Polycyclic Aromatic Hydrocarbons in Food[1]

Scientific Opinion of the Panel on Contaminants in the Food Chain

(Question N° EFSA-Q-2007-136)

Adopted on 9 June 2008

SUMMARY

Polycyclic aromatic hydrocarbons (PAHs) constitute a large class of organic compounds that are composed of two or more fused aromatic rings. They are primarily formed by incomplete combustion or pyrolysis of organic matter and during various industrial processes. PAHs generally occur in complex mixtures which may consist of hundreds of compounds. Humans are exposed to PAHs by various pathways. While for non-smokers the major route of exposure is consumption of food, for smokers the contribution from smoking may be significant. Food can be contaminated from environmental sources, industrial food processing and from certain home cooking practices.

In the past decade PAHs were evaluated by the International Programme on Chemical Safety (IPCS), the Scientific Committee on Food (SCF) and by the Joint FAO/WHO Expert Committee on Food Additives (JECFA). SCF concluded that 15 PAHs, namely benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene, benzo[*ghi*]perylene, benzo[*a*]pyrene, chrysene, cyclopenta[*cd*]pyrene, dibenz[*a,h*]anthracene, dibenzo[*a,e*]pyrene, dibenzo[*a,h*]pyrene, dibenzo[*a,i*]pyrene, dibenzo[*a,l*]pyrene, indeno[1,2,3-*cd*]pyrene and 5-methylchrysene show clear evidence of mutagenicity/genotoxicity in somatic cells in experimental animals *in vivo* and with the exception of benzo[*ghi*]perylene have also shown clear carcinogenic effects in various types of bioassays in experimental animals. Thus, SCF reasoned that these compounds may be regarded as potentially genotoxic and carcinogenic to humans and therefore represent a priority group in the assessment of the risk of long-term adverse health effects following dietary intake of PAHs. SCF suggested to use benzo[*a*]pyrene as a marker of occurrence and effect of the carcinogenic PAHs in food, based on examinations of PAH profiles in food and on evaluation of a carcinogenicity study of two coal tar mixtures in mice.

---

[1] For citation purposes: Scientific Opinion of the Panel on Contaminants in the Food Chain on a request from the European Commission on Polycyclic Aromatic Hydrocarbons in Food. *The EFSA Journal* (2008) 724.

Using the assessments of IPCS and SCF as starting points and taking into account newer studies, the JECFA re-evaluated PAHs in 2005. Overall, the JECFA concluded that 13 PAHs are clearly genotoxic and carcinogenic. Except benzo[*ghi*]perylene and cyclopenta[*cd*]pyrene the compounds were the same as those stated by SCF. The JECFA also concluded that benzo[*a*]pyrene could be used as a marker of exposure to, and effect of, the 13 genotoxic and carcinogenic PAHs. In addition, the JECFA recommended to include benzo[*c*]fluorene as a further compound into future analyses as data on its occurrence in food are still scarce but rat studies indicate that benzo[*c*]fluorene may contribute to the formation of lung tumours after oral exposure to coal tar.

Following a recommendation on the further investigation into levels of PAHs in certain foods (2005/108/EC)[2], eighteen Member States submitted almost 10,000 results for PAH levels in different food commodities. An evaluation of these data performed by EFSA in June 2007 and updated in June 2008 demonstrated that benzo[*a*]pyrene could be detected in about 50% of the samples. However, in about 30% of all the samples other carcinogenic and genotoxic PAHs were detected despite testing negative for benzo[*a*]pyrene. Of the individual PAHs, chrysene was most commonly found in the samples negative for benzo[*a*]pyrene with the highest level of 242 µg/kg. In view of these findings, the Commission requested a full review of the 2002 SCF opinion on PAHs.

The EFSA Panel on Contaminants in the Food Chain (CONTAM Panel) reviewed the available data on occurrence and toxicity of PAHs. As no new toxicological data could be identified that would lead to the inclusion of further compounds into the list of priority PAHs, the CONTAM Panel decided to cover the 15 PAHs identified by SCF in 2002 and additionally benzo[c]fluorene as suggested by the JECFA in 2005 in the present opinion. Special attention was paid to those eight carcinogenic and genotoxic PAHs that were measured in the coal tar mixtures used in the carcinogenicity studies, which provided the basis of the SCF and JECFA risk assessments.

The CONTAM Panel explored whether a toxic equivalency factor (TEF) approach in the risk characterisation of the PAH mixtures in food could be applied and concluded that the TEF approach is not scientifically valid because of the lack of data from oral carcinogenicity studies on individual PAHs, their different modes of action and the evidence of poor predictivity of the carcinogenic potency of PAH mixtures based on the currently proposed TEF values. Therefore the CONTAM Panel concluded that the risk characterisation should be based upon the PAHs for which oral carcinogenicity data were available, i.e. for benzo[*a*]pyrene and the other PAHs that were measured in the two coal tar mixtures used in the carcinogenicity studies of Culp *et al.* (1998): benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*ghi*]perylene, chrysene, dibenz[*a,h*]anthracene and indeno[*1,2,3-cd*]pyrene. The CONTAM Panel concluded

[2] OJ L 34, 8.2.2005, p.43

that these eight PAHs (PAH8), either individually or in a combination, are currently the only possible indicators of the carcinogenic potency of PAHs in food.

In total, results from 9714 PAH analyses in 33 food categories/subcategories were evaluated. As in about 30% of the samples analysed for all 15 priority PAHs as recommended by SCF other carcinogenic and genotoxic PAHs were detected despite testing negative for benzo[*a*]pyrene, individual compounds were grouped and summed in order to check whether their sums would better reflect the occurrence of carcinogenic and genotoxic PAHs in different food categories. The selection of the individual PAHs was based on the frequency of their results above the limit of detection (LOD).

Besides the sum of the above mentioned eight PAHs (PAH8), the sum of benzo[*a*]pyrene, chrysene, benz[*a*]anthracene and benzo[*b*]fluoranthene (PAH4) as well as the sum of benzo[*a*]pyrene and chrysene (PAH2) were calculated. The correlation between PAH2 and PAH4 or PAH8 was 0.92 and between PAH4 and PAH8 was 0.99. Of samples negative for PAH2, 26% and 18% identified concentrations above the LOD for at least one other PAH for samples tested for all PAH15 or all PAH8, respectively. The frequency varied between 2% and 9% for the individual PAHs or PAH combinations. Of samples negative for PAH4, 14% and 6% identified concentrations above the LOD for at least one other PAH for samples tested for all 15 PAHs or all PAH8, respectively. The frequency varied between 1% and 6% for the individual PAHs or PAH combinations. Overall, the Panel concluded that PAH4 and PAH8 were better indicators of the occurrence of PAHs than PAH2.

For different food categories and subcategories, the data on PAH8, PAH4 and PAH2 were then used for the exposure calculation as well as the estimation of margins of exposure (MOEs) based on the bench mark dose lower confidence limit for a 10% increase in the number of tumour bearing animals compared to control animals ($BMDL_{10}$).

The median dietary exposure across European countries was calculated both for mean and high dietary consumers and varied between 235 ng/day (3.9 ng/kg b.w. per day) and 389 ng/day (6.5 ng/kg b.w. per day) respectively for benzo[*a*]pyrene alone, 641 ng/day (10.7 ng/kg b.w. per day) and 1077 ng/day (18.0 ng/kg b.w. per day) respectively for PAH2, 1168 ng/day (19.5 ng/kg b.w. per day) and 2068 ng/day (34.5 ng/kg b.w. per day) respectively for PAH4 and 1729 ng/day (28.8 ng/kg b.w. per day) and 3078 ng/day (51.3 ng/kg b.w. per day) respectively for PAH8. The two highest contributors to the dietary exposure were cereals and cereal products, and sea food and sea food products.

The CONTAM Panel used a MOE approach based on dietary exposure for average and high level consumers to benzo[*a*]pyrene, PAH2, PAH4 and PAH8, respectively and their corresponding $BMDL_{10}$ values derived from the two coal tar mixtures that were used in the carcinogenicity studies of Culp *et al*. (1998). The resulting MOEs for average consumers were 17,900 for benzo[*a*]pyrene, 15,900 for PAH2, 17,500 for PAH4 and 17,000 for PAH8. For high level consumers, the respective MOEs were 10,800, 9,500, 9,900 and 9,600. These MOEs indicate a

low concern for consumer health at the average estimated dietary exposures. This applies to the full range of estimates of average exposures across EU Member States (3.1-4.3 ng/kg b.w. per day, MOEs: 16,300-22,600 for benzo[*a*]pyrene alone and 23.6-35.6 ng/kg b.w. per day, MOEs: 13,800-20,800 for PAH8). However, for high level consumers the MOEs are close to or less than 10,000, which as proposed by the EFSA Scientific Committee indicates a potential concern for consumer health and a possible need for risk management action. Comparison of the MOEs calculated for benzo[*a*]pyrene, PAH2, PAH4 and PAH8, indicates that PAH2, PAH4 and PAH8 can be used as alternatives to benzo[*a*]pyrene alone as markers of the carcinogenicity of the genotoxic and carcinogenic PAHs, and would be equally effective.

The CONTAM Panel concluded that benzo[*a*]pyrene is not a suitable indicator for the occurrence of PAHs in food. Based on the currently available data relating to occurrence and toxicity, the CONTAM Panel concluded that PAH4 and PAH8 are the most suitable indicators of PAHs in food, with PAH8 not providing much added value compared to PAH4.

Keywords: Polycyclic aromatic hydrocarbons (PAHs), food, occurrence, indicators, exposure, risk assessment, benchmark dose lower confidence limit (BMDL), margin of exposure (MOE), toxic equivalency factor (TEF)