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Lead and Cadmium in meat and meat products consumed by a Spanish population (Tenerife Island, Spain)

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3 **Lead and cadmium in meat and meat products consumed by the population in**
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5 **Tenerife Island, Spain**
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15 **Keywords**

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17 Lead, cadmium, meat, meat products, graphite furnace atomic absorption
18 spectrophotometry, dietary intake.
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27 **Abstract**

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29 The aim of this study was to determine the levels of lead and cadmium in chicken, pork,
30 beef, lamb and turkey samples (both meat and meat products), collected in the island of
31 Tenerife (Spain). Lead and cadmium were measured by graphite furnace atomic
32 absorption spectrometry (GFAAS). Mean concentrations of lead and cadmium were
33
34 6.94 and 1.68 $\mu\text{g kg}^{-1}$ in the chicken meat samples respectively; 5.00 and 5.49 $\mu\text{g kg}^{-1}$ in
35 the pork meat samples; 1.91 and 1.90 $\mu\text{g kg}^{-1}$ in the beef meat samples and 1.35 and
36 1.22 $\mu\text{g kg}^{-1}$ in the lamb meat samples. Lead was below the detection limit in the turkey
37 samples and the mean cadmium concentration was 5.49 $\mu\text{g kg}^{-1}$. The mean
38 concentrations of lead and cadmium in the chicken meat products samples were 3.16
39 and 4.15 $\mu\text{g kg}^{-1}$ respectively; 4.89 and 6.50 $\mu\text{g kg}^{-1}$ in the pork meat products samples;
40 6.72 and 4.76 $\mu\text{g kg}^{-1}$ in the beef meat products samples and 9.12 and 5.98 $\mu\text{g kg}^{-1}$ in the
41 turkey meat products samples. The contribution, in %, of the two considered metals to
42 the PTWIs (Provisional Tolerable Weekly Intake), was calculated for meat and meat
43 products. Statistically significant differences were found for the lead content in meats
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3 between the chicken and pork groups and the turkey and beef groups, whereas for the
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5 cadmium concentrations in meats, significant differences were observed between the
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7 turkey and the chicken, beef and lamb groups. In meat products, no clear differences
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9 were observed for lead and cadmium between the various considered groups.
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12 13 14 15 **Introduction**

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17 The main human exposure to heavy metals usually comes from food. After continuously
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19 evaluating studies on food additives and their toxicity, the WHO has come to the
20
21 conclusion that even low levels of some metals, such as lead and cadmium, can give rise
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23 to diseases in humans (WHO 2000, WHO 2001). This is produced by the capacity of
24
25 these metals to accumulate in living organisms. Lead, for example, bio-accumulates in
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27 plants and animals. Its concentration is generally magnified in the food chain (Halliwell
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29 et al., 2000). Cadmium has a long residence time in human tissues (10-40 years),
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31 especially in the kidneys (Rubio et al., 2006). For these reasons, it is of the utmost
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33 importance to monitor the lead and cadmium content in dietary intakes.
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41 The main toxic effect of lead is nervous system dysfunction of the foetus and infants. In
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43 adults, it causes: adverse blood effects, reproductive dysfunctions; damage to the
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45 gastrointestinal track; nephropathies; damage to the central as well as the peripheral
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47 nervous system and interferences in the enzymatic systems that synthesise the HEME
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49 group (Sierra and Hardisson, 1991; Rubio et al., 2005).
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55 The toxic effects of cadmium are noticeable in various ways. It can interfere with some
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57 of the organism's enzymatic reactions, substituting zinc and other metals, manifesting
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59 its action in several pathological processes such as renal dysfunctions, hypertension,
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3 arteriosclerosis, inhibition of growth, damages in the nervous system, bone
4 demineralisation and endocrine disruption. In rats, this metal increases the plasma
5 levels of testosterone, induces a phase advance of the nocturnal peak of norepinephrine
6 and abolishes the daily pattern of plasma luteinizing hormone levels (Lafuente et al.,
7 2004 a). Cadmium can, also, stimulate or inhibit the immune activity according to the
8 dose. Doses of 5 and 10 mg/kg of cadmium inhibit the humeral and cellular immune
9 response in rats, whereas doses of 25, 50 and 100 mg/kg produce opposite effects
10 (Montoro et al., 1989; Kosanovic et al., 2002; Lafuente et al., 2004 b).
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25 The health risks produced by lead and cadmium are well known and the levels in food
26 as well as the migration of these metals from food containers are regulated. However,
27 cases of accidental exposure to higher levels of lead and cadmium are often reported
28 within the EU. For example, in Sweden in 2004, a man was poisoned by lead after using
29 ceramics bought in another EU country, which had not been properly fabricated
30 (National Food Administration in Sweden, 2004).
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41 These are but a few cases which show that there exists a continuous need to monitor and
42 control both possible sources of lead and cadmium in food and items used for food
43 processing. Total diet studies have been performed in various countries during the last
44 decades. For example, lead and cadmium intake has been calculated for total diets in the
45 UK (Ysart et al., 2000), Denmark (Larsen et al., 2002), the USA (Pennington et al.,
46 1986) and, also, in Spain (Cuadrado et al., 1995). However, in Spain, the food pattern
47 varies significantly from region to region (Cuadrado et al., 1995) and, therefore, the
48 intake of heavy metals and its consequent risk, also, differs considerably between
49 regions. Cuadrado et al. (1995), showed that meat and meat products were one of the
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3 most important food groups for the total intake of lead, contributing from 11 to 21%,
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5 depending on the part of Spain where the study was performed. However, most heavy
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7 metal intake studies carried out in Spain were done in the Iberian Peninsula. Peripheral
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9 parts, such as Tenerife (Canary Islands) have never been considered before.
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15 Considering the fact the Tenerife has a very high population density, approximately 365
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17 inhabitants per square kilometre, and that it is annually visited by millions of tourists, it
18
19 is of great interest to determine accurately the content of different heavy metals on the
20
21 food products which are consumed in this island. In addition, the Canary Islands depend
22
23 heavily on food imports due to its limited resources. It is, therefore, essential to assure
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25 that local as well as imported primary products reach the maximum standards of quality.
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29 As a consequence of what has been mentioned above, the objectives of this study were
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31 selected and divided in the following: (1) to analyse the lead and cadmium content of
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33 meats and meat products sampled in Tenerife; (2) to check that the measured
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35 concentrations were below the maximum values allowed by the current legislation; (3)
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37 to compare the measured concentrations with those reported by other authors; (4) to
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39 estimate the contribution, in %, of lead and cadmium to the PTWIs for the meat and
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41 meat products analysed, and (5) to study if there were any statistical differences
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43 between the different groups of meat samples in meat and meat products regarding their
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45 lead and cadmium concentrations.
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51 52 53 **Materials and method**

54 55 Samples

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57 Meat and meat product samples were divided in the following groups: chicken, pork,
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59 beef, lamb and turkey. The criteria of selection were made by the consumption
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3 percentage of these products in Tenerife. This information is published in the
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5 Nutritional Survey of Canary Islands (2000), which is called ENCA 1997-1998. In this
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7 mentioned survey, 2600 people were considered. The type and amount of consumed
8
9 food were evaluated using both, a 24-hours intake record and a questionnaire of the
10
11 consumption frequency of 77 different food types.
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17 The meat samples studied in this work were extracted from: chicken legs (12); chicken
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19 breasts (12), pork loins (10), pork steaks (10), bacon from pork (7), beef steaks (10),
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21 beef stews (10), minced beef meat (8), lamb legs (8), lamb steaks (7), lamb ribs (7) and
22
23 turkey breasts (10). The meat product samples analysed were chicken sausages (10),
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25 chicken hamburgers (8), chicken pâté (7), pork (boiled ham, dry ham, hard pork,
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27 sausage, mortadella, salami) sausages (12), pork sausages (8), pork liver pâté (7), beef
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29 hamburgers (10), corned beef (7), chopped beef (7), turkey sausages (8), turkey
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31 hamburgers (7) and chopped turkey (7). Lamb meat products were not analysed in his
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33 study because in the Canary Islands, this kind of products are hardly consumed. The
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35 consumption percentages of liver and kidney are, also, not very high and that is why we
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37 decided not to include these meats in our study.
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46 All the samples were collected from January till June 2004 in different commercial
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48 centres spread across the island. Once the samples were homogenised, they were stored
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50 at -18°C in clean polyethylene recipients. The plastic materials used for storing and
51
52 treating the samples were cleaned to avoid contamination of the samples with traces of
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54 any metal. This procedure was carried out using 5% nitric acid during 24 hours
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56 followed with two washes with Milli-Q water.
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Determination of lead and cadmium

Each homogenised sample (2 g) was placed in a porcelain crucible. To avoid cross-contamination between the samples, single used plastic tools were utilised to transfer the material. Each sample was then dried in an oven at a temperature ranging between 60 to 80°C for at least 12 hours. The crucibles with the samples were then introduced in muffle ovens and burned to ash at 450°C. The temperature in the muffle ovens were increased at a rate of approximately 50°C per hour and maintained at 450°C during 18 to 24 hours. The white ashes obtained with this procedure were then dissolved in 5% nitric acid to a volume of 50 mL.

The spectrophotometer used to carry out the measurements was a Perkin-Elmer, model 4100 ZL Zeeman, which is equipped with a graphite furnace tube with an automatic sampler.

Table I shows the optimal working conditions in the graphite furnace for the determination of lead and cadmium, indicating the temperature and the times employed in each of the phases. Remark 3 of referee 2: We explain why matrix modifier was not used In the initial lead and cadmium analyses, a mixture of $\text{NH}_4\text{H}_2\text{PO}_4$ and $\text{Mg}(\text{NO}_3)_2$ were used as matrix modifiers. However, no improvements were appreciated in the results and therefore this practice was disregarded later on. The detection limits, calculated as three times the standard deviation of 15 blanks for the acid digest, were 0.28 and 0.065 $\mu\text{g L}^{-1}$ for lead and cadmium respectively.

“[Insert Table I about here]”

Quality control of the analytical measurements was performed using blank samples and the following reference materials: the NBS SRH 1577a Bovine Liver from the National

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3 Institute of Standards and Technology (NIST) and the BCR-278 R Bovine Muscle for
4 the determination of lead and the BCR CRM 184 Bovine Muscle as well as the BCR-
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8 278 R Muscle Tissue for the determination of cadmium. The recovery obtained with the
9
10 reference materials were all above 92% (see table II).
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12 “[Insert Table II about here]”
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15 During all the analytical procedures, each batch of 20 samples were analysed together
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18 with a least a blank and a reference sample. The calibration was performed using the
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20 calibration curve method.
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24 All the results were tested for normality with the Kolmogorov-Smirnov model (Xu et
25
26 al., 2002) and for homogeneity in the variance with the Levene test (Pan, 2002). Since
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28 our data did not show a normal distribution, the following statistical tests were used
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31 (Choy et al., 2001). The non-parametric Kruskal-Wallis test, which allows
32
33 discriminating individual samples with significantly different results, and the Mann
34
35 Whitney U test, was used to establish whether there are significant differences between
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38 sample groups.
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43 **Results and Discussion**

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45 The number of samples, number of measurements below detection limits and number of
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47 undetectable samples, median value, standard deviation, minimum and maximum for all
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49 the meat and meat products analysed for each animal species are shown in table III.
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52 “[Insert Table III about here]”
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55 The results show a large variability of lead and cadmium concentrations in some of the
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57 meat and meat products groups. However, this variability in biological samples is
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59 considered to be normal since the sources of this metal are numerous. Furthermore the
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3 lead and cadmium concentrations, also, depend on the environmental conditions and the
4 food production methods. Even within a certain type of food, concentration variations
5 can be large produced by heterogeneities in the distribution of the metal (Reilly, 1991).
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8 In our case, the samples were taken in different times and seasons. Thus the exposure to
9 different metals was not constant contributing to a larger variability.
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17 It can be observed in the data presented in this study that the concentrations of the
18 considered metals are slightly higher in meat product samples than in meat samples.
19 This difference may be explained by the fact that offal (mainly liver and kidney) is often
20 used as an ingredient in meat products and is, also, an important source of lead and
21 cadmium.
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29 The maximum lead and cadmium concentrations which are allowed in meat from
30 different animals are regulated by the EU Directive 466/2001. The authorised levels for
31 lead and cadmium are 100 and 50 $\mu\text{g kg}^{-1}$ respectively. The concentrations of these
32 metals measured in this work are all within the accepted limits.
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41 Regarding the meat samples, table IV shows a comparison of our results with
42 previously published results (1986-2003). In our study, the lead concentrations in pork
43 are similar to those reported for Sweden (Jorhem et al., 1991), but lower than those
44 measured in Holland, Poland, Finland 1987-1988, Finland 1991, Slovakia and Denmark
45 (Vos et al., 1986; Falandysz et al., 1989; Niemi et al., 1991; Tahvonen and
46 Kumpulainen, 1994; Doganoc, 1996; Larsen et al., 2002). Regarding cadmium
47 concentrations in pork, our values are higher than in Holland, Sweden, Finland and
48 Denmark (Vos et al., 1986; Jorhem et al., 1991; Niemi et al., 1991; Tahvonen and
49 Kumpulainen, 1994; Larsen et al., 2002) but lower than Poland (Falandysz et al., 1989).
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3 It can be observed that lead concentrations in beef are lower than the values that have
4 been measured in other areas. The cadmium concentrations, except for the value found
5 by López-Alonso for Galicia (Northern Spain), our values are similar than those found
6 in the literature.
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15 The lead and cadmium concentrations measured in chicken are within the range given
16 for Poland, Finland and Denmark by Falandysz, 1991; Tahvonen and Kumpulainen,
17 1994 and Larsen et al., 2002. In lamb, one can see that lead concentrations are lower
18 than in Denmark, although cadmium concentrations are similar, whereas in turkey our
19 lead concentrations are non detected and cadmium concentrations are higher than
20 Denmark (Larsen et al., 2002).
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29 “[Insert Table IV about here]”
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31 Regarding the analysed meat product samples, both the lead and cadmium
32 concentrations measured in this study were well below the values found in recent
33 literature.
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39 “[Insert Table V about here]”
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41 Considering that the total meat intake by the population in the Canary Islands is 78 g
42 day⁻¹ and the total meat products intake is 25.9 g day⁻¹ (ENCA 1997-1998), the daily
43 intake of lead due to the consumption of meats and meat products is 0.296 µg day⁻¹
44 (2.072 µg week⁻¹) and 0.155 µg day⁻¹ (1.082 µg week⁻¹) respectively. This represents,
45 for an average person weighting 65 kg, approximately 0.127 % of the PTWI due the
46 meat consumption and 0.066 % of the PTWI due the meat products consumption, as
47 established by FAO/WHO (25 µg kg⁻¹ week⁻¹) (WHO, 1993). The average dietary
48 cadmium intake due to the consumption of meats and meat products calculated in this
49 study is 0.246 µg day⁻¹ and 0.138 µg day⁻¹ respectively. This represents about 0.4 % of
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3 the PTWI due the meat consumption and 0.2 % of the PTWI due the meat products
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5 consumption for this metal. Meats contribute to approximately 9% of the total lead and
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7 cadmium intake in Tenerife (Canary Islands) and this is the reason why one should
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9 consider that there are other sources of these two metals to the diet.
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15 A statistical comparison of the lead and cadmium concentrations in the different meat
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17 groups and meat products showed the following: (1) regarding the lead concentrations
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19 measured in meats, no significant differences were found between the diverse meat
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21 groups when they were considered individually. However, significant differences were
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23 measured between the chicken and pork groups and the turkey and beef groups; (2)
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25 regarding the cadmium concentrations measured in meats, significant differences were
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27 observed between the turkey and the chicken, beef and lamb groups. In the case with the
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29 pork, no significant differences were measured due to the high variability found
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31 between this and all other groups; (3) in meat products, no clear differences were
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33 observed for the lead and cadmium between the various considered groups. This was,
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35 most likely, produced by the high variability of the samples that were analysed here.
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43 **Conclusions**

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45 The lead and cadmium levels in meat and meat products analysed in this study were
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47 well below the legal limits established by the current EU legislation. These levels are,
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49 also, comparable to results recently published for other countries. It has been shown
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51 here that the consumption of meats in the Canary Islands contribute to a 0.1 % and 0.4
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53 % of the PTWI for lead and cadmium respectively, whereas the consumption of meats
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55 products contribute to a 0.1 % and 0.2 % of the PTWI for lead and cadmium.
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60 Nevertheless, meats and meat products contribute to approximately 9 % of the total lead

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3 and cadmium intake in Tenerife (Canary Islands) and there are other sources of
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5 exposure of these two metals. In addition, the results of this study show that there exist
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7 needs to evaluate and monitor lead and cadmium levels in foodstuffs to establish the
8
9 intake values which are safe for the population.
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12 13 14 15 **Acknowledgements**

16
17 This study has been carried out thanks to the help provided by the Health Section of the
18
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21 Canarias).
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Table I. Thermal programme used for the determination of lead and cadmium in the graphite furnace.

Phase	Temperature (°C)	Rise Time	Hold Time	Argon Flux (mL/min)
Evaporation of the solvent	100	10	20	250
drying	130	25	20	250
Pirolysis	450	15	20	250
Pre-treatment	800 ^(*1) 700 ^(*2)	5	10 ^(*3) 5 ^(*4)	250
Atomisation	1250	0	3	0
Cleaning	2500	2	3	250

(*1) *Pre-treatment temperature for the Pb*

(*2) *Pre-treatment temperature for the Cd*

(*3) *Time at which the temperature for the pre-treatment of the Pb is maintained*

(*4) *Time at which the temperature for the pre-treatment of the Cd is maintained*

Injection temperature: 20° C

Wavelength of the Pb: 283,3 nm

Wavelength of the Cd: 228,8 nm

Volume of the injection: 20 µL

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Element	Material	N ^a	Concentration			Procedure
			Measured ^b ($\mu\text{g Kg}^{-1}$)	Certified ^c ($\mu\text{g Kg}^{-1}$)	Recovery %	
Pb	NBS SRH 1577a Bovine Liver	11	130 \pm 20	140 \pm 20	92,85	AAS graphite furnace
Pb	BCR-278 R Mussel Tissue	11	2.000 \pm 40	1.970 \pm 70	101,52	AAS graphite furnace
Cd	BCR CRM 184 Bovine Muscle	11	12 \pm 1	13 \pm 2	92,30	AAS graphite furnace
Cd	BCR-278 R Mussel Tissue	11	348 \pm 7	347 \pm 8	100,28	AAS graphite furnace

^a N^o of samples

^b Mean \pm standard deviation

^c Confidence interval: 95%

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	Meat		Meat products	
	Chicken		Chicken	
	Lead	Cadmium	Lead	Cadmium
Number of samples	24	24	25	25
Number of not detectable samples	0	0	2	0
Median value ($\mu\text{g kg}^{-1}$)	6,94	1,68	3,16	4,15
Standard deviation	4,63	1,76	0,48	1,34
Minimum ($\mu\text{g kg}^{-1}$)	0,93	0,52	2,76	2,09
Maximum ($\mu\text{g kg}^{-1}$)	13,43	5,21	3,71	5,22
	Pork		Pork	
	Lead	Cadmium	Lead	Cadmium
Number of samples	27	27	27	27
Number of indetectable samples	1	0	5	0
Median value ($\mu\text{g kg}^{-1}$)	5,00	5,49	4,89	6,50
Standard deviation	4,79	5,11	3,84	3,93
Minimum ($\mu\text{g kg}^{-1}$)	1,02	0,42	0,35	0,52
Maximum ($\mu\text{g kg}^{-1}$)	11,55	13,24	13,23	13,54
	Beef		Beef	
	Lead	Cadmium	Lead	Cadmium
Number of samples	28	28	24	24
Number of indetectable samples	3	0	3	0

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Median value ($\mu\text{g kg}^{-1}$)	1,91	1,90	6,72	4,76
Standard deviation	0,007	1,86	1,49	4,93
Minimum ($\mu\text{g kg}^{-1}$)	1,91	0,50	5,66	1,76
Maximum ($\mu\text{g kg}^{-1}$)	1,92	4,45	7,78	13,50
	Lamb		Lamb	
	Lead	Cadmium	Lead	Cadmium
Number of samples	22	22	0	0
Number of indetectable samples	1	0	-	-
Median value ($\mu\text{g kg}^{-1}$)	1,35	1,22	-	-
Standard deviation	0,80	0,59	-	-
Minimum ($\mu\text{g kg}^{-1}$)	0,59	0,72	-	-
Maximum ($\mu\text{g kg}^{-1}$)	2,20	2,09	-	-
	Turkey		Turkey	
	Lead	Cadmium	Lead	Cadmium
Number of samples	10	10	22	22
Number of indetectable samples	10	0	1	0
Median value ($\mu\text{g kg}^{-1}$)	N.D.	5,49	9,12	5,98
Standard deviation	-	0,68	8,65	3,10
Minimum ($\mu\text{g kg}^{-1}$)	-	4,70	2,56	1,03
Maximum ($\mu\text{g kg}^{-1}$)	-	5,90	21,30	9,46

* N.D. = Non Detected

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Reference	Origin	Type of meat	Pb ($\mu\text{g kg}^{-1}$)	Cd ($\mu\text{g kg}^{-1}$)
Vos et al., 1986	Netherlands	Pork meat	10	2
Falandysz et al., 1989	Poland	Pork meat	130	21
Jorhem et al., 1991	Swedish	Pork meat	5	1
Niemi et al., 1991	Finland	Pork meat	15	1,5
Tahvonen and Kumpulainen, 1994	Finland	Pork meat	9	N.D.
Doganoc, 1996	Slovenia	Pork meat	< 50	10
Larsen et al., 2002	Denmark	Pork meat	< 15	< 1
This study	Tenerife (Spain)	Pork meat	5,00	5,49
Jorhem et al., 1991	Swedish	Beef	< 5	1
Niemi et al., 1991	Finland	Beef	13	1,3
Falandysz, 1993	Poland	Beef	40	6
Tahvonen and Kumpulainen, 1994	Finland	Beef	10	N.D.
Doganoc, 1996	Slovenia	Beef	50	4
López Alonso et al., 2000	Galicia (Spain)	Beef	9	1
Larsen et al., 2002	Denmark	Beef	< 16	< 1
López Alonso et al., 2003	Galicia (Spain)	Beef	14,7	35,7
This study	Tenerife (Spain)	Beef	1,91	1,90
Falandysz, 1991	Poland	Chicken	< 10-20	< 5
Tahvonen and Kumpulainen, 1994	Finland	Chicken	6	N.D.
Larsen et al., 2002	Denmark	Chicken	< 14	< 1
This study	Tenerife (Spain)	Chicken	6,94	1,68
Larsen et al., 2002	Denmark	Lamb	< 14	1,8
This study	Tenerife (Spain)	Lamb	1,35	1,22
Larsen et al., 2002	Denmark	Turkey	< 14	< 1
This study	Tenerife (Spain)	Turkey	N.D.	5,49

* N.D. = Non Detected

Table V. Lead and Cadmium mean concentrations in meat products reported internationally.

Reference	Origin	Type of meat product	Pb ($\mu\text{g kg}^{-1}$)	Cd ($\mu\text{g kg}^{-1}$)
Catalá et al., 1983	Spain	Ham	320	32
Cattaneo and Balzaretì 1984	Italy	Ham	380	67
Becerra et al., 1987	Spain	Ham	2.240	N.D.
Cervera et al., 1988	Spain	Ham	29	6
Brito et al., 1990	Spain	Ham	570	84
Karavoltzos et al., 2002	Greece	Ham	-	0,6
Dabeka and McKenzie, 1991	Canada	Cured Ham	90	3
Noirfálisse, 1980	France	Pork liver paté	268	37
Nuurtamo et al., 1980	Finland	Pork liver paté	< 20.000	20
Becerra et al., 1987	Spain	Pork liver paté	360	N.D.
Cervera et al., 1988	Spain	Pork liver paté	30	28
Brito et al., 1990	Spain	Pork liver paté	300	73
Ybáñez et al., 1982	Spain	Sausages	380	36
Beltrán et al., 1987	Cuba	Sausages	-	9
Karavoltzos et al., 2002	Greece	Sausages	-	1,6
Meah, 1989	UK	Corned beef	666	-
Onianwa et al., 2000	Nigeria	Corned beef	-	70

* *N.D.* = *Non Detected*