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ORIGINAL ARTICLE

Exploratory and descriptive study on nutritional characteristics and quality of eggs from Chilean partridge (*Nothoprocta perdicaria*)

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ABSTRACT

This work aims to contribute more information on tinamou eggs by performing an exploratory and descriptive study of some of their nutritional and quality characteristics. The chemical composition of tinamou egg showed a high protein content in white (85% dry basis) and high lipid concentration in yolk (52% db). The iron (Fe) content in white was higher than hen egg (0.47 mg/100 g) and this could be associated with the observed pinkish color of the white. As in the hen egg, the major fatty acids in tinamou yolk were: oleic (39%), linoleic (23%) and palmitic (20%). The cholesterol content of tinamou was 21.2 mg/g of yolk, and 100 g of whole egg provides 589 mg of cholesterol. As in the hen egg, tinamou egg white showed high levels of lysine, sulfur-containing amino acids, threonine and valine with respect to the recommended allowance for an adult man. All essential amino acids with the exception of histidine cover the adult requirements. The shell inorganic composition of these eggs is calcium carbonate and the morphology was similar to other avian eggs. Tinamou egg is small and elongated, with a dark brown color. The eggshell is thinner and experiences more deformation but less breaking strength than hen eggshell.

Key words: *eggs, morphology, nothoprocta perdicaria, nutritional characteristics, quality, tinamo.*

INTRODUCTION

Egg consumption has doubled worldwide and in developing countries a stronger increase has been observed, since it is often the only animal protein source that is accessible to the general population. Future patterns of consumption indicate that the intake of eggs will continue to rise (Kearney 2010) to the year 2050. Compared with any other food of animal origin, eggs are eaten by so many people in the world due to their versatility, excellent nutritional value, low cost and wide availability (Surai & Sparks 2001). Among avian eggs, hen eggs are the most widely consumed in the world, and there is enough information on their nutritional composition and quality (Thapon & Bourgeois 1994; Cherian 2011; Seuss-Baum *et al.* 2011; Van Immerseel *et al.* 2011). However, proportionally less information is available in relation to eggs of other domestic or game birds (Tserveni-Goussi *et al.* 2011). Additionally, this information is specially limited for exotic avian species such as the partridge. Research on partridge eggs has mainly focused on describing egg production and quality of red-legged partridge (*Alectoris rufa*), a popular European bird, grey partridge (*Perdix perdix*) and rock partridge (*Alectoris graeca*) (Çetin 2002; Kirikçi *et al.* 2007; Cucco *et al.* 2012). Chilean tinamou is locally known as partridge and is the only tinamou species in Chile. While European partridges belong to the family Phasianidae, tinamou belongs to the family Tinamidae, which is closely related to the ratites group (Harshmann *et al.* 2008). There is no information on the nutritional composition and quality of eggs from the Chilean partridge or tinamou (*Nothoprocta perdicaria*). An interesting feature of these eggs is the pinkish color of their egg white, which could be due to a greater amounts of ovotransferrin (Varon *et al.* 2013), and consequently a higher concentration of Fe could be expected. This work aims to contribute more information on tinamou eggs by performing an exploratory and descriptive study of some of their nutritional and quality characteristics.

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MATERIALS AND METHODS

Samples

Whole eggs ($N = 40$), fresh egg white (500 mL) and yolk (500 mL) samples in triplicate were sourced from Tinamou Chile, and then stored at 4°C. Tinamou Chile is the only tinamou farm currently existing in Chile and is located in Los Ángeles, Bio Bio region. Birds from 1 to 5 years old are kept in this farm under free range conditions to better simulate their natural habitat and fed twice a day (in the morning and afternoon). Diets consisting mostly of milled corn, soybean bran, rape seed, vegetables (varieties of lettuce), legumes (*Trifolium repens*, *Trifolium* sp, *Medicago sativa*, *Lotus uliginosus*), rye-grass (*Lolium perenne*), weeds (*Plantago lanceolate*, *Vigna radiata*), and mineral salts (crude protein: 18–20% and metabolizable energy: 2900–3100 Kcal/kg). They also have ad libitum access to natural water troughs in which water is replaced daily.

Nutritional analysis

Chemical composition

Egg white and yolk were analyzed according to the Association of Official Analytical Chemists (AOAC 1996) for content of moisture (method 945.15), crude protein (Kjeldahl method 945.18, $N \times 6.25$), ether extract (method 945.16) and ash (method 920.153).

Mineral composition

Determination of Fe, Zn and Cu were done in samples of egg white and yolk according to the AOAC (1990). Micromineral concentrations were measured at specific wavelengths for each element (Fe: 248.3; Zn: 213.9; and Cu: 324.7 nm) using an atomic absorption spectrophotometer (GBC, 905AA, Victoria, Australia).

Determination of fatty acid composition

Lipids were saponified and derivatized to their methyl esters for fatty acid analysis in samples of dried yolk (AOCS 1990; Method Ce 1b-89). The fatty acid methyl esters were analyzed by gas chromatography–flame ionization detection (GC–FID) using a GC Agilent Technologies 6890N gas chromatograph, with a capillary column Omega wax 320 (30 m × 0.25 mm × 0.25 μm) (Supelco, Bellefonte, PA, USA) and FID detector. The temperature parameters were: injector 140-190-220°C–240°C and detector 270°C. The gas flows were as follows: N_2: 20 mL/min, H_2: 40 mL/min, synthetic gas (commercial mixture of N_2 and O_2) 250 mL/min. To identify each fatty acid methyl ester, available pure standards of saturated, monounsaturated and polyunsaturated fatty acids (Sigma Co., St. Louis, Mo, USA) were used. Each reported result was the average value of two analyses.

Determination of cholesterol content in yolk

Cholesterol was analyzed in dried yolk after saponification of the samples according to the 994.10 method (AOAC 1996) by GC–FID using a GC Agilent Technologies 6890N gas chromatograph, with a capillary column HP5-MS (30 m × 0.320 mm × 0.17 μm) (Hewlett Packard, Bellefonte, PA, USA) and FID detector. The temperature parameters were: injector 190°C–230°C–255°C and detector 300°C. The gas flows were as follows: N_2: 20 mL/min, H_2: 30 mL/min, synthetic gas (commercial mixture of N_2 and O_2) 280 mL/min.

Amino acids profile

The total amino acids were determined in samples after conventional hydrolysis, to release the constituent amino acids according to White *et al.* (1986). Sample preparation and chromatographic conditions were according to White *et al.* (1986). High-performance liquid chromatography (HPLC) method (HPLC Shimadzu, Kyoto, Japan); HPLC pump LC-20AD with diode-array detection (SPD-M20A detector; SIL-20A injector, Shimadzu Corporation, Kyoto, Japan) were used to identify and quantify the amino acids. Separation of the derivatives was attained using a RP-18 (250 × 4.6 mm, 5–3 μm particle size; Inertsil® ODS-3, Shimadzu Corporation, Kyoto, Japan).

An amino acid score was computed for the main limiting amino acids for humans, using Food and Agriculture Organization/World Health Organization (FAO/WHO) suggested requirement for children of 2–5 years and adults by the following equation:

$$\text{Amino acid score} = \frac{\text{AA test protein}}{\text{AA in reference pattern}}$$

where: AA is amino acid.

Eggshell morphology

Pieces of dried eggshell were observed with a Hitachi TM 3000 (Tokyo, Japan) scanning electron microscope with a Bruker Quantax 70 EDS System (New York, USA) for elemental analysis.

Egg quality analysis

Egg diameters were measured by a digital Vernier caliper. Shape index was calculated by dividing the short (equator) diameter by the long diameter. Shell thickness was measured by a digital micrometer (Mitutoyo, Kanagawa, Japan). Deformation and shell breaking strength was measured by an Instron testing machine (QC-SPA, TSS, England). White height was measured by a digital gauge (TSS Warwick, West Midlands, England). Haugh unit was calculated as described elsewhere (Haugh 1937). Shell color was measured by a colorimeter (QCR, TSS). Yolk and white color were measured by a Minolta colorimeter (CR-400 Chrome meter; Konica Minolta, Tokyo, Japan).

Statistical analyses

All samples were analyzed in triplicate and the results were expressed as mean ± standard deviation. All statistical analyses were performed using the Microsoft Excel 2013 software (Microsoft Corp., Redmond, WA, USA).

RESULTS AND DISCUSSION

Chemical and micromineral characterization

Tinamou eggs are characterized by their oval shape and bright uniform chocolate color (Fig. 1A). As expected, high crude protein contents (85% dry basis) and high lipid contents (52% dry basis) were found in egg white and egg yolk, respectively. Chemical analyses values (Table 1) were similar to those from eggs of other avian species (Song *et al.* 2000; Di Meo *et al.* 2003; Krawczyk 2009; Tserveni-Goussi *et al.* 2011; Van Immerseel *et al.* 2011).

Published data of trace elements content in eggs of various avian species are very limited. Micromineral analysis showed a similar Fe, Cu and Zn content of tinamou egg yolk (Table 1) compared with hen egg (Kiliç *et al.* 2002). Iron contents in egg whites were higher in tinamou eggs (Table 1) than in hen eggs (0.10–0.24 mg/100 g) (Kiliç *et al.* 2002; Bess *et al.* 2012) and rhea eggs (0 mg/g dry matter) (Navarro *et al.* 2003). An interesting characteristic of the fresh tinamou egg white is its distinctive pinkish color (Fig. 1B). Alderton *et al.* (1946) described that ovotransferrin is pinkish when Fe is saturated. Varon *et al.* (2013) reported that tinamou egg white contained 20% more ovotransferrin than hen egg,

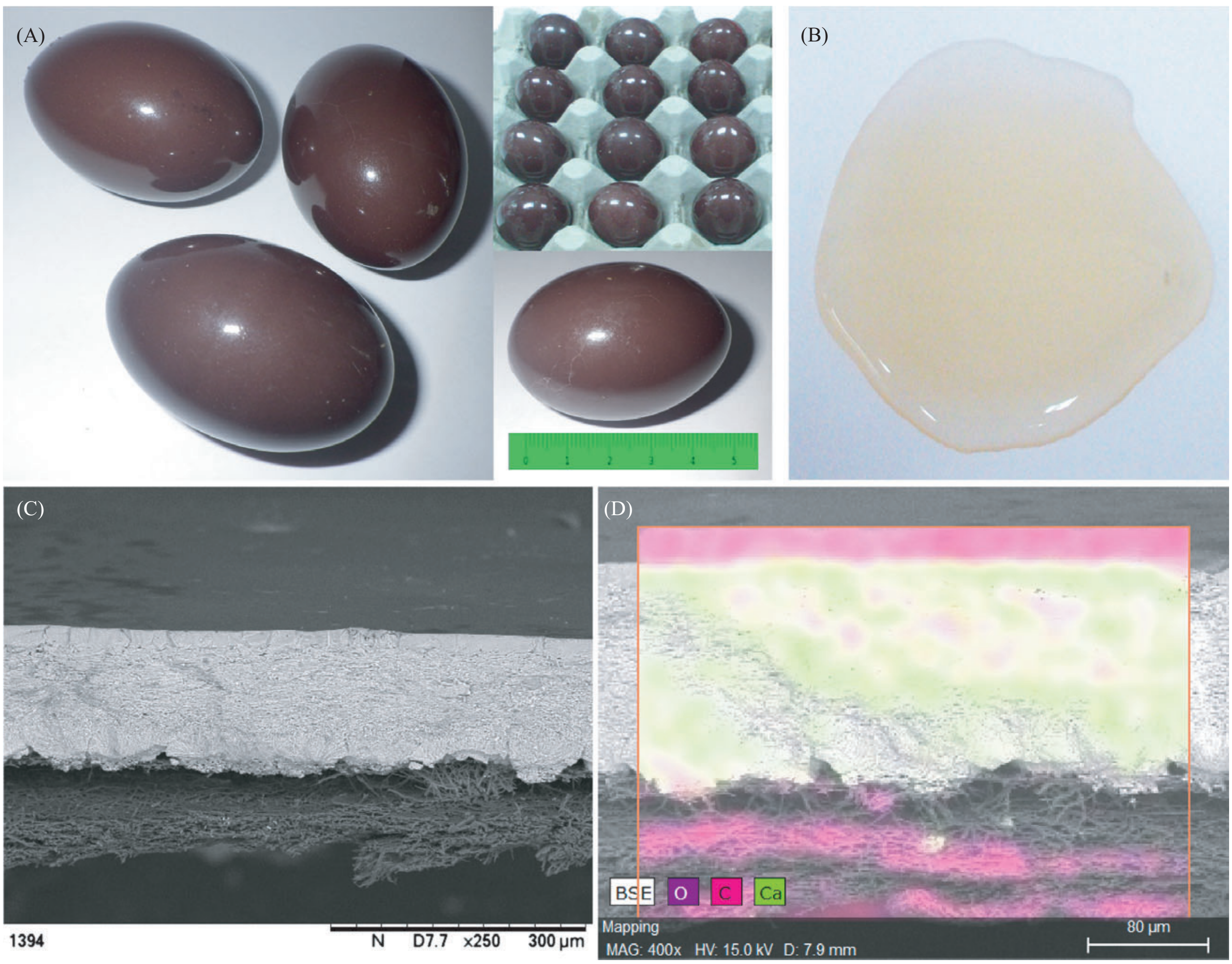

Figure 1 (A) Digital photographs of tinamou eggs. (B) Digital photographs of tinamou egg white. (C) Scanning electron microscopy (SEM) images of tinamou eggshell. (D) Energy dispersive X-ray spectroscopy (EDS) mapping of tinamou eggshell (O: oxygen, C: carbon, Ca: calcium).

Table 1 Chemical and mineral composition of tinamou egg (mean ± SD)

Components	Egg white	Egg yolk
Moisture (%)	87.7 ± 0.3	57.2 ± 0.5
Crude protein (%)	10.5 ± 0.4	15.3 ± 0.9
Ether extract (%)	0.0 ± 0.0	22.4 ± 0.3
Crude fiber (%)	0.0 ± 0.0	0.0 ± 0.0
Nitrogen-free extract (%)	1.2 ± 0.0	3.7 ± 0.1
Ash (%)	0.7 ± 0.1	1.6 ± 0.1
Fe (mg/100 g)	0.47 ± 0.07	1.43 ± 0.10
Cu (mg/100 g)	0.16 ± 0.03	0.76 ± 0.07
Zn (mg/100 g)	0.21 ± 0.18	3.22 ± 0.18

which presented a greater antimicrobial activity that native hen ovotransferrin. Even more, these authors suggested that tinamou ovotransferrin may represent a natural antimicrobial agent suitable for use in food matrices or on food preparation surfaces.

The Cu and Zn contents of tinamou egg white (Table 1) also were greater to values reported for hen egg (Kiliç *et al.* 2002), but lower than rhea egg (Navarro *et al.* 2003).

Fatty acid and cholesterol content

In tinamou egg yolk, nine fatty acids were identified as the most representative (Table 2). Fatty acid percentages in egg yolk decreased in the order of monounsaturated (MUFA) > saturated (SFA) > polyunsaturated (PUFA). A similar sequence has been reported for eggs of other avian species (Milinsk *et al.* 2003; Navarro *et al.* 2003; Cherian 2011; Sinanoglou *et al.* 2011; Golzar Adabi *et al.* 2013; Polat *et al.* 2013). The major fatty acids in tinamou egg were: oleic, linoleic and palmitic (Table 2). The published information on the fatty acid profile of partridge egg is limited. Polat *et al.* (2013) reported for partridge egg yolk mainly the following fatty acids: oleic (38.8%), palmitic (23.8%) and linoleic (22.4%), similar to the proportion of fatty acids reported here for tinamou egg yolk.

As has been reported in other avian egg yolks (Navarro *et al.* 2003; Cherian 2011; Tserveni-Goussi *et al.* 2011; Golzar Adabi *et al.* 2013; Polat *et al.* 2013), oleic acid was the major fatty acid in tinamou. Palmitoleic acid was found in lower concentrations than hen eggs (3–4%) (Cherian 2011; Simčič *et al.* 2011) and other avian eggs (2.62–6.54%) (Polat *et al.* 2013). Other minor MUFA are present in trace amounts as heptadecanoic (0.08%) and eicosanoic (0.20%) acids in tinamou egg.

Palmitic and stearic acids were prevalent SFAs (Table 2). This is consistent with results from Polat *et al.* (2013) who reported that the main SFA for eggs of nine bird species (including European partridge) was palmitic acid (21.1–26.3%), followed by stearic acid (4.2–8.1%).

Table 2 Fatty acid profile of tinamou egg yolk (mean ± SD)

Fatty acid	Composition (%)
Myristic (14:0)	0.32 ± 0.01
Palmitic (16:0)	20.34 ± 0.17
Stearic (18:0)	10.55 ± 0.21
Saturated fatty acid	**31.21 ± 0.19**
Palmitoleic (16:1)	1.17 ± 0.04
Oleic (18:1, *n* = 9)	39.01 ± 0.56
Monounsaturated fatty acid	**40.18 ± 0.29**
Linoleic (18:2, *n* = 6)	23.43 ± 0.09
α-Linolenic (18:3, *n* = 3)	1.60 ± 0.11
Arachidonic (20:4, *n* = 6)	2.07 ± 0.04
Docosahexaenoic acid (22:6, *n* = 3)	0.96 ± 0.04
Polyunsaturated fatty acid	**28.06 ± 0.20**

Unsurprisingly, linoleic acid was the prevalent PUFA (Table 2). This was expected as it is the major omega-6 fatty acid in eggs (Cherian 2011; Polat *et al.* 2013). Nonetheless, the high content level of linoleic acid (Table 2) was an interesting feature, and it resembled values that have been reported for eggs of European partridges (Polat *et al.* 2013), meanwhile it almost doubled those reported for eggs of ostrich, turkey, quail, duck and goose (Sinanoglou *et al.* 2011; Golzar Adabi *et al.* 2013). Fatty acids composition, especially omega-6 and 3 fatty acids is strongly dependent on bird diet (Van Immerseel *et al.* 2011). The tinamou is a bird in which the diet is based on various types of seeds that have a high content of linoleic acid. We do not know if these reported differences could be related to the rearing system.

Docosahexaenoic acid and α-linolenic acid were the main omega-3 fatty acids found in tinamou egg yolk. Both were within the concentration range that has been reported for hen eggs (Cherian 2011; Van Immerseel *et al.* 2011), but higher than for ostrich, quail and duck eggs (Sinanoglou *et al.* 2011). We did not detect eicosapentaenoic (20:5, *n* = 3) in this study.

The SFA/PUFA ratio was 1.12 and falls within the range of 0.97–2.51 that has been reported for hen and goose eggs, respectively (Polat *et al.* 2013). Such a low ratio value is indicative of a healthy egg, considering that tinamou eggs show higher PUFA concentration levels than eggs from other species.

Tinamou eggs showed higher cholesterol contents (21.16 ± 0.14 mg/g of egg yolk) than the range of 11 to 14 mg/g of egg yolk that has been reported for hen eggs (Cherian 2011). However, this value is within the range that Bair and Marion (1978) reported for several different avian species (12.77–21.99 mg of cholesterol/g of yolk). Comparing an even base of 100 g of eggs, it has been established that while hen eggs provide 420 mg of cholesterol (Van Immerseel *et al.* 2011), tinamou eggs provide 589 mg of cholesterol.

Amino acids composition

Egg proteins are regarded among the best sources of protein for humans because of their high digestibility (>90%) essential amino acid content. Whole egg protein is considered to be 100 and is used as a standard for measuring nutritional quality of other food proteins (Cherian 2011).

The amino acid composition of tinamou egg white is presented in Table 3; FAO/WHO suggested requirements (Friedman & Brandon 2001), and recommended daily intake (RDI) for an adult man (70 kg) were included for comparison. As expected tinamou egg white has high levels of essential and non-essential amino acids, with exception of histidine the value of which was lower than expected as compared with hen egg (Thapon & Bourgeois 1994). Tinamou egg white has high levels of lysine, sulfur-containing amino acids, threonine and valine with respect to the RDI (Table 3), therefore it is perfectly recommended for human intake.

According to the suggested FAO/WHO requirements for 2–5-year-old infants, tinamou egg white has high levels of lysine, sulfur-containing amino acids and valine, and similar isoleucine, leucine, aromatic amino acids and threonine concentrations. All the essential amino acids, with the exception of histidine, cover the requirements for adults (Table 3). Only histidine is a limiting amino acid for 2–5-year-old infants or adults.

Table 3 Amino acids composition of tinamou egg white (mean ± SD), and comparison of essential amino acids with recommended daily intake (RDI) for an adult man (70 kg), and Food and Agriculture Organization/World Health Organization (FAO/WHO) suggested requirements according 2–5-year-olds and adults

Amino acids	Egg white (mg/g)	RDI (mg/day)	% RDI covered by 2 whole egg	FAO/WHO (mg/g protein)	
				2-5 years	>18 years
Histidine	5.4 ± 0.2	840	13	19	16
Isoleucine	35.9 ± 0.8	1400	54	28	13
Leucine	68.1 ± 0.6	2400	60	66	19
Lysine	87.2 ± 0.7	2450	75	58	16
Methionine and cystine	48.3 ± 3.6	1400	73	25	17
Phenylalanine and tyrosine	66.1 ± 12.4	2240	62	63	19
Threonine	41.4 ± 1.5	1120	78	34	9
Valine	48.4 ± 0.6	1340	76	35	13
Alanine	32.2 ± 0.8				
Arginine	12.2 ± 0.7				
Aspartic acid	108.8 ± 1.5				
Glycine	31.8 ± 0.8				
Glutamic acid	127.8 ± 6.9				
Proline	31.7 ± 1.4				
Serine	55.2 ± 0.7				

Table 4 Quality characteristics of tinamou egg compared with hen egg

Characteristics	Tinamou egg (mean ± SD)	Hen egg† (mean)
Long diameter (mm)	49.5 ± 2.2	53–59
Short diameter (mm)	35.5 ± 1.5	42–47
Shape index	71.8 ± 5.1	78 average; 65 (long eggs), 82 (rounded eggs)
Egg weight, g	34.7 ± 1.4	49 to ≥70
Shell thickness, mm	0.36 ± 0.07	0.38
Deformation, mm	0.43 ± 0.15	0.35–0.41
Shell breaking strength, g	1,330 ± 226	2000 (large eggs)–3500 (small eggs)
Albumen height, mm	3.6 ± 0.7	4 (low quality eggs)–6.6 (fresh eggs)
Haugh unit	47 ± 10	80–90 (fresh eggs) ≤60 (low quality eggs)
Shell color (%)	10.0 ± 1.5	28 (early lay)–32 (very late lay) in coloured eggs 75 (white eggs)
Yolk color (Yyx)	Y: 128.0 ± 17.9, y: 0.40 ± 0.02, x: 0.38 ± 0.02	Y: 64, y: 0.42, x: 0.40 (pale yolk) Y: 32, y: 0.42, x: 0.55 (red yolk)
Albumen color (Yyx)	Y: 55.1 ± 2.8, y: 0.33 ± 0.00, x: 0.33 ± 0.00	Y: 48.73 ± 4.09, y: 0.32 ± 0.00, x: 0.32 ± 0.00

†Data obtained from Arias Laboratory, and Vuilleumier (1969); Thapon and Bourgeois (1994); Roberts *et al.* (2013).

Eggshell structure

As other bird eggshells, tinamou eggshell consists of inner and outer fibrillar eggshell membranes (Fig. 1C), a calcified (calcium carbonate) palisade growing from mammillary bodies and an outer colored cuticle (Fig. 1D). Although thinner than hen eggshell, tinamou eggshell show similar structure and low crystalline orientation of the palisade layer that is consistent with a higher strength as compared with other wild bird eggshells (Nys *et al.* 1999; Fraser & Cusack 2002; Zhang *et al.* 2005; Rodriguez-Navarro 2007).

Eggshell quality properties

A comparison of partridge and hen egg physical features is shown in Table 4. Tinamou egg is small and lighter but more elongated than the hen egg. The eggshell is thinner and experiences more deformation but less breaking strength than the hen eggshell. Haugh unit was invented for describing the decrease of albumen height as a function of egg weight occurring during the time of storage of hen eggs. Applied to the tinamou egg, it shows only half of the Haugh unit showed by fresh hen eggs. Tinamou yolk color was paler than a pale hen egg yolk but brighter. The tinamou egg albumen was pinkish (Fig. 1B) compared with the transparent yellowish albumen of the hen egg.

Conclusions

Results indicate that tinamou eggs have a chemical composition similar to eggs from hens and other avian species. These eggs are quite beneficial for human consumption, due to their high concentration of micro minerals (Fe, Cu and Zn), high content of MUFA and PUFA (which represent 62% of total fatty acids composition), and an optimal amino acids profile that meets the requirements of adults and infants (with the exception of histidine). Although the cholesterol content was higher than what has been reported for hen eggs per 100 g (589 vs. 420 mg), this value fell within the range described for other avian species.

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