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Research Article

Dietary Intake of Metals from Fresh Cage-Reared Hens' Eggs in Tenerife, Canary Islands

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The concentrations of 20 metals (Na, K, Ca, Mg, V, Mn, Fe, Cu, Zn, Cr, Mo, Co, B, Ba, Sr, Ni, Si, Al, Pb, and Cd) in cage-reared hens' eggs have been determined in this study using inductively coupled plasma atomic emission spectroscopy (ICP-OES). There were significant differences in the metal content depending on the edible part of the egg, with the yolk having the greater concentrations of metals. The daily consumption of eggs (24.3 g/person/day for children and 31.2 g/person/day for adults) contributes to the intake of trace metals, notably Fe (3.8% children, 3.2% women, and 6.5% men) and Zn (4.5% children, 6.6% women, and 4.9% men). In addition, the consumption of eggs does not imply a high contribution of toxic metals.

1. Introduction

Hen's eggs have long been one of the most important foods for man because of their high nutritional value, low cost, and easy preparation [1]. It is a food that contributes to the intake of nutrients, proteins, vitamins (B_1, B_2, B_{12}, niacin, biotin, choline, pantothenic acid, A, E, K, and D) and minerals (Se, K, P, I, Zn, Cu, Mn, and Fe) [2]. The nutritional value varies markedly between the yolk and the white. The fat, cholesterol, and some micronutrients are located in the yolk, while the egg white is mainly formed of water and protein. On the other hand, some minerals and water-soluble vitamins are found in higher concentrations in the yolk [3, 4].

Average consumption data for the Spanish regional areas indicate that the consumption of eggs in the Canary Islands is 31.5 g/person/day [5]. On the other hand, the average consumption recommended by the Spanish Agency for Food Safety and Nutrition (AESAN) is 24.3 g/person/day for children between the ages of 7 and 12 years and 31.2 g/person/day for adults over 17 years old [6].

Diet is an important source of metals [7], among which can be found macroelement metals (Ca, K, Na, and Mg) that are required in large quantities, which are found in greater proportion in the tissues of living beings [8].

The trace elements (Mn, Fe, Cu, Zn, Cr, Mo, and Co) are present in small quantities and are necessary for the adequate development of the physiological functions [9–14]. In the case of chromium, some institutions such as the Institute of Medicine, Food and Nutrition Board [15] or the FESNAD (Spanish Federation of Societies of Nutrition and Dietetics) [16] reported in the past that Cr (III) is an essential metal with a function in carbohydrate metabolism and in particular in maintaining normal blood glucose levels. However, a recent assessment by the European Food Safety Authority (EFSA) however highlighted that Cr is not an essential element based on insufficient proofs of a functional role [17]. Cobalt is an essential element as a part of cobalamin (vitamin B_{12}), and a deficiency of this vitamin causes anaemia and retarded growth [18, 19].

Several enzymes, such as ferroxidases, cytochrome C oxidase, or tyrosinase, contain copper, which is an essential trace metal; however an excess could damage the liver and cause gastrointestinal distress. Iron is one of the most abundant metals and is an essential element that plays an important role in the human organism participating in the oxygen transport in blood and muscle tissue and in redox processes. Regarding zinc functions, this metal is necessary for some biochemical processes such as DNA and RNA synthesis, elimination of free radicals, or the preservation of the integrity of the cell membrane [15, 19].

Manganese is necessary for bone formation, and it also has a role in carbohydrate metabolism, but Mn in excess is neurotoxic. Molybdenum is an important metal due to it being a cofactor for enzymes [15, 18].

The toxic metals (V, B, Ba, Ni, Sr, Al, Pb, and Cd) are characterized as having a long biological half life and as lacking a biological function and being accumulative in nature [14, 20–22]. The toxicity of the barium is because of an accumulation of this metal in the skeleton and in the pigmented parts of the eye. In addition, Ba seems to be an antagonist of potassium and calcium. Barium acts in blocking the potassium channels of the N-K pump in cell membranes [23].

Boron does not have a function in the human organism and the adverse effects of an excessive intake of this metal are manifested in reproductive and developmental effects; however, these effects have been shown in experimental animals [15].

Vanadium (V) is a toxic metal that could produce damage in the liver, kidney, and nervous system. However, the gastrointestinal absorption of V is low in humans [15, 18].

The compounds of nickel are considered as carcinogens by the International Agency for Cancer Research (IARC). The EFSA has recently reduced the tolerable daily intake (TDI) of nickel from 8 μg/day to 2.8 μg/day [24]. The adverse effects of nickel intake decrease with gain in body weight. People who are nickel hypersensitive or have kidney dysfunction accumulate toxic metals in many tissues like muscle and in the case of kidney and liver tissue over a long period of time. Both metals act by interfering with some zinc-dependent enzymatic reactions causing renal dysfunctions, hypertension, or endocrine disruption [19]. Aluminium is a neurotoxic metal which has been suggested to be responsible for increasing the probability of suffering Alzheimer's disease [18].

Silicon is a metalloid that, at present, has not been convincingly demonstrated to have a biological function in humans. The adverse effects derived from an excessive intake of silicon from food and water are unknown [15]. Although strontium is another toxic metal, an overdose of Sr has not been reported in humans. A high intake of this metal could produce insoluble compounds with phosphorus causing a deficiency in P [25].

Due to the great importance of the some metals and the properties of hen's egg, which is a basic food ingredient, this study has been conducted to determine the concentration level of different metals, using, for this purpose, inductively coupled plasma atomic emission spectroscopy (ICP-OES), a multielement analytical technique that has favourable detection limits for refractory elements, a high capacity for simultaneous sequential analysis, and a wide linear range [7, 26]. The analysis of the metallic content allows the estimation of the nutritional importance of the egg and the assessment of toxic risk, which is of great interest for food quality and safety.

The European Regulation (EC) number 1881/2006 sets maximum levels for certain contaminants, such as Pb and Cd, in foodstuffs [27]; however, these maximum levels have not been set for hen's eggs.

The objectives of this study are to determine the content of 21 metals (Na, K, Ca, Mg, V, Mn, Fe, Cu, Zn, Cr, Mo, Co, B, Ba, Li, Sr, Ni, Si, Al, Pb, and Cd) in fresh eggs of hens kept in cages, differentiating between the edible parts of the egg (yolk and white) and to evaluate the intake of these metals taking into account the intake recommendations and limits for each metal.

2. Material and Methods

2.1. Samples. A total of 144 fresh eggs from caged hens were used, the samples were comprised of 12 egg boxes with 12 eggs in each box. The samples were separated depending on the edible parts of the eggs:

(i) 144 yolk samples

(ii) 144 egg white samples

(iii) 144 homogenized egg samples

The samples were collected in local shops on the island of Tenerife (Canary Islands, Spain) from November 2012 to April 2013. They were transported to the laboratory and stored at 4°C until treatment.

2.2. Treatment of Samples and Analysis. Three grams of the separated samples (yolk, egg white, and homogenized egg) were placed in porcelain crucibles that were desiccated for 24 hours in an oven at 70°C. The samples were then subjected to incineration in a muffle furnace with a temperature-time programme of 450±25°C-24 to 48 hours, until the production of white ash [28–30]. The white ashes were diluted in 1.5% HNO_3 to a volume of 25 mL.

The laboratory material was previously washed to prevent contamination and to eliminate possible traces of metals. The material was kept for 24 hours in 5% HNO_3 and then washed with milli-Q grade deionized water [31–33].

The metals were determined by an inductively coupled plasma atomic emission spectrometer (ICP-OES) model ICAP 6300 Duo Thermo Scientific. The instrumental conditions were as follows: approximate RF power, 1150 W; gas flow (nebulizer gas flow, auxiliary gas flow), 0.5 L/min; injection of the sample to the pump flow, 50 rpm; stabilization time, 0 s.

Quality controls were performed to verify the accuracy of the analytical procedure. These controls were based on the study of the recovery percentage obtained with the reference material measured under reproducible conditions. The quality controls with the reference materials were performed following the same incineration process as the samples. The following reference materials were used: SRM 1515 Apple Leaves; SRM 1548a Typical Diet; SRM 1567a Wheat Flour, from NIST (National Institute of Standards and Technology) [34, 35]. The recovery rates obtained were higher than 96.5% (Table 1). The detection and quantification limits, under reproducibility conditions, were calculated as three and ten

Table 1: Reference metals and recovery study of the analyzed metals.

Metal	Material	Certified concentration	Obtained concentration	Recovery study%
Na	SRM 1515 apple leaves	24.4 ± 1.2	24.3 ± 0.8	99.6
	SRM 1548a typical diet	8132 ± 942	8001.9 ± 476	98.4
	SRM 1567a wheat flour	6.1 ± 0.8	6.1 ± 0.3	99.2
K	SRM 1515 apple leaves	1.61 ± 0.02	1.57 ± 0.04	97.8
	SRM 1548a typical diet	6970 ± 125	6858.5 ± 318	98.4
	SRM 1567a wheat flour	0.133 ± 0.003	0.132 ± 0.02	99.3
Ca	SRM 1515 apple leaves	1.53 ± 0.02	1.57 ± 0.05	102.3
	SRM 1548a typical diet	1967 ± 113	1961.1 ± 158	99.7
	SRM 1567a wheat flour	0.02 ± 0.00	0.02 ± 0.02	101.4
Mg	SRM 1515 apple leaves	0.27 ± 0.01	0.26 ± 0.03	98.1
	SRM 1548a typical diet	580 ± 26.7	580 ± 26.7	97.7
	SRM 1567a wheat flour	0.04 ± 0.00	0.04 ± 0.03	102.6
Fe	SRM 1515 apple leaves	80.0 ± 0.0	79.6 ± 0.2	99.5
	SRM 1548a typical diet	35.3 ± 3.77	35.6 ± 5.17	101.3
	SRM 1567a wheat flour	14.1 ± 0.5	13.9 ± 0.3	98.9
Mn	SRM 1515 apple leaves	54.0 ± 3.0	54.8 ± 6.2	101.5
	SRM 1548a typical diet	5.75 ± 0.17	5.71 ± 0.36	99.3
	SRM 1567a wheat flour	9.4 ± 0.9	9.6 ± 1.5	102.4
Cu	SRM 1515 apple leaves	5.6 ± 0.24	5.58 ± 0.32	98.9
	SRM 1548a typical diet	2.32 ± 0.16	2.34 ± 0.29	100.7
	SRM 1567a wheat flour	2.1 ± 0.2	2.09 ± 0.4	99.7
Zn	SRM 1515 apple leaves	12.5 ± 0.3	12.7 ± 0.5	101.9
	SRM 1548a typical diet	24.6 ± 1.79	24.3 ± 1.32	98.7
	SRM 1567a wheat flour	11.6 ± 0.4	11.9 ± 0.2	102.7
Cr	SRM 1515 apple leaves	0.30 ± 0.00	0.29 ± 0.03	97.8
Mo	SRM 1515 apple leaves	0.09 ± 0.01	0.09 ± 0.02	99.4
	SRM 1548a typical diet	0.26 ± 0.02	0.26 ± 0.05	98.6
	SRM 1567a wheat flour	0.48 ± 0.03	0.48 ± 0.06	99.6
Co	SRM 1515 apple leaves	0.09 ± 0.00	0.09 ± 0.03	101.5
	SRM 1567a wheat flour	0.006 ± 0.00	0.006 ± 0.002	102.4
B	SRM 1515 apple leaves	27.0 ± 2.0	27.0 ± 1.5	99.9
	SRM 1548a typical diet	4.16 ± 0.04	4.23 ± 0.02	101.8
Ba	SRM 1548a typical diet	1.10 ± 0.10	1.13 ± 0.09	102.5
Sr	SRM 1515 apple leaves	25.0 ± 2.0	24.6 ± 4.0	98.3
	SRM 1548a typical diet	2.93 ± 0.10	2.91 ± 0.25	99.2
Ni	SRM 1515 apple leaves	0.91 ± 0.12	0.92 ± 0.18	100.6
	SRM 1548a typical diet	0.37 ± 0.02	0.38 ± 0.04	102.3
V	SRM 1548a typical diet	0.26 ± 0.03	0.26 ± 0.06	100.6
	SRM 1567a wheat flour	0.011 ± 0.00	0.011 ± 0.00	99.4
Al	SRM 1515 apple leaves	286 ± 9	285.1 ± 26	99.7
	SRM 1548a typical diet	72.4 ± 1.52	71.2 ± 3.23	98.3
	SRM 1567a wheat flour	5.7 ± 1.3	5.7 ± 2.6	99.2
Pb	SRM 1515 apple leaves	0.47 ± 0.02	0.47 ± 0.04	100.3
	SRM 1548a typical diet	0.044 ± 0.000	0.044 ± 0.013	98.9
	SRM 1567a wheat flour	<0.02	<0.02	99.5
Cd	SRM 1515 apple leaves	0.014 ± 0.00	0.014 ± 0.003	99.3
	SRM 1548a typical diet	0.035 ± 0.015	0.036 ± 0.006	102.2
	SRM 1567a wheat flour	0.026 ± 0.002	0.026 ± 0.008	98.4

Table 2: Detection and quantification limits.

Metal	Wavelength (nm)	Detection limit (mg/kg)	Quantification limit (mg/kg)
Al	167.0	0.033	0.100
B	249.7	0.025	0.100
Ba	455.4	0.008	0.042
Ca	317.9	4.833	16.29
Cd	226.5	0.003	0.008
Co	228.6	0.005	0.017
Cr	267.7	0.025	0.067
Cu	327.3	0.033	0.100
Fe	259.9	0.017	0.042
K	769.9	4.708	15.70
Mg	279.1	4.858	16.19
Mn	257.6	0.017	0.067
Mo	202.0	0.006	0.017
Na	589.6	9.142	30.46
Ni	231.6	0.006	0.025
Pb	220.3	0.003	0.008
Si	185.0	0.017	0.050
Sr	407.7	0.006	0.025
V	310.2	0.008	0.042
Zn	206.2	0.017	0.058

times the standard deviation (SD) resulting from the analysis of 15 blanks [36], and they are shown in Table 2.

2.3. Statistical Analysis. Statistical analysis was performed using the statistical package IBM Statistics SPSS 22.0 (Statistical Package for the Social Sciences). In order to test the normality of the analyzed data, the Kolmogorov-Smirnov and Shapiro-Wilk tests were performed [37] and Levene's test was used for the test of homogeneity of the variances [29]. Parametric tests were performed by means of the ANOVA test for those data in which normality existed, whereas, for data in which there was no normality, a nonparametric study was performed using the Kruskal-Wallis test. These analyses were carried out in order to confirm the existence or not of significant differences between the study samples [38]. The samples have been classified by the edible part of the egg (yolk, egg white, and homogenized). Values of $p < 0.05$ were considered statistically significant.

3. Results and Discussion

Table 3 shows the concentration and standard deviation (SD) of each metal analyzed in the egg white, yolk, and homogenized egg samples.

The highest concentration of metals was found in the egg yolk, where the highest levels of K, Ca, Fe, Mn, Cu, Zn, Mo, Ba, Sr, Ni, and Pb were recorded, whereas the levels of B, Si, and Al were the highest in the egg whites. Finally, the homogenized egg samples had the highest concentrations of Na, Mg, Cr, and V. Na was the macroelement found in greater proportions in the egg white, with levels of 1092 mg/kg, followed by K > Ca > Mg. Na was also found in the highest proportion (1149 mg/kg) in the homogenized egg samples followed by K > Ca > Mg, whereas Ca was the macroelement found in the highest proportion in the yolk samples (775 mg/kg), followed by K > Na > Mg.

Furthermore, Si was the most abundant trace element in egg whites with a concentration of 18.03 mg/kg; the rest of the trace elements were found in the following sequence Al > Sr > Cu > Fe > Zn > B > Ba > V > Ni > Pb > Cr. The aforementioned sequence changes in the egg yolk samples, in which the major trace element is Fe (18.63 mg/kg), followed by Zn > Al > Si > Cu > Sr > B > Mn > V > Cr > Mo > Ni > Pb. In the case of homogenized egg samples, Al is the major trace element, which is a toxic metal, with a concentration of 9.41 mg/kg, followed by the sequence Si > Fe > Zn > Cu > Sr > Ba > B > V > Cr > Mn > Ni > Pb > Mo.

Significant differences ($p > 0.05$) were detected in the Cr, Ca, Mg, Mo, and Si levels, as well as in concentrations of B, Ba, Ca, Fe, K, Mn, Na, Sr, Ni, Zn, V, Al, and Pb, among the different sample types (yolk, egg white, and homogenized egg). The detected levels of Co and Cd were below the quantification limit. Notable concentrations of the metals Si, Al, Fe, and Zn were found in the different samples. Several authors suggest that bioaccumulation of metals in hen's eggs may occur from the ingestion of contaminated food or from soil contamination [4, 39], besides which the reason why higher concentrations of metals are detected in the yolk is because this is part where the greatest amount of fats is found, as the metals are accumulated in fat [4].

As regards toxic metals, European legislation does not establish any limits on toxic metals in hen's eggs.

TABLE 3: Mean concentration ± standard deviation of the studied metals in fresh cage reared hens (mg/kg).

Metal	White (n = 144)	Yolk (n = 144)	Homogenized egg (n = 144)
Ca	78.3 ± 35.8	775 ± 185	174 ± 83.3
K	541 ± 177	628 ± 143	491 ± 217
Na	1092 ± 105	307 ± 110	1149 ± 96.2
Mg	81.2 ± 26.5	31.7 ± 11.1	87.5 ± 26.1
Fe	1.46 ± 0.90	18.6 ± 7.82	5.49 ± 4.10
Mn	<LOQ	0.36 ± 0.13	0.10 ± 0.11
Cu	1.69 ± 0.76	3.21 ± 2.79	2.22 ± 1.10
Zn	0.92 ± 0.56	14.9 ± 3.16	3.37 ± 1.73
Cr	0.02 ± 0.04	0.12 ± 0.13	0.17 ± 0.24
Mo	<LOQ	0.07 ± 0.04	0.01 ± 0.01
Co	<LOQ	<LOQ	<LOQ
B	0.55 ± 0.36	0.52 ± 0.17	0.31 ± 0.41
Ba	0.50 ± 0.24	1.75 ± 0.72	0.72 ± 0.30
Sr	2.28 ± 2.94	2.32 ± 2.38	2.05 ± 2.73
Ni	0.03 ± 0.03	0.07 ± 0.04	0.05 ± 0.03
V	0.12 ± 0.10	0.15 ± 0.08	0.21 ± 0.04
Si	18.0 ± 16.8	7.26 ± 1.95	7.80 ± 3.69
Al	15.3 ± 14.9	11.2 ± 8.32	9.41 ± 11.9
Pb	0.02 ± 0.01	0.04 ± 0.03	0.02 ± 0.02
Cd	<LOQ	<LOQ	<LOQ

3.1. Comparison with Other Authors. Table 4 shows the comparison of the content of the metals studied (mg/kg) in different hen's egg samples with data obtained by other authors.

The macroelement concentrations obtained here in the different samples were lower (with the exception of Ca in the egg whites) than those recorded by the consulted authors. On the other hand, the concentrations obtained here for the trace elements were lower than those found by the authors (except Cu, Cr, Ba, Sr, Ni, and Al in homogenized egg samples).

Table 5 shows the comparison of the content of metals analyzed (mg/kg) with the concentration obtained by other authors who analyzed eggs from hens raised in cages.

The concentrations of Cu and V obtained by Demirulus [43] are higher than those obtained in the present study. The concentration of Mg obtained by Alam Chowdhury et al. [48] is lower (43.26 mg/kg) than that obtained here (81.2 mg/kg), and the level of nickel is higher (12.81 mg/kg) than that obtained at the present study. Giannenas et al. [42] reported lower concentrations of Cr, Ni, and V than those obtained here, except for the Cu and Zn levels which are higher than those obtained here.

As regards the metal content obtained in the yolk samples in the present research, the levels of Cu, Mn, Ni, and Zn obtained by Demirulus [43] are higher than those obtained here. The concentrations of Cu, Zn, Mn, and Mo reported by Giannenas et al. [42] are higher than those obtained in the present study. Alam Chowdhury et al. [48] reported higher concentrations of Fe, Mg, Ni, and Zn than those found here.

As for the metal content of the homogenized eggs, the concentrations of Fe, Mg, Pb, and Zn obtained by Alam Chowdhury et al. [48] are higher than those obtained in the present study. González-Weller et al. [46] reported higher concentrations of Ni (15.6 mg/kg) than those obtained here (0.05 mg/kg).

3.2. Evaluation of Dietary Intake. Consumption data, provided by the Spanish Agency for Food Safety and Nutrition (AESAN), has been used to evaluate the contribution to the daily intake for the metals studied which is 24.3 g/person/day for children aged between 7 and 12 and 31.2 g/person/day for adults over the age of 17 [6]. In addition, the average weight of 34.48 and 68.48 kg for children and adults, respectively, has been used for the evaluation of the toxic metals [6].

The daily requirements (recommended daily intake, RDI) for children and adults in the Spanish population have been established by Spanish Federation of Nutrition, Food and Dietetic Societies (FESNAD) and are as follows [16]:

(i) 1200–1500 mg Na/day for children (6–13 years) and 1500 mg/day for men and women

(ii) 2000–3100 mg K/day for children (6–13 years) and 3100 mg/day for men and women

(iii) 800–1100 mg Ca/day for children (6–13 years) and 900–1000 mg/day for men and women

(iv) 170–280 mg Mg/day for children (6–13 years), 300 mg/day for women, and 350 mg/day for men

(v) 0.7–1.0 mg Cu/day for children (6–13 years) and 1.1 mg/day for men and women

(vi) 9–12 mg Fe/day for children (6–13 years), 18 mg/day for women, and 9 mg/day for men

Table 4: Comparison of metal concentrations in hen eggs from nonspecified breeder system.

(a) Comparison of metal concentration levels in the egg whites

Metal	Souci et al. [40]	CESNID [41]	Moreiras et al. [2]	Giannenas et al. [42]	Demirulus [43]	This study (2015)
Ca	110	60	50	—	—	78.3
Cr	—	—	—	0.048	—	0.02
Cu	1.3	—	—	0.212	7	1.69
Fe	2	1	1	—	—	1.46
K	1550	1420	1500	—	—	541
Mg	120	100	110	—	—	81.2
Na	1700	1600	1900	—	—	1092
Ni	—	—	—	0.064	3.7	0.03
Pb	—	—	—	—	—	0.02
V	—	—	—	0.013	—	0.12
Zn	0.2	Traces	1	1.003	7.4	0.92

(b) Comparison of metal concentration levels in the egg yolks

Metal	Souci et al. [40]	CESNID [41]	Moreiras et al. [2]	Giannenas et al. [42]	Demirulus [43]	This study (2015)
Ca	1400	1370	1300	—	—	775
Cr	—	—	—	0.066	—	0.12
Cu	3.5	—	—	1.357	10.5	3.21
Fe	70	55	61	—	—	18.6
K	1400	970	1200	—	—	628
Mg	160	130	150	75.96	—	31.7
Mn	0.5–2	—	—	0.836	1.9	0.36
Mo	—	—	—	0.26	—	0.07
Na	500	500	500	—	—	307
Ni	—	—	—	0.063	1.7	0.07
Pb	—	—	—	—	—	0.04
V	—	—	—	0.012	—	0.15
Zn	40	39	39	20.68	35.6	14.9

(c) Comparison of metal concentrations levels in the homogenized egg

Metal	Moreiras et al. [2]	Fakayode and Olu-Owolabi [44]	Abduljaleel and Shuhaimi-Othman [45]	González-Weller et al. [46]	Iwegbue et al. [47]	This study (2015)
Al	—	—	17.11	2.930	—	9.41
Ba	—	—	—	0.468	—	0.72
Ca	570	—	—	—	—	174
Cr	—	—	3.24	0.115	0.32	0.17
Cu	—	0.78	—	—	1.03	2.22
Fe	19	23.20	—	—	—	5.49
K	1300	—	—	—	—	491
Mg	120	—	—	—	—	87.5
Na	1400	—	—	—	—	1149
Ni	—	0.03	1.11	0.038	0.86	0.05
Pb	—	0.59	0.420	—	0.82	0.02
Sr	—	—	—	0.388	—	2.05
Zn	13	13.75	34.22	—	6.45	3.37

(vii) 1.5–1.6 mg Mn/day for children (6–13 years), 1.8 mg Mn/day for women, and 2.3 mg/day for men.

(viii) 6.5–8 mg Zn/day for children (6–13 years), 7 mg Zn/day for women, and 9.5 mg/day for men

(ix) 15–21 mg Cr/day for children (6–13 years), 25 mg Cr/day for women, and 35 mg/day for men

(x) 22–34 mg Mo/day for children (6–13 years) and 45 mg/day for men and women.

Table 5: Comparison of metal concentrations in eggs from cage-reared hens.

(a) Comparison of metal concentration levels in the egg whites

Metal	Giannenas et al. [42]	Alam Chowdhury et al. [48]	Demirulus [43]	This study (2015)
Cr	0.048	<LOQ	—	0.02
Cu	0.212	0.1	7.0	1.69
Fe	—	2.96	—	1.46
Mg	—	43.26	—	81.2
Ni	0.064	12.81	3.7	0.03
Pb	—	1.06	—	0.02
V	0.013	—	—	0.12
Zn	1.003	16.88	7.4	0.92

(b) Comparison of metal concentration levels in the egg yolks

Metal	Giannenas et al. [42]	Alam Chowdhury et al. [48]	Demirulus [43]	This study (2015)
Cr	0.066	<LOQ	—	0.12
Cu	1.357	0.16	10.5	3.21
Fe	—	27.27	—	18.6
Mg	—	75.96	—	31.7
Mn	0.836	—	1.9	0.36
Mo	0.26	—	—	0.07
Ni	0.063	2.79	1.7	0.07
V	0.012	—	—	0.15
Zn	20.68	81.97	35.6	14.9

(c) Comparison of metal concentrations levels in the homogenized egg

Metal	González-Weller et al. [46]	Alam Chowdhury et al. [48]	This study (2015)
Al	2.930	—	9.41
Ba	0.468	—	0.72
Cr	0.115	<LOQ	0.17
Cu	—	0.26	2.22
Fe	—	30.66	5.49
Mg	—	119.22	87.5
Ni	15.6	0.038	0.05
Pb	—	1.06	0.02
Sr	0.388	—	2.05
Zn	—	98.85	3.37

Concerning the toxic metals, different values have been used. The European Food Safety Authority (EFSA) has established the following limits:

(i) The tolerable daily intake (TDI) of nickel is 2.8 μg Ni/kg bw/day [24].

(ii) The tolerable weekly intake (TWI) of aluminium is 1 mg Al/kg bw/week [49].

The Institute of Medicine, Food and Nutrition Board (IOM) set the following tolerable upper intake levels (ULs):

(i) The UL of vanadium is 1.8 mg V/day for adults (19–>70 years) [15].

(ii) The UL of boron is 3–6 mg/day for children (1–8 years) and 17–20 mg/day for adults (18–>70 years) [15].

The Scientific Committee of Health and Environmental Risk (SCHER) established the TDI value of barium in 0.02 mg Ba/kg bw/day [23].

The World Health Organization (WHO) established a tolerable daily intake (TDI) of 0.13 mg Sr/kg bw/day for the Sr [50].

In the case of lead, the EFSA has calculated a $BMDL_{01}$ whose values are 0.5 μg/kg bw/day (developmental neurotoxicity), 0.63 μg/kg bw/day (effects on the prevalence of chronic kidney disease), and 1.50 μg/kg bw/day (effects on systolic blood pressure) [51]. Based on this fact, the AESAN (Spanish Agency for Food Safety and Nutrition) has suggested a value of 30 μg per day for a person of 60 kg of body weight as a substitute of the tolerable daily intake (TDI) [52].

Taking into account the average consumption of the cage-reared hens' eggs, the daily intake and their contribution to

Table 6: Estimation of the daily intake (mg/day) and contribution (%) to the recommended daily intake (RDI) of the essential metals analyzed.

(a)

	Edible part[b]	EDI (mg/day)[a]	EDI (mg/day)[a]	% RDI		
				Men	Women	Children
Macroelements						
Na	White	26.5	34.1	2.27	2.27	1.77
	Yolk	7.46	9.58	0.64	0.64	0.50
	H	27.9	35.9	2.39	2.39	1.86
K	White	13.2	16.9	0.55	0.55	0.42
	Yolk	15.3	19.6	0.63	0.63	0.49
	H	11.9	15.3	0.49	0.49	0.39
Ca	White	1.90	2.44	0.24	0.24	0.17
	Yolk	18.8	24.2	2.42	2.42	1.71
	H	4.23	5.43	0.54	0.54	0.39
Mg	White	1.97	2.53	0.72	0.85	0.71
	Yolk	0.77	0.99	0.28	0.33	0.28
	H	2.13	2.73	0.78	0.91	0.76
Trace elements						
Cu	White	0.04	0.05	4.79	4.79	4.10
	Yolk	0.08	0.10	9.11	9.11	7.80
	H	0.05	0.07	6.31	6.31	5.40
Fe	White	0.04	0.05	0.51	0.25	0.30
	Yolk	0.45	0.58	6.46	3.23	3.77
	H	0.13	0.17	1.90	0.952	1.11
Mn	White	—	—	—	—	—
	Yolk	0.01	0.01	0.48	0.62	0.54
	H	3.00[c]	3.00[c]	0.14	0.18	0.16
Zn	White	0.02	0.03	0.30	0.41	0.28
	Yolk	0.36	0.46	4.87	6.62	4.51
	H	0.08	0.11	1.11	1.50	1.02
Cr	White	4.00[c]	1.00[c]	0.002	0.002	0.002
	Yolk	3.00[c]	4.00[c]	0.001	0.02	0.01
	H	4.00[c]	5.00[c]	0.02	0.02	0.02
Mo	White	—	—	—	—	—
	Yolk	2.00[c]	2.00[c]	0.01	0.01	0.004
	H	0.03[c]	0.03[c]	0.001	0.001	0.001

(b)

	Edible part[b]	EDI (mg/day)[a]	EDI (mg/day)[a]	% UL, PTWI, or TDI	
				Adults	Children
Toxic metals					
Al	White	0.37	0.48	4.88	7.47
	Yolk	0.27	0.35	3.57	5.47
	H	0.23	0.29	3.00	4.59
Sr	White	0.06	0.07	0.80	1.22
	Yolk	0.06	0.07	0.81	1.24
	H	0.05	0.06	0.72	1.10
V	White	2.92[c]	3.74[c]	0.21	0.16
	Yolk	3.65[c]	4.68[c]	0.26	0.20
	H	5.10[c]	6.55[c]	0.36	0.28

(b) Continued.

	Edible part[b]	EDI (mg/day)[a]	EDI (mg/day)[a]	% UL, PTWI, or TDI	
				Adults	Children
B	White	0.01	0.02	0.10	0.45
	Yolk	0.01	0.02	0.10	0.42
	H	7.53[c]	9.67[c]	0.06	0.25
Ba	White	0.01	0.02	1.14	1.74
	Yolk	0.04	0.06	3.99	6.10
	H	0.02	0.02	1.64	2.51
Ni	White	0.73[c]	0.94[c]	0.49	0.75
	Yolk	1.70[c]	2.18[c]	1.14	1.74
	H	1.22[c]	1.56[c]	0.81	1.25
Pb	White	0.49[c]	0.62[c]	1.82	2.53
	Yolk	0.97[c]	1.25[c]	3.64	5.05
	H	0.49[c]	0.62[c]	1.82	2.53

[a]Data for mean consumption of hen's egg established by the AESAN (24.3 g/person/day for children, 31.2 g/person/day for adults).
[b]H: the homogenized egg.
[c]Expressed in μg/day.

the RDI and to the TDI of the different studied metals have been estimated and the results are shown in Table 6.

Egg yolks are, in general, the part that contributes most to the recommended daily intake of the essential metals, except for the contribution percentages for Na and Mg, which are higher in the homogenized egg. It was found that egg yolks have the highest contribution of Ca for adults (2.4%), whereas the homogenized egg provides the highest Na contribution for children (1.9%), followed by Mg and K.

Cu is the trace element that makes the highest contribution to daily intake (9.1% for adults, 7.8% for children), followed by Fe, Zn, and Mn. On the other hand, the contribution of Mo and Cr to the daily intake is low.

Regarding the toxic metals, the highest percentage contributions are found in the egg white for Al (4.88% adults, 7.47% children) and in the yolk for Ba (3.99% adults, 6.10% children) and for Pb (3.64% adults, 5.05% children). However, these contribution percentages do not pose a health risk.

4. Conclusions

Macroelement metals and trace metals have been determined in cage-reared hen's eggs on the island of Tenerife (Canary Islands, Spain) by means of ICP-OES. This study shows that, in general, the yolk is the part of the egg that has the most metals, with significant differences in the levels of the metals studied with the other part of the egg. Eggs are an acceptable source of essential elements, in particular of Cu, Fe, and Zn. In addition, the consumption of eggs does not mean a high contribution of toxic metals.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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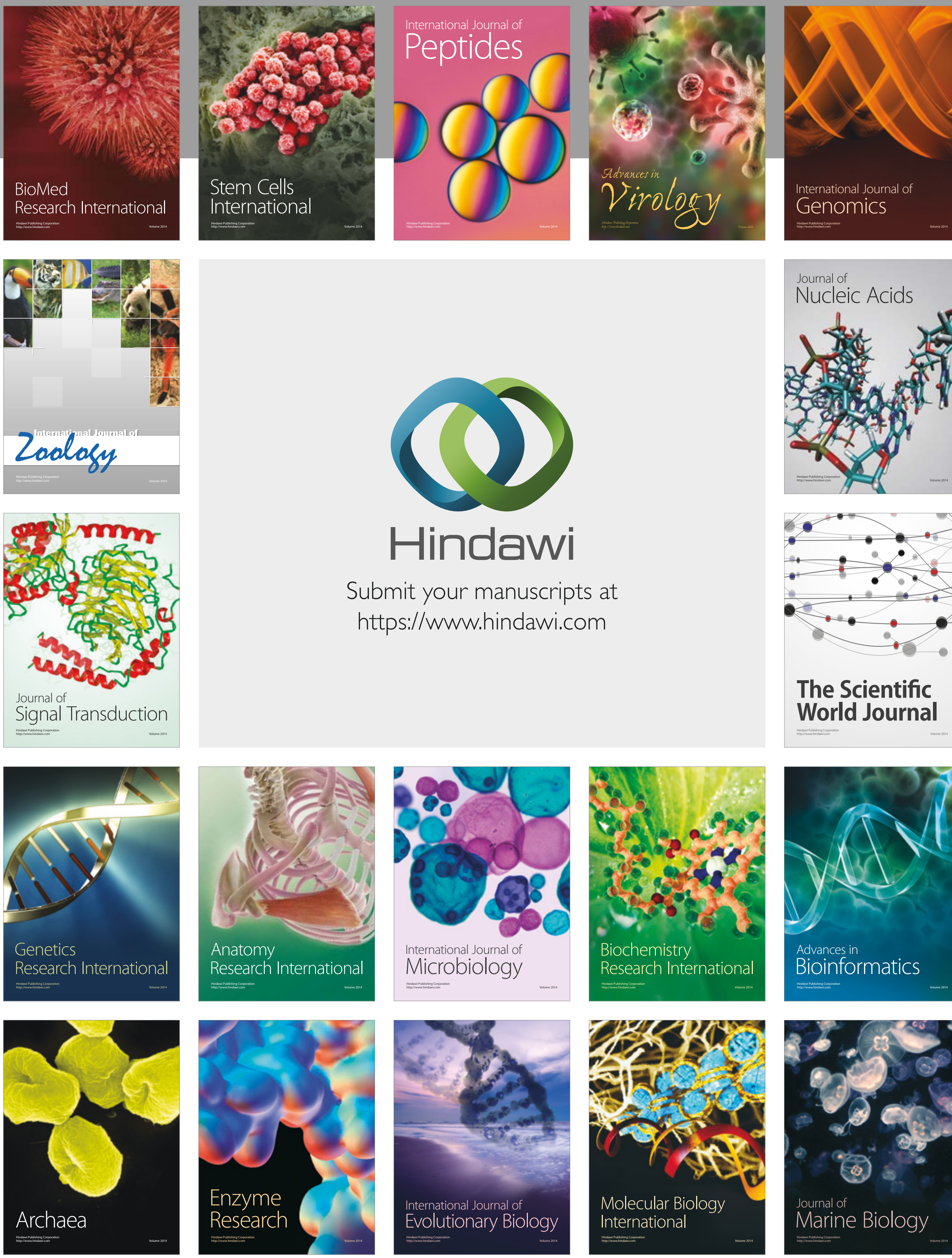
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