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Dietary Intake of Aluminum in a Spanish Population (Canary Islands)

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The aim of this study was to analyze the aluminum content in foods and beverages most commonly consumed by the Canary Island population to determine the dietary intake of this metal throughout the Canary Islands as a whole and in each of the seven islands (Gran Canaria, Lanzarote, Fuerteventura, Tenerife, La Palma, La Gomera, and El Hierro). Four hundred and forty samples were analyzed by ICP-OES. Estimated total intake of aluminum for the Canary population was 10.171 mg/day, slightly higher than the provisional tolerable weekly intake (PTWI; 10 mg/day for a person weighing 70 kg). Aluminum intake by age and sex of the Canary Island population was also determined and compared values from other populations, both national and international.

KEYWORDS: Aluminum; atomic emission spectrometry; dietary intake; Spanish population; Canary Islands

INTRODUCTION

Although metals are perhaps the oldest known most toxic agents, interest in them has not declined, and knowledge concerning their potential toxic effects and mechanisms of action has increased in recent years (*1*). Metals such as iron, copper, and zinc, among others, are considered to be essential minerals for humans, whereas heavy metals such as lead and cadmium are considered to be toxic environmental contaminants in food (*2*). Compared with other toxic substances, heavy metals are considered to be the most harmfully toxic to living systems. The main sources of these metals for humans are food and water (*3*, *4*). In fact, the main source of aluminum for humans is food (*5*, *6*). Aluminum is one of the most abundant elements in the earth's crust. It is present in soil, minerals, and rocks and even water and food. It seems to have no function in human or animal biology (*5*). It may be naturally present in food or obtaine through the addition of additives or through contact with food packaging, containers, aluminum foil, or kitchen utensils containing this metal (*5*, *7*). However, the amount of aluminum that comes from the diet is low in comparison with that present in certain pharmaceutical preparations such as antacids (*5*).

The content of this metal in most foods does not exceed 10 mg/kg, the most common concentrations being between 0.1 and 1 mg/kg (*8*). Some vegetables (spices, herbs, tea leaves) contain more aluminum than animal foods. The content in plants varies depending on the species and the soil pH (*9*). This element is consumed mainly through cereal, cheese, and salt, although, as noted above, there are certain types of tea and spices that contain high levels of aluminum naturally. Therefore, we must take into account that certain foods are a significant source of aluminum for children (*8*).

In humans, aluminum is potentially neurotoxic (*5*, *10*, *11*). Its health effects can be divided into three categories: neurological disorders, cognitive decline, and dementia or Alzheimer's disease (*11*). The accumulation of high amounts of this metal seem to be involved in the development of this disease (*7*, *11*); several studies indicate that this metal is toxic to nerve cells and causes Alzheimer's disease due to pathological or biochemical changes in animal brain (*12*). Importantly, there are groups at particular risk for its toxic effects: people with chronic renal failure, children with immature or impaired renal function, and premature babies (*13*, *14*). Apart from its neurotoxic effects, aluminum can also cause toxicity in bones. Specifically in bone tissue, aluminum can cause inhibition of hydroxyapatite formation and suppression of the proliferation and inhibition processes of bone cell activity, leading to decreased mineralization and bone formation (*15*).

For these reasons, and given the lack of dietary studies in the Canary Islands or Spain, the main objective of this work was to determine the dietary intake of aluminum in the Canary Islands.

MATERIALS AND METHODS

Samples. We analyzed a total of 440 food samples collected over 28 months (between March 2006 and July 2008) in different shopping malls in the island of Tenerife, on a weekly basis. The total diet was divided into 22 food groups. For each group, 20 samples were analyzed. Food groups, origin, and types of foods in each group are specified in **Table 1**. Several brand names of each product, representing the most widely accepted and most frequently consumed in the Canary Islands, were selected for testing. These groups of selected foods were those that the Canary Nutritional Survey (*16*) established as those of highest consumption in our community. This survey established food consumption per individual participant.

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Table 1. Aluminum Content in Food Groups and Types of Foods Studied (Wet Weight)

food group	origin	types of food	aluminum content: mean (mg/kg) ± SD in type of foods	aluminum content: mean (mg/kg) ± SD in food groups
cold meat and sausages	Tenerife (Spain), Gran Canaria (Spain), Soria (Spain), Girona (Spain), and Italy	ham	1.99 ± 0.44	2.74 ± 1.06
		other meats (sausage, bologna, and salami)	3.06 ± 1.09	
poultry, rabbit	Tenerife (Spain)	chicken drumsticks	4.25 ± 1.02	6.35 ± 2.83
		chicken breast	9.12 ± 1.65	
		rabbit meat (muscle)	5.56 ± 2.88	
viscera	Tenerife (Spain), Barcelona (Spain), and Toledo (Spain)	liver samples	11.19 ± 6.42	11.15 ± 6.15
		other organ meats (sweetbreads and kidneys)	11.05 ± 6.02	
red meat	Tenerife (Spain)	pork samples	9.78 ± 5.14	9.31 ± 4.85
		beef samples	8.74 ± 4.72	
fish	Morocco, Mauritania, Spain, and South Africa	white fish	3.57 ± 3.23	3.48 ± 2.33
		bluefish	3.90 ± 1.97	
milk[a]	Gran Canaria (Spain), Asturias (Spain), Burgos (Spain), Lugo (Spain), Granada (Spain), and Galicia (Spain)	whole milk	0.37 ± 0.09	0.61 ± 1.15
		skimmed milk and semiskimmed milk	0.82 ± 1.59	
yogurt	Tenerife (Spain) and Gran Canaria (Spain)	whole yogurt	0.72 ± 0.58	0.82 ± 0.50
		skimmed yogurt	0.99 ± 0.37	
cheese	The Netherlands, France, Cantabria (Spain), La Palma (Spain), Gran Canaria (Spain), and Tenerife (Spain)	fresh cheese	2.09 ± 1.84	2.17 ± 1.57
		hard cheese and semihard cheese	2.34 ± 0.98	
dairy-based dessert	Gran Canaria (Spain), Tenerife (Spain), Barcelona (Spain), and Granada (Spain)	Pudding and custard	2.56 ± 2.59	1.71 ± 2.24
		samples of dairy desserts (pettit suisse, Bio, yogurt mousse	0.43 ± 0.19	
pulses	León (Spain), Madrid (Spain), La Rioja (Spain), Navarra (Spain), Albacete (Spain), and Zaragoza (Spain)	chickpeas and lentils	3.99 ± 3.04	3.88 ± 2.47
		peas	4.10 ± 2.23	
		Jewish and beans	3.69 ± 2.29	
fruit	Canary Islands (Spain)	apples and citrus	4.73 ± 3.33	14.64 ± 21.38
		banana	32.80 ± 33.05	
		other fruits (peaches, pears, plums	9.68 ± 6.88	
vegetables	Tenerife (Spain), Murcia (Spain), Valencia (Spain), and Valladolid (Spain)	tomatoes and onions	5.41 ± 2.16	20.12 ± 32.69
		other vegetables (squash, carrots, bubang, cabbage, watercress, spinach)	27.47 ± 38.47	
potatoes	Tenerife (Spain)	white potato	6.81 ± 3.79	5.88 ± 3.29
		Nice potato	5.54 ± 2.59	
		black potato	3.84 ± 3.08	
cereals	Tenerife (Spain), Gran Canaria (Spain), Madrid (Spain), and Germany	bread	3.02 ± 1.74	3.56 ± 2.40
		breakfast cereals and "gofio" (a food from the Canary Islands consisting of roasted grain flour)	4.23 ± 2.99	
nuts	United States, Spain, and Turkey	almonds	11.95 ± 10.98	5.19 ± 5.82
		peanuts (groundnuts)	2.67 ± 1.37	
		other nuts (hazelnuts, dried figs)	4.89 ± 1,.97	
pastries	Tenerife (Spain), Gran Canaria (Spain), Zaragoza (Spain), Valencia (Spain), Madrid (Spain), and Barcelona (Spain)	muffins, croissants, and donuts	6.41 ± 2.72	5.62 ± 2.62
		other bakery products	4.83 ± 2.38	
sweet cakes	Tenerife (Spain)	sweet egg yolk and chocolate	10.83 ± 11.22	14.20 ± 35.17
		other sweets (candy apple, cream, almond, cherry, pineapple, mango, mocha)	18.31 ± 52.40	

Table 1. Continued

food group	origin	types of food	aluminum content: mean (mg/kg) ± SD in type of foods	aluminum content: mean (mg/kg) ± SD in food groups
eggs	Tenerife (Spain), Gran Canaria (Spain), and Ourense (Spain)	grade A eggs sizes L and XL	3.39 ± 3.49	2.93 ± 2.95
		grade A eggs size M	2.23 ± 1.86	
soft drinks[a]	Canary Islands (Spain), Madrid (Spain), and Barcelona (Spain)	carbonated drinks	1.26 ± 0.83	1.24 ± 0.70
		noncarbonated drinks	1.23 ± 0.58	
alcoholic beverages[a]	Tenerife (Spain), Gran Canaria (Spain), Barcelona (Spain), England, Scotland, and The Netherlands	wine	2.42 ± 2.03	1.70 ± 1.85
		other alcoholic beverages (gin, whiskey, rum, beer)	0.50 ± 0.32	
water[a]	Tenerife (Spain), Gran Canaria (Spain), Badajoz (Spain), Granada (Spain), Girona (Spain), and Cuenca (Spain)	drinking water		0.12 ± 0.06
		bottled drinking water		
fats and oils	Gran Canaria (Spain), Madrid (Spain), Sevilla (Spain), and Asturias (Spain)	oils		6.64 ± 2.81
		butters and margarines		

[a] Concentrations in mg/L.

Specifically, it used two 24 h recalls (administered on two nonconsecutive days) and a comprehensive food frequency questionnaire of 77 food items.

Before sample preparation, all laboratory materials used were washed with Acationox laboratory cleaning agent (Merck, Darmstadt, Germany) to avoid contamination and remove any possible trace metals, kept in 5% nitric acid for 24 h, and then washed with Milli-Q quality water.

After collection and classification, the food samples were homogenized and conserved at −18 °C, for later analysis within 2 months.

Determination of Aluminum. In previously weighed porcelain capsules, 20 g of each homogenized sample was weighed in triplicate. The capsules were oven-dried at 60−80 °C for 12−14 h. The crucibles with samples were introduced into a muffle furnace, gradually raising the temperature (50 °C every hour or so) to 450 ± 15 °C for 18−24 h to destroy any organic matter present in the sample. The white ash obtained by this procedure was dissolved in nitric acid 1.5% to a volume of 50 mL.

To prepare samples of fats and oils we used wet digestion in a microwave oven. For this, 0.8 g of each sample was placed in a Teflon container to which we added 3 mL of 69% nitric acid and 7 mL of Milli-Q deionized water. Then the containers were placed in a high-pressure microwave oven for sample digestion. Once digested, deionized Milli-Q water was added to the samples to fill 25 mL flasks. The pressure ramps and time used in the microwave oven were as follows: stage 1, a pressure of 160 psi was reached with a ramp time of 10 min and a maintenance time of 10 min; stage 2, the pressure was increased to 290 psi with a ramp time of 10 min and a maintenance time of 10 min; stage 3, the pressure was increased to 420 psi with a ramp time of 10 min and a maintenance time of 10 min; and finally stage 4, during which a pressure of 580 psi was reached with a ramp time of 20 min and a maintenance time of 20 min. In all stages power and temperature were kept at 100% and 230 °C, respectively.

Note: samples of liquids, both drinking water and bottled drinks, were excluded from any process of digestion.

Once digested by either of the two procedures, the samples were transferred to 100 mL polyethylene bottles, numbered and labeled, for aluminum content determination within 1 month. The content was analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES), a reference technique for the determination of metals showing high sensitivity and result reproducibility (*17*); we used the Thermo Jarrell Ash Atom Scan 25 spectrometer (Thermo Jarrell Ash, Genesis Laboratory Systems Inc.). The programmed conditions of ICP-OES for aluminum determination were as follows: wavelength (nm), 308.215; gas flow (torch gas flow, high flow; auxiliary gas flow, 1.0 L/min); peristaltic pump parameters (flush pump rate (rpm), 200; relaxation time (s), 10; pump tubing typem, EP-19); approximate RF power (W), 1150; pump rate (rpm), 100; nebulizer gas (psi), 30.1; and observation height (mm), 14.9. The limits of instrumental detection and quantification, calculated as 3 and 10 times the standard deviation of the analysis of 15 targets for acid digest in terms of reproducibility (*18*), were 0.0308 and 0.1032 mg/L, respectively.

Quality control of the analytical measurements was performed using blank samples and the following reference materials: SRM Apple Leaves, SRM 1566 b Oyster Tissue, SRM 1570 Trace Elements in Spinach Mild, and SRM 1577 b Bovine Liver from the National Institute of Standards and Technology (NIST). The recoveries obtained with the reference materials were 104.2, 98.4, 102.6, and 97.3%, respectively. During all of the analytical procedures, each batch of 20 samples was analyzed together with at least a blank and a reference sample. Calibration was performed using the calibration curve method.

All of the results were tested for normality with the Kolmogorov−Smirnov model and for homogeneity in variance with the Levene test. Because our data did not show a normal distribution, the Kruskal−Wallis test was used as the nonparametric test. To test data normality, the Kolmogorov−Smirnov and Shapiro−Wilk tests were used. Although the variances were homogeneous, the non-normal distribution of our data indicated the need to use the nonparametric tests to check any significant differences between measurements. In this case, the Kruskal−Wallis test was used.

RESULTS AND DISCUSSION

Table 1 shows the types of foods included in each group, the origin, and the aluminum concentrations (wet weight) and standard deviations (SD) for each food and type group analyzed. The metal was present in detectable concentrations in the 20 groups, the highest and lowest being found in vegetables and water, with concentrations of 20.12 ± 32.69 mg/kg and 0.12 ± 0.06 mg/L, respectively. The other groups, in descending order, were as follows: fruit > sweet cakes > viscera > meat > fats and oils > poultry, rabbit > potatoes > pastries > nuts > vegetables > grain > fish > eggs > cold meats and sausages > cheese > milk-based desserts > alcoholic drinks > soft drinks > yogurt > milk.

No food group differed significantly from the rest. Vegetables, with 20.12 ± 32.69 mg/kg, showed higher aluminum bioaccumulative capacity than the other groups. Notably, large variability was obtained in the groups vegetables, fruits, and sweet cakes; although aluminum concentrations were above average, high levels of SD were observed. However, this variability in biological samples is considered to be normal, because the metal content of foods, both plant and animal, depends on various factors ranging from environmental conditions to production and processing methods (*19*) (**Table 1**). The concentration of aluminum in the food groups of the viscera, red meat, fish, milk, yogurt, cheese, dairy-based desserts, pulses, fruits, vegetables, potatoes, cereals, nuts, pastries, eggs, and soft drinks did not differ significantly

Table 2. Dietary Intake of Aluminum in the Canary Islands

food group	dietary intake (mg/day)							
	Canary Islands	Gran Canaria	Lanzarote	Fuerteventura	Tenerife	La Palma	La Gomera	El Hierro
cold meats and sausages	0.071	0.074	0.065	0.075	0.080	0.077	0.068	0.083
poultry, rabbit	0.203	0.218	0.183	0.177	0.225	0.192	0.154	0.215
viscera	0.013	0.006	0.000	0.037	0.017	0.021	0.002	0.004
red meat	0.428	0.434	0.479	0.388	0.476	0.442	0.391	0.440
fish	0.159	0.155	0.190	0.198	0.153	0.124	0.150	0.171
milk[a]	0.184	0.204	0.175	0.124	0.178	0.184	0.154	0.168
yogurt	0.038	0.043	0.028	0.050	0.040	0.025	0.028	0.038
cheese	0.054	0.059	0.044	0.039	0.050	0.068	0.033	0.074
dairy-based dessert	0.033	0.033	0.029	0.016	0.035	0.036	0.023	0.033
pulses	0.106	0.082	0.128	0.150	0.102	0.106	0.143	0.115
fruit	3.197	3.452	2.869	2.369	3.161	3.156	2.230	3.509
vegetables	2.169	2.213	1.425	1.517	2.390	1.976	1.539	2.131
potatoes	0.841	0.805	0.680	0.480	0.959	0.847	1.403	0.700
cereals	0.446	0.465	0.554	0.347	0.443	0.449	0.409	0.569
nuts	0.010	0.011	0.006	0.001	0.009	0.010	0.009	0.009
pastries	0.186	0.174	0.212	0.167	0.212	0.221	0.239	0.254
sweet cakes	0.693	0.785	0.859	0.388	0.675	0.612	0.579	0.714
eggs	0.074	0.073	0.077	0.062	0.076	0.070	0.065	0.128
soft drinks[a]	0.734	0.997	0.567	0.137	0.753	0.484	0.492	0.493
alcoholic beverages[a]	0.107	0.085	0.156	0.063	0.127	0.067	0.315	0.079
water[a]	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240
fats and oils	0.185	0.210	0.161	0.108	0.205	0.175	0.189	0.167
total	10.171	10.819	9.128	7.133	10.608	9.584	8.856	10.337

[a] Concentrations in mg/L.

from the Al content in the different types of foods included in each group. That means that aluminum concentrations were similar among the different types of foods in each group. Because a large number of samples from the natural drinking waters, bottled drinking waters, and fats and oils were below the detection limit, a statistical study with these groups could not be performed. However, in the case of cold meat and sausages, the amount of aluminum in the food type "other meats" was significantly higher ($P < 0.05$) than that observed for ham. This difference could be due to the different origins of the samples and the different processings that follow meats like salami and ham.

The type of food with higher concentrations of aluminum ($P < 0.05$) was chicken breast. Similar concentrations were observed between types of chicken drumsticks and rabbit, although the latter presented a greater variability in the results. Because all of the samples came from the island of Tenerife, these differences may be due to heterogeneity in the distribution of metal within a certain type of food (*20*) or the processing conditions (*19*).

In the fruit group, the concentrations of apples and citrus fruits were significant lower than those of bananas ($P < 0.05$).

With respect to the group of sweets, the concentration of aluminum in the food type "other sweets" was significantly higher ($P < 0.05$) than the levels found in fresh egg yolk and chocolate, probably due to manufacturing methods of this type of sweets. As can be seen in the type "other sweets," there is huge variability in the results. This is because a sample of sweet creamy cherry cake showed abnormally high concentrations of this element.

The group of alcoholic beverages shows that the aluminum concentration was significantly higher in wines ($P < 0.05$). Specifically, the concentration of this metal in wine is about 5 times higher in than other alcoholic beverages. This difference may be due to processes that follow the grapes for wine production or containers used for fermentation.

Comparing our aluminum concentrations with those obtained by other authors for samples (wet weight) from different sources, we found differences for cold meats and sausages, poultry, viscera, and red meat. In the case of red meat, the Al concentration obtained in this study (9.31 mg/kg) is much higher than that reported in ref *21* (0.21 mg/kg). In the food group of fish, our mean aluminum concentration is 3.48 mg/kg, lower than that reported in refs *22* and *23* (5.5 and 6.1 mg/kg, respectively) but higher than those from refs *5* (0.4−0.7 mg/kg), *24* (0.85 mg/kg), and *21* (0.51 mg/kg).

The mean level of aluminum in milk consumed in the Canary Islands (0.61 mg/L) is similar to that reported in ref *5* (0.7 mg/L). The aluminum content in analyzed cheeses is far below the concentration found in ref *5* (15.7 mg/kg). Dairy-based dessert samples, compared with those from other authors, showed higher levels of aluminum.

In the food group of cereals the mean aluminum level is 3.56 mg/kg, well below that from ref *22* (78 mg/kg). Our mean concentration of aluminum in pulses (3.88 mg/kg) is under the range reported in ref *25* (6.50−30.20 mg/kg), but higher than that published in ref *21* (1.08 mg/kg). With regard to fruit, the levels reported in refs *26* (0.5−3 mg/kg), *22* (0.57 mg/kg), *23* (0.29 mg/kg), *5* (0.1−0.4 mg/kg), and *21* (0.41 mg/kg) are much lower than those found in this study (14.64 mg/kg). In vegetables, our mean aluminum value (20.12 mg/kg) is within the range reported in ref *5* (3.4−25 mg/kg).

For nuts, our results (5.19 mg/kg) are similar to those of refs *23* (4 mg/kg) and *21* (4.10 mg/kg). For eggs, our Al levels (2.93 mg/kg) are higher than those reported in refs *21*−*24*, with concentrations of 0.27, 0.14, 0.38, and 0.10 mg/kg, respectively.

For beverages (soft drinks, alcoholic drinks, and water), our mean aluminum concentration (0.12 mg/L) is slightly higher than the levels reported by other authors except for water, where our levels were within the range reported in ref *27* (0.004−0.165 mg/L) and exactly the same as the results of ref *28*. Finally, for fats and oils, our mean Al concentration (6.64 mg/kg) is higher than the data from refs *22* (1.2 mg/kg), *23* (1.1 mg/kg), and *21* (0.05−0.08 mg/kg).

The estimated total aluminum intake for the Canary Islands is presented in **Table 2**. The total intake has been estimated considering the average Al concentrations in the different studied food groups and their consumptions according to the Canarian Nutritional Survey. Fruits and vegetables were found to contribute most to aluminum intake in the Canary Islands population, whereas viscera and nuts contributed the least.

The estimated total intake of aluminum for the Canary population was 10.171 mg/day (71.199 mg/week), slightly above the level established as the PTWI (provisional tolerable weekly intake) (1 mg/kg/week = 70 mg/week or 10 mg/day for a person weighing 70 kg) (*29*). With respect to each island, estimated total intake of aluminum exceeded the PTWI level in Gran Canaria, Tenerife, and El Hierro; the lowest intake corresponded to the island of Fuerteventura.

Different dietary and nutritional habits among the seven islands explain these differences in aluminum intakes. Nevertheless, in all of the islands, fruits and vegetables are the food groups that contribute most to the intake of aluminum. In La Palma and La Gomera, these are followed by potatoes, sweet cakes, and soft drinks ranking third, fourth, and fifth, whereas in Fuerteventura and El Hierro these are red meat and cereals, which do not appear to be significant in the rest of the islands in terms of aluminum intake.

Analysis of aluminum intake from the 22 food groups by age group and sex (**Table 3**) shows that, for males, the 45−54 year age group presented the highest intake with 12.23 mg/day and boys aged 6−10 years presented the lowest, with 8.36 mg/day. With regard to females, the highest aluminum intake was also found in the group aged 45−54 years (10.68 mg/day) and the lowest in girls aged 11−17 years, with 8.34 mg/day.

Table 3. Dietary Intake of Aluminum by Age and Sex in the Canary Islands

age group (years)	total intake (mg/day)
Females	
6−10	8.58
11−17	8.34
18−24	8.67
25−34	8.99
35−44	9.64
45−54	10.68
55−64	10.42
65−75	10.25
Males	
6−10	8.36
11−17	10.04
18−24	10.34
25−34	11.28
35−44	11.95
45−54	12.23
55−64	10.77
65−75	11.43

Once the total intake of aluminum for the Canary Islands population had been established, we then compared it with the results of several studies published over the past 12 years for different populations. This comparison is shown in **Table 4**. The table specifies the year of the study, the number of samples analyzed, and the processing and measurement techniques used. It can be observed that the Canary Islands intake (10.171 mg/day) is very similar to the Al intake for the United Kingdom population in 1999 (*22*). Furthermore, the Canarian intake is lower than the Al intake for the Tokyo population in 2006 (*30*), but higher than the estimated Al intake for India in 2002 (*28*), France, in 1998, 2003, and 2005 (*9*, *21*, *31*), and the United Kingdom in 2000 (*23*).

In conclusion, the total intake of aluminum for our population was slightly higher than that recommended as the PTWI (for a person weighing 70 kg). The islands of Gran Canaria and Tenerife showed the highest intakes of aluminum. By age and sex, aluminum intake was highest in men aged 45−54 years and lowest in girls aged 11−17 years. Whereas fruits and vegetables constitute the food groups that most contribute to dietary aluminum intake in the Canary Island population, viscera (such as liver and other organ meats (sweetbreads and kidneys)) and nut food groups contribute the least. The present study is of great interest in terms of nutrition, toxicology, and food safety for the Canary Islands population, given the absence of previous studies to determine dietary aluminum intake, not only for the Autonomous Community of the Canary Islands but also at the national level.

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Table 4. Comparison of Mean Daily Intake of Aluminum: Canary Islands Population versus Other Populations

population	year of study	no. of samples	sample processing technique	sample measurement technique	intake (mg/day)	ref
France	1998	192	microwave digestion system	ICP-MS	4.2	*9*
United Kingdom	1999	400	microwave digestion sytem	ICP-MS and HG-ICP-MS	11	*23*
United Kingdom	2000	400	microwave digestion sytem	ICP-MS and HG-ICP-MS	3.4	*23*
India	2002	45 samples of “duplicate diet”	microwave digestion sytem	ET-AAS	6.4	*28*
France	2003		microwave digestion sytem	ICP-MS	2.03	*31*
France	2005	1080 individual food composites samples	multiwave closed microwave system	ICP-MS	1.62	*21*
Tokyo, Japan	2006		ultrapure grade nitric acid using a double vessel digestion bomb	ICPCCMS	12.1	*30*
Canary Islands	2010	440	dry ashing	ICP-OES	10.17	this study

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