	4 samples of canned and bottled cola (Canada);	(6)
3			HPLC-MS of DNPH-derivative	
4		< 2 (LOD) ^a	5 samples of canned soft drink (UK); HPLC of	(7)
5			DNPH derivative	
6	Beer	0.1-1.5	9 samples of canned and bottled beer	(6)
7			(Canada); HPLC-MS of DNPH-derivative	
8		< 1 (LOD)	5 samples of canned beer (UK); HPLC of DNPH	(7)
9			derivative	
10	Coffee	3.4-4.5	Higher levels of formaldehyde were found in	(8)
11			instant coffees than in brewed coffees, perhaps	
12	Instant coffee	10-16.3	because formaldehyde escapes from coffee	(8)
13			during brewing (USA)	
14				

15 7

16 8 (1) IPCS (1989); (2) CFS (2008); (3) Mason *et al.* (2004); (4) Afssa (2004); (5) IPCS (2002); (6) Lawrence

17 9 & Iyengar (1983); (7) FSA (1998) (8) Hayashi *et al.* (1986)

18 10 ^(a) limit of detection

11 **Table III.** Intake of formaldehyde by the consumption of mushrooms.

12

	[Formaldehyde] ¹ Consumption ²		Intake ³	
	mg/kg	g/day	mg/day	µg/kg bw per day
Mean	0.288	49	0.01	0.19
P50	0.275	34	0.01	0.12
P95	0.547	160	0.09	1.15
P97,5	0.585	200	0.12	1.54
P99	0.624	233	0.15	1.91
P100	0.650	465	0.30	3.98

13

14 ¹ 29 samples, see Table I

15 ² usual consumption of the Belgian population ('consumers only') – 460 consumption days (Devriese *et*
16 *al.* 2005)

17 ³ calculated deterministically; the body weight was assumed to be 76 kg

18 **Table IV.** Formaldehyde intake by the consumption of different foodstuffs.

19

	[Formaldehyde] ¹	Average consumption ²	Intake ³	
	mg/kg	g/day	mg/day	µg/kg bw per day
Vegetables ⁴	15.1	138.3	2.1	27.48
Fruit	33.2	118.2	3.9	51.56
Meat	10.0	120.7	1.2	15.92
Fish and seafood	49.5	23.9	1.2	15.57
Milk and dairy beverages	1.7	90.6	0.2	1.97
Cheese	1.7	30.2	0.1	0.66
Yoghurt and pudding	1.7	63.1	0.1	1.38

20 ¹ concentration = average of minimum and maximum concentration reported (Table II); it was assumed
 21 that preparation of food (e.g. cooking) did not reduce the formaldehyde concentration

22 ² usual average consumption of the Belgian population (Devriese *et al.* 2005)

23 ³ calculated deterministically; the body weight was assumed to be 76 kg

24 ⁴ Shiitake mushrooms excluded