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Analytical Methods

Trace mineral content of conventional, organic and courtyard eggs analysed by inductively coupled plasma mass spectrometry (ICP-MS)

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ABSTRACT

We investigated the contents in yolk and albumen of the trace minerals Se, Zn, Mn, Co, Cu, Mo, V, Cr, Ni, Tl, As and Cd in eggs from hens from three husbandry systems by ICP-MS. Conventional hens were given a commercial feed with added minerals, organic hens were given a feed based on organic feedstuffs also with added minerals, and courtyard hens were fed on cereals, legumes, grass and swill. Dietary Se, Zn, Mn, Co and Cu concentrations were lower in courtyard compared to conventional and organic diets; Cr concentration was highest in courtyard compared to organic diet. Trace element contents in yolks were higher than those in albumen. The highest content of Se in yolks was in organic, followed by conventional eggs. Zn contents were highest in courtyard yolk, followed by conventional, which in turn was higher than organic. Mn yolk contents were lowest in courtyard eggs; Cr contents were highest in courtyard eggs. The differences in albumen were in Zn and Cr values, which were highest in courtyard eggs. The results provide baseline measurements of trace mineral contents of eggs and suggest measurable differences amongst eggs from hens in different husbandry systems; the physiological significance of these differences are discussed.

1. Introduction

Knowledge of the mineral composition of avian eggs is increasingly required for different purposes; these include the estimation of accumulation of toxic and heavy minerals in the egg from the feed and the environment (Pappas et al., 2006), the role of egg composition for embryonic development (Surai, 2002) and the nutritional value of eggs for human consumption (Kovacs-Nolan, Phillips, & Mine, 2005; Sparks, 2006). The concentration of trace elements in eggs of wild birds, as well as, reptiles or amphibians is used as a bio-indicator to monitor pollution trends (Burger & Gochfeld, 1995; Lam et al., 2006) from human activities such as mining, fuel combustion and farming. Egg composition and micro mineral composition in particular, contributes to the growth and development post hatching both in the short (Speake, Murray, & Noble, 1998) and the long term (Kowalczyk, Daiss, Halpern, & Roth, 1985).

Until recently, there have been some problems with the estimation of the micro mineral composition in eggs. The used methodologies had been either time consuming and costly, or importantly did not allow simultaneous estimation of the micro minerals concerned. Inductively coupled plasma mass spectrometry (ICP-MS) is well established as a method for multi elemental analysis and the determination of isotope ratios (Date & Gray, 1983), and overcomes many of these problems. This methodology allows simultaneous analysis of a wide range of trace elements in the same sample and has been used in this study.

As far as consumption of eggs by humans is concerned, chicken eggs are increasingly recognised as an important source of nutrients, including micro minerals (Surai & Sparks, 2001) and information on their trace mineral composition is being sought after (Kilic, Akar, Ulasam, & Ilim, 2002; Kovacs-Nolan et al., 2005; Richards, 1997). The development of 'designer eggs' has suggested that their composition may be manipulated to meet the specific needs of human diets. The development of eggs rich in omega fatty acids (Takahata, Monobe, Tada, & Weber, 1998) and Se is a good case in point (Surai & Sparks, 2001). There are many factors that influence the purchase and consumption of eggs from the various systems. Many consumers in Europe believe that eggs originating from free range or organic farms taste better, have a higher nutritional value and can be beneficial for human health (Rodic, Peric, Vukelic, & Milosevic, 2006). However, this perception is not based on any measurements about the specific qualities of organic or (semi) free-range eggs over conventional eggs (Hidalgo, Rossi, Clerici, & Ratti, 2008).

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Despite the considerable interest in the micro mineral composition of chicken eggs from many perspectives, data on the levels of trace elements in eggs of various types of husbandry are limited. The objective of the present study was the analysis of trace element levels in the yolk and albumen of chicken eggs deriving from different systems, using ICP-MS. The aims were to establish a baseline dataset of trace mineral egg composition and to assess differences amongst trace element concentrations in eggs from hens kept under different housing systems, namely conventional, organic and courtyard, family-scale.

2. Materials and methods

2.1. Animals, housing and diets

Eggs from domestic hens (*Gallus gallus*) were collected from a conventional poultry farm, a courtyard small-scale farm and an organic farm, all located in central northern Greece. The first two farms were located in Axos, near Gianitsa (latitude 40.77°, longitude 22.45°) and the organic poultry farm in Basilika (latitude 40.46°, longitude 22.94°). All three farms were located near to small villages, free from any localised pollution by coal burning, mining or irrigation. In this study, 60 female adult birds of the same line (Lohmann type) per each housing system were used; within each system birds were divided in groups of 10 birds. Each group in conventional, organic and courtyard system was kept in floor pens covered with wood shavings; each pen contained a food through and a bell drinker. Lighting programme was common for all hens with 17 h of light daily.

Conventional hens were given a basal, commercial ration with added minerals and vitamins. Organic hens were given a feed based on certified organic feedstuffs, with the addition of minerals and vitamins. Courtyard hens were fed mainly with cereals, legumes and their by-products, and swill; no added vitamins or micro minerals were provided. The composition of the diets for conventional, organic and courtyard hens, respectively is shown in Table 1. Birds on organic and courtyard systems had free access to yards with self – sown grass and soil; each group of 10 birds had access to a range area of $2 \times 5\ m^2$ during daytime (June–July, approximately 0900–1400 h). Range areas were divided by metal fences and contained a food trough and a bell drinker. Feed and water were provided *ad libitum*.

Table 1
Ingredients and composition of the diet of conventional, organic and courtyard hens

Ingredients	Composition (g/kg)		
	Conventional diet	Organic diet	Courtyard diet
Maize, grains	480	439	421
Wheat, grains	100	120	120
Soybean meal	240	–	–
Full fat soy	–	125	180
Soy oil	25	–	–
Pea	–	150	100
Wheat bran	30	30	80
Corn gluten meal	12.5	25	–
Limestone	87.9	91	80
Dicalcium phosphate	15	13.3	15
Sodium chloride,	3.4	4	4
Sodium bicarbonate	3	–	–
Choline chloride	0.7	0.7	–
Methionine	2.5	–	–
Vitamin premix[1]	1	1	–
Mineral premix[2]	1	1	–
Total	1000	1000	1000
Proximate analysis[3]	%	%	%
Dry matter	89.2	89.4	89.3
Crude protein	16.6	16.4	15.9
Ether extract	4.9	4.9	4.8
Crude fibre	3.2	3.4	3.5
Ash	11.2	10.9	11.4
Calculated analysis	%	%	%
Calcium	3.5	3.5	3.5
Phosphorus (total)	0.55	0.55	0.60
Metabolizable energy, kcal/kg	2800	2800	2750
Trace element analysis by ICP-MS[4]			
Se, mg/kg	0.40 ± 0.02^a	0.44 ± 0.02^a	0.09 ± 0.01^b
Zn, mg/kg	89.46 ± 6.5^a	81.87 ± 3.5^a	64.56 ± 3.8^b
Mn, mg/kg	109.06 ± 5.2^a	111.42 ± 6.4^a	26.11 ± 2.1^b
Co, mg/kg	0.34 ± 0.02^a	0.33 ± 0.02^a	0.22 ± 0.02^b
Cu, mg/kg	21.31 ± 1.4^a	19.23 ± 1.2^a	9.9 ± 0.8^b
Mo, mg/kg	2.56 ± 0.8	2.22 ± 1.2	1.98 ± 0.7
V, mg/kg	2.15 ± 0.3	2.77 ± 1.1	2.09 ± 1.1
Cr, mg/kg	4.26 ± 0.6^c	7.24 ± 0.8^b	12.90 ± 1.2^a
Ni, mg/kg	2.21 ± 0.3	3.05 ± 0.6	2.36 ± 0.4
Tl, mg/kg	0.01 ± 0.002	0.01 ± 0.001	0.01 ± 0.002
As, mg/kg	0.17 ± 0.02	0.25 ± 0.01	0.16 ± 0.02
Cd, mg/kg	0.12 ± 0.04	0.18 ± 0.02	0.20 ± 0.04

[1] Provided per kg of feed: vitamin A 10,000 IU, vitamin D_3 2500 IU, vitamin E 15 mg, vitamin B_1 1 mg, vitamin B_2 5 mg, vitamin B_6 3 mg, vitamin B_{12} 20 µg, vitamin K_3 1 mg, nicotinic acid 30 mg, pantothenic acid 10 mg, folic acid 0.8 mg, biotin 0.05 mg, and vitamin C 10 mg.
[2] Provided per kg of feed: Zn 100 mg, Mn 120 mg, Fe 25 mg, Cu 10 mg, Co 0.2 mg, I 0, 5 mg, and Se 0.3 mg.
[3] According to AO AOAC, 1990.
[4] Trace element values are means ± S.E.M. Numbers with different superscript are significantly ($p < 0.05$) different with respect to row.