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Reassessment of the acrylamide risk: Belgium as a case-study

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ABSTRACT

Acrylamide is a food process contaminant with carcinogenic and genotoxic properties. As a result of intensive research, numerous mitigation initiatives to prevent its formation were suggested and various of them were implemented in the food chain. To evaluate if the mitigation strategies applied were significant, a comparison was made between two time periods (2002–2007 versus 2008–2013) in terms of acrylamide food levels and dietary exposure in Belgian.

The most important changes observed are a significant decrease of the acrylamide content in potato crisps and gingerbread, and a significant increase in (instant) coffee. Additionally, the acrylamide content of breakfast cereals, bread and rolls, chocolate and baby biscuits showed a downward trend, whereas for coffee substitute and ready-to-eat French fries (mainly obtained from catering facilities), an upward, although not significant, trend was observed. These changes resulted in only a slight, but insignificant decline of the overall dietary exposure of adults, adolescents and children.

The mean and P95 intake estimated in the 2008–2013 period for these consumer groups corresponded to margins of exposure (MOE) ranging between 515 and 236 and between 155 and 71, respectively, when based on the endpoint for neoplastic effects ($BMDL_{10}$ = 0.17 mg/kg bw per day). Such low MOE values indicate that acrylamide remains an issue for public concern, requiring renewed attention.

1. Introduction

Acrylamide (AA, CH_2=CHCONH$_2$, CAS nr. 79-0601) is almost exclusively used for the synthesis of polyacrylamides, which have various applications, such as in waste water treatment and paper processing. Its presence was also reported in tobacco smoke (ECB, 2002). In 2002 unexpected high levels of this chemical substance were found in various foods, leading to intensive research encompassing its occurrence, analysis, chemistry and toxicology (Claeys, De Vleeschouwer, & Hendrickx, 2005; EFSA, 2008; Friedman & Levin, 2008; JECFA, 2005; Stadler & Scholz, 2004; Taeymans et al., 2004; Tardiff, Gargas, Kirman, Carson, & Sweeney, 2010).

AA is neurotoxic and probably also carcinogenic and genotoxic for humans (IARC, 1994; JECFA, 2005). It is naturally formed at temperatures above 120 °C (and low moisture), principally via the Maillard reaction and mainly in foods containing free asparagine and reducing sugars.

Since its finding in food, AA levels were monitored in various countries and the observed results indicated a public health concern. As such, several research-based initiatives were taken in order to reduce the level of this process contaminant in food, amongst which the regular organization of stakeholder meetings, workshops and forums (Busk, 2010). For instance, the European Commission (EC) and Food Drink Europe (FDE, formerly the Confederation of the European Food and Drink Industry or CIAA)

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organized a joint workshop in 2006, where government, industry and academia discussed the issue. The workshop resulted in a number of concrete actions, including a European monitoring program of the AA levels in a number of foods (Recommendation 2007/331/EC, later extended by Recommendation 2010/307/EU) and the development and dissemination of sector-specific brochures and leaflets offering small to medium sized food companies guidelines for minimizing the AA content of their products (EFSA, 2009). The FDE developed additionally the "AA Toolbox", a regularly updated guide for industry with possible intervention steps for reducing AA levels in food (FDE, 2014). Similarly the European Potato processors' association launched the multilingual GoodFries initiative (www.goodfries.eu) for food services and consumers.

From the onset of the AA issue, the Belgian Federal Agency for the Safety of the Food Chain (FASFC) monitors the AA content of different foodstuffs. Based on monitoring results obtained between 2002 and 2007, the AA intake of the Belgian population was evaluated a first time and potential mitigation strategies were evaluated (Claeys et al., 2010). Since then, a large amount of new data on AA levels in food and on AA toxicity became available (EFSA, 2015). Therefore, AA data measured in food between 2008 and 2013 are reassessed in the present paper, not only to reevaluate the risk related to the AA intake of the Belgian population, but also to discuss the potential progress at the industrial and food service level regarding the minimization of AA in food products.

2. Material & methods

2.1. Acrylamide levels

AA levels were monitored in various foodstuffs on the Belgian market within the framework of the control programme of the FASFC (Maudoux et al., 2006). The AA content of the food samples was determined by a liquid chromatography-mass spectrometry (LC-MS)-ISO 17025 accredited method in the Federal Laboratory for the Safety of the Food Chain (FLVVG, 9050 Gentbrugge, Belgium), with a limit of quantification (LOQ) of 50 μg/kg and a limit of detection (LOD) of 25 μg/kg. More details are provided in Claeys et al. (2010).

Foods were grouped in different categories according to their AA level and in line with the grouping applied in other studies (Boon et al., 2005; Claeys et al., 2010; EFSA, 2012a, 2015; Matthys et al., 2005; Mestdagh et al., 2007) and as specified in Recommendation 2013/647/EU on investigations into the levels of AA in food. AA concentrations below the LOQ were replaced by LOQ/2 (middle-bound scenario).

Most samples concerned ready-to-eat foods. Regarding French fries, most samples were taken at the level of catering (e.g. chip shops, community kitchens). Only 10 samples were taken in 2011 of pre-cooked, frozen fries, which were fried according to the instructions mentioned on the packaging prior to analysis.

The distributions of AA levels analyzed in the period 2008–2013 and in the period 2002–2007 were compared with the Kruskall-Wallis test (SPSS 21; SPSS Inc., USA).

2.2. Food consumption data

To estimate the AA intake of the Belgian population, three different food consumption databases were used.

Food consumption data of adults were obtained from the Belgian Food Consumption Survey (BFCS) performed in 2004 by the Scientific Institute of Public Health (Devriese et al., 2005). The survey involved 3214 participants of 15 years or older, which were interviewed twice about their consumption during the last 24 h (repeated non-consecutive 24 h recall) in combination with a self-administered food frequency questionnaire.

Consumption data of adolescents were received from the Department of Public Health, Ghent University. The Belgian chapter of the survey, which was performed in the framework of the European HELENA project (Moreno et al., 2008), involved 245 adolescents aged between 12.5 and 17.5 years (Ghent region) who completed a 24-h recall twice (once by self-report and once by interview) using the YANA-C tool (Young Adolescents Nutrition Assessment on Computer) (Vereecken et al., 2008).

Consumption data of children were obtained from a dietary pattern study in pre-school children conducted in Flanders (Dutch-speaking part of Belgium) between 2002 and 2003 by the Department of Public Health, Ghent University. Diets of 662 pre-school children between 2.5 and 6.5 years old were assessed with parentally reported estimated dietary records for 3 days (Huybrechts & De Henauw, 2007).

The individual intakes over the different survey days were considered without the application of a usual-intake model. As a consequence, exposure estimates are probably more conservative, particularly with regard to the upper tail of the distribution (Kettler et al., 2015; Van Klaveren, Goedhart, Wapperom, & van der Voet, 2012). However, recent findings on the impact of usual intake models on the dietary exposure estimation of AA have shown that the use of usual-intake model did not bring any changes in terms of risk assessment (Mancini, Sirot, Busani, Volatier, & Hulin, 2015).

2.3. Estimation of the acrylamide intake

The dietary exposure to AA was determined by a probabilistic approach considering all data or the full distribution of the different variables (i.e. AA content and consumption). The variability of the consumption and contamination levels was characterized by a non-parametric, discrete, uniform distribution. By means of Monte Carlo simulations, individual consumption data and AA concentration data were sampled randomly by the Latin Hypercube method from the databases and combined for the relevant food consumed. Summing over foods provided an estimate of the exposure distribution. All estimated exposures were adjusted for the individual's body weight reported in the surveys and expressed as μg/kg bw/day. The number of Monte Carlo simulations was 100,000. To quantify the uncertainties in the exposure calculations due to sampling uncertainty of consumption and concentration data, the bootstrap method was used. With this method a bootstrap database is generated of the same size as the original database for both consumption and concentration by a theoretical resampling from the original databases. These two bootstrap databases are then used for the Monte Carlo exposure calculation and derivation of the relevant percentiles. By repeating this process 500 times, 500 'bootstrap' datasets are obtained, on which the same statistical calculations (e.g. 97.5th, 99.9th percentile, etc.) can be applied as on the original dataset. As such a 'bootstrap' distribution of 500 97.5th, 99.9th percentiles, etc. is created that characterizes the uncertainty of the original dataset (Vose, 2008). Calculations were performed by the software @Risk® (Palisade Corporation, Version 6, NY, USA).

For the conversion of the AA level of roasted or grounded coffee beans (coffee surrogate) to liquid coffee (coffee surrogate) a conversion factor of 0.046 was applied (van Dooren, Boeijen, van Klaveren, & van Donkersgoed, 1995). Variability in preparation conditions (e.g. deep-frying of crisps, toasting of bread, etc.) was not taken into account.