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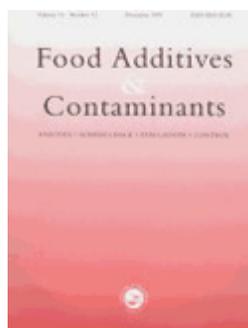
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Dietary exposure to acrylamide from potato crisps to Spanish population

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Additives/Contaminants:	Acrylamide
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3 **1 Dietary exposure to acrylamide from potato crisps to Spanish**
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6 **2 population**
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1
2
3 **Abstract**
4

5
6 Potato crisps are one of the food commodities which contributes most to overall dietary
7
8 human exposure of acrylamide. This investigation has estimated the dietary exposure to
9
10 acrylamide from potato crisps in the Spanish population. Sampling of potato crisps (n
11
12 = 36) from 16 different producers were carried out in March 2008. An average level of
13
14 740 $\mu\text{g}/\text{kg}$ (ranging from 81 to 2622 $\mu\text{g}/\text{kg}$; min:max) and a median of 592 $\mu\text{g}/\text{kg}$ were
15
16 obtained. Acrylamide levels in marketed potato crisps have been significantly reduced
17
18 (nearly to 50%) compared with a previous sampling performed 4 years earlier. The
19
20 observed signal value (90th percentile) was 1377 $\mu\text{g}/\text{kg}$ with 86% of the samples with
21
22 acrylamide levels lower than 1000 $\mu\text{g}/\text{kg}$. Dietary exposure to acrylamide from potato
23
24 crisp consumption in total Spanish population was estimated to be 0.042 $\mu\text{g}/\text{kg}$ bw/day
25
26 by using a deterministic approach based on National consumption database. In a second
27
28 study, dietary exposure (based on 3-day food record) was determined to be 0.053 $\mu\text{g}/\text{kg}$
29
30 bw/day for the adult population (17-60 years) and 0.142 $\mu\text{g}/\text{kg}$ bw/day for children (7-
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32 12 years). The contribution of potato crisps to the estimated dietary acrylamide
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34 exposure of the Spanish population is moderate as compared with other European
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36 member states.
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20 **Keywords:** *acrylamide, dietary intake, potato crisps, food contaminant*

21

1 Introduction

2 Since the announcement of the presence of acrylamide in a wide range of foods
3 (Tareke et al. 2002), a large number of studies have been published and summarized in
4 reviews (Friedman 2003; Wenzl et al. 2003; Taeymans et al. 2004; Zhang et al. 2005)
5 where basically acrylamide levels can be seen to depend on the raw materials, additives
6 and processing parameters. Acrylamide is clearly genotoxic and carcinogenic in studies
7 in animals, and causes increased tumor incidence at a variety of sites (IARC 1994; EC
8 2000). The International Agency on Research on Cancer has classified ACRYLAMIDE
9 as "probably carcinogenic to humans (IARC Group 2A)". The MOE (Margin of
10 Exposure) is calculated by dividing the toxicity estimate from animal experiments by
11 the estimated intake from food. Consequently, the lower the MOE the greater is the
12 public health concern. The MOEs were thus calculated to be 300 for the general
13 population and just 75 for high consumers, including children; being concluded that
14 acrylamide in food is a potential public health hazard (FAO/WHO 2005). The Scientific
15 Committee of EFSA (EFSA 2005) also endorsing a MOE approach for compounds that
16 are both carcinogenic and genotoxic is of the view that a MOE of 10,000 or larger
17 would be of low concern from a public health point of view and might be considered as
18 a low priority for risk management actions (HEATOX project, final report, April 2007).
19 Toxic effects have been evaluated by IARC (1994), WHO/JECFA (2005), reported in
20 special issues (i.e. Mutation Research 2005), and its nutritional risk evaluated
21 (Alexander 2006). A comprehensive review of acrylamide toxicity including
22 mechanisms and risk assessment has recently appeared (Shipp et al. 2006; Parzefall
23 2008). Last EFSA experts meeting (22-23, May, Tabiano, Italy) on acrylamide agreed
24 to maintain the level of concern and to revise the situation in 2009 with new
25 epidemiological data.

1 Potato products, such as crisps and French fries, are among the major
2 contributors to the acrylamide daily intake, especially for children and teens (Wilson et
3 al. 2006). Many studies have been accomplished to find strategies to minimize the
4 levels of acrylamide, such as controlling levels of reducing sugars in fresh tubers
5 (Amreim et al. 2004; Matthäus et al. 2004), agronomical factors (Noti et al. 2003) apply
6 appropriate storage conditions (De Wilde et al. 2005), modifying soaking or blanking
7 (Pedreschi et al. 2004), reducing frying temperature and time (Gertz and Klostermann
8 2002; Kita et al. 2004; Franke et al. 2005), addition of additives (Mestdash et al. 2008)
9 or cations (Gökmen and Senyuva, 2007). Alternatives to traditional frying such as
10 vacuum frying (Granda et al., 2004) or combined pre-treatment by microwave heating
11 (Edoggu et la., 2007) or pre-frying (Pedreschi et al., 2007) have been proposed. The
12 subject has been recently reviewed by Morales et al. (2008).

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

23 In 2007, the European Commission made recommendations to monitor levels of
24 acrylamide in certain food categories (2007/331/EC), these data will be compiled by
25 members states and reported to EFSA on a yearly basis for the next three years (EC

1 2007). Activities have not been equal across EU since overall dietary exposure has only
2 been estimated for a certain numbers of member states. In Spain, like many other
3 Mediterranean countries, estimation has not been undertaken yet. It might be anticipated
4 that there will be considerable differences between EU countries due to differences in
5 food consumption habits, including traditional foods.

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

14

1 **Materials and methods**

2 *Chemicals.*

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

8 *Samples*

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

18 *LC-ESI-MS determination of acrylamide.*

19 Sample preparation as described by Şenyuva and Gökmen (2006) was used with minor
20 modifications. A finely ground sample (0.450 g) was then weighed into a 10 mL
21 centrifuge tube. The sample was spiked with 100 µL $^{13}\text{C}_3$ -labelled acrylamide (10
22 µg/mL) for recovery, and 5 mL of Milli-Q water was added. Then the mixture was
23 vortexed, kept for five minutes at room temperature and subsequently homogenized for
24 1 min (Ultraturrax). Then, 750 µL Carrez I and 750 µL Carrez II solution were added,
25 vortexed and left to stand for 10 minutes. Tubes were centrifuged at 5000 rpm for 15

1 minutes at 4 °C. The clear supernatant (1 mL) was clarified onto a pre-conditioned HLB
2 cartridge. The first drops were discharged and the rest of the eluate was collected in
3 amberlite vials for analysis.

4
5 LC-ESI-MS analyses were performed as described by Rufian-Henares et al. (2007) with
6 minor modifications (Morales and Arribas-Lorenzo 2008) using an Agilent 1100 HPLC
7 system (Waldbronn, Germany) consisting of a quaternary pump, an autosampler and a
8 temperature-controlled column oven, coupled to an Agilent 1100 MS detector equipped
9 with an electrospray ionization interface. The analytical separation was performed on an
10 Inertsil ODS-3 column (250 × 4.6 mm, 5 µm) using an isocratic mixture of 0.2%
11 aqueous solution of formic acid at a flow rate of 0.6 mL/min at 25°C. Data acquisition
12 was performed, with a delay time of 8 min, in a selected ion monitoring (SIM) mode
13 using the following interface parameters: a drying gas (N₂, 100 psig) flow of 12 L/min,
14 nebulizer pressure of 45 psig, drying gas temperatures 350°C, a capillary voltage of 3
15 kV and a fragmenter voltage of 70 eV. Monitored ions were 72.1 *m/z* for acrylamide
16 and 75.1 *m/z* for ¹³C₃-labeled acrylamide. An acrylamide calibration curve was built in
17 the range of 2-100 µg/L and a limit of quantification was determined to be 25 µg/kg for
18 potato crisps. The method was in-house validated for linearity, precision and recovery.
19 Furthermore, the accuracy was recently demonstrated for potato crisps in an
20 interlaboratory comparison study launched by IRMM, yielding a z-score of -0.5.
21 Precision (reproducibility) was lower than 12% and recovery between 84-109 %. The
22 analyses are integrated within the scope of a certified laboratory controlled by AENOR
23 (Spanish Association for Standardisation and Certification).

24
25 *Food consumption data.*

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2
3 1 In order to calculate the dietary intake of acrylamide from potato crisps two different
4
5 2 food consumption data were used. A first exposure study was carried out from the
6
7 3 Spanish National Agricultural, Fishing and Food Administration based on a yearly
8
9 4 consumption database. It is a food survey annually published (MAPA 2007). This is the
10
11 5 most recent measurement of dietary consumption in Spain at a national level. In this
12
13 6 survey data are collected from 8240 interviews to non-institutionalized households and
14
15 7 898 interviews to restaurants, catering services, Institution (hospital, public schools,
16
17 8 penitentiary, etc), covering 2006. The statistical universe of the study compile a
18
19 9 balanced, representative and stratified probability sample of the Spanish population
20
21 10 taking into account, gender, ages, regions, socio-economic status, among others. An
22
23 11 average body weight of 70 kg was used to estimate the total daily intake of acrylamide
24
25 12 to total population and expressed as $\mu\text{g}/\text{kg bw}/\text{day}$. A second exposure study was
26
27 13 calculated from food consumption data survey from the National Food Safety and
28
29 14 Nutrition Agency in Spain (AESAs 2006). This study was elaborated in 2003 with Food
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31 15 Frequency Questionnaires over 1963 subjects from 0 – 60 years grouped in six levels of
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33 16 age (> 1 year, 1-2 years, 2-7 years, 7-12 years, 12-17 years, and > 17 years) in three
34
35 17 consecutive days.
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43 44 45 19 *Statistical Analysis.*

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48 20 Analyses were performed using Statgraphics Plus, version 5.1, 2001 (Statistical
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50 21 Graphics Corp, Rockville, MD, USA). At least, two independent analyses were carried
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52 22 out per sample.
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1 Results and Discussion

2 Thirty-six classical potato chips from 16 different producers, without flavor or species
3 added were analyzed for acrylamide content. Acrylamide content ranged from 81 to
4 2622 $\mu\text{g}/\text{kg}$ with a mean value of 740 $\mu\text{g}/\text{kg}$ and a median of 592 $\mu\text{g}/\text{kg}$. Similar values
5 were reported by other authors (Becalski et al. 2003; Roach et al. 2003; Rosen and
6 Hellenas 2002; Tareke et al. 2002; Matthys et al. 2005) who found acrylamide levels
7 ranged between 224 and 3700 $\mu\text{g}/\text{kg}$. Recently a survey on acrylamide levels in potato
8 crips in the Turkish market showed a median level of 818 $\mu\text{g}/\text{kg}$ (59 – 2336, min-max)
9 (Ölmez et al., 2008). Institute of Reference of Measurements and Materials developed a
10 monitoring database which was last updated in June 2006 (IRMM 2006; Wenzl and
11 Anklan, 2007). A median level of 528 $\mu\text{g}/\text{kg}$ (5 - 4215 $\mu\text{g}/\text{kg}$; min - max, n = 836) is
12 reported which is in line with values obtained in current survey. Results are also in
13 concordance with the monitoring database (2002-2004) from FDA with a mean of 612
14 $\mu\text{g}/\text{kg}$ and a median of 462 $\mu\text{g}/\text{kg}$ (www.cfsan.fda.gov). **Figure 1** depicted the
15 acrylamide distribution in the survey. All samples analysed contains ACRYLAMIDE
16 levels higher the LOQ.

17 However, levels of acrylamide in potato crisp marketed in Spain has been
18 significantly reduced as compared with a previous sampling dated on 2004 (Rufian-
19 Henares and Morales 2005). In the 2004 sampling, a median and mean of 1180 and
20 1484 $\mu\text{g}/\text{kg}$ was obtained where nearly a 50% reduction is reached in the current study.
21 In addition, values for the first quartile and third quartile are diminished as well, and
22 subsequently minimizing the heterogeneity of the distribution (**Figure 2**).

23 Acrylamide reduction was analytically confirmed in the potato crisps marketed
24 in Spain as compared with 4 years ago. Toolbox from the CIAA compile a number of
25 recommendations for effective acrylamide mitigation at industrial scale which seems to

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

17
18 WHO/JEFCA and the Scientific Panel on Contaminants in the Food Chain (CONTAM)
19 of the European Union aimed to investigate strategies to reduce acrylamide formation
20 by implementing the ALARA principle (as low as reasonably or technically
21 achievable). The German Federal Office of Consumer Protection and Food Safety
22 (BVL) stated a signal value 1000 µg/kg for potato crisps, as a concept of minimization
23 (BVL 2006). The signal value is defined as the lowest level of the 10% containing the
24 highest level of acrylamide in a food commodity. If acrylamide contents were above
25 this signal value, food producers should be recommended to take adequate actions to

1 lower such contents, but at present there is not regulations or obligation in the European
2 countries. Since 2002, BVL published yearly the observed value for potato crisps being
3 1500, 1200, 1470, 1029, and 1333 $\mu\text{g}/\text{kg}$ for the years 2002, 2003a, 2003b, 2004 and
4 2005 respectively. If the German minimisation concept is applied to the Spanish potato
5 crisps survey, most of the samples (86%) contained acrylamide levels lower than 1000
6 $\mu\text{g}/\text{kg}$. However the observed value was calculated to 1377 $\mu\text{g}/\text{kg}$ being about 61%
7 lower than value recorded in the 2004-sampling.

8
9 For monitoring the progress in the minimisation strategies by industrials, it is useful to
10 define limits for quality control. Three levels can be identify, acceptable (below 50th
11 percentile), under evaluation (50th – 90th percentile) and unacceptable (> 90th
12 percentile), as displayed in **Figure 1**. Samples lying in the upper region should
13 reconsider the internal quality strategy, for instance, increasing quality controls to fresh
14 potato suppliers. Many studies demonstrated that it is possible to define time–
15 temperature processing conditions which guarantee low acrylamide concentration and
16 the retention of sensorial properties in terms of colour, flavour, and starch gelatinization
17 (i.e. Pedreschi et al. 2006). It is necessary an adjustment of the traditional frying
18 conditions, supervision of the process, and improve traceability of fresh potatoes during
19 storage period by potato suppliers. Monitoring database of the IRMM which tend to
20 resemble the situation across Europe members states, recorded at the 90th percentile of
21 1442 $\mu\text{g}/\text{kg}$ (Wenzl and Anklan, 2007), which is also in line with reported for the
22 Spanish market.

23
24 *Dietary intake of acrylamide from potato crisp*

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

19

20 First exposure assessment was estimated from the National consumption database
21 monitored during 2006 (MAPA 2007). Although the point estimate (deterministic
22 approach) does not assess the probability or uncertainties or even do not identify high
23 risk consumers since is based on population and not in subjects, it is a first
24 approximation and a useful screening tool in order to design a more specific study in
25 case of a potential risk. Indeed, many of the earlier data reported in literature have been

1 obtained from generalist food intake studies for nutritional or economical monitoring
2 purposes but they were not specifically designed for food safety issues (Dybing et al.
3 2005). Furthermore, other studies link national consumption patterns with general
4 acrylamide databases (Boon et al. 2005). In summary, to date a comprehensive study
5 specifically designed for assessing the dietary acrylamide exposure is missing due to its
6 complexity.

7
8 During 2006, 16% of the fresh potatoes consumed in Spain were processed, and mostly
9 bought directly by consumers (84%) as compared with consumption at restaurants,
10 catering services or Institutions (hospitals, penitentiary, schools, etc.). It represents an
11 overall estimation of consumption of 1,44 kg processed potato products per capita. In
12 this estimation, it has not been included the frozen potato products with are mainly par-
13 fried French fries. Average contribution of potato crisps to dietary acrylamide exposure
14 in Spain (assuming a body weight of 70 kg) is calculated to 0.042 μg acrylamide/kg
15 bw/day. One limitation of the calculation is that one single level of consumption is used,
16 but it has been compared with the distribution of acrylamide calculated in the
17 commercial sampling. The risk scenario (95th percentile) is obtained with a level of
18 0.117 μg acrylamide/kg bw/day but this level does not identify subjects with high
19 consumption patterns. Selecting high residue levels (95th percentile) in potato crisps will
20 very likely to overestimate the exposure. More realistic estimates of low and high
21 exposure are obtained by using probabilistic models (i.e. Monte Carlo modelling) that
22 include residues and distribution consumption patterns. As formerly explained, the
23 deterministic method applied in this study is a useful tool for estimating mean exposure
24 of population to acrylamide.

1 The sources of acrylamide in foods vary with national or even local dietary habits. The
2 contribution of potato products is high but can vary among countries. **Table I** describes
3 the estimation of total dietary exposure to acrylamide and contribution calculated for
4 potato crisps as reported in different studies. For some other studies, sum of French
5 fries, potato crisps, and roasted potatoes is reported. Potato crisps, French fries and
6 other products are consumed at relatively high amounts in the US (35% of the daily
7 intake of acrylamide) (FDA 2004), but it is even higher in The Netherlands with French
8 fries and crisps taken together contributing up to 50% (Konings et al. 2003; Boon et al.
9 2005). In general, JECFA has estimated the variability in the potato crisps contribution
10 between 6 to 46% of the dietary acrylamide exposure, although recently Ariseto et al.
11 (2007) reported a contribution up to 60% of potato products in the Brazilian population.
12 Dietary acrylamide exposure of Spanish consumers has been significantly reduced as
13 compared with previous study (Morales 2004, unpublished). It is nearly 3.5-fold lower
14 than in The Netherlands (Konings et al. 2003) but in line with Sweden (Svensson et al.
15 2003). According to the most recent data, average human intake is estimated to be 0.4
16 $\mu\text{g}/\text{kg}$ bw/day from two years of age onwards. However, intake may vary widely from
17 0.3 to 2 $\mu\text{g}/\text{kg}$ bw/day or may reach even 5 $\mu\text{g}/\text{kg}$ bw/day at the 99th percentile
18 (WHO/JECFA 2005).

19
20 In consumer exposure assessments it is also important to know whether there are
21 significant differences among different subgroups of the population. National
22 consumption database identify 5 classes for indexing according to regions (17 levels for
23 different Autonomous Communities), size of cities (5 levels), socioeconomic status (4
24 levels), family members (5 levels) and cycle of life (8 levels). It was observed that there
25 are great differences depending on the different categories studied, almost doubling the

1 estimated exposure (**Table II**). In a simplistic overview, it can be observed that highest
2 risk of exposure is recorded for young singles of high+medium-high socioeconomic
3 status living at large cities in Catalonia. At the opposite, lowest exposure is expected for
4 large families with kids with low socioeconomic status living in villages (< 2000
5 inhabitants) at the Canaries Islands.

6
7 The second study for exposure estimation was applied on the basis of a consumption
8 study performed on food frequency questionnaires in three consecutive days to different
9 population groups (AESAs 2006). In this study it is recorded two levels of consumers
10 apart to obtain the average daily level of potato crisps intake. Regular consumers are
11 identified as subjects with some consumption of the product and represent the 33.11 %
12 of the children population and 21.32% of the adult population. It is also identified the
13 acute consumption at 97.5th percentile. **Table III** summarised the results. Average
14 dietary exposure to acrylamide for children is 2.6 fold the exposure for adults. This is
15 expected due to a combination of lower body weight and higher caloric demand giving
16 a higher net consumption. But also by a different dietary pattern, with higher
17 consumption of certain foodstuffs rich in acrylamide, such as French fries and potato
18 crisps (Dybing et al. 2005; Wilson et al. 2006). It is thus clear that certain subgroups
19 demonstrate especially high exposure to acrylamide. This ratio is in line with compiled
20 by earlier studies (WHO 2005; EFSA 2005). In the worst scenario the highest intake
21 will be 1.064 and 0.602 $\mu\text{g}/\text{kg}\cdot\text{bw}/\text{day}$ for children and adults. In 2004, our group
22 estimated the contribution of potato crisps to total dietary intake to be 22% (Morales,
23 2004 unpublished). In the assumption that the pattern will be maintained, a risk intake
24 (97.5th percentile) of 3.01 $\mu\text{g}/\text{kg}\cdot\text{bw}/\text{day}$ is expected which is lower than 4 $\mu\text{g}/\text{kg}$
25 bw/day , calculated by WHO (WHO 2005).

1
2
3 1 Average levels of acrylamide exposure determined by food consumption database (adult
4
5 2 population, 0.053 $\mu\text{g}/\text{kg}$ bw/day) and 3-day food records (total population, 0.042 $\mu\text{g}/\text{kg}$
6
7 3 bw/day) studies are rather similar, and both values are low when compared with other
8
9 4 countries (**table I**). Again, it is noteworthy to mention that expected exposure of
10
11 5 Spanish population to acrylamide from potato crisps is moderate. But, industrials should
12
13 6 keep the inspections and controlling the process chain to reduce, if still technically
14
15 7 possible, the levels in the acrylamide in the final product to achieve the lowest
16
17 8 contribution of potato crisps to global exposure to acrylamide on the Spanish
18
19 9 population. However, pattern of consumption are rather different among the Spanish
20
21 10 regions and some effort should be addressed by local administrations to reduce potato
22
23 11 crisp consumption in regions with acute exposure levels although globally the exposure
24
25 12 is moderate as compared with other countries. It is mandatory in near future to design a
26
27 13 specific consumers study for acrylamide. In the study, foods which are known to be
28
29 14 potential sources for acrylamide should be clearly identified. On the other hand, there is
30
31 15 a need to maintain a balance between health-promoting and nutritional components of
32
33 16 the foods with minimisation strategies to reduce acrylamide exposure, apart to sensorial
34
35 17 properties accepted by consumers. Before any proposal of risk management or
36
37 18 intervention by regulatory bodies, a critical evaluation of the situation is necessary.
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1 **Figures Captions.**

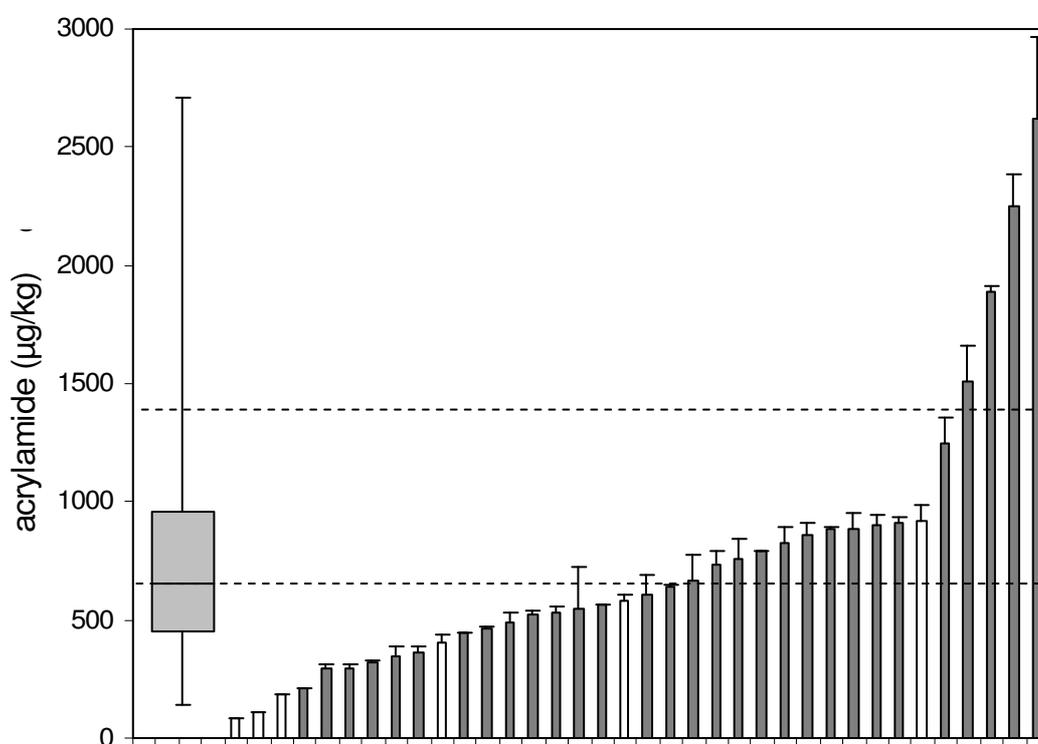
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3 **Figure 1.** Box-and-Whisker plot (a) and distribution graph for acrylamide content in
4 Spanish potato crisps. Empty bar represent samples declared as low fat content (< 25%)
5 by industrials. Dotted lines represent media and observed signal value.

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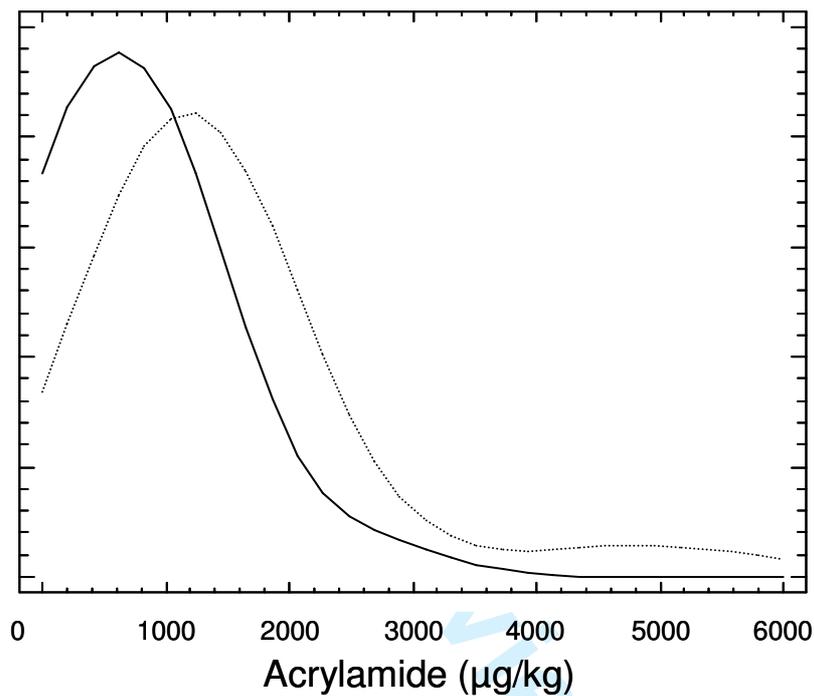
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Figure 2. Smooth density plot for levels of acrylamide in the 2008 potato crisps sampling and 2004 sampling (Rufian-Henares and Morales, 2005; dotted line).



6

1 TABLES

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Table I. Contribution of potato crisps to dietary acrylamide exposure in different studies. Sum of potato crisps, French fries and roasted potatoes contribution (*).

Country	Reference	Total intake µg/kgbw/day	Potato crisps %	partial contribution µg/kgbw/day	Age Year
USA	FDA (2006)	0,440	11	0,045	> 2
Sweedden	Svensson et al. (2003)	0,500	9	0,045	18 - 74
The Netherlands	Konings et al. (2003)	0,480	31	0,149	1 – 97
The Netherlands	Konings et al. (2003)	1,040	31	0,322	7 – 18
The Netherlands	Boon et al. (2005)	0.5	15	0.075	1 - 97
The Netherlands	Boon et al. (2005)	1.1	18	0.198	1 - 6
Norway	Dybing & Sanner (2003)	0,490	18	0,086	16 – 79 ♂
Norway	Dybing & Sanner (2003)	0,460	17	0,080	6 – 79 ♀
Norway	Dybing & Sanner (2003)	0,530	40	0,212	10 – 30 ♂
Germany	Mosbach-Schulz et al. (2003)	0,987	38*	0,371*	7 – 14
Germany	Mosbach-Schulz et al. (2003)	0,573	29*	0,166*	19 – 64
Belgium	Matthys et al. (2005)	0,513	12	0,062	13 – 18
Brazil	Arisseto et al. (2007)	0,550	60*	0,330*	11 – 17
France	AFSSA (2005)	1,400	26*	0,357*	3 – 8
France	AFSSA (2005)	0,500	32*	0,161*	9 – 14
France	AFSSA (2005)	0,500	24	0,122	> 15
Spain	Morales (2004, unpublished)	0,409	22	0,090	total

1 Table II. Contribution of potato crisps to the dietary exposure to acrylamide ($\mu\text{g}/\text{kg}\cdot\text{bw}/\text{day}$) for the total Spanish population according to
 2 different categories based on household consumption. Total National included household + Institutions + Restaurants consumption.
 3

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

4 Results expressed as $\mu\text{g}/\text{kg}\cdot\text{bw}/\text{day}$, in a body weight basis of 70 kg.
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1 Table III. Exposure (based on 3-day records) to acrylamide for children (body weight
 2 34.48 kg, n=903) and adult (body weight 68.48 kg, n= 1060) Spanish population. Data
 3 expressed as $\mu\text{gAA}/\text{kg}\cdot\text{bw}/\text{day}$. Risk consumers are estimated at percentile 97.50. Mean,
 4 min, max and P(90) refers to mean, minimum, maximum and percentile 95 of
 5 acrylamide distribution in commercial potato crisps.

Children (7-12 years)	mean	min	max	P(95)
Average consumer =	0.142	0.016	0.502	0.379
Regular consumer =	0.428	0.047	1.516	1.145
Risk consumer =	1.064	0.116	3.769	2.848
Adults (> 17-60 years)	Mean	Min	Max	P(95)
Average consumer =	0.053	0.006	0.189	0.143
Regular consumer =	0.250	0.027	0.887	0.670
Risk consumer =	0.602	0.066	2.131	1.610

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