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Dietary exposure to acrylamide in adolescents from a Canadian urban center

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ABSTRACT

The distribution of acrylamide in food items frequently consumed by Canadian adolescents was determined along with estimates of their contribution to the overall dietary intake of acrylamide. A total of 196 non-smoking adolescents (10–17 years old) were recruited in Montreal Island population, Canada. Participants were invited to fill out a 2-day food diary and a food frequency questionnaire over the last month. 146 samples of foods most frequently consumed by participants were analyzed for acrylamide contents. The highest acrylamide contents were measured in deep-fried french fries and potato chips (mean ± SD: 1053 ± 657 and 524 ± 276 ng/g respectively). On the basis of the 2-day food diary, median total daily intake of acrylamide was estimated at 0.29 μg/kg bw/d, as compared to 0.17 μg/kg bw/d on the basis of the food frequency questionnaire. These values are similar to those reported in comparable populations. Deep-fried french fries consumption contributed the most to daily acrylamide intake (50%) followed by potato chips (10%), oven-baked french fries (8%) and breakfast cereals (8%). Margins of exposure based on genotoxic benchmark dose limits were estimated to be low (≈<100) in high-consumer adolescents, indicating the need to continue efforts to reduce dietary acrylamide exposure.

1. Introduction

In April 2002, the identification of acrylamide in a variety of commonly consumed food raised public health concern (WHO, 2002). Acrylamide has been classified as a probable human carcinogen (Group 2A) (IARC, 1994) and is an effective clastogen (FAO/WHO, 2011). The neurotoxicity of acrylamide in humans is also well established following occupational or accidental exposures, while experimental studies have shown adverse reproductive effects in animals (WHO, 2011).

Acrylamide is formed when food high in carbohydrates and low in proteins are cooked at high temperature or undergo thermal processing at temperatures of 120 °C or higher (JECFA, 2006). It is formed by a Maillard reaction, in which the free amino acid asparagine is decarboxylated and deaminated in the presence of reducing sugars or other carbonyl compounds during heating (JECFA, 2011). Most acrylamide is generated during final stages of baking, grilling or frying processes as food loses its moisture contents and surface temperature rises (JECFA, 2006).

Potato chips (European potato crisps) and french fries (European potato chips) are among the food items that contain the highest levels of acrylamide, although concentrations may vary significantly from one item to the other. Becalski et al. (2003) documented concentrations of acrylamide in commercial potato chips and french fries ranging from 530 to 3700 ng/g and 200 to 1900 ng/g, respectively. Breakfast cereals, cookies, brewed coffee and bread were also found to contain varying concentrations of acrylamide (Dybing et al., 2005).

Dietary acrylamide exposure estimates are mainly available for the general adult population; they have been documented to range from 0.3 to 0.8 μg/kg bw/d and may reach 6 μg/kg bw/d for the 98th percentile consumer (WHO, 2002). Dietary acrylamide intake in children, youngsters and adolescents has been suggested to be significantly higher than that of adults (Dybing et al., 2005). The

Abbreviations: JEFCA, Joint FAO/WHO Expert Committee on Food Additives; LC–MS/MS, liquid-chromatography tandem mass-spectrometry; LOQ, limit of quantification; MOE, margin of exposure.

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WHO (2002) reported that acrylamide intake in children is generally two to threefold higher than that of adults, when expressed on a body weight basis. In addition to having a higher average food intake per kg body weight than adults, children and adolescents also consume acrylamide rich-food, such as potato chips and french fries, on a more regular basis than the rest of the population (Dybing et al., 2005). Nevertheless, there is a paucity of data on actual dietary intake of acrylamide among Canadian adolescents. To our knowledge, only two North American studies have attempted to document this exposure among teenagers (Tran et al., 2010; Katz et al., 2012). It is thus important to monitor levels of acrylamide in food regularly consumed by adolescents and to assess their dietary intake. The aim of the present study was to determine the distribution of acrylamide concentrations in food items frequently consumed by Canadian adolescents and in turn estimate their contribution to the overall dietary intake of acrylamide.

2. Material and methods

This study was approved by the Human Research Ethics Committees of the Faculty of Medicine of the Université de Montréal and of Heath Canada, and it was conducted between October 17th 2009 and February 7th 2010.

2.1. Study population

A total of 200 non-smoking adolescents of both genders, aged between 10 and 17 years old were recruited in the general population of the Island of Montreal in the Province of Quebec, Canada. The Montreal Island is the largest metropolitan area of the Province and the second in Canada according to most recent census (Statistics Canada, 2011).

Individuals with acute or chronic liver or kidney pathologies or with cancer were excluded from the study at recruitment stage, because these conditions may alter metabolism and excretion of xenobiotics. Four participants were later excluded from the study because they had urinary cotinine values above 150 μg/l.

2.2. Study sampling and participation

Adolescents were randomly recruited either online or by phone from a list of names, addresses and phone numbers of residents of the Island of Montreal. First, the project was explained to one of the parental authority who was then invited to consent to his or her adolescent participation in this study. In the affirmative, name and birthday of adolescents aged between 10 and 17 years old who lived in the residence were requested. The adolescent whose birthday was closest to the date of telephone contact was then sollicitated. The study was explained to the adolescents prior to asking for their consent to participate in the study. Those who were spontaneously interested in participating in the study were invited to answer a prevalidated questionnaire designed to assess their eligibility and to collect sociodemographic information. Up to two adolescents were recruited per civic address.

Following recruitment, each adolescent accompanied by one of the parental authority was met at home by a nurse to (i) explain in details the study, (ii) obtain written consent of the parental authority and written assent of the adolescent to participate in the study, (iii) provide and explain how to fill the self-administered questionnaire and food diary and (iv) present real food models of standardized portions that have been used in many studies (Santé Québec, 1998; Dewailly et al., 1999).

2.3. Dietary and lifestyle questionnaires

Participants were invited to complete two dietary questionnaires. First, during two consecutive days, they were asked to fill out a food diary to describe types and amounts of selected foods and beverages consumed at each meal. Participants were asked to report consumed number of portions of specific foods or drinks containing acrylamide (breakfast cereals, toasted bread, deep-fried french fries, oven-baked french fries, potato chips, corn chips, popcorn, pretzels, roasted almonds, crackers, cookies, chocolate chips, black olives, brewed coffee and prune juice). Furthermore, they were asked to report brands of foods and drinks, meal time and place of consumption. Secondly, the usual intake of acrylamide food sources was measured using a food frequency questionnaire. The questionnaire documented the frequency of consumption over the preceding month (i.e., never, once/month, 2–3 times/month, 1–2 times/week, 3–4 times/week, 5–6 times/week, once/day, 2 or more times/day) of exactly the same foods and drinks (same brands) as those recorded in the food diary. For both dietary questionnaires, real food models of standardized portions were used to help participants to better describe amounts of foods and drinks consumed. These models are based on everyday tableware and correspond to a known volume/weight.

Thirdly, participants also completed a brief questionnaire on their lifestyle habits. Topics covered by this questionnaire were current body weight, second hand smoke exposure, alcohol consumption and the use of personal hygiene products potentially leading to polyacrylamide exposure. All questionnaires were pre-tested before the study. After their completion, a research assistant checked answers with the participants. Smoke exposure was also confirmed by measuring urinary cotinine at the Institute for Work and Health (Lausanne, Switzerland) using a standard and validated liquid-chromatography tandem mass-spectrometry (LC–MS/MS) method.

2.4. Food sampling and preparation

Acrylamide concentration was measured in foods reported to be most often consumed by the participants, on the basis of answers to the dietary questionnaires. Since levels of acrylamide can vary considerably in the same product and from one product to other, food sampling took into consideration both the types of consumed acrylamide-containing foods and variability within a batch and between batches. Thus, a total of 146 samples of different foods representing the 14 food categories assessed by questionnaire were purchased at supermarkets and fast-food restaurants in the Montreal metropolitan region for analysis of acrylamide concentrations. These samples included deep-fried french fries ($n = 18$), oven-baked french fries ($n = 8$), potato chips ($n = 12$), corn chips ($n = 8$), popcorn ($n = 4$), pretzels ($n = 4$), roasted almonds ($n = 4$), crackers ($n = 12$), cookies ($n = 16$), chocolate chips cookies ($n = 8$), breakfast cereals ($n = 16$), bread ($n = 28$), black olives ($n = 4$) and brewed coffee ($n = 4$). Sample size is based on prior data gathered by Health Canada (Becalski et al., personal communication).

All food samples were analyzed as consumed. For deep-fried french fries, potatoes were peeled into pieces (approximately with a size of 8 mm as in restaurants) and fried in batches of 150 g in 2 l of preheated vegetable oil in an electric frying pan according to parameters shown in Table 3 and subsequently drained and cooled. The oven-baked french fries were prepared according to manufacturer's instructions. The bread was toasted, in a toaster, to a light brown degree of doneness. The popcorn was baked in a microwave according to manufacturer's instructions. Coffee was brewed in a filter coffee machine using six cups of water (1500 ml) and two tablespoons of ground coffee. Food samples were pulverized in a blender until homogeneous and stored at −20 °C prior to analysis.

2.5. Analysis of acrylamide in food

The concentrations of acrylamide in food samples were determined by LC–MS/MS using electrospray ionization in the positive ion mode using a standardized Health Canada method described in Becalski et al. (2004). The limit of quantification (LOQ) was 10 ng/g. Ten samples out of the 146 analyzed samples had a concentration below the LOQ and were attributed a value of LOQ/2 ($n = 2$ for toasted bread, $n = 4$ for olives and $n = 4$ for brewed coffee).

2.6. Assessment of dietary acrylamide intake

The assessment of total dietary intake of acrylamide (in μg/kg bw/d) with the 2-day diary was calculated using the following equation:

$$\mathrm{DI}_i = \frac{\sum_{v=1}^{14} (F_{v,i} \times C_v)}{\mathrm{BW}_i \times 1000} \quad (1)$$

where DI_i is the total daily intake to acrylamide of the subject i (μg/kg bw/d), $F_{v,i}$ is the daily amount (g/d) of food v consumed by the subject i, V is the food consumed, C_v is the mean acrylamide content of food v, expressed in ng/g, BW_i is the body weight (kg) of subject i, 1000 is the conversion factor from ng/g to μg/g.

For each participant, daily amounts in grams of each food item (average daily consumption based on the 2-day diary) were thus multiplied by corresponding measured mean concentration of acrylamide (ng/g). When data on acrylamide contents of some brands of food or drinks were not available due to restricted number of analyses, mean values from literature data were used; Canadian data were prioritized (Becalski, personal communication) (applied to $n = 0$–20 brands of food depending on the food item) followed by US data (FDA, 2006a,b) (applied to $n = 0$–3 brands of food depending on the food item). The intake of acrylamide from each food category were then summed and divided by the body weight (kg bw) of the adolescent yielding a distribution of daily acrylamide intake.

Dietary intake (in μg/kg bw/d) was also calculated from the food frequency questionnaire data. These data provided estimates of the consumption frequency and usual intake in grams of acrylamide food sources on a daily, weekly and monthly basis. Consumption frequency of the different food items (converted to a daily basis) was multiplied by amounts consumed (in grams) and by the measured concentrations of acrylamide (converted to μg/g) and then dividing by the body weight (in kg).

In addition to the contribution of a given food item to total daily intake (in μg/kg bw/d), contribution of a given meal (breakfast, lunch, dinner and snacks) to total daily acrylamide intake were also determined along with gender and age subgroup differences in daily intakes. Breakfast corresponded to foods and beverages consumed before noon; lunch was considered between ≈noon and 1 pm, dinner