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Estimation of dietary exposure to acrylamide of Polish teenagers from an urban environment

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A B S T R A C T

The aim of this study was to evaluate the dietary exposure to acrylamide (AA) in a group of teenagers (n = 261) from an urban environment. The intake of AA from food was estimated based on a 7-day food record diary (consecutive days). The food rations obtained (n = 1827) were used to calculate the amounts of the consumed food products, which were the main sources of AA. In the case of girls, the estimated dietary intake of AA per kg body weight (BW) amounted to 0.09 µg/kg BW/day (50th percentile), 0.32 µg/kg BW/day (75th percentile) and 1.04 µg/kg BW/day (95th percentile), and among boys it was 0.13, 0.41, and 1.18 µg/kg BW/day, respectively. The main sources of AA exposure were French fries, potato crisps, corn flakes, bread and salty sticks. The lowest values for margin of exposure (MOE) were calculated for the P95th percentiles of exposure, and ranged from 152 to 173.

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1. Introduction

A diet based on highly processed foods provides nutrients, but also compounds formed during the processing and storage of these foods. Thermal processes used in food technology protect food mainly against microbial agents, but also respond to current organoleptic requirements of consumers regarding color, taste, texture and the appearance of the product consumed. Since the mid twentieth century, a rapid development has been observed in heat treatment technology, e.g. drying, frying or baking, both in food factories and in individual households.

During food production, compounds may be formed that exert carcinogenic, mutagenic and neurotoxic effects. One of these compounds is acrylamide (AA), relatively recently found in food by scientists from Sweden (SNFA, 2002). It is produced primarily in potato and cereal products treated at temperatures above 120 °C. AA is one of the products of the Maillard reaction between free asparagine and reducing sugars (primarily glucose and fructose). The selection of potato varieties that contain low amounts of AA and proper storage conditions contribute to a decrease of AA in potato snacks. In cereal products, the AA content in the final product is dependent on a low amount of free asparagine in the raw material and certain formula parameters, e.g., high humidity, lack of leavening agents or reduced processing temperature (Biernat et al., 2007; Friedman and Levuin, 2008; Tajner-Czopek et al., 2008). Bråthen and Knutsen (2005) stated that the formation of AA in French fries was very much dependent on the duration and temperature of processing. However Palazoğlu and Gökmen (2008a, 2008b) reported that French fries of 10 × 10 mm size contain higher levels of AA (980 µg/kg) than French fries of 8.5 × 8.5 mm size (1502 µg/kg). In 2007 the European Union Commission recommended continuous monitoring of AA content in food, and as a result, researchers and manufacturers have undertaken actions aimed at reducing the amount of AA in the final product (Palazoğlu and Gökmen, 2008a, 2008b). These modifications were mainly based on proper selection of e.g. potatoes, and lowering the temperature of frying and baking. Data from the Institute of Food and Nutrition on AA content of food in Poland shows that between 2005 and 2007 there was a decrease in AA content in French fries prepared in eating establishments from 313 to 294 µg/kg, a decrease from 827 to 641 µg/kg in French fries prepared from semi-finished products at home, from 904 to 699 µg/kg in potato crisps, from 223 to 162 µg/kg in corn flakes, from 188 to 140 µg/kg in corn crisps, from 69 to 59 µg/kg in bread, from 430 to 259 µg/kg in crisp bread, from 344 to 292 µg/kg in salty sticks, from 198 to 161 µg/kg in cookies, and from 859 to 738 µg/kg in crackers (Mojska et al., 2006, 2009, 2010).

To assess the dietary exposure to AA in different population groups it is necessary to have information on the AA content in food

Abbreviations: AA, acrylamide; BW, body weight; EFSA, European Food Safety Authority; IARC, International Agency for Research on Cancer; JECFA, The Joint FAO/WHO Expert Committee on Food Additives; SNFA, Swedish National Food Administration.

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as well as on the consumption levels of the relevant products. Numerous previously published studies (Boniecka et al., 2009; Kiczorowska and Samolińska, 2013; Malczyk et al., 2012; Wyka et al., 2012) have found that teenagers are more likely than other age groups to consume snack products, i.e., potato crisps, French fries, salty sticks or cookies, which they buy in school shops and fast food restaurants. According to the European Food Safety Authority (EFSA), in this age group (11–17 years) the average exposure to AA expressed in µg per kg body weight (BW), depending on the country, ranges from 0.39–0.43 µg/kg BW/day in France (lowest intake) to 1.29–1.36 µg/kg BW/day in the Czech Republic (highest intake). The above-cited studies showed that the 95th percentile of intake in the groups of teenagers from these countries amounted to 0.89–0.94 µg/kg BW/day and 2.92–3.06 µg/kg BW/day, respectively (EFSA, 2011). In Poland, the average intake of AA via food among 7- to 18-year-old youth was estimated at 0.62 AA µg/kg BW/day. Among girls it was 0.58 µg/kg BW/day, and among boys 0.67 µg/kg BW/day. Values of the 95th percentile intake of this compound were 2.45 µg/kg BW/day in the whole group of teenagers, 2.35 µg/kg BW/day in girls and 2.54 µg/kg BW/day in boys (Mojska et al., 2010). Based on these data it was found that at the 95th percentile of intake teenagers had a significantly higher intake of dietary AA compared to the lowest percentile of intake. This higher intake was very likely due to higher than average consumption of snack products containing high levels of AA by this age group.

Some studies have shown an association between AA intake and increased risk of cancer through biomarkers in humans, but this association is not consistent. A dose–response relationship has been set based on animal data (Mojska, 2012; Sirot et al., 2012). The Joint FAO/WHO Expert Committee on Food Additives (JECFA, 2011) proposed two different $BMDL_{10}$ (lower limits on the benchmark dose for a 10% response) for AA: 0.31 mg/kg BW/day for the induction of mammary tumors in rats and 0.18 mg/kg BW/day for Harderian gland tumors in mice. In its recent evaluation, the JECFA applied a margin of exposure (MOE) approach for the health risk assessment of acrylamide. The MOE is defined as the point of comparison on the dose–response curve (usually based on animal experiments in the absence of human data) divided by the estimated intake by humans. This approach is also currently proposed by the European Food Safety Authority Scientific Committee for compounds that have both genotoxic and carcinogenic properties (EFSA, 2005).

So far in Poland the nationwide exposure to AA in groups of different ages has been studied. To our knowledge, there is a paucity of data on the actual dietary intake of AA among Polish adolescents, especially according to gender. It was interesting to assess the exposure of teenagers who lived in an urban environment and to whom processed products, e.g. fast-foods were readily available. The aim of this study therefore was to assess the dietary exposure of young people from a large urban area (Wroclaw n = 600,000, South-West Poland) to AA, as well as to identify the food products that are the main sources of exposure. The risk connected with dietary exposure to AA was calculated. To assess MOE values, $BMDL_{10}$ 0.18 and 0.31 mg/kg BW/day and intake of AA from Me (median), 75th percentile and 95th percentile were used.

2. Materials and methods

2.1. Sampling

Nutritional pattern assessment was conducted from November 2010 to May 2011 in a group of 261 young people, of whom 57% were girls. The ages of the youth were in the range of 16–18 years, with 17-year-olds representing the largest group (47%). Most of the subjects lived in Wroclaw (94%), while the remaining young people came from rural areas or small towns and commuted to school every day. The largest group of young people (54%) was the first grade students of general education secondary schools. The students recruited were randomly selected pupils from four schools. Each school participated in the “Health-Promoting School” program, financially supported by the city of Wroclaw, whose purpose was health education and preventive care. The criteria for rejecting access to the group were lack of consent of a parent or student, long-term absence from school due to illness, and participation in school contests or competitions.

2.2. Food consumption data

The consumption of each product group was assessed based on a 7-day food record diary (consecutive days, excluding weekend days and holidays like Christmas). Food records (n = 1827) were obtained face-to-face by trained interviewers. The size of food rations was estimated with the use of an “Album of Photographs of Food Products and Dishes” (Szponar et al., 2000). The food rations included several products containing AA that were frequently consumed by the subjects. Products such as coffee, crackers, cookies, different baked goods and bread crusts were excluded based on the outcome of the study, in which a very low consumption of them was stated. The concentrations of AA in the food group were taken from the national database of the Institute of Food and Nutrition in Warsaw (Mojska et al., 2009). The AA content of the food group was determined using gas chromatography with tandem mass spectrometry (GC-MS/MS). One sample comprised two portions of the product, sampled from the same manufacturing batch, in a minimum quantity of 200–1000 g, depending on the food group (Mojska et al., 2009, 2010). Daily consumption per food group was added up from a 7-day record diary and divided by 7 to give the median consumption per food group for each subject. Based on median daily consumption and analytical data about the median content of AA per food group (in µg AA/kg), AA intake per food group was calculated and subsequently added up in order to calculate the total dietary intake of AA per subject. This was done under the assumption that AA intake was only from: French fries, potato crisps, corn flakes, bread and salty sticks. All estimated daily intakes were divided by BW per person (declared in kg) to calculate the median daily intake per kg of BW in the whole group. The median BW was 59.5 kg for girls and 67.5 kg for boys. The AA exposure was expressed as µg per kg of BW per day.

2.3. Statistical analysis

Statistical analysis of the results estimated the differences in consumption of particular food groups and AA intake in µg/kg BW/day between girls and boys. Distributions of consumed amounts of each food group were not gaussian. Therefore the Mann–Whitney U test and the median values for non-parametric dates were used. The data were presented in percentile distribution. Statistical analyses were performed using STATISTICA 10.0 software at a significance level of $p < 0.05$.

3. Results

3.1. Food groups in food rations

Consumption of individual food groups in the food rations of girls and boys is shown in Table 1. Daily consumption of bread was significantly higher in boys than girls.

At the 95th percentile of intake, the consumption of French fries was more than 28 g. At the 75th percentile of intake subjects

Table 1
Intake of food groups as sources of AA (in grams) in food rations (n = 1827) of the surveyed teenagers.

Percentile	French fries		Potato crisps		Corn flakes		Bread[a]		Salty sticks	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
5	0	0	0	0	0	0	26.2	55.5	0	0
25	0	0	0	0	0	0	59.3	101.3	0	0
50	0	0	0	0	5.4	6.4	87.1	147.1	0	0
75	0	11.4	14.3	14.0	11.3	23.7	115.5	199.3	5.1	4.6
95	28.6	28.4	43.2	55.2	35.7	60.5	170.5	316.2	31.8	20.6

[a] Statistical differences between girls and boys, Mann–Whitney-U test, $p < 0.05$.

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