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Cadmium in the Diet of the Local Population of Seville (Spain)

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Cadmium is an oligoelement which is not essential for biological systems but is toxic to most organisms. It is widely distributed in the environment at relatively low concentrations (Dunnick et al. 1988). It is not found in the free state but accompanies Zn in the majority of its minerals. It is used almost exclusively to form alloys, metal for ball bearings, for soldering, in batteries and electric accumulators and as an anticorrosive. Its residues have contaminated the environment and its presence in sedimentation sludges used to manufacture fertilizers has given rise to an increase in the content of this metal in trophic chains.

The inhalation of industrial powders and smoke represents the principal form of occupational exposure. For the general population the major route of exposure is food, because vegetables absorb it from contaminated soil and water. Tobacco is an even more important source, as absorption of inhaled particles ranges from 10 to 60%, depending on their size and solubility (Nordberg et al. 1985).

The literature indicates great variability in the concentrations of this element in foods in different countries, but in general the concentration ranges between 0.005-0.1 mg/kg wet weight (Friberg et al. 1986). The lowest concentrations in foods are found in milk and dairy products (a few µg/Kg), followed by meat, fish and fruit, (1-50 µg/Kg), vegetables and cereals (0.01-0.15 mg/Kg). Liver and kidney of some animals and molluscs can contain higher concentrations (Bermejo et al. 1981; Lopez-Artiguez et al. 1989).

Due to its toxicity and high accumulation capacity, the

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Committee of Experts in Food Additives FAO/WHO emphasized the importance of studies on the contribution of different foods to the total body burden/exposure of cadmium to humans, in addition to the other sources mentioned above (FAO-OMS 1973).

The purpose of this study was to determine the levels of cadmium in foods eaten by the population of Seville, Spain, and to compare the weekly intake with the Provisional Tolerable Weekly Intake (PTWI) established in 1972 by the Committee of Experts of the FAO-WHO.

MATERIALS AND METHODS

Samples (158) of foods corresponding to the different basic groups in an alimentary shopping basket (INE 1985) were purchased at five different points of sale (markets and food shops). Of our samples, approximately 9% was meat, 13% fish, 13% dairy products (whole milk, skimmed milk, and milk shakes) and eggs, 16.5% fruits and vegetables (including tubers), 16.5% drinks, 11% cereals and pulses (lentils and chick peas), 11% fats and oils, 8% clams (Donax trunculus) and 2% sugar.

The preparation of the different types of sample was carried out according to the nature of the same. Solid samples were digested with concentrated HNO_3 in an MDS-81D microwave instrument with a teflon PFA container with pressure valves, following the microwave procedure for acid digestion provided by the CEM-Corporation. Approximately 0.5 g of dry sample were digested with 2 mL concentrated HNO_3 in the microwave oven. When cold the solution was diluted with deionized water to a volume of 25 mL and stored in polyethylene bottles.

The oils were incinerated at low temperature and the ashes collected in 1 N HCl. Dairy products (milk and milk shakes) were diluted 1:10 with deionized water.Drinking water and wines needed no preparation.

In each case standards were treated in the same way as the samples.

All the resulting solutions were measured by atomic absorption spectrophotometry in a Perkin Elmer 1100 B spectrophotometer with a HGA-500 graphite furnace and an AS-400 automatic injector.

As measurements were always made in aqueous solutions the same sequence of stages of drying (120°C), mineralization

(600°C) and atomization (1600°C) were used, with a 0.2% monobasic diamine phosphate solution as matrix modifyer, using the maximum heating power (STPF conditions). For each measurement 20 μL of sample and 20 μL of modifyer were injected. The resonance line for measurement was at 228.8 nm.

All the water used in the analyses (washing, dilutions) was purified in a Milli-Q system (Millipore Corporation) at a resistance of 18 mega ohms/cm. The reagents were Suprapur quality (Merck) and the standards of Titrisol quality (Merck).

Plastic and glass laboratory materials were kept in 5% HNO_3 solution for one night and then washed with deionized water and dried in an atmosphere free from dust.

Recuperation of cadmium was assessed by analysis of bovine liver (National Bureau of Standards, USA, SRM 1577) and homogenate of fresh fish (International Atomic Energy Agency, Vienna) MAA2-TM. The mean recuperation coefficient was 98%. The detection limit was of 0.002 μg/g Cd.

The levels of Cd found as also the values corresponding to average consumption were subjected to statistic analysis using the SIGMA programme (Horus Hardware) in a Schneider Tower-AT computer System N220.

Basic parameters were established for Cd content in the different foods, for the Cd intake calculated from the amount of each food ingested, and for Cd intake calculated from each group of foods. We also carried out a bilateral contrast between the groups of foods to show the differences in the contribution of each group to the intake of Cd.

RESULTS AND DISCUSSION

The mean level of Cd in the foods studied is shown in Table 1. Fish and shellfish, followed by pulses, cereals and fruits are those which contain greater quantities of Cd, while the lowest levels of the element are found in the groups of milk products ($x<0.01$ μg/L) and eggs ($x<0.01$ μg/Kg).

Considering each type of food separately, in fish, the highest values are found in swordfish (even reaching values of 100 μg/Kg), which were similar to those found

Table 1. Levels of Cadmium in each of the food staples analyzed. In solids µg/Kg, in liquids µg/L.

Food	Mean	S.D.	Range	No of samples
Pork	9.68	1.96	7.88-12.00	5
Chicken	8.97	0.75	7.89-9.41	4
Veal	23.26	6.37	16.13-31.77	5
Swordfish	53.91	31.69	15.00-100.00	11
Sole	18.80	8.17	12.00-33.00	5
Hake	13.38	9.89	7.50-31.00	5
Butter	39.01	25.78	14.55-79.11	5
Lard	41.02	-	-	1
Olive oil	-		<0.01-0.30	7
Sunflower seed oil	-		<0.01-8.00	4
Lentils	25.73	12.46	<0.01-34.70	4
Chick peas	20.25	9.70	10.00-29.50	4
Rice	32.20	25.94	15.00-78.00	5
Bread	6.05	2.18	3.50-8.40	4
Oranges	41.10	26.27	6.00-68.00	5
Pears	<0.01	-	-	5
Cauliflower	15.09	5.72	10.00-23.00	4
Lettuce	14.34	6.30	9.12-12.00	4
Tomatoes	53.25	40.82	23.00-110.00	4
Potatoes	24.67	6.77	15.00-29.40	4
Drinking water	0.24	0.26	<0.01-0.58	6
White wines	-	-	<0.01-0.15	5
Red wines	0.40	0.24	<0.01-0.71	5
Coffee	16.08	9.97	7.70-29.10	5
Tea	39.98	28.37	21.00-90.00	5
Clams	53.38	25.00	20.00-106.00	13
Eggs	<0.01	-	-	5
Sugar	18.28	11.73	4.30-33.00	4
Dairy products	<0.01	-	-	15
Light tobacco	1039.16	593.25	232.80-1788.50	5
Dark tobacco	1304.60	245.09	1080.00-1708.00	5

in clams (Donax trunculus)

The concentration of Cd in fruits and vegetables was variable; the highest levels occurring in tomatoes and oranges. Cadmium was undetectable in pears, however.In cereals and pulses, rice had the highest concentration of 32.2 μg/Kg. The cadmium level in bread was rather high compared with the literature (Bermejo et al 1981).

Levels in veal (23.26 μg/Kg) were approximately double those found in chicken and pork.

The values found in sugar were similar to those in coffee, but lower than those in tea. The mean level of cadmium was also low in red wines (x=0.40 μg/L) and practically undetectable in white wines; oils and the remaining foods and drinks had low mean levels.

In these cases, the mean level was not included in Table 1, since the majority of the samples analyzed had contents below the limit of detection of the method.

Cadmium levels were analyzed in Spanish cigarettes of light and of dark tobacco. The mean level of both types of tobaccos was 1171.88 μg/Kg, corresponding to approximately 1 μg Cd/cigarette.

Once the levels of Cd in the foods studied were known, the daily intake per person of this element was calculated. The data on food consumption in southern Spain, provided by the National Institute of Statistics (INE 1985), was used for this analysis. Table 2 shows the estimated daily intake per person of basic foods and the estimated Cd intake based on the results of this study.

To obtain a better analysis of the levels of Cd intake per person per day, the foods were grouped into meat, fish, fruits and vegetables, pulses and cereals, drinks, fats, oils, dairy products and eggs. Within each group high standard deviations were observed; this was not due to a deficiency in random sampling, but to the very variety of the items making up one group both in content and in intake (Table 3). Nevertheless, statistically significant differences in intake of Cd were obtained based on the various food groups (Table 4).

Fruits and vegetables provide a significantly greater quantity of Cd than pulses and cereals, followed by meat, with a similar contribution from drinks and fish; the quantity provided by fats is practically insignificant.

Table 2. Basic statistics of the values of Cd intake per day.

Food	Average intake per person/day Food g or mL	Cd µg	S.D.	Range	No of samples
Pork	30.95	0.30	0.06	0.24-0.37	5
Chicken	58.04	0.52	0.04	0.46-0.55	4
Veal	16.68	0.39	0.11	0.27-0.53	11
Swordfish	5.66	0.30	0.18	0.08-0.57	5
Sole	5.66	0.11	0.05	0.07-0.19	5
Hake	26.56	0.35	0.26	0.20-0.82	5
Butter	1.19	0.05	0.03	0.02-0.09	5
Lard	0.49	0.02	-	-	1
Oils	0.085	<0.01	-	<0.01	11
Lentils	7.25	0.94	1.36	<0.01-2.51	4
Chick peas	14.64	0.29	0.14	0.15-0.43	4
Rice	21.33	0.69	0.55	0.32-1.66	5
Bread	229.64	1.39	0.50	0.80-1.93	4
Oranges	73.26	3.00	1.92	0.44-4.98	5
Pears	29.09	<0.01	-	<0.01	5
Cauliflower	6.14	0.09	0.04	0.06-0.14	4
Lettuce	25.34	0.36	0.16	0.23-0.56	4
Tomatoes	64.30	3.42	2.62	1.48-7.07	4
Potatoes	181.14	4.47	1.22	2.72-5.32	4
Drinking water	2000.00	0.48	0.53	<0.01-1.16	6
Wines	0.05	<0.01	-	<0.01	10
Coffee	6.99	0.11	0.07	0.05-0.20	5
Tea	0.01	<0.01	-	<0.01	5
Clams	3.40	0.18	0.08	0.07-0.36	13
Eggs	44.71	<0.01	-	<0.01	5
Sugar	39.46	0.72	0.46	0.17-1.30	4
Dairy products	0.30	<0.01	-	<0.01	5

On calculating the total cadmium intake from a basic diet in the population of Seville, a result of 18.18 µg cadmium per day per person is obtained, corresponding to 0.127 mg/week/person. This value is below the PTWI (Provisional Tolerable Weekly Intake) of 0.4 - 0.5 mg/week/person established by FAO-WHO (1973). The estimation of said daily cadmium intake is within the usual range of 10-60 µg/day/person corresponding to non-contaminated areas (Elinder 1985). Said average intake is

Table 3. Basic statistics of the values of Cd intake calculated for the groups of foods.

Group	Mean	S.D.	Range	No of samples
Meat	0.39	0.12	0.24-0.55	14
Fish	0.27	0.20	0.07-0.82	21
Fruits and vegetables	2.31	2.24	<0.01-7.07	26
Pulses and cereals	0.81	0.74	<0.01-2.51	17
Drinks	0.27	0.38	<0.01-1.16	26
Fats	0.05	0.03	0.02-0.09	6
Dairy products	<0.01	-	-	15
Eggs	<0.01	-		5
Oils	<0.01	-		11

Table 4. Bilateral contrast between groups of foods regarding calculated average Cd intake.

Groups compared		Significance level
	Fish	P < 0.05
	Fruits and vegetables	P < 0.001
Meat	Fats	P < 0.001
	Pulses and cereals	P < 0.005
	Drinks	N.S.
	Fruits and vegetables	P < 0.001
	Fats	P < 0.001
Fish	Pulses and cereals	P < 0.05
	Drinks	N.S.
	Fats	P < 0.001
Fruits and vegetables	Pulses and cereals	P < 0.01
	Drinks	P < 0.001
Fats	Pulses and cereals	P < 0.001
	Drinks	N.S.
Pulses and cereals	Drinks	P < 0.05

equivalent to approximately 28% of the PTWI, a higher value than that found in foods and diets in Finland (Kumpulainen 1988).

If we accept that only 10% of the amount of Cd in a cigarette is absorbed (Sradkowski et al. 1969), our results indicate that an individual who smokes 20 cigarettes a day has an average daily intake of 2.34 μg Cd.

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