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Dietary exposure to acrylamide from potato crisps to Spanish population

G. ARRIBAS-LORENZO and F.J. MORALES*

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Abstract

Potato crisps are one of the food commodities which contributes most to overall dietary human exposure of acrylamide. This investigation has estimated the dietary exposure to acrylamide form potato crisps in the Spanish population. Sampling of potato crisps (n = 36) from 16 different producers were carried out in March 2008. An average level of 740 µg/kg (ranging from 81 to 2622 µg/kg; min:max) and a median of 592 µg/kg were obtained. Acrylamide levels in marketed potato crisps have been significantly reduced (nearly to 50%) compared with a previous sampling performed 4 years earlier. The observed signal value (90th percentile) was 1377 µg/kg with 86% of the samples with acrylamide levels lower than 1000 µg/kg. Dietary exposure to acrylamide from potato crisp consumption in total Spanish population was estimated to be 0.042 µg/kg bw/day by using a deterministic approach based on National consumption database. In a second study, dietary exposure (based on 3-day food record) was determined to be 0.053 µg/kg bw/day for the adult population (17-60 years) and 0.142 µg/kg bw/day for children (7-12 years). The contribution of potato crisps to the estimated dietary acrylamide exposure of the Spanish population is moderate as compared with other European member states.

Keywords: acrylamide, dietary intake, potato crisps, food contaminant
Introduction

Since the announcement of the presence of acrylamide in a wide range of foods (Tareke et al. 2002), a large number of studies have been published and summarized in reviews (Friedman 2003; Wenzl et al. 2003; Taeymans et al. 2004; Zhang et al. 2005) where basically acrylamide levels can be seen to depend on the raw materials, additives and processing parameters. Acrylamide is clearly genotoxic and carcinogenic in studies in animals, and causes increased tumor incidence at a variety of sites (IARC 1994; EC 2000). The International Agency on Research on Cancer has classified ACRYLAMIDE as "probably carcinogenic to humans (IARC Group 2A)". The MOE (Margin of Exposure) is calculated by dividing the toxicity estimate from animal experiments by the estimated intake from food. Consequently, the lower the MOE the greater is the public health concern. The MOEs were thus calculated to be 300 for the general population and just 75 for high consumers, including children; being concluded that acrylamide in food is a potential public health hazard (FAO/WHO 2005). The Scientific Committee of EFSA (EFSA 2005) also endorsing a MOE approach for compounds that are both carcinogenic and genotoxic is of the view that a MOE of 10,000 or larger would be of low concern from a public health point of view and might be considered as a low priority for risk management actions (HEATOX project, final report, April 2007). Toxic effects have been evaluated by IARC (1994), WHO/JECFA (2005), reported in special issues (i.e. Mutation Research 2005), and its nutritional risk evaluated (Alexander 2006). A comprehensive review of acrylamide toxicity including mechanisms and risk assessment has recently appeared (Shipp et al. 2006; Parzelfall 2008). Last EFSA experts meeting (22-23, May, Tabiano, Italy) on acrylamide agreed to maintain the level of concern and to revise the situation in 2009 with new epidemiological data.
Potato products, such as crisps and French fries, are among the major contributors to the acrylamide daily intake, especially for children and teens (Wilson et al. 2006). Many studies have been accomplished to find strategies to minimize the levels of acrylamide, such as controlling levels of reducing sugars in fresh tubers (Amreim et al. 2004; Matthäus et al. 2004), agronomical factors (Noti et al. 2003) apply appropriate storage conditions (De Wilde et al. 2005), modifying soaking or blanking (Pedreschi et al. 2004), reducing frying temperature and time (Gertz and Klostermann 2002; Kita et al. 2004; Franke et al. 2005), addition of additives (Mestdash et al. 2008) or cations (Gökmen and Senyuva, 2007). Alternatives to traditional frying such as vacuum frying (Granda et al., 2004) or combined pre-treatment by microwave heating (Edoggu et al., 2007) or prefrying (Pedreschi et al., 2007) have been proposed. The subject has been recently reviewed by Morales et al. (2008).

JECFA estimated that the major contributing foods to total human exposure to acrylamide for most countries are potato chips (French fries, 16-30%), potato crisps (chips, 6-46%), coffee (13-39%), pastry and sweet biscuits (cookies, 10-20%), bread, rolls and toast (10-30%) and others (< 10%). JECFA concluded that based on national estimates, an intake of acrylamide of 1 µg/kg bw/day could be taken to be representative as average for the general population and that an intake of 4 µg/kg bw/day could be taken to represent consumers with a high intake, including children. Estimating consumer exposure to acrylamide is a high priority for governments and industry alike where new exposure models have been recently developed that provide estimates of exposure of typical consumers and extreme consumers as well (Dybing et al. 2005).

In 2007, the European Commission made recommendations to monitor levels of acrylamide in certain food categories (2007/331/EC), these data will be compiled by members states and reported to EFSA on a yearly basis for the next three years (EC
Activities have not been equal across EU since overall dietary exposure has only been estimated for a certain numbers of member states. In Spain, like many other Mediterranean countries, estimation has not been undertaken yet. It might be anticipated that there will be considerable differences between EU countries due to differences in food consumption habits, including traditional foods.

Given the popularity of potato crisps, particularly among younger age groups, it is important to assess the daily intake of acrylamide from crisps in the Spanish diet. In parallel it is also relevant to obtain a picture of the current situation and monitoring progress in minimisation strategies applied at industrial level and to compare the intake with other EU state members before to further decision on risk management. This investigation present a survey on commercial potato crisps in Spain and its contribution to daily intake of acrylamide based on two exposure models, as a comprehensive step to afford a precise study in a future by Spanish Administration bodies.
Materials and methods

Chemicals.

All chemicals used were of an analytical grade and were obtained from Sigma-Aldrich (St. Louis, MO, USA), unless mentioned otherwise. $^{13}$C$_3$-Acrylamide (isotopic purity 99%) was from Cambridge Isotope Labs (Andover, MA, USA). Oasis-HLB cartridges (30 mg, 1 mL) were from Waters (Milford, MA, USA).

Samples

Experiments were conducted with a series of commercial potato chips (36 brands from 16 producers) randomly purchased on different supermarkets between 10th to 18th March 2008. In this period, stored potatoes were likely used by producers. Samples from the same brand containing different flavorings and/or spices added were not included in the sampling since frying variables and raw material should be similar. Samples (200 - 500 g) were mixed and thinly sliced to assure a homogeneous distribution of potential hot-spots. A portion (200 g) was distributed in four containers and stored under vacuum and light protected at 4ºC until analysis.

LC-ESI-MS determination of acrylamide.

Sample preparation as described by Şenyuva and Gökmen (2006) was used with minor modifications. A finely ground sample (0.450 g) was then weighed into a 10 mL centrifuge tube. The sample was spiked with 100 µL $^{13}$C$_3$-labelled acrylamide (10 µg/mL) for recovery, and 5 mL of Milli-Q water was added. Then the mixture was vortexed, kept for five minutes at room temperature and subsequently homogenized for 1 min (Ultraturrax). Then, 750 µL Carrez I and 750 µL Carrez II solution were added, vortexed and left to stand for 10 minutes. Tubes were centrifuged at 5000 rpm for 15
minutes at 4 ºC. The clear supernatant (1 mL) was clarified onto a pre-conditioned HLB cartridge. The first drops were discharged and the rest of the eluate was collected in amberlite vials for analysis.

LC-ESI-MS analyses were performed as described by Rufian-Henares et al. (2007) with minor modifications (Morales and Arribas-Lorenzo 2008) using an Agilent 1100 HPLC system (Waldbronn, Germany) consisting of a quaternary pump, an autosampler and a temperature-controlled column oven, coupled to an Agilent 1100 MS detector equipped with an electrospray ionization interface. The analytical separation was performed on an Inertsil ODS-3 column (250 × 4.6 mm, 5 µm) using an isocratic mixture of 0.2% aqueous solution of formic acid at a flow rate of 0.6 mL/min at 25°C. Data acquisition was performed, with a delay time of 8 min, in a selected ion monitoring (SIM) mode using the following interface parameters: a drying gas (N₂, 100 psig) flow of 12 L/min, nebulizer pressure of 45 psig, drying gas temperatures 350°C, a capillary voltage of 3 kV and a fragmenter voltage of 70 eV. Monitored ions were 72.1 \textit{m/z} for acrylamide and 75.1 \textit{m/z} for \textsuperscript{13}C₃-labeled acrylamide. An acrylamide calibration curve was built in the range of 2-100 µg/L and a limit of quantification was determined to be 25 µg/kg for potato crisps. The method was in-house validated for linearity, precision and recovery. Furthermore, the accuracy was recently demonstrated for potato crisps in an interlaboratory comparison study launched by IRMM, yielding a z-score of -0.5. Precision (reproducibility) was lower than 12% and recovery between 84-109%. The analyses are integrated within the scope of a certified laboratory controlled by AENOR (Spanish Association for Standardisation and Certification).

\textit{Food consumption data.}
In order to calculate the dietary intake of acrylamide from potato crisps two different food consumption data were used. A first exposure study was carried out from the Spanish National Agricultural, Fishing and Food Administration based on a yearly consumption database. It is a food survey annually published (MAPA 2007). This is the most recent measurement of dietary consumption in Spain at a national level. In this survey data are collected from 8240 interviews to non-institutionalized households and 898 interviews to restaurants, catering services, Institution (hospital, public schools, penitentiary, etc), covering 2006. The statistical universe of the study compile a balanced, representative and stratified probability sample of the Spanish population taking into account, gender, ages, regions, socio-economic status, among others. An average body weight of 70 kg was used to estimate the total daily intake of acrylamide to total population and expressed as µg/kg bw/day. A second exposure study was calculated from food consumption data survey from the National Food Safety and Nutrition Agency in Spain (AESA 2006). This study was elaborated in 2003 with Food Frequency Questionnaires over 1963 subjects from 0 – 60 years grouped in six levels of age (> 1 year, 1-2 years, 2-7 years, 7-12 years, 12-17 years, and > 17 years) in three consecutive days.

Statistical Analysis.

Analyses were performed using Statgraphics Plus, version 5.1, 2001 (Statistical Graphics Corp, Rockville, MD, USA). At least, two independent analyses were carried out per sample.
Results and Discussion

Thiry-six classical potato chips from 16 different producers, without flavor or species added were analyzed for acrylamide content. Acrylamide content ranged from 81 to 2622 µg/kg with a mean value of 740 µg/kg and a median of 592 µg/kg. Similar values were reported by other authors (Becalski et al. 2003; Roach et al. 2003; Rosen and Hellenas 2002; Tareke et al. 2002; Matthys et al. 2005) who found acrylamide levels ranged between 224 and 3700 µg/kg. Recently a survey on acrylamide levels in potato crips in the Turkish market showed a median level of 818 µg/kg (59 – 2336, min-max) (Ölmez et al., 2008). Institute of Reference of Measurements and Materials developed a monitoring database which was last updated in June 2006 (IRMM 2006; Wenzl and Anklan, 2007). A median level of 528 µg/kg (5 - 4215 µg/kg; min - max, n = 836) is reported which is in line with values obtained in current survey. Results are also in concordance with the monitoring database (2002-2004) from FDA with a mean of 612 µg/kg and a median of 462 µg/kg (www.cfsan.fda.gov). Figure 1 depicted the acrylamide distribution in the survey. All samples analysed contains ACRYLAMIDE levels higher the LOQ.

However, levels of acrylamide in potato crisp marketed in Spain has been significantly reduced as compared with a previous sampling dated on 2004 (Rufian-Henares and Morales 2005). In the 2004 sampling, a median and mean of 1180 and 1484 µg/kg was obtained where nearly a 50% reduction is reached in the current study. In addition, values for the first quartile and third quartile are diminished as well, and subsequently minimizing the heterogeneity of the distribution (Figure 2).

Acrylamide reduction was analytically confirmed in the potato crisps marketed in Spain as compared with 4 years ago. Toolbox from the CIAA compile a number of recommendations for effective acrylamide mitigation at industrial scale which seems to
be effective among Spanish potato crisps producers (CIAA 2007). But, implementation
of the Toolbox guidelines to SMEs is a challenge where accessibility to information is
mediated by local federations of producers. Guidelines are focussed on agronomical
factors, storage conditions, pre-treatment and processing conditions. At this level, it
cannot be stated if acrylamide reduction in the Spanish potato crisps market has been
due to implementation of one guideline or it is a sum of all of them. Selection of an
adequate potato tuber variety with reducing sugars content lower that 0.3% is
appropriate for potato crisps (CIAA, 2007). It is also noteworthy to mention that
Spanish Food Safety and Nutrition Agency (AESAN) has implemented a global strategy
to reduction the consumption of fat, called NAOS. According to the package label as
declared by companies, 6 samples (aprox. 17% from total) contained levels of fat lower
than 25% and claiming for light potato crisp in the container. Indeed, fat content was the
variable with higher dispersion among the samples, if compared with protein and
carbohydrate content. Therefore it was found any significant correlation between fat
content and levels of acrylamide. Samples with low fat content are depicted in figure 1
as well.

WHO/JEFCA and the Scientific Panel on Contaminants in the Food Chain (CONTAM)
of the European Union aimed to investigate strategies to reduce acrylamide formation
by implementing the ALARA principle (as low as reasonably or technically
achievable). The German Federal Office of Consumer Protection and Food Safety
(BVL) stated a signal value 1000 µg/kg for potato crisps, as a concept of minimization
(BVL 2006). The signal value is defined as the lowest level of the 10% containing the
highest level of acrylamide in a food commodity. If acrylamide contents were above
this signal value, food producers should be recommended to take adequate actions to
lower such contents, but at present there is not regulations or obligation in the European
countries. Since 2002, BVL published yearly the observed value for potato crisps being
1500, 1200, 1470, 1029, and 1333 µg/kg for the years 2002, 2003a, 2003b, 2004 and
2005 respectively. If the German minimisation concept is applied to the Spanish potato
crisps survey, most of the samples (86%) contained acrylamide levels lower than 1000
µg/kg. However the observed value was calculated to 1377 µg/kg being about 61%
lower than value recorded in the 2004-sampling.

For monitoring the progress in the minimisation strategies by industrials, it is useful to
define limits for quality control. Three levels can be identify, acceptable (below 50\textsuperscript{th}
percentile), under evaluation (50\textsuperscript{th} – 90\textsuperscript{th} percentile) and unacceptable (> 90\textsuperscript{th}
percentile), as displayed in Figure 1. Samples lying in the upper region should
reconsider the internal quality strategy, for instance, increasing quality controls to fresh
potato suppliers. Many studies demonstrated that it is possible to define time–
temperature processing conditions which guarantee low acrylamide concentration and
the retention of sensorial properties in terms of colour, flavour, and starch gelatinization
(i.e. Pedreschi et al. 2006). It is necessary an adjustment of the traditional frying
conditions, supervision of the process, and improve traceability of fresh potatoes during
storage period by potato suppliers. Monitoring database of the IRMM which tend to
resemble the situation across Europe members states, recorded at the 90\textsuperscript{th} percentile of
1442 µg/kg (Wenzl and Anklan, 2007), which is also in line with reported for the
Spanish market.

Dietary intake of acrylamide from potato crisp
Spanish authorities (Spanish National Agency of Food Safety and Nutrition, AESAN, http://www.aesan.msc.es/) have not reported yet mean intake values for acrylamide for the Spanish population and the most contributing food categories are lacking as well. This investigation is a starting point to characterise the exposure to potato crisp which is one of the most contributing food categories to acrylamide intake. In general, target food categories can be grouped in three classes according to moderate consumption but high concentration of acrylamide (a), foods with high consumption but relatively low levels of acrylamide (b), and tailored-foods to specific population groups such as elders or infants. Potato crisps have been identified as a major source of exposure by several previous studies (Svensson et al. 2003; Matthys et al. 2005; Boon et al. 2005). But contribution of regional and local foods should be explored, like fried-dough pastries (Morales and Arribas-Lorenzo 2008). Although the levels of acrylamide in some of these products are low, they can contribute significantly to the overall intake of acrylamide. The intake of acrylamide depends consequently on the consumption pattern and the acrylamide levels in foods. Contribution of individual foods to total exposure can be best identified by the deterministic approach (Petersen and Tran 2005). Two different consumption databases have been used for estimation of the dietary acrylamide exposure from potato crisp.

First exposure assessment was estimated from the National consumption database monitored during 2006 (MAPA 2007). Although the point estimate (deterministic approach) does not assess the probability or uncertainties or even do not identify high risk consumers since is based on population and not in subjects, it is a first approximation and a useful screening tool in order to design a more specific study in case of a potential risk. Indeed, many of the earlier data reported in literature have been
obtained from generalist food intake studies for nutritional or economical monitoring purposes but they were not specifically designed for food safety issues (Dybing et al. 2005). Furthermore, other studies link national consumption patterns with general acrylamide databases (Boon et al. 2005). In summary, to date a comprehensive study specifically designed for assessing the dietary acrylamide exposure is missing due to its complexity.

During 2006, 16% of the fresh potatoes consumed in Spain were processed, and mostly bought directly by consumers (84%) as compared with consumption at restaurants, catering services or Institutions (hospitals, penitentiary, schools, etc.). It represents an overall estimation of consumption of 1.44 kg processed potato products per capita. In this estimation, it has not been included the frozen potato products with are mainly par-fried French fries. Average contribution of potato crisps to dietary acrylamide exposure in Spain (assuming a body weight of 70 kg) is calculated to 0.042 µg acrylamide/kg bw/day. One limitation of the calculation is that one single level of consumption is used, but it has been compared with the distribution of acrylamide calculated in the commercial sampling. The risk scenario (95\textsuperscript{th} percentile) is obtained with a level of 0.117 µg acrylamide/kg bw/day but this level does not identify subjects with high consumption patterns. Selecting high residue levels (95\textsuperscript{th} percentile) in potato crisps will very likely to overestimate the exposure. More realistic estimates of low and high exposure are obtained by using probabilistic models (i.e. Monte Carlo modelling) that include residues and distribution consumption patterns. As formerly explained, the deterministic method applied in this study is a useful tool for estimating mean exposure of population to acrylamide.
The sources of acrylamide in foods vary with national or even local dietary habits. The contribution of potato products is high but can vary among countries. Table I describes the estimation of total dietary exposure to acrylamide and contribution calculated for potato crisps as reported in different studies. For some other studies, sum of French fries, potato crisps, and roasted potatoes is reported. Potato crisps, French fries and other products are consumed at relatively high amounts in the US (35% of the daily intake of acrylamide) (FDA 2004), but it is even higher in The Netherlands with French fries and crisps taken together contributing up to 50% (Konings et al. 2003; Boon et al. 2005). In general, JECFA has estimated the variability in the potato crisps contribution between 6 to 46% of the dietary acrylamide exposure, although recently Arisseto et al. (2007) reported a contribution up to 60% of potato products in the Brazilian population. Dietary acrylamide exposure of Spanish consumers has been significantly reduced as compared with previous study (Morales 2004, unpublished). It is nearly 3.5-fold lower than in The Netherlands (Konings et al. 2003) but in line with Sweden (Svensson et al. 2003). According to the most recent data, average human intake is estimated to be 0.4 µg/kg bw/day from two years of age onwards. However, intake may vary widely from 0.3 to 2 µg/kg bw/day or may reach even 5 µg/kg bw/day at the 99th percentile (WHO/JECFA 2005).

In consumer exposure assessments it is also important to know whether there are significant differences among different subgroups of the population. National consumption database identify 5 classes for indexing according to regions (17 levels for different Autonomous Communities), size of cities (5 levels), socioeconomic status (4 levels), family members (5 levels) and cycle of life (8 levels). It was observed that there are great differences depending on the different categories studied, almost doubling the
estimated exposure (Table II). In a simplistic overview, it can be observed that highest risk of exposure is recorded for young singles of high+medium-high socioeconomic status living at large cities in Catalonia. At the opposite, lowest exposure is expected for large families with kids with low socioeconomic status living in villages (< 2000 inhabitants) at the Canaries Islands.

The second study for exposure estimation was applied on the basis of a consumption study performed on food frequency questionnaires in three consecutive days to different population groups (AESA 2006). In this study it is recorded two levels of consumers apart to obtain the average daily level of potato crisps intake. Regular consumers are identified as subjects with some consumption of the product and represent the 33.11% of the children population and 21.32% of the adult population. It is also identified the acute consumption at 97.5th percentile. Table III summarised the results. Average dietary exposure to acrylamide for children is 2.6 fold the exposure for adults. This is expected due to a combination of lower body weight and higher caloric demand giving a higher net consumption. But also by a different dietary pattern, with higher consumption of certain foodstuffs rich in acrylamide, such as French fries and potato crisps (Dybing et al. 2005; Wilson et al. 2006). It is thus clear that certain subgroups demonstrate especially high exposure to acrylamide. This ratio is in line with compiled by earlier studies (WHO 2005; EFSA 2005). In the worst scenario the highest intake will be 1.064 and 0.602 µg/kg-bw/day for children and adults. In 2004, our group estimated the contribution of potato crisps to total dietary intake to be 22% (Morales, 2004 unpublished). In the assumption that the pattern will be maintained, a risk intake (97.5th percentile) of 3.01 µg/kg-bw/day is expected which is lower than 4 µg/kg bw/day, calculated by WHO (WHO 2005).
Average levels of acrylamide exposure determined by food consumption database (adult population, 0.053 µg/kg bw/day) and 3-day food records (total population, 0.042 µg/kg bw/day) studies are rather similar, and both values are low when compared with other countries (table I). Again, it is noteworthy to mention that expected exposure of Spanish population to acrylamide from potato crisps is moderate. But, industrials should keep the inspections and controlling the process chain to reduce, if still technically possible, the levels in the acrylamide in the final product to achieve the lowest contribution of potato crisps to global exposure to acrylamide on the Spanish population. However, pattern of consumption are rather different among the Spanish regions and some effort should be addressed by local administrations to reduce potato crisp consumption in regions with acute exposure levels although globally the exposure is moderate as compared with other countries. It is mandatory in near future to design a specific consumers study for acrylamide. In the study, foods which are known to be potential sources for acrylamide should be clearly identified. On the other hand, there is a need to maintain a balance between health-promoting and nutritional components of the foods with minimisation strategies to reduce acrylamide exposure, apart to sensorial properties accepted by consumers. Before any proposal of risk management or intervention by regulatory bodies, a critical evaluation of the situation is necessary.

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Figures Captions.

Figure 1. Box-and-Whisker plot (a) and distribution graph for acrylamide content in Spanish potato crisps. Empty bar represent samples declared as low fat content (< 25%) by industrials. Dotted lines represent media and observed signal value.
Figure 2. Smooth density plot for levels of acrylamide in the 2008 potato crisps sampling and 2004 sampling (Rufian-Henares and Morales, 2005; dotted line).
Table I. Contribution of potato crisps to dietary acrylamide exposure in different studies. Sum of potato crisps, French fries and roasted potatoes contribution (*).

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<th>Country</th>
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<tr>
<td>France</td>
<td>AFSSA (2005)</td>
<td>1.400</td>
<td>26*</td>
<td>0.357*</td>
<td>3 – 8</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>AFSSA (2005)</td>
<td>0.500</td>
<td>32*</td>
<td>0.161*</td>
<td>9 – 14</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>AFSSA (2005)</td>
<td>0.500</td>
<td>24</td>
<td>0.122</td>
<td>&gt; 15</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>Morales (2004, unpublished)</td>
<td>0.409</td>
<td>22</td>
<td>0.090</td>
<td>total</td>
<td></td>
</tr>
</tbody>
</table>
Table II. Contribution of potato crisps to the dietary exposure to acrylamide (µg/kg-bw/day) for the total Spanish population according to different categories based on household consumption. Total National included household + Institutions + Restaurants consumption.

<table>
<thead>
<tr>
<th>Category</th>
<th>Class</th>
<th>AA exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total National</td>
<td></td>
<td>0.042</td>
</tr>
<tr>
<td>Household National Level</td>
<td></td>
<td>0.035</td>
</tr>
<tr>
<td>Autonomous Community</td>
<td>Min Canary Islands</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td>Max Catalonia</td>
<td>0.046</td>
</tr>
<tr>
<td>Population size</td>
<td>Min &lt; 2000 inhabitants</td>
<td>0.026</td>
</tr>
<tr>
<td></td>
<td>Max &gt; 500000 inhabitants</td>
<td>0.041</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td>Min Low</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td>Max High+medium-high</td>
<td>0.046</td>
</tr>
<tr>
<td>Family members</td>
<td>Min 5 or more subjects</td>
<td>0.026</td>
</tr>
<tr>
<td></td>
<td>Max 1 subject</td>
<td>0.055</td>
</tr>
<tr>
<td>Cycle of life</td>
<td>Min Couples with kids (&lt;7 years) &amp; Couples with sons (&gt; 17 years)</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>Max Young singles</td>
<td>0.064</td>
</tr>
</tbody>
</table>

Results expressed as µg/kg-bw/day, in a body weight basis of 70 kg.
Table III. Exposure (based on 3-day records) to acrylamide for children (body weight 34.48 kg, n=903) and adult (body weight 68.48 kg, n= 1060) Spanish population. Data expressed as µgAA/kg-bw/day. Risk consumers are estimated at percentile 97.50. Mean, min, max and P(90) refers to mean, minimum, maximum and percentile 95 of acrylamide distribution in commercial potato crisps.

<table>
<thead>
<tr>
<th>Children (7-12 years)</th>
<th>mean</th>
<th>min</th>
<th>max</th>
<th>P(95)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average consumer</td>
<td>0.142</td>
<td>0.016</td>
<td>0.502</td>
<td>0.379</td>
</tr>
<tr>
<td>Regular consumer</td>
<td>0.428</td>
<td>0.047</td>
<td>1.516</td>
<td>1.145</td>
</tr>
<tr>
<td>Risk consumer</td>
<td>1.064</td>
<td>0.116</td>
<td>3.769</td>
<td>2.848</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adults (&gt; 17-60 years)</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>P(95)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average consumer</td>
<td>0.053</td>
<td>0.006</td>
<td>0.189</td>
<td>0.143</td>
</tr>
<tr>
<td>Regular consumer</td>
<td>0.250</td>
<td>0.027</td>
<td>0.887</td>
<td>0.670</td>
</tr>
<tr>
<td>Risk consumer</td>
<td>0.602</td>
<td>0.066</td>
<td>2.131</td>
<td>1.610</td>
</tr>
</tbody>
</table>