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Fluoride exposure from consumption of some animal-based foods in an outermost region of Europe

Juan R. Jáudenes-Marrero [a,b], Soraya Paz-Montelongo [a,b,*], Arturo Hardisson [a,b], Carmen Rubio [a,b], Santiago Cerdán-Pérez [a], Ángel J. Gutiérrez-Fernández [a,b]

[a] Area of Toxicology, Universidad de La Laguna, La Laguna, Tenerife, Canary Islands 38071, Spain
[b] Grupo Interuniversitario de Toxicología Ambiental y Seguridad de los Alimentos y Medicamentos, Universidad de La Laguna, La Laguna, Tenerife, Canary Islands 38071, Spain

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ABSTRACT

Fluoride is an anion that is widely distributed in nature and can be found in varying levels in water supplies and foodstuffs. This study has been carried out considering the toxic effects in cases of chronic and high fluoride intake and the presence of this anion in foods of animal origin. The fluoride content in a total of 96 samples of animal origin (meat, poultry and poultry products; fish and seafood; milk, dairy products and eggs) was determined by potentiometry with a fluoride selective electrode (ISE). The overall mean concentration was 3.92 ± 6.04 mg/kg, with a minimum for milk (values below the detection limit of 0.01 mg/kg) and a maximum for shrimps (32.1 mg/kg). Seafood was found to have the highest fluoride concentrations and the estimated daily intake (EDI) and the percentage contribution to the adequate intake (AI) and upper-level intake (UL) were calculated. Overall, the percentage contribution to UL was less than 20 %. It was concluded that the intake of the analysed animal-based foods does not pose a toxic risk.

1. Introduction

Fluoride is an anion which has a high chemical reactivity and occurs naturally in various minerals such as fluorspar or cryolite (Christe & Schneider, 2018). The main sources of this ion can be natural (such as volcanic emissions) or anthropogenic, using fluoride-based products (such as pesticides and chemical reagents). In the form of aerosols, it can be transported over long distances by wind, depending on the deposition velocity of the particles, which in turn depends on climatic conditions (in winter wet deposition would occur with rain). Deposition can take place on soils or water surfaces (Liteplo et al., 2002; Casagrande Marimon et al., 2007).

Fluoride, at high concentrations, can also be toxic to the human. Chronic exposure to high levels of fluoride can lead to fluorosis, a disease characterised by the involvement of tooth enamel and osteosclerosis (Liteplo et al., 2002; González Sacramento et al., 2015; Revelo-Mejía et al., 2023). In addition, adverse effects on the central nervous system, the cardiovascular system and the immune system have also been described in exposure to extremely high doses.

In some cases, fluoride food poisoning has been reported in populations consuming water and foods with high concentrations of fluoride. For example, in India, fluorosis has been reported in populations consuming water with high levels of fluoride and ingesting large amounts of tea, one of the main dietary sources of fluoride in the region (Mahantesha et al., 2016). Fluorosis has also been described in populations consuming food grown in soils with high fluoride concentrations, as is the case in parts of Africa and China. In the Canary Islands, the problem with fluoride is due to its presence in high concentrations in the water supply, but, unlike other regions, this is a naturally occurring contamination due to volcanic minerals containing this ion in varying concentrations, which subsequently enters the water in underground galleries (Linhares et al., 2016; González Sacramento et al., 2015; Revelo-Mejía et al., 2023).

Soluble fluorides are bioaccumulated by aquatic and terrestrial organisms, preferentially accumulating in the skeleton and soft tissues with a tendency to calcify (ATSDR, 2003). There will be a higher accumulation during the growth period of the animals, as well as during moulting periods in animals with an exoskeleton (Liteplo et al., 2002). Studies on red mullet from Gabès Bay show tissue fluoride concentrations 4–5 times higher than mullet from Tunis Bay. Gabès Bay in

* Corresponding author at: Area of Toxicology, Universidad de La Laguna, La Laguna, Tenerife, Canary Islands 38071, Spain.
E-mail address: spazmont@ull.edu.es (S. Paz-Montelongo).

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southern Tunisia has numerous sources of fluoride (Milhaud et al., 1981). Canned fish such as sardines or salmon contain higher amounts of F- than other fish species (Ganta et al., 2015; Chowdhury et al., 2018).

The source of the fluoride that bioaccumulates in marine animals appears to be the water in which they are found, rather than diet (Liteplo et al., 2002). For example, one study found that in crabs (*Austropotamobius pallipes*) body fluoride content increased with increasing fluoride concentration of the water and exposure time (Aguirre-Sierra et al., 2013). Another study determined that with the increase in concentration and temperature, the bioaccumulation of F- in the mollusk (*Dreissena polymorpha*) increased (Del Piero et al., 2012). On the other hand, it decreases with increasing intraspecific body size and calcium and chloride content in the water (Camargo, 2003).

In the case of terrestrial mammals, it has been found that in areas close to an aluminium smelter in the UK (a major anthropogenic source of fluoride), field mice (*Microtus agrestis*) contained significantly higher concentrations of bone fluoride than those in the control area (Walton, 1987). In this case, the source of the fluoride that bioaccumulates appears to be, more importantly, the food that is ingested (Liteplo et al., 2002).

The numerous articles on fluoride intake and risk assessment that have been published place special emphasis on the determination of fluoride in water supplies and beverages such as tea or coffee. However, as previously mentioned, animals can bioaccumulate fluoride in their structure (bones, muscle, etc) (Walton, 1987; Liteplo et al., 2002; Camargo, 2003; Shi et al., 2009; Del Piero et al., 2012; Aguirre-Sierra et al., 2013; Chen et al., 2013; Ranjan & Ranjan, 2015), and consequently, animal origin foods could be an important fluoride exposure way. Therefore, on the assumption that animal origin food may be a risk to the population, this study has been carried out with the following objectives: 1) to determine the fluoride concentration in different animal-based foods samples, and 2) to assess the fluoride intake from the consumption of those samples.

2. Material and methods

The reagents used in this study are of reagent grade for chemical analysis. Distilled water and Mili-Q water were obtained from a specific water filtration system (Merck KGaA, Darmstadt, Germany). The material used was previously washed with laboratory detergent and distilled water.

2.1. Samples

A total of 12 different foods were selected, based on the most consumed foods. A total of 96 samples were analysed. The foodstuffs were purchased in different commercial supermarkets and markets on the island of Tenerife (Canary Islands, Spain). Once purchased, they were kept refrigerated and samples were taken and treated immediately after opening. Table 1 lists the foods and samples analysed.

Table 1
Types and number of samples analysed.

Sample type	Product	No. samples
Meat, poultry and derivatives	Pork	8
	Pork sausages	8
	Chicken	8
	Veal	8
Fish and seafoods	Tuna	8
	Shrimp	8
	Hake	8
	Octopus	8
Milk, dairy products and eggs	Eggs	8
	Cow's milk	8
	Cheese	8
	Yoghurt	8
Total		96

2.2. Equipment and reagents

Apart from the usual laboratory equipment, nickel (Ni) crucibles (Metal Technology, USA) of 0.6 mm thickness and 50 mL capacity were required. The solutions and reagents used for sample treatment and subsequent analysis are as follows (Table 2).

2.3. Sample preparation

The procedure used to treat the samples was basic digestion (Pérez Olmos, 1985; Kjellevold Malde et al., 2001; Rocha-Barrasa, 2013). A fresh sample of 0.5 g, previously homogenised, was taken. Samples were homogenised using a stainless-steel blender (Braun Minipimer 5220, Braun GmbH, Germany) until a completely homogeneous sample was obtained. Homogeneity tests were performed by taking subsamples of the homogenised sample and no significant differences were found in the subsamples.

In the case of liquid or semi-liquid foods samples, they were subjected to freeze-drying (Orrego Alzate, 2008). Freeze-dryer (Christ Gamma 1–16) carried out three stages: freezing, sublimation and desorption. In the first stage, the material to be freeze-dried is rapidly frozen at temperatures below −40 °C. During the second stage, vacuum and temperature is applied to the frozen material and the water present in it is sublimated. Finally, in the desorption stage, the last traces of water are removed by applying a vacuum and further increasing the temperature (Orrego Alzate, 2008).

Then, to achieve the basic digestion, the sample is placed in a nickel crucible and 8 mL of NaOH 8 M solution is added. It is dried in the oven (Nabertherm, Germany) at a temperature of 65 °C for 48 hours. After drying in the oven, the sample was placed in the muffle furnace (Nabertherm, Germany) with a temperature - time programme of 16 h – 200 ºC and 3 h – 525 ºC.

A melting cake is obtained and dissolved in distilled water. The resulting solution is neutralised by adding 12 M HCl solution, brought to a total volume of 25 mL in a plastic volumetric flask. It was filtered to remove the insoluble oxides of interfering cations of Si, Fe, Al, Ca and Mg (Pérez Olmos, 1985). Once the treatment of the samples was completed, they were analysed.

2.4. Fluoride determination

The standard additions method was used, measuring the fluoride concentration before and after the addition of a known amount of fluoride (Paz et al., 2017). The fluoride analysis was carried out by Ion Selective Potentiometry with an ISE potentiometer model HACH SensION-MM340 (HACH, Düsseldorf, Germany) and a F- ion selective

Table 2
Solutions and reagents used.

Solution	Reagents	Preparation	Material
Fluoride stock solution (1 g/L)	NaF (sodium fluoride) analytic purity (Merck, Germany)	By dissolving 4.199 mg NaF in distilled water (1 L).	1 L volumetric plastic flask
NaOH 8 M	NaOH (Sigma Aldrich, Germany)	By dissolving 320 g NaOH in distilled water (1 L).	1 L volumetric flask
Buffer TISAB-CDTA II	NaCl (sodium chloride). Glacial acetic acid.CDTA (1,2-Cyclohexylene Dinitrile Tetraacetic Acid).50 % NaOH solution.(Sigma Aldrich, Germany).	500 mL deionised water + 58 g NaCl + 57 mL glacial acetic acid + 4 g CDTA. Adjust the pH to 5–5.5 with 50 % NaOH solution.	1 L beaker
HCl 12 M	HCl (Sigma Aldrich, Germany)	493.2 mL HCl + 6.8 mL distilled water.	500 mL volumetric flask

electrode (HACH ISE F-9655C, Düsseldorf, Germany).

The instrumental parameters were: range (0.01–19,000 mg/L), pH range (4–8), linear range (0.1–19,000 mg/L), slope (59 mV/pF) and operating temperature (5–50 °C). To the solution, 6 mL of TISAB-CDTA II buffer solution was added to eliminate possible interferences and adjust the ionic strength of the solution (Rocha-Barrasa, 2013; Martín Delgado et al., 1991). The potential difference is measured in mV.

The following equation (Eq. (1)) was used to obtain the molar concentration of fluoride in the obtained solution. Knowing the molecular weight of the ion, the volume of the solution and the amount of feed initially used, we finally obtained the fluoride concentration in mg/kg feed. The blank signal was taken into account.

$$(1)\textit{Fluoride concentration}(M) = Cs\cdot[Vs/(Vp+Vs)] \quad / \quad [10\Delta E/S\text{–}((Vp+Vs)/Vp)]$$

Where: Cs, fluoride concentration of the added solution (M); Vp, volume of the solution to be analysed (mL); Vs, volume of the added solution (mL); ΔE, potential difference the measured potential (mV); S, slope of the electrode (mV).

2.5. Quality control and method validation

First, a calibration curve was prepared using known fluoride concentrations ranging from 10^{-1} to 10^{-5} M and measuring its potential (mV). The detection and quantification limit of the method was established following the recommendations of the IUPAC (International Union of Pure and Applied Chemistry) (IUPAC, 1976). Based on the IUPAC recommendations, the LOD was obtained by measuring the potential of 15 standard solutions at the concentration levels indicated in the calibration curve. The LOD was obtained from the graph in which two linear segments were plotted and corresponding to the abscissa of the intersection point (Spano et al., 2023). The LOD is 0.01 mg/kg and the LOQ is 0.03 mg/kg. The methodology was validated with the use of certified material which reference is NCS ZC73014 from the National Analysis Center for Iron & Steel (NACIS) (Beijing, China). The validation parameters of the method were: specificity, precision and accuracy. These parameters were checked by measuring, under reproducibility conditions, 10 fortified samples at the limits of quantification for fluoride and by measuring 10 times, under reproducibility conditions, the reference material previously indicated. The recovery percentages obtained were 95–98 %.

2.6. Dietary intake calculations

The study of dietary exposure to fluoride was carried out considering the data provided by Borges-Álamo (2008), as this is the most up-to-date scientific source from which data on the consumption habits of this population can be obtained. The consumption data (g/day) for the 18–34 age group are: dairy products (620), fish (38.4), red meat (44.8), sausages (52.3), poultry (97.3) and eggs (18.3). Consumption data (g/day) for the 35–54 age group: dairy (616), fish (43.6), red meat (43.6), sausages (36.6), poultry (95.5), eggs (16.2). Consumption data (g/day) for the 55–75 age group: dairy (557), fish (40.8), red meat (31.9), sausages (21.2), poultry (75.6), eggs (12.5) (Borges-Álamo, 2008).

Calculations of dietary exposure have been carried out by first calculating the estimated daily intake (EDI) (Eq. 2). The contribution percentage (Eq. 3) is obtained based on the EFSA reference value. The EFSA reference values (DRV, 2023) used were adequate intake (AI) and upper-level intake (UL).

$$(2)\textit{EDI}(mg/day) = \textit{Consumption}(L/day) \times \textit{Fluoride concentration}(mg/L)$$

$$(3)\textit{Contribution percentage}(\%) = [\textit{EDI}/\textit{Reference value}] \times 100$$

The AI is the amount of a mineral or nutrient that is assumed to be adequate for the needs of the population. The AI value for adult women is 2.9 mg/day and for adult men is 3.4 mg/day. On the other hand, the UL value for adults is 7 mg/day. UL is defined as the tolerable upper intake level, which refers to the maximum chronic daily amount that can be ingested without risk to health.

2.7. Statistical analysis

The statistical analysis was performed using the IBM Statistic SPSS 23.0 (Statistical Package for the Social Sciences) statistical package (IBM Corp. Armonk, NY, USA) for Windows™. To check for normality of the analysed data, the Kolmogorov-Smirnov and Shapiro-Wilk tests (Razali & Wah, 2011) and the test of homogeneity of variances through Levene's statistic were used for each of the analysed parameters (Lee et al., 2010). The data did not follow a normal distribution and, therefore, a non-parametric study was performed using the Kruskal-Wallis H-test and Mann-Whitney U-test.

These statistical analyses were performed to confirm the existence, or not, of significant differences between the different groups (Meat, poultry and derivatives; fish and seafoods; milk, dairy products and eggs) of this study ($p<0.05$) (Sheskin, 2004).

3. Results and discussion

3.1. Fluoride concentration

Table 3 shows the mean fluoride concentrations (mg/kg), the standard deviations and the maximum and minimum values recorded for each of the foods analysed. The mean concentration determined for all samples is 3.92 ± 6.04 mg/kg, the minimum and maximum values being for milk (under the detection limit of 0.01 mg/kg) and shrimps (32.1 mg/kg), respectively.

The type of analysed food with the highest fluoride content appears to be those of marine origin (octopus, tuna, hake and shrimp), which are 8.30 ± 8.62 mg/kg. Animal origin samples (pork, chicken and veal) are 2.42 ± 1.17 mg/kg and derivatives and others (sausages, cheese, egg,

Table 3
Fluoride concentration in the analysed samples.

Type	Samples	Mean (mg/kg)	Min. Value (mg/kg)	Max. Value (mg/kg)
Animal origin	Pork	3.38 ± 1.26	1.94	6.03
	Chicken	1.90 ± 0.96	0.92	3.65
	Veal	1.93 ± 0.58	1.29	2.86
Marine origin	Octopus	3.75 ± 0.47	3.13	4.52
	Tuna	4.24 ± 0.82	2.92	5.21
	Hake	3.47 ± 1.57	2.16	6.94
	Shrimp	21.8 ± 7.01	10.1	32.1
Derivatives and others	Sausages	0.62 ± 0.66	< LOD	2.09
	Cheese	4.06 ± 0.78	2.49	4.76
	Egg	0.78 ± 0.33	0.08	1.20
	Milk	0.09 ± 0.10	< LOD	0.26
	Yoghurt	0.26 ± 0.10	0.14	0.48
Total		3.92 ± 6.04	< LOD	32.1

milk and yoghurt) are 1.19 ± 1.54 mg/kg.

It should be noted that all the samples of animal origin were taken from the muscle mass, tissue that is usually intended for consumption and where fluorides can concentrate due to its high perfusion. In the case of the samples of the crustacean analysed, shrimps, they were processed with the exoskeleton due to the percentage of the population that consumes this type of food without removing the cuticle, by slurping it. This is a possible explanation for the high concentration of fluoride found in these samples. Shrimps are the food with the highest average concentration (21.8 mg/kg) of the fish and shellfish of the meats, poultry and meat products it is pork (3.38 mg/kg) and of the dairy, dairy products and eggs it is cheese (4.06 mg/kg).

LOD: 0.01 mg/kg; LOQ: 0.03 mg/kg

Cantoral et al. (2019) analysed the fluoride content in foods from Mexico City, obtaining concentrations of 371 μg/100 g in seafood. Meanwhile, studies conducted by Rocha et al. (2013a) also in seafood, recorded concentrations of 29.6 and 21.2 mg/kg in European anchovy, concentrations similar to those recorded in the present study for seafood such as shrimp (21.8 mg/kg).

Another study by Waldbot (1963) found values in marine products of (1–8.72) ppm. In turn, Chowdhury et al. (2018) obtained F- concentrations in fish of (1.45–2.30) ppm and Cantoral et al. (2019) described values in tuna of 17.87 mg/100 g. On the other hand, concentrations of 18.7 mg/kg were recorded in shrimp samples (Rocha et al., 2013b).

In reference to meat products, Cantoral et al. (2019) in their study determined fluoride concentrations in pigs of (38.05–100.19) micrograms/100 g and in chicken of (27.11–55.65) micrograms/100 g. While for Waldbot (1963) the pig samples obtained values of 3.3 ppm, similar figures found in pork with this study. Poureslami et al. (2008) found values of (0.13–0.25) mg/kg in chicken and for Singer & Ophaug (1986) meat, fish and poultry obtain concentrations of 0.35 ± 0.069 ppm.

For foods such as eggs, this study yielded figures of 0.78 ± 0.33 mg/kg, thus being one of the foods with the least amount of F- and agreeing with results obtained in studies such as that of Cantoral et al. (2019) who found values around 2.32 micrograms/100 g. Waldbot (1963) also recorded that the mean concentrations for these were also as low as around (0.2 – 0.4) ppm. Poureslami et al. (2008) obtained lower figures than this study; their results were (0.06 – 0.12) mg/kg.

Regarding dairy products and their derivatives, according to Cantoral et al. (2019) these first, yielded concentrations of 27.18 micrograms/100 g. While in another study by Singer & Ophaug (1986) the results obtained were 0.15 ± 0.040 ppm for dairy products.

On the other hand, Ocak & Köse (2018) determined values (0.02–0.18) ppm for milk and (0.02–0.19) ppm for cheese. Waldbot (1963) obtained higher results than those of Ocak & Köse where milk registered (0.09–0.32) ppm and cheese (0.16–1.31) ppm. For Buzalaf et al. (2006) whole milk was (0.02–0.07) ppm.

Comparing the results of the present study with data reported by other authors on animal products, significant variability in the fluoride levels found can be observed. These differences may be due to factors such as geography, the type of feed used for livestock feeding, the amount of water used in feed production and the processing techniques used in feed production. It is therefore important to take these differences in results into account when considering daily dietary fluoride exposure.

Furthermore, the concentrations obtained in foods of animal origin are generally higher than those found in foods of plant origin, which concentrations have been determined in other studies (Jáudenes et al., 2020).

There are areas of the planet where, historically, or currently, the amount of fluoride has been or is above average. Whether due to geological causes (such as volcanism, the existence of sediments of marine origin in the soil or the presence of granitic or geogenic rocks), there are niches in geographical regions where the population suffers from endemic fluorosis, as occurs in the Canary Islands (Rubio et al., 2020), Venezuela (Arellano et al., 1998), Ethiopia (Mulualem et al., 2022), north of Iran (Mohammadi et al., 2017), Jordania (Al Warawreh et al., 2020), India (Mahantesha et al., 2016), Thailand (Rojanaworarit et al., 2021), China (Li et al., 2020), Ghana (Firempong et al., 2013), western of Estonia (Indermitte et al., 2009), Mexico (Molina-Frechero et al., 2015), Argentina (Rocha et al., 2017), Australia (Do et al., 2020), Iran (Nilchian et al., 2018), Colombia (Saldarriaga et al., 2021) or the United States of America (Beltrán-Aguilar et al., 2010), among others; or by various anthropogenic processes, which cause induced fluorosis (Johnston & Strobel, 2020), as is the case of Mexico, where there is contamination by arsenic and fluoride (Limón-Pacheco et al., 2018), or China due to the burning of fluorinated coal (Yang et al., 2023).

As previously mentioned, the Canary Islands, which are a group of islands that make up an archipelago of volcanic origin located in the Macaronesia region; especially the northern regions of the island of Tenerife (28°16′07″ N 16°36′20″ W) are areas of endemic fluorosis. This is because, historically, the drinking water supply of the island of Tenerife comes from rainwater infiltrations that cross the porous volcanic soil and end up accumulating in underground galleries (Rubio et al., 2020). This water, when its contact with rocks rich in F- compounds, may have higher concentrations of this element and can be a health problem. In fact, a study carried out by Revelo-Mejía et al. (2022) revealed that around 65.5 % of the waters of the different municipalities of this island exceeded the parametric levels established in Directive 2020/2184 of the European Parliament, that is, they reached values greater than 1.5 mg/L (European Union, 2020). Likewise, this problem can be aggravated when there is a lack of rainfall and the natural water recharge is less than the reserves, producing a significant increase in the levels of F- in the water.

3.2. Dietary exposure to fluoride

Table 4 shows the calculations of dietary intake and its percentage contribution (%) considering the reference values of the AI (adequate intake) for fluoride established by EFSA (European Food Safety Authority) (EFSA, 2024).

Considering the adequate intake (AI) values, the highest contribution percentages are obtained for dairy products, with percentages ranging from 25 % to 27.9 % for men and 29.3–32.8 % for women (Table 5). This contribution is considered significant and adequate. However, it should be noted that the bioavailability of the fluoride ion contained in dairy products is impaired, as the presence of calcium ion reduces its presence due to the formation of insoluble calcium fluoride compounds.

The second food that has the highest contribution percentages is fish, with percentages ranging from 9.4 % to 10 % in men and 11–12.4 % in women, assuming half the contribution of dairy products. This contribution is considered adequate and significant.

The rest of the foods have low percentages, and their contribution is considered insufficient and insignificant. Within this group, eggs and sausages are the ones that make the least fluoride contributions to the diet with contribution ranges that go from 0.3 % for both sexes; and 0.3–0.9 % in men and 0.3–1 % in women, for these products respectively.

Considering the results of this study for only these foods, if they were consumed together, dietary fluoride intakes would be adequate. This could have positive consequences for the health of the population, since these levels promote the formation of fluoropathite in the teeth, help fight bacterial plaque, slow down demineralization and act as a catalyst in the remineralization of enamel and increases bone hardness.

Table 4 shows the intake values and percentage contribution to the UL established by EFSA (EFSA, 2006). The UL contribution values indicate a higher contribution from dairy consumption, with percentages of 12.1–13.6 % for adult men and women. However, this percentage contribution does not pose a health risk for adults.

For the rest of the food group, the contribution percentages are very low, being the minimum 0.1 % (for eggs) and the maximum 5.1 % (for fish). Such a contribution to the diet, as with dairy products, does not

Table 4
EDI values and contribution percentages to the AI by food type.

Food type	EDI (mg/day)			Contribution (%) to AI					
				Men			Women		
	18–34 yrs	35–54 yrs	55–75 yrs	18–34 yrs	35–54 yrs	55–75 yrs	18–34 yrs	35–54 yrs	55–75 yrs
Dairy products	0.95	0.94	0.85	27.9	27.6	25.0	32.8	32.4	29.3
Fish	0.32	0.36	0.34	9.4	10.6	10.0	11.0	12.4	11.7
Red meat	0.12	0.12	0.08	3.5	3.5	2.4	4.1	4.1	2.8
Sausages	0.03	0.02	0.01	0.9	0.6	0.3	1.0	0.7	0.3
Poultry	0.18	0.18	0.14	5.3	5.3	4.1	6.2	6.2	4.8
Eggs	0.01	0.01	0.01	0.3	0.3	0.3	0.3	0.3	0.3

Table 5
EDI values and contribution percentage to the UL by food type.

Food type	EDI (mg/day)			Contribution (%) to UL		
	18–34 yrs	35–54 yrs	55–75 yrs	18–34 yrs	35–54 yrs	55–75 yrs
Dairy products	0.95	0.94	0.85	13.6	13.4	12.1
Fish	0.32	0.36	0.34	4.6	5.1	4.9
Red meat	0.12	0.12	0.08	1.7	1.7	1.1
Sausages	0.03	0.02	0.01	0.4	0.3	0.1
Poultry	0.18	0.18	0.14	2.6	2.6	2.0
Eggs	0.01	0.01	0.01	0.1	0.1	0.1

pose a health risk to adults. However, the fluoride intake from other food groups and especially from drinking water and other beverages needs to be assessed.

4. Conclusions

The foods with the highest fluoride content are predominantly those of marine origin, with a remarkably high exposure to fluoride in nature. Shrimps, which have an exoskeleton, stand out within this group. In comparison, meats have somewhat lower and relatively uniform fluoride concentrations. Dairy products, on the other hand, generally show low concentrations of this anion. However, when analysing the percentages in relation to the reference values for adequate intake, it is observed that dairy products contribute the most to the total fluoride intake due to their higher consumption by the population. In terms of risk assessment of elevated fluoride exposure, the intake of the foods analysed does not represent a toxic risk.

Although the current results do not indicate a health risk for adult consumers, it is crucial to consider that the total dietary intake of fluoride could be higher. It should also be noted that an in-depth study of each food group sampled is necessary to establish a more accurate risk assessment. This study establishes the basis as to which animal food group marketed in the Canary Islands region (Spain) has the highest fluoride concentrations.

In addition, further studies including other food groups are required. Conducting a comprehensive analysis of total dietary intake of fluoride will allow a better understanding of the overall exposure and help to establish more precise recommendations for the population. In addition, it would be beneficial to investigate fluoride intakes in different demographic groups, including children, to ensure that all populations are adequately protected against.

CRediT authorship contribution statement

Soraya Paz-Montelongo: Writing – review & editing, Software, Data curation, Conceptualization. **Arturo Hardisson:** Supervision, Resources, Project administration, Conceptualization. **Juan R. Jáudenes-Marrero:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ángel J. Gutiérrez-Fernández:** Validation, Supervision, Software, Project administration, Conceptualization. **Carmen Rubio:** Visualization, Supervision. **Santiago Cerdán-Pérez:** Methodology, Data curation.

Declaration of Competing Interest

The authors declare no conflict of interest.

Data availability

No data was used for the research described in the article.

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