Determination of Selenium in Meat Products by Hydride Generation Atomic Absorption Spectrometry—Selenium Levels in Meat, Organ Meats, and Sausages in Spain

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The selenium contents, in samples of meat, organ meats, and sausages, have been determined using hydride generation atomic absorption spectrometry. Repeatability expressed as relative standard deviation ranged from 2.28% to 4.65%. Mean Se concentrations varied from 0.028 μg/g (fresh weight) for lamb to 1.196 μg/g (fresh weight) for pork kidney. The daily dietary intake of selenium supplied by this source is estimated to be 18.468 μg/person, on the basis of considering the average daily individual consumption of these foods in Andalusia (southern Spain) and their edible fraction. In the meat group, pork and chicken (4.689 and 2.726 μg/person, respectively) provide useful amounts of Se because of their high concentration and consumption in the daily diet.

Keywords: *Selenium in meat, organ meats, and sausages; daily dietary intake; HG-AAS*

INTRODUCTION

Selenium is an essential element in the animal diet, which is required at a minimum level (0.04 ppm) and fulfills an optimum beneficial role at about 0.1 ppm. On the other hand, at over 4 ppm it has a toxic character (Lakin, 1973). This element is ingested by animals in the different forms in which it appears in plants as well as from selenites and selenates introduced by supplementation. Once selenium is in the organism, it mainly accumulates in both kidney and liver (Jaffar and Ashraf, 1988; Caurant, 1994; Aro et al., 1994).

Some authors have found a direct correlation between the quantity that found in pastures and the concentration detected in the blood of the livestock that grazed there (McLaughlin et al., 1989). Another important factor affecting the presence of this element in food is protein content (Weaver et al., 1988; Stacchini et al., 1989; Zhang et al., 1993). For this reason there tend to be higher concentrations of the element in animal products (meat and fish) (Benemariya et al., 1991; Díaz-Alarcón et al., 1994a).

Selenium is also an essential element in the diet of human beings. The lack of this element has been related to different diseases such as a severe congestive cardiomyopathy (Peng et al., 1992), neurological diseases (Alvárez Prieto et al., 1994) or hepatic problems (Nomura and Takekoshi, 1994), and certain types of cancer (Li et al., 1993; Taylor et al., 1994). In 1989 the Food and Nutrition Board of the U.S. National Research Council established the Recommended Dietary Allowances for selenium at 70 μg/day for adult men and 55 μg/day for adult women. A lower quantity was proposed for children, according to their weight and an adjustment factor added for growth (Levander and Burk, 1994).

Therefore, the aim of this study was to determine the content of Se in 46 samples from different species of the most commonly consumed meat, organ meats, and sausages in southeastern Spain by hydride generation atomic absorption spectrometry. Moreover, by using tables of food consumption in Spain, we have quantified the daily dietary intake of Se from meat products in the normal diet, as previously undertaken in studies on the Se provided by fresh fish (Díaz-Alarcón et al., 1994a) and vegetables and fruits (Díaz-Alarcón et al., 1994b).

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MATERIALS AND METHODS

Apparatus. All analytical measurements were made with a Perkin-Elmer Model 1100B atomic absorption spectrometer equipped with a Perkin-Elmer MHS-10 hydride generator. A selenium hollow cathode lamp (Perkin-Elmer Corp., Norwalk, CT) was operated under the conditions recommended by the manufacturer (11 mA).

Reagents. All reagents were of analytical grade: HNO_3 (65%), HCl (37%) (Carlo Erba, Italy), $NaBH_4$, and NaOH (Merck Suprapur). All solutions were prepared with ultrapure water with a specific resistivity of 18 MΩ cm obtained by filtering doubled-distilled water through a Milli-Q purifier (Millipore, Bedford, MA) immediately before use. A commercially available 1000 μg/mL selenium standard solution (prepared from SeO_2 in 0.5 mmol/mL HNO_3) was used (Tritisol, Merck).

Samples. The samples of meat, organ meat, and sausage were bought in local supermarkets and butchers' shops of Motril (a coastal city of southeastern Spain). They were then transported to the laboratory of the Department of Nutrition and Bromatology, where they were dried in an oven at 60 °C for 48 h, their edible parts having been previously separated. Finally, samples were homogenized and kept in polyethylene bottles at −18 °C until analyzed. Three 300-mg fractions were taken from each sample for analysis.

Procedure. Sample mineralization was carried out according to the classic method of wet digestion with concentrated HNO_3 that had been used for Se determination in fresh fish in the same area (Díaz-Alarcón et al., 1994a). Dried and homogenized samples (300 mg) were mineralized and reduced according to the analytical procedure established by Díaz-Alarcón et al. (1994a).

Reproducibility and Accuracy. Mean recovery for the added samples was 100.27%. The selenium concentration determined in the Community Bureau of Reference—Commission of the European Communities (CBR-CEC) certified refer-

S0021-8561(95)00702-3 CCC: $12.00

Table 1. Selenium Content (Micrograms per Gram, Fresh Weight) of Meat, Organ Meats, and Sausages from Southeastern Spain

sample	*n*	range	mean
meat			
chicken breast	3	0.058−0.084	0.073
veal	2	0.036−0.054	0.045
lamb	2	0.027−0.030	0.028
pork chop	3	0.061−0.116	0.081
pork chine	2	0.322−0.444	0.383
rabbit	2	0.074−0.106	0.090
organ meats			
rabbit tongue	1		0.127
chicken liver	3	0.280−1.420	0.789
chicken heart	2	0.239−0.395	0.317
lamb lung	1		0.171
pork kidney	2	0.849−1.543	1.196
pork liver	3	0.256−0.800	0.487
pork lung	3	0.053−0.106	0.086
pork brain	1		0.033
pork heart	1		0.115
rabbit kidney	1		1.165
sausages			
chorizo[a]	3	0.137−0.739	0.355
sausage	3	0.103−0.151	0.128
ham	3	0.089−0.105	0.087
chopped	1		0.087
mortadella	1		0.071
cured ham	3	0.108−0.285	0.179

[a] Sausage seasoned with red peppers.

ence material (CRM 278) was 1.62 ± 0.12 μg/g (n = 10) for a certified value of 1.66 ± 0.04 μg/g (Diaz-Alarcon et al., 1994a). The relative standard deviation was better than 5%, in the range of the samples analyzed in the study.

Method. The hydride generation method was used here because by generating the selenium hydride by addition of a reducing agent ($NaBH_4$) to an acidified sample solution, the analyte is separated from the bulk matrix, which leads to a substantial elimination of interference, as compared with the flame or graphite furnace methods (Mayer et al., 1992).

RESULTS AND DISCUSSION

Taking into account the results obtained in the study for both precision and accuracy, the analytical technique proposed in our study is adequate for the determination of Se in meat samples.

The levels of selenium detected in the different samples are shown in Table 1. We can infer from the results that the highest concentrations of Se are found in the samples of kidney (1.186 μg/g, fresh weight), liver (0.638 μg/g) and chine (0.383 μg/g, fresh weight) of pork and the lowest in lamb (0.028 μg/g, fresh weight) and pork brain (0.033 μg/g, fresh weight). The greater capacity for accumulation of Se in animal viscera, mainly in liver and kidney, has been established by other authors (Beker et al., 1994; Caurant, 1994; Aro et al., 1994).

If we compare the mean concentrations obtained in the meat samples analyzed with those obtained by other authors in Spain and other countries (Table 2), we can observe that all of the amounts found in our study fall between the highest and the lowest concentrations found in different places except for lamb, the Se concentration of which falls below all of the levels obtained by the other authors (Table 2).

In general, the concentrations shown in Table 2 differ widely. This fact is quite logical, if we consider that the Se levels in animals depend on their diet (Levander and Burk, 1994; Caurant, 1994), i.e., on the fodder plants of the breeding areas. These plants have different contents of this element depending on whether pasture grounds and, consequently, the plants cultivated there are rich in Se or not (McLaughlin et al., 1989; Humphreys, 1990; Levander and Burk, 1994).

The Se levels determined in sausages (0.151 μg/g) and organ meats (0.484 μg/g) (Table 1), show a mean concentration of Se higher than that determined in meat (0.118 μg/g). On comparison of the two, organ meats (including kidney in this group) have higher Se content. In the case of sausages, chorizo (sausage seasoned with red peppers) presents the highest concentration (0.355 μg/g) and mortadella the lowest (0.071 μg/g).

If we compare the results obtained from the organ meats analyzed here with those determined by Moreno Dominguez et al. (1983) in Salamanca (central Spain), we note that the Se concentrations from the samples common to both studies are higher in our case (0.484 μg/g) than those determined by the other authors (0.325 μg/g). However, the mean concentration we obtained in this type of samples fits the range (0.120−0.930 μg/g) established by Mejuto Martí et al. (1987) in organ meats of animals in Galicia (northwestern Spain). We can also observe that the highest levels of Se found in kidney (pork, 1.196 μg/g; rabbit, 1.165 μg/g) (Table 1) fit the range (1−10 μg/g) obtained by Pfannhauser (1983) in these kinds of samples in Austria (Table 2).

In sausages, the mean value obtained in our study (0.151 μg/g) is higher than the one found by Mejuto Martí et al. (1987) (0.127 μg/g). The mean concentration found in chorizo (0.355 μg/g) is higher than that found by Moreno Domínguez et al. (1983) (0.060 μg/g) and that of Simonoff and Simonoff (1991) (0.058 μg/g). However, the concentration obtained by the latter in samples of ham (0.083 μg/g) is similar to the one determined in our study (0.087 μg/g).

Considering the Se concentrations determined in the meat products we analyzed, the tables corresponding to the edible fraction of each (Jiménez Cruz et al., 1990), and the tables of Spanish food consumption (Dirección General de Política Alimentaria, 1991), we calculated the daily intake of Se from such food in the current diet of the inhabitants of Motril (coastal city of southeastern

Table 2. Selenium Content (Micrograms per Gram, Fresh Weight) in Meat from Different Countries

Se in meat, μg/g						
veal	pork	chicken	rabbit	lamb	country	ref
0.020	0.040			0.050	U.S.A. (Ohio)	Moxon and Palmquist (1980)
0.020	0.300	0.160			Canada	Arthur (1982)
0.010	0.060	0.200		0.050	Spain (Salamanca)	Moreno Dominguez et al. (1983)
0.290	0.310			0.310	U.S.A. (Dakota)	Olson and Palmer (1984)
0.080	0.040	0.160	0.030	0.040	Spain (Galicia)	Mejuto Martí et al. (1987)
0.080	0.107	0.054	0.167	0.067	France	Simonoff and Simonoff (1991)
0.165	0.129				Russia (Ural region)	Golubkina and Khotimchencko (1994)
		0.607[a]			Croatia	Beker et al. (1994)

[a] Dry weight.

Table 3. Contributions of Meat, Organ Meats, and Sausages to Mean Selenium Intake by the Andalusian Population

sample	daily consumption, g/person	edible fraction, %	daily Se intake, μg/person
veal	12.012	100.00	0.541
chicken	53.351	70.00	2.726
rabbit	3.744	65.00	0.248
mutton	2.496	70.00	0.049
pork	24.648	82.00	4.689
processed meat	44.145	100.00	6.666
viscera	7.332	100.00	3.549
total			18.468

Spain) (Table 3). The value determined was 18.468 μg/person. Taking into consideration the total daily intake of Se from fish (15.78 μg/person) (Díaz-Alarcón et al., 1994a) and vegetables and fruits (1.21 μg/person) (Díaz-Alarcón et al., 1994b) in the same area, we obtain a final value of 35.458 per person per day. Of all animal meats considered, pork (4.689 μg/person) provides the highest intake in the daily diet (Table 3); 6.666 μg per person per day should be added to this quantity, as this is the amount corresponding to processed meats (including sausages) that in Spain are also almost always byproducts of pork. This high intake of Se in the daily diet is due to both the high concentration (0.232 μg/g in pork and 0.151 μg/g in byproducts) in pork and the high daily consumption of pork (24.648 g/person of pork and 44.145 g/person of processed meats) (Table 3).

In view of these data, we infer that the intake of Se mainly occurs by consumption of protein foods such as meat and fish (Oster and Prellwitz, 1989; Benemariya et al., 1991; Zhang et al., 1993). Moreover, if we consider the intake that could be added by the remaining foods (milk, dairy products, cereals and legumes) consumed, it seems there should be no problem of dietary Se deficiency in the inhabitants of the area according to the recommendations of the Food and Nutrition Board (1989). Nevertheless, some supervision should be considered, as should the possibility of Se supplementation in the diet of strict vegetarians and lactovegetarians, who mainly present Se deficiency because of the low content present in this type of diet (Donovan et al., 1992; Gibson, 1994). In these cases, the intake would be lower than the RDA, which is due to both the low content of Se in plant-based food and the lack of consumption of protein foods, mainly meat and fish (Stacchini et al., 1989; Benemariya et al., 1991; Díaz-Alarcón et al., 1994a).

Studies are necessary on the bioavailability of Se in these foods, to determine the intake accurately. There is usually a large number of factors affecting absorption of a mineral from foods, such as the quantity of the mineral in the diet, its oxidation state, its chemical form, and the presence of factors that increase or decrease its absorption (Thurlund, 1991). For this reason, if we consider that only a small fraction of the total Se ingested is absorbed and transformed into a biologically active form (Cantor et al., 1975a,b; Yoshida et al., 1984; Simonoff and Simonoff, 1991; Levander and Burk, 1994) and that the bioavailability of Se in foodstuffs is slightly less than 25% (Cantor et al., 1975a,b; Simonoff and Simonoff, 1991), the amount of bioavailable Se in meat products in the area under consideration would be approximately 4.617 μg per person per day.

LITERATURE CITED

Alvárez Prieto, M.; Cordeiro Naranjo, C.; Pina Luis, G.; Mora de la Cruz, G.; Fe Napoles, C.; Fleites Mestre, P. Determination of selenium in blood and serum of patients with epidemical neuritis by ETAAS. *Quim. Anal.* **1994**, *13*, 182−186.

Aro, A.; Kumpulainen, J.; Alfthan, G.; Voshchenko, A. V.; Ivanov, V. N. Factors affecting the selenium intake of people in Transbaikalian Russia. *Biol. Trace Elem. Res.* **1994**, *40*, 277−285.

Arthur, D. Selenium contents of Canadian foods. *Can. Inst. Food Sci. Technol. J.* **1982**, *5*, 165−169.

Beker, D.; Satovic, V.; Vukelic, N. Selenium content in chicken meat in Croatia. *Nahrung* **1994**, *38*, 267−272.

Benemariya, H.; Robberecht, H.; Deelstra, H. Atomic absorption spectrometric determination of zinc, copper and selenium in fish from Lake Tanganyika, Burundi, Africa. *Sci. Total Environ.* **1991**, *105*, 73−95.

Cantor, A. H.; Scott, M. L.; Noguchi, T. Biological availability of selenium in feeds and selenium compounds for prevention of exudative diathesis in chicks. *J. Nutr.* **1975a**, *105*, 96−105.

Cantor, A. H.; Langevin, M. L.; Noguchi, T.; Scott, M. L. Efficacy of selenium in selenium compounds and feeds for prevention of pancreatic fibrosis in chicks. *J. Nutr.* **1975b**, *105*, 106−111.

Caurant, F. Bioaccumulation de quelques éléments traces (As, Cd, Cu, Hg, Se, Zn) chez le globicephale noir (*Globicephala melas*, Delphinidé), pêché au large des Iles fereoé. Doctoral Thesis: University of Nantes, Nantes, France, 1994.

Díaz-Alarcón, J. P.; Navarro-Alarcón, M.; López-Martínez, M. C.; López Gª de la Serrana, H. Determination of selenium in fresh fish from southeastern Spain for calculation of daily dietary intake. *J. Agric. Food Chem.* **1994a**, *42*, 334−337.

Díaz-Alarcón, J. P.; Navarro-Alarcón, M.; López-Gª de la Serrana, H.; López-Martínez, M. C. Determination of selenium levels in vegetables and fruits by hydride generation atomic absorption spectrometry. *J. Agric. Food Chem.* **1994b**, *42*, 2848−2851.

Dirección General de Política Alimentaria (Secretaría General de Alimentación, Ministerio de Agricultura, Pesca y Alimentación). In *El Consumo Alimentario en España*; Gráficas Monterreina: Madrid, 1991.

Donovan, U. M.; Gibson, R. S.; Ferguson, E. L.; Ounpuu, S.; Heywood, P. Selenium intakes of children from Malawi and Papua New Guinea consuming plant-based diets. *J. Trace Elem. Electrolytes Health Dis.* **1992**, *6*, 39−43.

Food and Nutrition Board (National Research Council). In *Recommended Dietary Allowances*, 10th ed; National Academy of Science: Washington, DC, 1989.

Gibson, R. S. Content and Bioavailability of trace elements in vegetarian diets. *Am. J. Clin. Nutr.* **1994**, *48*, 859−862.

Golubkina, N. A.; Khotimchencko, S. A. Selenium in the food products of Ural economic region. *Git Sanit* **1994**, *7*, 12−14.

Humphreys, D. J. In *Toxicología Veterinaria*; Interamericana: Madrid, 1990; 74 pp.

Jaffar, M.; Ashraf, M. Selected trace metal concentrations in different tissues of fish from coastal waters of Pakistan (Arabian Sea). *Ind. J. Mar. Sci.* **1988**, *17*, 231−234.

Jiménez Cruz, A.; Cervera Ral, P.; Barcardi Gascon, M. In *Tabla de Composición de Alimentos*; Wander, Empresa Sandoz Nutrition: Barcelona, 1990; pp 32−36.

Lakin, H. W. In *Trace Elements in the Environment*; Advances in Chemistry 123; Kothny, E. L., Ed.; American Chemical Society: Washington, DC, 1973; 96 pp.

Levander, O. A.; Burk, R. F. In *Selenium, in Modern Nutrition in Health and Disease*, 8th ed.; Shils, M. E., Olson, J. A., Shike, M., Eds.; Lea and Febiger: London, 1994; 242 pp.

Li, J. Y.; Li, B.; Blot, W. J.; Taylor, P. R. Preliminary report on the results of nutrition prevention trials of cancer and other common diseases among residents in Linxian, China. *Chung. Hua. Chung. Liu. Tsa. Chih.* **1993**, *15*, 165−181.

Mayer, D.; Haubenwallner, S.; Kosmus, W.; Beyer, W. Modified electrical heating system for hydride generation atomic

absorption spectrometry and elaboration of a digestion method for the detemnation of arsenic and selenium in biological materials. *Anal. Chim. Acta* **1992,** *268*, 315−321.

McLaughlin, J. G.; Cullen, J.; Forristal, T. Blood selenium concentrations in cattle on seleniferous pastures. *Vet. Rec.* **1989**, *124*, 426−427.

Mejuto Martí, M. C.; Bollain, M. H.; Bermejo, F. Contenido de selenio en carnes, vísceras y embutidos de Galicia (Selenium in meats, organ meats, and sausages of Falicia (Spain)). *Agroquim. Tecnol. Aliment.* **1987**, *27*, 451−456.

Moreno Domínguez, T.; Mateos Notario, P.; García Moreno, C. Selenium in foods. *Anal. Bromatol.* **1983**, *35*, 1−8.

Moxon, A. L.; Palmquist, D. L. Selenium content of foods grown on soil in Ohio. *Ohio Rep. Res. Dev.* **1980**, No. 13.

Nomura, F.; Takekoshi, K. Zinc and selenium metabolism in liver cirrhosis. *Nippon Rinsho* **1994**, *52*, 165−169.

Olson, O. E.; Palmer, I. S. Selenium in foods purchased or produced in South Dakota. *J. Food Sci.* **1984**, *49*, 446−452.

Oster, O.; Prellwitz, W. The daily dietary selenium intake of West Germany adults. *Biol. Trace Elem. Res.* **1989**, *20*, 1−14.

Peng, A.; Yang, C.; Rui, H.; Li, H. Study on the pathogenic factors of Kashin-Beck disease. *J. Toxicol. Environ. Health* **1992**, *35*, 79−90.

Pfannhauser, W. Species of heavy metals present in some foods. *Chemosphere* **1983**, *12*, 1061−1064.

Simonoff, M.; Simonoff, G. In *Le Selenium et la Vie*; Masson; Paris, 1991; pp 69−70.

Stacchini, A.; Coni, E.; Baldini, M.; Beccaloni, E.; Caroli, S. S. Selenium intake with diet in Italy: a pilot study. *J. Trace Elem. Electrolytes Health Dis.* **1989**, *3*, 193−198.

Taylor, P. R.; Li, B.; Dawsey, S. M.; Li, J. Y.; Yang, C. S.; Guo, W.; Blot, W. J. Prevention of esophageal cancer: the nutrition intervention trials in Linxian, China. Linxian Nutrition Intervention Trials Study Groups. *Cancer Res.* **1994**, *54*, 2029s−2031s.

Turnlund, J. R. Biovailability of dietary minerals to humans: the stable isotope approach. *Crit. Rev. Food Sci. Nutr.* **1991**, *30*, 387−396.

Weaver, C. M.; Davis, J.; Marks, H. S.; Sensmeier, R. K. Selenium content of processed soybeans. *J. Food Sci.* **1988**, *53*, 300−301.

Yoshida, M.; Iwami, K.; Yasumoto, K. Determination of nutritional efficiency of selenium contained in processed skipjack meat by comparison with selenite. *J. Nutr. Sci. Vitaminol.* **1984**, *30*, 395−400.

Zhang, X.; Shi, B.; Spallholz, J. E. The selenium content of selected meats, and vegetables from Lubbock, Texas. *Biol. Trace Elem. Res.* **1993**, *39*, 161−169.

Received for review October 24, 1995. Accepted March 19, 1996.[⊗]

JF950702L

[⊗] Abstract published in *Advance ACS Abstracts,* May 1, 1996.