Journal of Food Safety and Food Quality 70, Heft 2 (2019), Seiten 31–56

Arch Lebensmittelhyg 70,
48–55 (2019)
DOI 10.2376/0003-925X-70-48

ISSN 0003-925X

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Acrylamide content in Algerian food and preliminary assessment of acrylamide exposure in Algerian households

Acrylamidgehalt in algerischer Nahrung und vorläufige Bewertung der Acrylamidbelastung in algerischen Haushalten

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Summary

The objective of this work is to investigate how exposed is the Algerian population to ACR. It is a toxic chemical that forms during the cooking of certain foods. Acrylamide content was analyzed in food typically found in the Algerian diet. The food was acquired randomly and classified into five groups: i) potatoes and derivatives; ii) cereals and cereal products; iii) stimulants; iv) protein-rich foods such as meat, fish and milk; v) non-carbonated beverages, and vi) others. ACR content was analyzed according to the ISO-EN-16618:2015 using liquid chromatography coupled with tandem mass spectrometry. Potato-based foods contained the highest level of ACR. ACR consumption levels were studied to estimate both, the frequency of consumption and the level of exposure to ACR. A questionnaire assessing the amount and the type of food consumed was used in 788 households families. The survey results were combined with the acrylamide content analysis. The study showed that Algerians were exposed to an average ACR concentration of 0.2 to 0.4 µg per kg of body weight per day. The major contributors to this exposure were potato fries and biscuits. Each person in the population studied appeared to have been exposed to ACR through diet. Mitigation strategies must be introduced to reduce ACR exposure among the Algerian population.

Keywords: acrylamide, process contaminant, exposure, frequency of food consumption

Zusammenfassung

Das Ziel dieser Arbeit ist zu untersuchen, wie die algerische Bevölkerung gegenüber ACR exponiert ist. Es ist eine giftige Chemikalie, die sich beim Kochen bestimmter Lebensmittel bildet. Der Acrylamidgehalt wurde in Nahrungsmitteln analysiert, die typischerweise in der algerischen Diät gefunden werden. Das Essen wurde zufällig gesammelt und in fünf Gruppen eingeteilt: i) Kartoffeln und Derivate; ii) Getreide und Getreideprodukte; iii) Stimulanzien; iv) proteinreiche Lebensmittel wie Fleisch, Fisch und Milch; und v) nicht kohlensäurehaltige Getränke. Der ACR-Gehalt wurde gemäß der ISO-EN-16618: 2015 durch Flüssigkeitschromatographie in Verbindung mit Tandem-Massenspektrometrie analysiert. Lebensmittel auf Kartoffelbasis enthielten das höchste ACR-Niveau. Die ACR-Verbrauchsmengen wurden untersucht, um sowohl die Häufigkeit des Konsums als auch die Höhe der ACR-Exposition zu schätzen. In 788 Familien wurde ein Fragebogen zur Bewertung der Menge und der Art der konsumierten Lebensmittel verwendet. Die Umfrageergebnisse wurden mit der Acrylamid-Gehaltsanalyse kombiniert. Die Studie zeigte, dass Algerier einer durchschnittlichen ACR-Konzentration von 0,2 bis 0,4 µg pro kg Körpergewicht pro Tag ausgesetzt waren. Die Hauptursachen für dieses Engagement waren Kartoffelchips und Kekse. Jede Person in der untersuchten Population schien ACR durch Diät ausgesetzt gewesen zu sein. Es müssen Minderungsstrategien eingeführt werden, um die ACR-Exposition der algerischen Bevölkerung zu reduzieren.

Schlüsselwörter: Acrylamid, Prozess Verunreinigung, Exposition, Häufigkeit des Verzehrs von Lebensmitteln

Introduction

The acrylamide (ACR), or 2-propenamide, is a transparent, odourless, water-soluble vinyl compound that can easily be assembled into polymers (polyacrylamide). It is widely used in chemical engineering, in water treatment and in the construction of dams, tunnels, roads or reservoirs. It is also used in the pulp and paper industry, cosmetics manufacturing, and analytical chemistry (chromatography, electrophoresis) (Besaratinia and Pfeifer, 2007). In 2002 it was discovered that potentially toxic molecules form in foods cooked at very high temperatures, such as ACR (Slayne and Lineback, 2005; Adewale et al., 2015). It has been detected in all types of foods, including meat, bread, and potato products prepared at high temperatures (>120 °C) (Tareke et al., 2002). ACR forms when the asparagine reacts either with reducing sugars, such as glucose, or the carbonyls groups of lipids through the Maillard reaction and direct deamination with the formation of 3-aminopropionamide (Becalski et al., 2003). Free amino acids, mainly asparagine, and reducing sugars are important precursors to ACR in foods. Furthermore, the processing conditions, such as temperature, water activity, and matrix, influence its formation and degradation (Keramat et al., 2011). ACR is an industrial pollutant to which humans are exposed every day (Santhanasabapathy et al., 2015). Exposure to ACR can occur in three ways. The main and most significant source of exposure is through diet (Brisson et al., 2014). In humans, the toxic effects of ACR on the nervous system following significant occupational or accidental exposure are well known (Eman and Amany, 2008). Several analytical methods are used to quantify ACR in foods. (Musser, 2002; Wenzl, De La Calle and Anklam, 2003) In 2005, analytical data on the presence of ACR in foods were obtained from 24 countries with most of the samples originating in Europe (67.6 %) and the United States (21.9 %). The other samples were from Asia (8.9 %) and the Pacific (1.6 %). No analytical data was received from Latin America and Africa. The Joint Expert Committee on Food Additives (JECFA) conducted a risk assessment of ACR in foods (FAO/WHO Expert Committee on Food Additives, 2006) and concluded that an intake of 1 and 4 µg ACR/kg bw-day could represent the average and that there are high consumers in the general population, including children (Viswanath, 2012). The Margin of Exposure (MoE) approach compares the margin between a level causing cancer in animals or humans with the estimated human exposure to that substance (FAO/WHO Expert Committee on Food Additives., 2010; Tardiff et al., 2010).

In Algeria, there are few studies regarding the presence of ACR in food and its detrimental effects. Karima, 2015, assessed the level of ACR in 16 varieties of coffee and, previously, we analyzed its effects on Wistar rats (Belhadj Benziane et al., 2018). This is the first study evaluating the level of ACR in different groups of food in Algeria, which give us an idea of the presence of ACR in the Algerian diet which can be considered as a risk assessment.

Materials and methods

Groups of food analyzed

The groups of foods included for the testing of the presence of ACR consist of the most representative foods from a standard Algerian diet. The study was carried out in five cities. Sampling was performed in October of 2015. Product names, lots, and the presence on shelves correspond to products offered at the time of sampling and might not represent all products sold. At least three brands of each foodstuff or type of food were collected, since ACR concentrations can vary considerably (Normandin, Bouchard, Ayotte, Fennell, et al., 2013). A total of 33 samples belonging to six food groups were selected for the determination of ACR as described in Table 1. Food groups were identified as i) potato and derivatives, ii) cereals and derivatives, iii) protein-rich foods such as meat, fish and eggs, iv) milk and fruit juices, v) stimulants, vi) others. For the determination of ACR in drinking water, it was determined the level of the chemical „polyelectrolyte" that is used for the treatment of drinking water (0.1 g /L) and it is likely to contain the monomer of ACR.

Sampling and determination of acrylamide

The analysis of ACR in food was carried out using liquid chromatography, coupled with tandem mass spectrometry (LC-MS/MS) with an isotopic dilution at the Institute of Food Science and Technology (ICTAN-CSIC, Madrid, Spain) according to the EN-16618:2018 norm, with minor modifications (Mesías and Morales, 2016). Each sample is grounded and homogenized in order to recover a representative amount of 250 g, 50 g of the sample were taken to extract and to determine the level of ACR. The grounded sample (0.500 g) was weighed and mixed with 9.4 mL of water in polypropylene centrifugal tubes. Two mL of hexane were added to the tubes in order to remove the fat content. The procedure was repeated twice. As an internal standard, 100 µL of a 5 µg/mL [13C3]-acrylamide methanolic solution were added to the sample, and it was then homogenized (Ultra Turrax, IKA, Mod-T10, Germany) for 10 minutes. Afterwards, the sample was treated with Carrez I (15 g potassium ferrocyanide/100 mL water) and Carrez II (30 g zinc acetate/100 mL water) solutions and centrifuged (9000 g for 10 min, at 4 °C). The samples were cleaned up using Oasis-HLB cartridges. The cartridges were preconditioned with 1 mL of methanol and 1 mL of water. An aliquot of the clear supernatant was loaded onto the cartridge at a flow rate of 2 mL/min, the first drops were discharged and the rest collected. Then, the solution was filtered through a 0.45 µm filter into an amberlite LC-MS vial. Sample extracts and calibration standards were analyzed on an Agilent 1200 liquid chromatograph coupled to an Agilent Triple Quadrupole MS detector (Agilent Technologies, Palo Alto, CA, USA). Analytical separation was achieved either with an Inertsil ODS-3column (250 × 4.6 mm, 5 µm; GL Sciences Inc., Tokyo, Japan) or with a Hypercarb column (50 x 2.1 mm, 5 mm; Thermo Scientific, Bremen, Germany) at 30 °C. Isocratic elution was achieved with a mobile phase of formic acid in water (0.2 mL/100 mL) at a flow rate of 0.4 mL/min. The injection volume was 10 µL. The electrospray ionization was set to the positive ionization mode. Under these chromatographic conditions, ACR eluted at 6.1 min. The needle was set at 1.0 kV. Nitrogen was used as nebulizer gas (12.0 L/min) and the temperature was set at 350°C. Signals at m/z72.1 – m/z 55.1 and m/z 75.1 – m/z 58.1 were isolated for ACR and [13C3]-ACR, respectively. For the transitions m/z 72.1 > m/z 55.1 and m/z 75.1 > m/z58.1 the fragmentation was set at 76 V and the collision energy at 8V. Masses were recorded using multiple reactions monitoring (MRM). For quantitation, the signals at m/z 75.1 and 78.1 were used, while signals at m/z 58.1 and 55.1 served for qualification.

ACR was quantified using standard solutions (5–100 µg/L) as a reference with 50 µg/L of [13C3]-acrylamide. The peak identity is confirmed by comparing the peak ratio from sample extracts and standard solutions for the transitions m/z 72 > 55 and 75 > 58, respectively. The limit of the quantitation was set at 15µg/kg. The accuracy of the results was recently demonstrated for potato crisps in another laboratory comparison study launched by the Food Analysis Performance Assessment Scheme (FAPAS) program (2013, 2015 and 2016), yielding a z-score of 0.3, –0.1 and 0.2, respectively. The analysis was performed in triplicate and the results were expressed as µg/kg of product. The recovery rate of ACR of the standard samples was usually between 90 and 106 %. The relative standard deviations (RSD) for the precision, repeatability, and reproducibility of the analysis were calculated to be of 2.8 %, 1.2 % and, 2.5 %, respectively. The limit of the quantitation was set at 15 µg/kg.

Estimation of the frequency of consumption

The frequency of food consumption is estimated by the ratio of the number of times a type of food was consumed per day, week and month and expressed by time/day. The consumption frequencies of 25 different food or group of food were estimated by this study from 788 households distributed over three *wilayas* (governorates) in western Algeria.

Evaluation of the deterministic exposure to acrylamide

The primary exposure assessment for ACR is conducted using the Canadian method of risk assessment (Normandin, Bouchard, Ayotte, Blanchet, et al., 2013) in which exposure to any chemical in food is affected by (1) the concentration of the chemical in food, and (2) the amount of food consumed. Both are required to assess exposure, which is usually expressed on a body weight basis.

Individuals had to complete a questionnaire that contained two sections. The first section was general information to classify the subjects, it had simple questions that allowed the subject to become familiar with the process (age, sex, and weight). The second section of the questionnaire was designed to assess the exposure to ACR. The subjects were asked about their consumption of certain types of food and their level of consumption. Each respondent was then asked to fill out information about a series of food, indicating one out of three frequencies of consumption and the quantity ingested each time (Mir, 2008). Using the data from the responses, the total dietary intake of ACR and the weight in grams of each food consumed were calculated. The exposure was expressed in µg ACR/day/kg body weight and evaluated as follows:

Exposure (µg/kg bw/day) = *[amount of food consumed (gram/day) × acrylamide dose per food (µg ACR/ 1000g)] / average body weight (kg).*

Statistical studies

The data was analyzed using an ANOVA statistical analysis (Microsoft Excel 2016) and the results obtained are summarized in Tables 1–2 and Figure 1 as the mean, standard deviation.

Results and discussion

The dosage of acrylamide in food products

The analysis of ACR in potato chips showed a high concentration of 4755 ± 468 µg / kg, and a concentration of 636 ± 70.4 µg / kg in fried potatoes (see Table 1). ACR values in cereal products were detected in most of the samples except for pasta with a concentration of 666 ± 9.6 µg / kg in biscuits.

Furthermore, it has been shown that the sugar content (glucose and fructose) of the raw potatoes correlates with the amount of ACR formed during cooking. The content of reducing sugars was an important factor in the formation of ACR, while asparagine content was less significant (FAO/WHO Expert Committee on Food Additives, 2006)

The bread (or cake) is a cereal product that has a 93 ± 2.0 µg / kg dose of ACR with regular consumption, a lower dose than biscuits. We also detected ACR in the samples of coffee and chocolates. Other research indicates that asparagine is probably the major determinant of the presence of ACR in coffee and chocolates (CCFAC, 2006).

Of the foods analyzed by Health Canada, potato chips and fried potatoes had the highest content of ACR, on the opposite side were bread and cereals with the lowest content of ACR (Slayne and Lineback, 2005; FAO/WHO Expert Committee on Food Additives, 2006).

The ACR is primarily found in plant-based foods; heat treated starchy foods such as potato, cereal, and bakery products that contain high levels of ACR (Svensson et al., 2003; Riboldi, Vinhas and Moreira, 2014). ACR is not found in foods that are not fried or baked such as boiled or microwaved food (Eriksson, 2005; Törnqvist, 2005) and it is found in low levels in animal-based food products such as meat and fish (Krishnakumar and Visvanathan, 2014).

Characteristic of the population studied

The total number of subjects of this study was of 788, 371 women and 417 men which represented 47.08 and 52.92 % of the sample, respectively. Considering the whole sample, the mean age was of 22.2 ± 9.68 years and the average weight was of 58.5 ± 15.54 kg. The average age and weight of **women** were 21.3 ± 8.22 years and 61.7 ± 16.71 kg. Meanwhile, **men** were 23.0 ± 10.76 years and had an average weight of 55.0 ± 13.29 kg.

The number of individuals weighing ≤55 kg is 303 with an average age and weight of 16.2 ± 5.56 years; 43.3 ± 9.09 kg. The number of individuals weighing between 55–60 kg was 153 with an average age and weight of 21.3 ± 6.28; 57.8 ± 2.12 kg. The number of individuals weighing ≥60 kg was 332 with an average age and weight of 28.1 ± 10.38 years, 72.8 ± 8.89 kg. There were 262 individuals in the age range of **14–19** years, with a mean age of 16.9 ± 1.32 and an average weight of 54.77 ± 9.03. There were 273 individuals in the age range of **20–27** years, with a mean age of 22.98 ± 2.06, and an average weight of 63.45 ± 10.81 kg. There were 149 individuals who were more than 27 years and had a mean age of 38.26 ± 8.96 and a mean weight of 73.38 ± 12.52.

Preliminary assessment on the exposure of the population

The results for the entire sample of 788 subjects can be seen in Table 2 and Figure 1.

In this part, the statistical study shows the presence of an Over-Dispersion which refers to the case where the variance of a dependent (response) variable exceeds the nominal variance, considering the respective conjectured distribution. This condition is frequently encountered when fitting a generalized linear model to categorical response variables (Agresti, 2018).

Potatoes and their derivatives have the highest contribution to ACR exposure, even with a low frequency of consumption. In the same group, we found that potato fries show the highest exposure with an average consumption frequency of 0.45 and a maximum frequency of 0.84 times/day; The high exposure can be explained by the high ACR content of these groups of food (Table 1).

Stimulants and stimulant-analogues have a frequency of consumption of 0.59 times/day, this means that this group accounts for the higher exposure to ACR (0.13 µg/kg bw/day) after the potatoes and its derivatives. Coffee was the most important contributor of ACR exposure in this group.

In the Algerian regulations; The limit for ACR content in coffee for human consumption is between 450 µg/kg in roasted coffee to 4000 µg/kg in other coffee substitutes according to the Executive Decree No. 17-99, taking into account: the characteristics of the coffee and the processing conditions for its consumption (Ministry of Commerce Algeria, 2017).

Cereals and cereal products were consumed on a regular basis by all subjects questioned with an average of 0.50 times per day, with an exposure of 0.12 µg/kg bw/day of ACR, and both biscuits and industrial bread were the most consumed types of food of this group. The determinant factor for ACR in cereal products is free asparagine, and it has been showed that free asparagine content varies widely (Konings et al., 2007).

Those results are in agreement with those found from other studies in which most of the ACR dietary exposure results from potato products, coffee, bakery products, and chocolate. ACR in potatoes and its products is formed during industrial processing, retail, catering, and even during regular cooking processes (Konings et al., 2003; Kwok, Qiao and Solomon, 2003; Vinci, Mestdagh and De Meulenaer, 2012; De Meulenaer, Medeiros and Mestdagh, 2016).

Milk and beverages did not represent a source of ACR because the level of ACR in this group of food is low, (below the limit of quantification (LOQ)). The frequency of consumption of this group was between 0.53 and 0.66 times per day. One study found that ACR was not detectable in eggs, milk, fruits, water, beverages and alcoholic beverages (Zhou et al., 2013) and we atribute this to the high content of water that confers high water activity, and also to the way that these types of food are prepared.

ACR could not be detected in unheated control or boiled foods (Tareke et al., 2002); Fish, meat, chicken, and eggs have a frequency of consumption almost equivalent to potatoes (0.28 times per day). The values of ACR were lower than the limit of quantification (LOQ: 15 µg / kg) in meat, fish, eggs, and sausages.

Yaylayan et al. (2004) reported the generation of ACR from the dipeptide carnosine in heated meat. This peptide hydrolyzes to b-alanine, which further reacts with the ammonium resulting from the Strecker degradation of amino acids. The low levels of ACR in this group are probably due to the formation of methyl derivatives from ACR and the toxic effects of this compounds (if any) are still unknown (Claus, Carle and Schieber, 2008). Foods that did not contain ACR or had an ACR content below the limit of quantification (LOQ: 10 ppm) included raw or cooked chicken, raw or cooked fish, raw potatoes, frozen

TABLE 1: *Content of acrylamide (µg ACR/kg of food) in six Food categories.*

Food category	Mean	Standard deviation
I) Potatoes and derivatives (n = 6)	**1386**	**1753,93**
Potato chips	4755	468,00
Fried Potato (Desireepotatoes)	636	70,00
Fried Potato (Spuntapotatoes)	491	7,00
Fried Potato	488	38,00
Potato Chips	558	2,00
Boiled Potato	<LOQ	<LOQ
II) Cereals and cereal products (n = 12)	**168**	**187,65**
Corn chips	106	4,00
Traditional bread	18	0,00
Factory-baked bread	93	2,00
Bread, chocolate	16	1,53
Cookies from cocoa powder	172	5,00
Cookie from dried milk	235	3,00
Food paste	<LOQ	<LOQ
Couscous	<LOQ	<LOQ
Cooked eggs	46	3,00
Improved bread	70	2,00
Chocolate biscuit	666	10,00
Wafer (Gaufrette)	259	6,00
III) Protein rich foods (n = 5)	**<LOQ**	**<LOQ**
Tuna	<LOQ	<LOQ
Sardines	<LOQ	<LOQ
Meat, chopped (corned beef)	<LOQ	<LOQ
pulley roast	<LOQ	<LOQ
Eggs, cooked	<LOQ	<LOQ
IV) Milk & drinks (n = 4)	**<LOQ**	**<LOQ**
Whole milk UHT	<LOQ	<LOQ
Fruit Juice, pasteurized	<LOQ	<LOQ
Juice, pasteurized	<LOQ	<LOQ
Skimmed milk UHT	<LOQ	<LOQ
V) Stimulants & analogues (n = 6)	**183**	**41,14**
Arabica coffee	172	3,00
Robusta coffee	125	7,00
Arabica & Robusta coffee	205	11,00
Tobacco	<LOQ	<LOQ
Tea	<LOQ	<LOQ
Chocolate	229	2,00
VI) Others (n = 3)	**<LOQ**	**<LOQ**
Poly electrolyte (n=2) Net and solution 0,1 g/l	<LOQ	<LOQ
Mashed tomato	<LOQ	<LOQ
TOTAL (accumulated/average)	**9985**	**526**

LOQ :limit of quantitation: 15 µg/kg

vegetables, soy sauce, meat, juice or gelatin (Klein, 2007). In contrast, it was found that the addition of meat or fish (nearly pure protein) during the cooking of different dishes significantly reduced ACR (Taeymans et al., 2004), and this is probably due to the reaction of formed ACR with the -SH and amino groups of the proteins (Schabacker, Schwend and Wink, 2004).

The dosage of ACR was carried out on samples of treated water. These samples were collected in different points: at the outlet of a treatment plant, at the structures and installations of the supply, storage, and distribution levels, and finally at the point where the treated water was taken for the manufacture of soft drinks, ice, and the packaging of foodstuffs. The different sources of water were differentiated according to the types of drinking water and/or quality control categories established in the Executive Decree No. 09-414 (Ministry of Water Resources Algeria, 2009).

The limit value for ACR in water for human consumption is 0.5 μg/L according to the Executive Decree No. 14-96 amending and the supplementing Executive Decree No. 11-125 on the quality of drinking water for humans (Ministry of Water Resources Algeria, 2014).

In Algeria, the ADE (Algerian Waters), that is attached to the Ministry of Water Resources and Environment (Drouiche et al., 2012), has Water Quality Control Laboratories that is responsible for these analyzes. We have recovered a sample of the polyelectrolyte used at 0.1 g/L in

TABLE 2: *Probabilistic estimates of food exposure to acrylamide in people of selected age groups.*

	Age [6–13] n = 104		Age [14–19] n = 262		Age [20–27] n = 273		Age ≥27 n = 149	
	frequency time/day	exposure µg/kg w/day	frequency time/day	exposure µg/kg w/day	frequency time/day	exposure µg/kg w/day	frequency time/day	exposure µg/kg w/day
Potatoes and Crunchy								
chips (potato)	0,51 ± 0,73	0,08 ± 0,22	0,28 ± 0,70	0,03 ± 0,13	0,19 ± 00,46	0,02 ± 00,06	0,05 ± 00,19	0,00
fried potatoes	0,35 ± 0,28	0,47 ± 1,05	0,48 ± 0,41	0,77 ± 1,61	0,49 ± 00,40	0,78 ± 02,65	0,38 ± 00,39	0,33 ± 00,81
potato pulp	0,20 ± 0,31	0,00	0,33 ± 0,48	0,00	0,29 ± 00,40	0,00	0,39 ± 00,43	0,00
mashed potatoes	0,08 ± 0,16	0,00	0,06 ± 0,15	0,00	0,09 ± 00,16	0,00	0,08 ± 00,14	0,00
Products containing cereal								
chips (corn based)	0,29 ± 0,41	0,00	0,24 ± 0,63	0,00	0,07 ± 00,24	0,00	0,05 ± 00,19	0,00
cookies	0,62 ± 0,68	0,22 ± 0,31	0,83 ± 3,54	0,32 ± 0,74	0,69 ± 00,66	0,22 ± 00,44	0,54 ± 00,56	0,12 ± 00,21
traditional bread	0,82 ± 0,71	0,07 ± 0,08	1,06 ± 0,86	0,09 ± 0,10	0,83 ± 00,84	0,06 ± 00,10	0,86 ± 00,76	0,05 ± 00,06
factory-baked bread	0,72 ± 0,61	0,13 ± 0,16	0,89 ± 2,68	0,10 ± 0,18	1,27 ± 00,98	0,17 ± 00,21	0,84 ± 00,87	0,08 ± 00,11
food pastes	0,23 ± 0,31	0,00	0,24 ± 0,33	0,00	0,34 ± 00,42	0,00	0,23 ± 00,27	0,00
couscous	0,19 ± 0,16	0,00	0,18 ± 0,16	0,00	0,17 ± 00,11	0,00	0,21 ± 00,19	0,00
Wafer (Gaufrette)	0,33 ± 0,51	0,09 ± 0,20	0,38 ± 0,46	0,10 ± 0,28	0,20 ± 00,33	0,030,09	0,22 ± 00,40	0,03 ± 00,11
Stimulant								
coffee	0,25 ± 0,62	0,04 ± 0,10	0,86 ± 0,94	0,14 ± 0,26	1,25 ± 01,24	0,18 ± 00,26	1,41 ± 01,28	0,20 ± 00,34
chocolate	0,38 ± 0,49	0,06 ± 0,16	0,49 ± 0,76	0,20 ± 1,19	0,31 ± 00,49	0,05 ± 00,16	0,26 ± 00,50	0,04 ± 00,16
tea	0,16 ± 0,42	0,00	0,26 ± 0,57	0,00	0,35 ± 00,66	0,00	0,80 ± 04,69	0,00
Drinks								
aerated beverages	0,63 ± 0,59	0,00	0,90 ± 2,65	0,00	0,67 ± 00,85	0,00	0,66 ± 00,79	0,00
drink juice	0,49 ± 0,51	0,00	0,44 ± 0,52	0,00	0,85 ± 01,91	0,00	0,62 ± 00,66	0,00
milk UHT	0,94 ± 0,76	0,00	0,72 ± 3,56	0,00	0,46 ± 00,79	0,00	0,57 ± 00,72	0,00
Fruit and vegetables								
fruit	0,12 ± 0,18	0,00	0,16 ± 0,22	0,00	0,20 ± 00,30	0,00	0,14 ± 00,19	0,00
vegetables (fried)	0,42 ± 0,41	0,00	0,78 ± 3,54	0,00	0,66 ± 00,72	0,00	0,45 ± 00,65	0,00
preserved tomato	0,56 ± 0,55	0,00	0,85 ± 0,65	0,00	0,73 ± 00,79	0,00	1,04 ± 04,66	0,00
Meat, fish, eggs								
tuna	0,12 ± 0,22	0,00	0,15 ± 0,28	0,00	0,29 ± 01,70	0,00	0,13 ± 00,25	0,00
sardines	0,06 ± 0,13	0,00	0,08 ± 0,13	0,00	0,14 ± 00,26	0,00	0,10 ± 00,23	0,00
chopped meat	0,11 ± 0,15	0,00	0,14 ± 0,21	0,00	0,24 ± 00,71	0,00	0,16 ± 00,21	0,00
pulley roast	0,36 ± 0,33	0,00	0,30 ± 0,34	0,00	0,31 ± 00,42	0,00	0,28 ± 00,31	0,00
cooked egg	0,55 ± 1,69	0,00	0,54 ± 0,57	0,00	0,69 ± 01,52	0,00	0,59 ± 00,76	0,00
average/day	**0,38 ± 0,24**	**0,15**	**0,47 ± 0,31**	**0,19**	**0,47 ± 0,33**	**0,19**	**0,44 ± 0,35**	**0,10**

the treatment of drinking water in Algeria, which may contain traces of ACR monomers. We carried out an assay to determine the ACR content both, on the crude product and in the 0.1 g/L polyelectrolyte. The ACR content was lower than the LOQ. The sampling was done at the SIDIYAAKOUB dam *Wilaya* of Chlef, Daira of Boukadir, town Oued Sly(BELAIB, 2008; Houari, 2009).

The analysis of pasteurized drinks and sterilized milk (containing 90 % of drinking water) revealed that the presence of ACR is below the limit of quantification (LOQ: 15 µg/kg), which is in accordance with the regulations.

According to Rodier et al (2009); Residues ACR are found in the coagulants used in the treatment of drinking water. The maximum allowable dose is usually 1 mg/L and if this product (coagulants) contains 0.05 % of ACR we will find a theoretical maximum ACR concentration of 0.5 g/L ACR (Taleb, 2005; Rodier, Legube and Merlet, 2009).

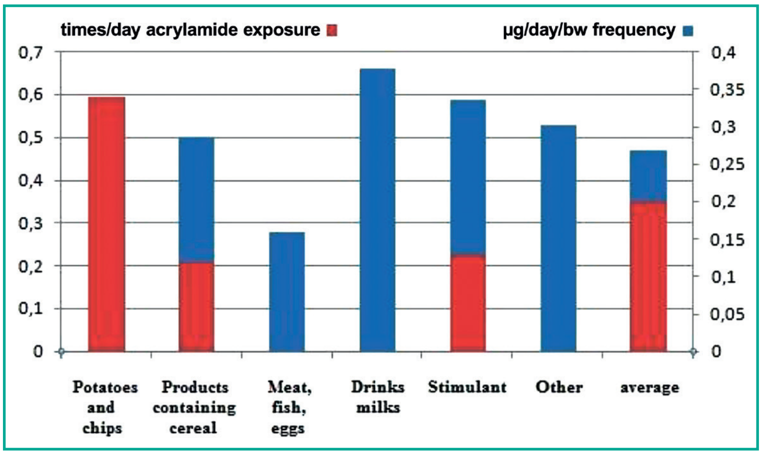

FIGURE 1: *The frequency of consumption and the exposure to the acrylamide in some food in Algeria.*

It is important to mention that only the average exposure to ACR was calculated. A mean value provided information about individuals whose body weight and eating habits were average, but it did not provide an overall perspective of the levels of exposure that can be observed in a diverse population. Based on dietary habits, the exposure rate of some people will be higher or lower than the average exposure to ACR (Normandin, Bouchard, Ayotte, Blanchet, et al., 2013).

In addition, JECFA (2005) specifies that, for the majority of countries, fries represent the food category which contributes the most to ACR intake (16–30 %), followed by potato chips (6–46 %), coffee (13–39 %), sweet biscuits and pastries (10–20 %), and toast (10–30 %) (FAO, 2011).

Dybing et al., 2005, compared the contribution of ACR from different food categories measured in different countries for different age groups and they found that for Belgian adolescents, the intake of french fries contributed to nearly 50 % of the exposure, which is comparable to the present study.

According to the study of (Bensalem, Agli and Oulamara, 2014) on the frequency of different food consumption in Algeria, cereals constituted the basis of household food (bread/cake: 2.6 times a day; pasta: once a week). Milk supplemented this basic diet with an average consumption of twice a day. Low consumption is observed for fruits and vegetables (less than once a day), red meats (2.2 times per week), poultry (4.3 times per week), eggs (2 eggs once a week), and fish (less than once a week). In the case of sodas and sweet products, consumption was once a day.

The FDA found that eight food groups (chips, baked French fries, breakfast cereals, toast, biscuits, white bread, and coffee) were the source of more than 80 % of the average intake of ACR in the population and that no single food alone was entirely responsible for the average amount of ACR ingested(Slayne and Lineback, 2005). Estimates of food exposures calculated in the United Kingdom showed that cereal products and potatoes are the main sources of ACR in foods of the United Kingdom(Elmore et al., 2015). The main food categories responsible for exposure to ACR appear to be the same in North America and Europe (CCFAC, 2006). However, the exposure values reported in this study are lower than those reported by JECFCA and Health Canada in 2012 (Brisson-Gauthier, 2012; Normandin, Bouchard, Ayotte, Fennell, et al., 2013).

Considering the general average consumption of all foods, the average exposure per Algerian inhabitant is 0.2–0.4 µg of ACR per day by body weight (µg/kg bw/day).

The dietary exposure to ACR in adults is between 0.3 and 0.4 micrograms per kilogram of body weight per day (µg/kg bw/day). The average ACR concentration values for each product and the mean food consumption data were used to calculate a single exposure value for the entire population rather than a range of values and, therefore, this preliminary assessment evaluates the exposure of the general population. The results of the preliminary deterministic assessment of Health Canada exposure are similar to other assessments of dietary exposure to ACR in other countries such as Sweden and the United States (Normandin, Bouchard, Ayotte, Fennell, et al., 2013; Cladière and Camel, 2017). Similar results were found in this study.

Although the Algerian regulations in force for the periodic control of ACR in drinking water and certain food groups (coffee and substitutes) exist, data on the content of ACR in food remains scarce, which has led to a lack of surveillance plan, and the population remains vulnerable to ACR exposure.

Although it is a preliminary deterministic assessment; this study needs to be extended by monitoring plans using a large number of samples with other techniques for assessing food consumption (such as food availability reports and consumption expenditure) because the frequency questionnaire method is not interested in not to actual consumption but usual consumption.

We recommend for any extended and comprehensive study to collaborate with global organizations and structures to strengthen regulations and customs in terms of food exchange between countries and risk prevention of chemical contaminants (such as acrylamide).

Conclusion

The ACR exposure of Algerian citizens is not far from the levels recorded in other countries. Also, in line with recommendations from the WHO-FAO, EFSA, and FDA, the exposure and the concentration of ACR in foods commonly present in the Algerian diet should be reduced. To reach that aim, it is necessary to create and apply a strategy to reduce the risks related to ACR in food. This strategy should be led by the government, and involve critical stakeholders such as the food sector, research and academic institutions, and those institutions responsible for the health of the citizens in order.

Acknowledgements

We would like to thank Dr. Francisco J. Morales and Dr. Marta Mesías (Institute of Food Science and Technology ICTAN-CSIC, Madrid, Spain) for their assistance in the analysis of ACR by liquid chromatography coupled with tandem mass spectrometry.

Conflict of interest

We, the authors, declare that we have no protected, financial, occupational or other personal interests in a product, service and/or a company which could influence the contents or opinions presented in the above-mentioned manuscript.

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