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Physicochemical and morphometric characterization of eggs from emus *(Dromaius novaehollandiae)*

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Abstract

There is a dearth of scientific information about the physicochemical characteristics of eggs from ratite birds including emus. Thus, an experiment was carried out with 19 laying emu ((*Dromaius novaehollandiae)* hens, maintained in cages, and divided into two groups according to age, to record morphometric and physicochemical characteristics of the eggs. The width, length, average weight, form index, Haugh unit, yolk index, percentage of egg components, yolk pigmentation, pH of yolk and albumen, and eggshell weight and thickness were recorded. This morphometric characterization was influenced by the age of the hen. Neither the yolk nor albumen pH was influenced by the age of the bird. The eggs from emus that were raised in captivity presented physical and morphometric characteristics that varied with age, although they remained within the ranges of observations that were previously observed for ratite species, but were different from those of domestic chickens. The high fragility and easy rupture of the vitelline membrane in the emu eggs may limit the use of this product in industrial applications. Further studies of emu eggs are needed to improve their suitability for consumption and for the food industry.

Keywords: egg quality, Haugh unit, ratite eggs, ratites, yolk index
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Introduction

The ratite birds, such as ostrich, rhea and emu, with rudimentary wings and no keel on the sternum are of increasing interest in producing eggs for human consumption and in the industrial and pharmacy sectors (Cervi *et al*., 2016). Infertile ostrich eggs are already used by the food industry because of their similarity in flavour and physicochemical properties to those of laying hens (Astúrias & Garita, 2001; Aquino *et al*., 2008). Thus, knowledge of these characteristics of eggs from ratites may provide insights into their improvement (Mineki, 2003; Cervi *et al*., 2016).

Measures of egg quality are important to indicate their nutritive value. After three days of cold storage ostrich eggs reportedly had values of 110 Haugh units (HUs) (Pleti *et al*., 2009). Cervi *et al.* (2015) described emu eggs as having values of 75.2 HU after seven days of cold storage. These authors observed that the HU values for ostrich and emu eggs decreased as storage time increased.

The albumen in emu eggs contains a high proportion of water-soluble protein, whereas the yolk contains mostly lipids, fatty soluble vitamins and minerals. The percentage of albumen from emu eggs varies between 29% and 47% (Sales, 2007). Sales (2007) also observed that these eggs contained 41% yolk, which was similar to the values observed by Majewska *et al*. (2008) and Szczerbińska *et al*. (2003).

Physical characteristics of the eggshell may affect gas exchange and the internal chemistry of the eggs. Poor eggshells may interfere with incubation, hatching, and the usefulness of the egg in commercial products. Eggshell quality can be assessed by measuring weight and thickness. The ratio of eggshell weight to egg weight can also be useful. The average thickness of eggshells from ratites is variable, with estimates of 2.00 mm (Sales *et al*., 1996), 1.94 mm (Sahan *et al.*, 2003), and 2.20 mm (Di Meo *et al*., 2003). Gonzalez

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et al. (1999) scored the quality of ostrich eggshells as a function of their thickness, namely low (<1.7 mm), average (>1.7 and ≤1.9 mm) and high (>1.9 mm).

There is little scientific information about the physicochemical characteristics of emu eggs in the literature. Thus, structural data from chicken eggs were used to describe eggs from emus. This study was conducted to provide benchmarks to characterize the morphometry and physicochemical quality of emu *(Dromaius novaehollandiae)* eggs.

Material and Methods

The study was conducted at Darcy Ribeiro North Fluminense State University (UENF), located in Campos dos Goytacazes municipality, Rio de Janeiro, 21°45'23" S and 41°19'40" O, at an altitude of 14 m. This investigation was approved by the Ethics Committee on Animal Use of UENF (Protocol No 346, 2016).

The birds used in this study were of two age groups, approximately 2 years old and 7 years old (Table 1). Each group was housed in a paddock with covered and uncovered areas. The paddocks were equipped with 40 kg feeders and 100 L water troughs. The uncovered area had a vegetative cover of guinea grass *(Megathyrsus maximus)*. The paddocks were fenced with a 1.8 m high galvanized wire fence. One month before the eggs were collected, the birds were weighed individually.

Table 1 Description of the two groups of emus that produced eggs for morphometric evaluation

Group	Age, years	Gender distribution	Average weight, kg	
			Male	Female
1	2	6 males, 3 females	38.15 ± 3.36	36.40 ± 2.53
2	7	3 males, 3 females	34.80 ± 0.28	39.02 ± 2.58

Water and feed were provided ad libitum. The diet was formulated according to the nutritional requirements of emus (Scheideler & Sell, 1997) based on the nutritional values of feeds in Rostagno *et al*. (2011). The diet was manufactured at the Support Unit to Animal Science Research from the Animal Science Laboratory (LZO) of CCTA/UENF.

The eggs were collected daily and identified by group and date of collection. Immediately after collection, the eggs were transported to LZO/CCTA/UNEF to assess their morphometric and physiochemical characteristics.

The eggs were weighed on a digital balance with 0.01 g precision. After recording the morphometric traits, the eggs were broken on a glass bench for additional assessment. The eggs were sawn carefully around their equatorial circumference while trying to preserve the integrity of the eggshell membrane (Figure 1A). Then these membranes were broken carefully and the contents were deposited on a glass bench, taking care to avoid disruption of the internal structures (Figure 1).

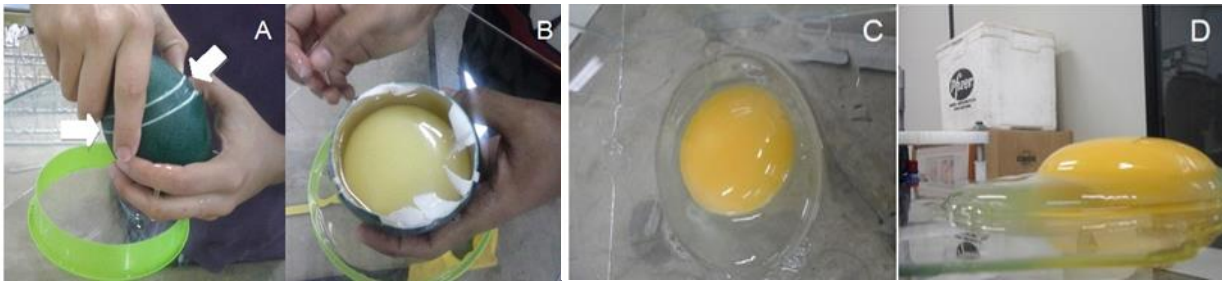

Figure 1 A: Emu egg cut open with a manual saw; B: Egg after breaking the eggshell membranes; C: Overhead view of egg on the glass bench; D: Profile view of egg on the glass bench

Sales *et al*. (1996) described the form index for emu eggs that was used in the present study. It was calculated as the length of shorter axis of the egg divided by the length of its longer axis. The measurements

were collected with a pachymeter of 0.01-mm precision. Values closer to 1 indicated more spherical eggs, whereas smaller values indicated eggs that are more elliptical.

Haught unit was determined as a function of egg weight (W, g) and the height (H, mm) of the dense albumen (Eisen *et al*., 1962).

$$HU = 100\log(H + 7.57 - 1.7W^{0.37}$$

The height of the albumen was measured at the insertion of the chalazas into the yolk with a tripod micrometer (Figure 2A).

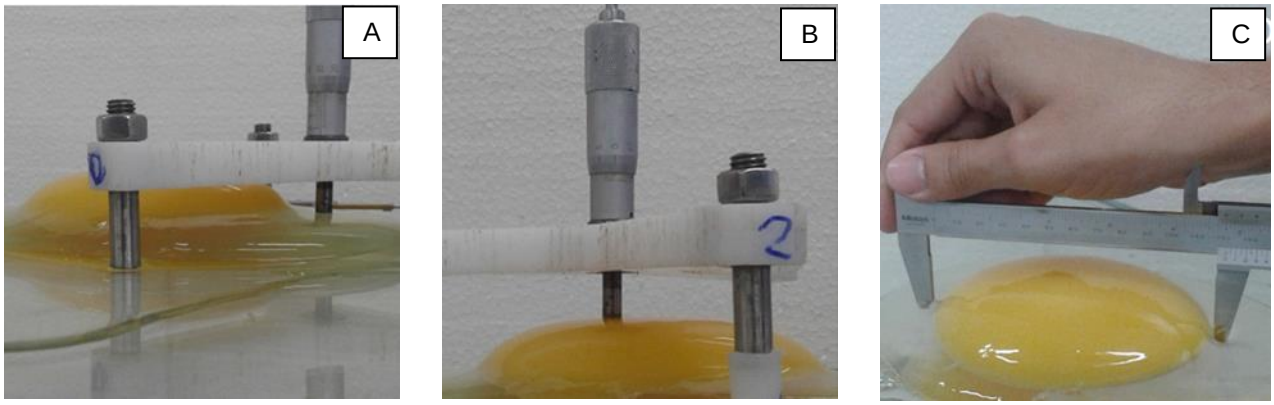

Figure 2 Measurements of A: albumen height, B: yolk height, and C: yolk diameter of emu egg

Yolk index was calculated as the ratio of its height to its diameter. After the yolk and albumen had been separated, yolk height (mm) was measured with a trivet micrometer (Figure 2B) and its diameter with a manual calliper (Figure 2C), using the chalaza insertions as reference points.

The percentages of egg components were assessed by separating the yolk from the white and weighing them on the digital balance. Eggshells were washed to remove residues of albumen and dried for 24 hours at room temperature to obtain the eggshell weight. Eggshell thickness was obtained as the average thickness of two fragments from the equatorial zone of the dried eggshell measured with a digital micrometer (Mitutoyo, Kawasaki, Kanagawa, Japan). Albumen weight was calculated as the difference between the egg weight and the sum of the yolk and eggshell weight. The percentages of the components were expressed relative to egg weight. Yolk pigmentation was evaluated from comparison with a colorimetric fan from Roche (Roche Holding AG, Basel, Switzerland).

Approximately 30 ml samples of yolk and albumen were collected in 50 ml tubes. The pH of these samples was measured with a bench digital pH meter from Watery Solutions Mpa-210 (MS Tecnopon, Piracicaba, Brazil).

The homogeneity of within-group variances was analysed with the F-test. When these variances were homogenous, differences between the groups were assessed with a non-paired t-test. When within-group variances were not homogeneous, a non-parametric test from Mann-Whitney was used at 5% probability of error to compare the means. Yolk pigmentation was analysed in a descriptive way.

Results and Discussion

The width and length of the eggs differed between groups, with the younger birds producing smaller eggs (Table 2). For comparison, Di Campos *et al.* (2005) observed eggs from caged emus in Goiás, Brazil, that were 176.8 mm long and 89.4 mm wide. Sales (2007) observed eggs from emus in cages at Occidental, Australia, that were 130 mm long and 90 mm wide.

Table 2 Morphometric characterization of eggs from groups of emus at ages two years and seven years

Group	N	Width, mm	Length, mm	Weight, g	Form index, %
1	4	83.1 ± 0.40	118.14 ± 0.64	517.28 ± 7.40	70.33 ± 0.21
2	5	85.9 ± 0.36	126.25 ± 0.42	587.93 ± 6.05	68.05 ± 0.32
P-value		<0.0001	<0.0001	<0.0001	<0.0001

Because of differences in length and width, the form index was influenced by the age of the emus, with greater values being observed for lighter eggs and those laid by younger birds. Similar results were observed by Senthilkumar *et al*. (2014), who studied eggs produced by females that were between three and nine years old. However, these results were greater than those found by Sales (2007). According to Altuntas and Sekeroglu (2008), the breaking strength of eggs from chickens depended largely on the form index, with greater strength indicated by higher values. Di Campo *et al.* (2005) reported lower values for rhea eggs than were observed in the present study.

Egg weight (Table 2) differed between the groups, with younger birds producing lighter eggs than the older ones. In the studies of Szczerbińska *et al.* (2003) and Dzialowski and Sotherland (2004) egg weights from emu hens were comparable with those produced by the older group in this study, namely 561.7 g and 586.78 g, respectively. Sales (2007) also observed similar emu egg weights to the present study (from 450 to 637 g). Senthilkumar *et al.* (2014) reported an average egg weight from emus of 488.98 g and observed an increase of 1.8 g (from 593 to 594.8 g) when comparing eggs produced by three-year-old hens with those of seven-year-old hens.

The weight of the eggshell was similar between the groups (Table 3). Christensen *et al.* (1996), who studied ostrich eggshells, observed an average weight of 245 g. Majewska *et al.* (2008) reported an egg weight of 57.4 g from emus at two years old. Similarly, Santos *et al.* (2007) that did not observe any difference in eggshell weight between younger and older chicken hens. In chickens, there was a constant deposition of calcium carbonate per unit of area of the egg, regardless of hen age. The amount of calcium that is mobilized to form the eggshell does not change with age (Ahmadi & Rahimi, 2011).

Despite the similarity in weight of eggs, the percentage of eggshell was influenced by the group. Younger birds produced eggs with relatively more shell. Majewska *et al.* (2008) observed that egg weight and percentage eggshell were not influenced by the age of emus they studied. Sales (2007) and Majewska *et al*. (2008) observed percentages of shell from emu eggs that were similar to those in the present study. In ostrich and rhea eggs, the observed percentages of eggshell were higher, namely 16.48% according to Christensen *et al.* (1996) and 16.6% according to Cervi *et al.* (2015).

Eggshell thickness was influenced by age. The older birds laid eggs with thinner shells. These emus laid larger eggs compared with the younger group, but there was no difference in the total weight of the eggshells. This also occurs in chicken eggs in which the volume of the egg increases, but the eggshell weight does not increase at the same rate (Ahmadi & Rahimi, 2011). Regardless of the age of the birds, the

Table 3 Physical characteristics of eggshells from emu eggs between two reproduction groups aged two and seven years

Group	N	EW, g	ET, mm	EP, %	ETA, cm^2	EV, cm^3
1	4	68.67 ± 0.87	1.156 ± 0.008	13.30 ± 0.12	302.28 ± 2.86	34.96 ± 0.38
2	5	69.07 ± 0.75	1.063 ± 0.008	11.72±0.09	329.87±2.17	35.08±0.35
P-value		0.7557	<0.0001	<0.0001	<0.0001	0.8082

EW: eggshell weight, ET: eggshell thickness, EP: eggshell percentage; ETA: eggshell total area, EV: egg volume

amount of mobilized calcium to form the eggshell was similar, resulting in lower deposition of calcium carbonate per unit of area (Ahmadi & Rahimi 2011). Majewska *et al.* (2008) did not observe any differences in eggshell thickness from emus at 5, 6, and 7 years old. These findings corroborated those of Senthilkumar *et al.* (2014) who studied the same females over seven years and did not observe differences among the eggshells. The thickness of shells for eggs from emus in the present study, namely 1.156 ± 0.008 and 1.063 ± 0.008, was less than the corresponding results for ostrich with average values of 0.85 mm (Di Campos *et al*., 2005), 1.95 mm (Pleti, 2009), 1.77 mm (Gamba *et al.*, 2012), and 2.13 mm (Szczerbińska *et al.*, 2003. The results of the present study were also lower than the observations of Cervi *et al.* (2015) (1.22 mm) for emu eggs.

Total eggshell area was influenced by the age of the emu hens, with the older birds producing lager eggs than younger hens (Table 3). The total eggshell area observed in this study was similar to the 337 cm^2 observed by Sales (2007). The volume of the egg was not influenced by the age of the emu hen. These results were similar to the findings of Sales (2007), which was 37.07 cm^3.

Age group did not influence the HU values of emu eggs (Table 4). However, HU values deteriorated with age (Lemos *et al*., 2014). Nevertheless, the HU may improve after a break in egg production, as the

forced moult is a rest period for the reproductive organs. In emus, this natural rest period is from eight to nine months. This interval may have influenced the maintenance of higher HU values in the present study. According to USDA (2009), when the HU of hen eggs exceeds 72, the egg quality is regarded as being excellent. The present results were similar to those of Cervi *et al.* (2015), who studied rhea eggs. However, the present results (Table 4) were lower than those of Pleti *et al.* (2009) for ostrich eggs.

Table 4 Physiochemical characteristics of emu eggs between groups of hens aged 2 and 7 years

Group	Haugh unit	Yolk index	Yolk weight, g	% Albumen	% Yolk	Yolk pigmentation	Yolk pH	Albumen pH
1	74.3 2 4.7	0.31 ± 0.01	197.6 ± 5.4	48.1 ± 0.4	38.5 ± 0.4	2.5 ± 0.1	6.57 ± 0.03	7.83 ± 0.05
2	85.3 ± 3.8	0.27 ± 0.04	251.0 ± 6.6	46.4 ± 0.9	41.9 ± 0.9	2.4 ± 0.1	8.06 ± 1.5	7.93 ± 0.05
P-value	0.0778	<0.0001	<0.0001	0.1541	0.0004	-	0.0885	0.1666

Lower weight yolks were observed in eggs laid by the younger birds. Santos (2007) observed an increase of 15.29% in the yolk weight in eggs produced by older broiler hens compared with younger birds. Dzialowski and Sotherland (2004) reported that three- to seven-year-old emu hens produced eggs with an average yolk weight of 237 g, which was heavier than in the present study (Table 2). The yolk weight in other ratite species varied from 179.5 to 330.9 g (Szczerbińska *et al*., 2003).

Greater values of yolk index were observed in the younger group of hens compared with their older counterparts. Results varying from 0.17 to 0.37 were found in the literature, from both caged emus and those produced under range-free systems (Sales, 2007; Szczerbińska *et al.,* 2003; Senthilkumar *et al*., 2014.; Al Obaidi & Shahrazad, 2015). Ordónez (2005) reported that a yolk index of laying hens below 0.25 indicated a fragile yolk. The values observed in the present study, namely 0.31 ± 0.01 and 0.27 ± 0.04, and particularly for the older emus, approached this benchmark. The yolks often broke during the characterization of the eggs, demonstrating their fragility.

The percentage of albumen was not influenced by group. These results were similar to those of Majewska *et al*., (2008), who did not find out differences in percentage of albumen in eggs that were laid by five-, six- and seven-year old birds. Conversely, the age of laying hens did influence the albumen, with older hens producing relatively less of this component (Ahmadi & Rahimi 2011). The results of this present study were similar to the findings of Sales (2007) which varied from 29% to 47%. Szczerbińska *et al*. (2003) found that emu eggs contained an average of 47.7% albumen. Majewska *et al.* (2008) observed 44.11% albumen in emu eggs. These results were greater than those of the present study. Compared with eggs and those of other species of ratites, the results from this study were lower than those described by Christensen *et al.* (1996), at about 53.9%, and by Szczerbińska *et al.* (2003) at about 58.8%. Cervi *et al.* (2015) observed a percentage of albumen of 51.6% in rhea eggs.

The percentage of yolk (Table 4) was influenced by the age of the birds. As hens become older, the percentage of yolk in their eggs rises (Padhi *et al.*, 2013). However, Majewska *et al*. (2008) did not find any differences in the percentage of yolk in eggs from mature emus. Numerically, the percentages of yolk observed in the present study (38.5 ± 0.4 1 for Group and 41.9 ± 0.9 for Group 2) (Table 4) corroborated the findings of Szczerbińska *et al.* (2003) (38.1%), Sales (2007) (41%) and Majewska *et al.* (2008) (41.94%). However, these results were greater than those observed in other species of ratites, including ostrich (Christensen *et al.*, 1996) and rhea (Szczerbińska *et al.*, 2003). Takeuchi and Nagashima (2010) described the yolk to albumen ratio from emu eggs as 1 : 1, whereas Christensen *et al.* (1996) observed a ratio of 2 : 1 for ostrich eggs. Mathematically, the percentage of yolk must increase with a decrease in the amount of albumen and vice versa (Padhi *et al.*, 2013). Therefore, these results might explain the fragility of the yolk.

Yolk pigmentation (Table 4) was not influenced by the age of the group. Majewska *et al.* (2008) did not observe differences in the yolk colour of eggs produced by emus at five, six, and seven years old. Eggs produced by birds in paddock systems may present more pigmented yolks, because of access to green forage and other vegetable materials that are rich in carotenoids (Rizzi & Marangon, 2012). Majewska *et al.* (2008) observed low values (4.81) of yolk pigmentation intensity (on the Roche scale) when emus were produced that received diets composed of barley, corn, oats, and soy and wheat bran without access to grazing. However, these values were higher than those found in the present study. Although the emus had been fed a diet that contained corn and had free access to pasture, they produced yolks extremely pale.

Age did not influence the pH values of yolk and albumen of emu eggs (Table 4). The yolk pH was more alkaline than reported in yolks produced by rheas, ostrich, and laying hens, which ranged between 6.34 (Cervi *et al*., 2015), 6.20 (Aquino *et al*., 2008), and 6.00 (Saccomani *et al*., 2019), respectively. Moreover, the albumen pH was more acidic than that reported in eggs produced by rheas and ostriches, which ranged between 8.56 (Cervi *et al*., 2015) and 8.05 (Aquino *et al*., 2008), and 8.2 to 9.0 for chicken eggs (Saccomani *et al*., 2019).

Conclusions

Eggs from emus that were raised in captivity presented physical and morphometric characteristics that varied with age, but remained within the norms for ratite species, and distinguished these species from domestic chickens. The high fragility and easy rupture of the vitelline membrane observed in emu eggs may limit the use of this product in certain industrial applications. Further studies with emu eggs are needed to improve their suitability for consumption and for the food industry.

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Authors’ Contributions

JCPQ, KAAT-C, YRM, SSR were responsible for animal management, data collection and laboratory analyses. JCPQ, KAAT-C, TLR, JEM and LFLC were responsible for statistical analysis and writing the scientific paper. All authors revised the manuscript critically and approved of the final version.

Conflict of Interest Declaration

The authors declare that there was no conflict of interest.

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