Serum biochemical profile of emus (*Dromaius novaehollandiae*) reared in captivity

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**ABSTRACT**

The emu, also known as Australian ostrich (*Dromaius novaehollandiae*), is a bird species native to the Australian plains. It is considered the largest bird in Oceania, and the second largest in the world. The correct interpretation of the serological analyses is essential in the development and implementation of sanitary control measures for emus bred and reared in captivity. This study calculates a reference interval for the biochemical profile of alanine aminotransferase, aspartate aminotransferase (AST), alkaline phosphatase, urea, creatinine, uric acid, glucose, total proteins and cholesterol in captive emus during pre-hatching and hatching stages, and compares the biochemical parameters of sera of males and females. Increased AST and cholesterol levels were observed in animals that initiated the hatching period. The values of the other parameters decreased. After hatching, all parameters exhibited a trend towards normal values. The results may be useful in the development of new breeding practices for the species, and enlarge the data available for emus.

**1. Introduction**

The emu, also known as Australian ostrich (*Dromaius novaehollandiae*), is the largest bird in Oceania, and the second largest bird in the world, after the ostrich. The emus belong to the ratite group of birds, like the ostrich and the rhea (Tully and Shane 1996a).

Today, breeding emus is a million-dollar business sector in the USA and in Australia, and is consistently spreading around the world. The abdominal fat of these animals is extracted and processed to produce an oil with therapeutic applications. Native inhabitants of Australia were using emu fat for pain and processed to produce an oil with therapeutic applications. The abdominal fat of these animals is extracted and processed to produce an oil with therapeutic applications. Native inhabitants of Australia were using emu fat for pain control long before the arrival of the British ships on the east coast of the country (Yoganathan et al. 2003; Qiu et al. 2005; Howarth et al. 2008; Lindsay et al. 2010; Abimosleh et al. 2012). The fat is also known for its cosmetic value (Zemstov et al. 1996). In addition, the meat and eggs of these animals are considered usable by-products (Tully and Shane 1996b).

Reference values for biochemical standards are a source of important biological data in ecological and behavioural studies, since they enable the diagnosis of clinical conditions and allow assessing nutritional status (Ferrer 1990). These blood standards have specific values for sex, age and species. Another advantage is that they reflect diet and management practices, which explains why they are essential in the evaluation of clinical and nutritional disorders that affect birds (Thrall et al. 2004; Blue-McLendon and Green 2010). In the veterinary medicine of birds, the development and adoption of best practices depend on the existence of reference values that consider the differences associated with geographic location and the variety of management techniques currently employed worldwide (Mushi et al. 1999; Schmidt et al. 2007).

According to Menon et al. (2013), little information has been published on haematological and biochemical standards of adult emus, especially for animals in the mating and hatching periods. The importance in the analysis of these standards lies in the fact that the clinical signs of the diseases affecting savanna birds and ratites are rather subtle and confusing (Black and Glatz 2011).

In this scenario, the accurate diagnoses of such diseases require the establishment of reference values for blood standards and the correct interpretation thereof considering factors like age, sex, body condition and stress levels to which the animal has been submitted (Fudge 2003). Blood profiles are used to detect subclinical as well as clinical diseases, changes in metabolism and inappropriate nutritional and management practices.

In the effort to increase the body of knowledge about breeding emus in captivity, this study describes the biochemical profile of alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), urea, creatinine, uric acid, glucose, total proteins and cholesterol in captive *D. novaehollandiae* during pre-hatching and hatching stages.

**2. Material and methods**

**2.1. Animals**

Fifteen emus (*D. novaehollandiae*), of which nine were females and six were males, were used in this study. All animals were...
kept in the scientific ratite nursery of the Universidade Estadual do Norte Fluminense Darcy Ribeiro (UENF), in Campos dos Goytacazes, state of Rio de Janeiro, Brazil. General health status and conditions of head, eyes, nostrils, beak, neck, legs, body and wings were examined in all individuals. Alertness, mobility and anomalies in walking were evaluated. Gender was established by palpation (Samour et al. 1984).

Analyses were carried out at three periods: pre-hatching (all animals), hatching (three males) and post-hatching (the three males that completed the hatching period). Blood samples were collected from animals after they were carefully immobilized following standard procedures, with attention to prevent stress by covering the heads of emus with a fabric hood.

### 2.2. Blood samples

An area around the jugular vein was shaved and sterilized with alcohol 70%. Blood was collected from the jugular vein using a sterilized disposable 25-ml syringe and needle and transferred to silicon-coated tubes containing separating gel, in order to obtain the serum. The material was labelled and sent to the Clinical Pathology Sector, UENF.

For animals during the hatching period, blood collection was repeated 20 days after. For animals analysed in the post-hatching period, collection was carried out 55 days after the beginning of hatching (1 day after the male left the nest).

### 2.3. Preparation of samples and serum biochemistry

Whole blood samples were centrifuged at $1.26 \times 10^4$g for 5 min. The serum obtained was frozen at $-20°C$ for subsequent use in quantitative analyses. Biochemical analyses were carried out in a semiautomatic spectrophotometer (Biosystems®/BTS 310) and specific reagent kits (Lallest®).

The parameters analysed were ALT, AST, ALP, urea, creatinine, uric acid, glucose, total proteins and cholesterol.

### 2.4. Statistical analysis

The statistical model used was: $Y_{ijk} = \mu + a_i + (i\alpha) + \tau_k + e_{ijk}$ where $Y_{ijk}$ is the value of a serum parameter recorded on the $k$th day, for the $j$th animal, of the $i$th sex. The model was adjusted using the maximum likelihood method, according to Littell et al. (2006). The $F$-test was used to analyse the effects of sex ($a_i$) and days ($\tau_k$). Least square means were calculated for both effects, as well as confidence intervals at 95%.

### 3. Results and discussion

General examination revealed that all animals were in good health condition, with no detectable problems upon visual inspection.

The means and standard deviations of parameters analysed at three different periods (Tables 1–3) were compared, and the relationship between the results obtained and some specific roles of the parameters analysed was determined.

In birds, normal AST values are below 275 IU/L (Thrall et al. 2004). The results obtained reveal that AST values in the birds examined in the present study were below the mean reported in the literature for emus (Fudge 2003; Kumar et al. 2009; Menon et al. 2013). Menon et al. (2013) investigated emus in Canada, and observed a mean AST value of 179 IU/L in healthy animals. As a rule, values of up to 350 IU/L are considered moderately increased. AST values above 800 IU/L, side by side with biliverdinuria or biliverdine indicate high risk of severe damage to liver cells (Thrall et al. 2004; Capitelli and Crosta 2013). Other causes of high values in the activity of aminotransferase include deficiencies in vitamin E, selenium or methionine, apart from intoxication by pesticides or carbon tetrachloride, and muscle damage (Hochleithner 1994).

Also, the values of all the other parameters in birds in the post-hatching period were observed to return to normal (pre-hatching values). Mean AST level in pre-hatching was 124.8 IU/L, which increased to 348.6 IU/L and fell to 271.53 IU/L during hatching and in the post-hatching period, respectively, showing the significant difference in AST values between the three periods ($p < .001$), as shown in Figure 1(a). Changes in AST values (associated with muscles and liver function) may be used as indicators of possible liver damage (Hochleithner 1994).

During the hatching period, a reduction in essentially all parameters was observed. It should be stressed that animals at this stage remain in a hypobiosis state, that is, metabolism is held at very low levels. These data may explain the low values of the parameters analysed during the hatching period. Cholesterol was the only parameter whose serum levels did not vary significantly during the experiment.

Concerning cholesterol levels, in pre-hatching emus, the mean cholesterol concentration was 95 mg/dL, increasing to 140 mg/dL during the hatching period and falling to 112.4 mg/dL in post-hatching (Figure 1(b)). Curiously, cholesterol levels in serum for emus during the hatching period remained significantly constant throughout the three periods considered ($p = .2857$). This result was not expected, since emus remain sitting virtually still on eggs, feeding very sporadically. These results indicate the possibility that cholesterol reserves are released in the blood circulation at this stage. Hypercholesterolemia may be caused by high-calorie diets or liver failure (Kaneko et al. 2008). Since cholesterol is cleared as biliary acids, increased levels in serum may be linked with extrahepatic biliary tract obstruction, liver fibrosis and biliary tract hyperplasia in birds (Campbell 2004). Serum cholesterol levels for most bird species range from 100 to 250 mg/dL (Lumeij 2008). Mean cholesterol levels in serum before the hatching period in this study were slightly lower than the known values for birds fasting for 12 h, that is, 100 to 250 mg/dL (Lumeij 2008).

The data obtained show that the hypobiosis period emus go through during hatching of eggs may affect internal mechanisms, causing liver cell changes (AST and cholesterol levels). Significantly higher AST levels indicate severe and diffuse hepatic lesion, apart from muscle dysfunctions, since AST is not hepatospecific (Kaneko et al. 2008).

In most species, variations in ALT activity are between 19 and 50 IU/L (Campbell 2004; Lumeij 2008). The results obtained for emus before and after hatching (40.6 and 31.37 IU/L, respectively) are in the normal interval described in the literature.
Table 1. Serum biochemical analyses of emus (D. novaehollandiae) in the pre-hatching period.

| Animal | Gender | AST (UI/L) | ALT (UI/L) | ALP (UI/L) | Urea (mg/dL) | Creatinine (mg/dL) | Glucose (mg/dL) | Cholesterol (mg/dL) | Total protein (g/dL) | Uric acid (mg/dL) |
|--------|--------|------------|------------|------------|--------------|-------------------|----------------|--------------------|---------------------|------------------|
| 1      | M      | 116.9      | 46.9       | 73.8       | 10.88        | 0.181             | 160            | 93                 | 4.80                | 5.3              |
| 2      | M      | 124.6      | 34.3       | 104.4      | 12.48        | 0.171             | 184            | 111                | 5.95                | 11.4             |
| 3      | M      | 116.9      | 45.4       | 118.8      | 12.4         | 0.251             | 174            | 144                | 5.78                | 18.7             |
| 4      | M      | 154.0      | 48.0       | 104.4      | 12.88        | 0.217             | 161            | 91                 | 4.94                | 9.3              |
| 5      | F      | 226.8      | 31.1       | 104.4      | 10.56        | 0.240             | 177            | 73                 | 3.77                | 17.3             |
| 6      | F      | 124.6      | 32.4       | 118.8      | 6.0          | 0.208             | 164            | 98                 | 4.41                | 11.4             |
| 7      | F      | 116.9      | 45.4       | 147.6      | 4.66         | 0.208             | 183            | 85                 | 3.60                | 12.2             |
| 8      | M      | 116.9      | 54.4       | 133.2      | 6.54         | 0.148             | 149            | 95                 | 4.37                | 11.9             |
| 9      | F      | 95.2       | 34.0       | 88.2       | 8.48         | 0.262             | 153            | 99                 | 5.04                | 15.4             |
| 10     | F      | 110.7      | 33.3       | 104.4      | 9.44         | 0.238             | 156            | 108                | 4.56                | 11.1             |
| 11     | M      | 181.9      | 44.8       | 118.8      | 9.76         | 0.215             | 173            | 86                 | 4.89                | 9.9              |
| 12     | M      | 142.5      | 32.8       | 88.2       | 10.96        | 0.232             | 122            | 94                 | 5.85                | 19.0             |
| 13     | F      | 110.7      | 34.3       | 104.4      | 9.36         | 0.251             | 148            | 64                 | 4.58                | 12.9             |
| 14     | F      | 134.9      | 42.3       | 104.4      | 9.52         | 0.233             | 179            | 69                 | 4.39                | 12.9             |
| 15     | F      | 139.3      | 49.7       | 104.4      | 8.4          | 0.293             | 166            | 115                | 5.56                | 19.5             |
| Mean   |        | 124.8      | 40.6       | 107.8      | 9.48         | 0.237             | 163            | 95                 | 4.83                | 13.2             |
| SD     | ±33.1  | ±7.7       | ±18.1      | ±2.4       | ±0.04       | ±16.4             | ±19.9          | ±0.7               | ±4.0                |                 |

Note: M: Male; F: Female; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; ALP: Alkaline phosphatase.

In turn, animals during the hatching period revealed a decrease in ALT activity, to the mean values of 10.1 IU/L. Normal ALT levels are observed in birds diagnosed with severe liver lesion, which reflects the fact that the activity of the enzyme in the hepatic tissue of some species is actually rather low. On the other hand, in prey birds, ALT seems to be a reliable indicator of liver damage, though it is not more advantageous than AST in that matter (Thrall et al. 2004). Due to the low specificity as a marker of liver lesion, the determination of AST is often left out in the biochemical evaluation of most birds (Harr 2002, 2005).

Mean ALT values were 40.6, 10.1 and 31.37 IU/L in before, during and after hatching, respectively (p = .002), with significant differences between periods (Figure 1(c)). ALT values have limited usefulness as a parameter to evaluate liver cell dysfunctions in birds. The enzyme is found in the cytosol of hepatocytes, of liver cells and other tissues in birds. ALT activity in most bird species varies between 19 and 50 IU/L (Campbell 2004).

The literature describes high levels of ALT in wild turkey females (Schmidt et al. 2007) during the reproduction period. There is little information published on these variables during pre-mating. ALT is omnipresent, and is not specific to any organ function in bird species and, therefore, is not recommended as a tool to diagnose diseases (Krautwald-Junghanns 2004). ALT, ALP, urea, creatinine, glucose, total protein and uric acid levels increased between pre-hatching and the hatching period, and fell again in post-hatching.

ALT has been associated with the metabolism of calcium and of phosphor, and its action mechanism has been implicated in the regulation of the growth process of birds, with roles in chondrogenic and osteoblastic activities (Rajman et al. 2006), with high activity levels in osteoblasts (Alonso-Alvarez 2005). The literature on domestic birds like lovebirds, canaries, cockatiels, parrots and macaws describes the normal value of ALP as varying between 8 and 108 IU/L (Fudge 2003). In the present study, the value of 107.8 IU/L obtained for emus is inside this interval. ALP mean values before, during and after hatching were 107.8, 33.5 and 56.6 IU/L, respectively, with significant differences between the periods considered (p < .0001), as observed in Figure 1(d). Higher ALP levels seem to be specific to increased osteoblast activity and bone changes associated with growth, trauma, restoration, osteomyelitis, neoplasia, secondary nutritional hyperparathyroidism and formation of the eggshell (Rajman et al. 2006), which is not valid in the present study. ALP activity reduction was not reported.

Normal urea values in non-carnivorous birds are lower than 5 mg/dL, while in carnivorous birds they are higher, around 10 mg/dL (Thrall et al. 2004; Capitelli and Crosta 2013). Here, the values obtained were higher than those reported in the literature for non-carnivorous birds, and lower than those reported for emus by other authors. However, these studies did not consider the effect of the reproduction period in their analyses (Okotie-Eboh et al. 1992; Costa et al. 1993; Andreasen et al. 1997; Fudge 2003; Kumar et al. 2009; Menon et al. 2013).

Mean urea values (9.48 mg/dL before, 3.67 mg/dL during and 10.79 mg/dL post-hatching, p = .0117) and uric acid

Table 2. Serum biochemical analyses of emus (D. novaehollandiae) during the hatching period.

| Animal (Males) | AST (UI/L) | ALT (UI/L) | FA (UI/L) | Urea (mg/dL) | Creatinine (mg/dL) | Glucose (mg/dL) | Cholesterol (mg/dL) | Total protein (g/dL) | Uric acid (mg/dL) |
|----------------|------------|------------|-----------|--------------|-------------------|----------------|--------------------|---------------------|------------------|
| 04             | 285        | 10.4       | 26.5      | 04           | 0.18              | 123            | 91                 | 3.5                 | 3.0              |
| 11             | 444        | 10.4       | 41.3      | 02           | 0.17              | 138            | 225                | 3.52                | 4.0              |
| 12             | 317        | 10.4       | 32.8      | 05           | 0.15              | 136            | 104                | 4.5                 | 4.4              |
| Mean           | 348.6      | 10.4       | 33.5      | 3.67         | 0.16              | 132.34         | 140                | 3.84                | 3.8              |
| SD             | 84.1       | 0          | 7.4       | 1.5          | 0.02              | 8.1            | 73.9               | 0.6                 | 0.7              |

Note: AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; ALP: Alkaline phosphatase.
values (13.2 mg/dL before, 3.8 mg/dL during and 5.1 mg/dL after hatching, \( p = .0043 \)) are biochemical assays carried out to assess general kidney function in birds. The values observed for the two parameters differed significantly between the three periods considered, as shown in Figure 1(e,h). Since these are uricotelic animals, small levels of urea are expected in serum. Normal concentration of urea in non-carnivorous birds ranges from zero to 5 mg/dL (Campbell 2004).

Creatinine is formed from the break of creatine in muscles (Hochleithner 1994). Creatinine levels are directly correlated with muscle mass and inversely correlated with age. Nevertheless, studies carried out in hens did not detect such correlation between age and creatinine (Rajman et al. 2006). Another study compared creatinine levels across different bird species, and observed that they were between 0.1 and 0.4 mg/dL, independently of muscle mass (Hochleithner

| Animal (Males) | AST (UI/L) | ALT (UI/L) | FA (UI/L) | Urea (mg/dL) | Creatinine (mg/dL) | Glucose (mg/dL) | Cholesterol (mg/dL) | Total protein (g/dL) | Uric acid (mg/dL) |
|----------------|------------|------------|-----------|--------------|-------------------|-----------------|---------------------|---------------------|------------------|
| 04             | 260.6      | 62.8       | 49.9      | 19.17        | 0.50              | 131             | 132.1               | 5.17                | 6.7              |
| 11             | 326.7      | 20.9       | 58.5      | 4.95         | 0.25              | 150             | 139.1               | 4.16                | 4.6              |
| 12             | 227.3      | 10.4       | 61.2      | 8.26         | 0.2               | 141             | 66                  | 5.39                | 4.0              |

Mean 271.53 31.37 56.5 10.79 0.32 140.67 112.4 4.91 5.1

SD 50.6 27.7 5.9 7.4 0.2 9.5 40.3 0.7 1.4

Note: AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; ALP: Alkaline phosphatase.

Table 3. Serum biochemical analyses of emus (D. novaehollandiae) in the post-hatching period.

Figure 1. Mean values of serum biochemical parameters of male emus bred in captivity (1) before, (2) during and (3) after brooding. (a) Aspartate aminotransferase; (b) cholesterol; (c) alanine aminotransferase; (d) alkaline phosphatase; (e) urea; (f) creatinine; (g) glucose and (h) uric acid.
The values obtained in the present study are similar to those described in the literature, and the comparison between the values obtained before, during and after hatching differed significantly \((p = .019)\). Also, the mean creatine value was higher in the post-hatching period, compared with the pre-hatching stage (Figure 1(f)).

Glucose serum concentrations obtained in the presented study are lower than those reported in the literature \((200–500 \text{ mg/dL})\) for healthy birds in general and for ostriches (Campbell 2004; Uhart et al. 2006), which may indicate a specific peculiarity of the species studied. The glucose levels were similar to those reported by several authors who also investigated emus (Okotie-Eboh et al. 1992; Andreasen et al. 1997; Fudge 2003; Kumar et al. 2009; Menon et al. 2013). However, the results reported by Costa et al. (1993) were almost twice as high as those obtained here. Oscillations in glucose levels may be associated with the management of animals, concerning aspects like stress, for example, due to the release of glucocorticoids (Siegel 1995). The emus examined in the present study were handled in such ways as to minimize stress during the blood collection effort. Normal glucose levels are maintained by liver glycogenolysis, during short fasting periods, when the loss of energy is associated with the reduction of fat levels and the mobilization of proteins, which in turn causes weight loss, observed in the reduction of chest muscle mass (Campbell 2004).

Mean glucose levels in the present study were 163, 132.34 and 140.67 mg/dL before, during and after hatching, respectively, indicating the statistical differences between periods \((p = .034)\), since means observed during hatching were lower, with a trend towards normality in the post-hatching period (Figure 1(g)). According to the literature, blood glucose levels in healthy birds vary between 200 and 500 mg/dL, and oscillate according to the circadian rhythm, reaching 800 mg/dL in hummingbirds. Therefore, the values obtained for emus may mean a peculiarity of the species. Glucose and total proteins indicate the nutritional status of animals (Krautwald-Junghanns 2004).

According to Campbell (2004), uric acid levels in serum below 15 mg/dL are normal. The same is said of urea concentrations, in spite of the fact that this parameter is not very useful in bird studies. The mean uric acid values differed significantly between the three periods considered, decreasing during the hatching period and increasing thereafter \((p = .043)\). Despite these differences, mean uric acid values remained within normal limits throughout the experiment (Figure 1(h)).

Concentrations of serum proteins in the samples collected from emus in the pre-hatching period were similar to the normal values \((2.5–4.5 \text{ g/dL})\) for birds, according to Uhart et al. (2006) and Lumeij (2008) in studies carried out with ostriches. In the male emus investigated in the present study, this parameter also varied significantly between the three periods considered (Figure 2(a)). Values diminished during the hatching period, though a trend towards the value observed before hatching was observed \((p = .017)\).

The statistical analyses carried out to compare males and females point to the significant difference only for total proteins \((p = .0358)\), indicating the statistical similarity of the values observed for both sexes (Figure 2(b)).

4. Conclusion

The hatching period signalled variations in biochemical parameters of emus reared in captivity, possibly due to the hypobiosis state males go through. Metabolism is radically reduced due to the fact that these birds do not leave the nest to feed, surviving solely on their existing energy sources and on the ingestion of small amounts of plants and insects. Cholesterol was the only parameter that did not vary significantly between the three periods considered, showing that stored cholesterol is used to meet the energy requirements of emus at this stage. In the post-hatching period, the values of all the other parameters showed a trend towards returning to the levels observed in pre-hatching. Statistical differences between males and females were observed only for total proteins.

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References

Abimosleh S, Lindsay RJ, Butler RN, Cummins AG, Howarth GS. 2012. Emu oil increases colonic crypt depth in a rat model of ulcerative colitis. Dig Dis Sci. 57:887–896.

Alonso-Alvarez C. 2005. Age-dependent changes in plasma biochemistry of yellow-legged gulls (Larus cachinnans). Comp Biochem Physiol A: Mol Integr Physiol Oxford. 140:512–518.
Andreasen CB, Andreasen JR, Thomas JS. 1997. Effects of hemolysis on serum chemistry analytes in ratites. Vet Clin Pathol. 26:165–171.
Black D, Glatz PC. 2011. Ratite health: welfare implications. In: Glatz P, Lunam C, Malecki I, editors. The welfare of farmed ratites. Berlin: Springer Verlag; p. 178–194.
Blue-Mcendon A, Green RA. 2010. Hematology of ratites. In: Weiss DJ, Capitelli R, Crosta L. 2013. Overview of psittacine blood analysis and comparative retrospective study of clinical diagnosis hematology and blood chemistry in selected psittacine species. Vet Clin North Am: Exot Anim Pract Texas 16: 71–120.
Costa ND, McDonald DE, Swan RA. 1993. Age-related changes in plasma biochemical values of farmed emus (Dromaius novaehollandiae). Aust Vet J. 70:341–344.
Ferrer M. 1990. Haematological studies in birds: the Condor. Cooper Ornithol Soc 92: 1085–1086.
Fudge AM. 2003. California avian laboratory reference ranges. California Avian Laboratory; [accessed 2014 December 16]. http://www2ndchanceinfo/goutfudgenormalspdf.
Harr KE. 2002. Clinical chemistry of companion avian species: a review. Vet Clin Pathol Santa Barbara 31:140–151.
Harr KE. 2005. Diagnostic value of biochemistry. In: Harrison GJ, Gwen BF, editors. Clinical avian medicine volume 1. South Palm Beach, FL: Spix Publishing; p. 223–245.
Howarth GS, Lindsay RJ, Butler RN, Geier MS. 2008. Can emu oil ameliorate inflammatory disorders affecting the gastrointestinal system? Aust J Exp Agric. 48:1276–1279.
Kaneko JJ, Harvey JW, Bruss ML. 2008. Clinical biochemistry of domestic animals. 6th ed. Waltham, MA: Academic Press; p. 839–872.
Menon DG, Bennett DC, Schaefer AM, Cheng KM. 2013. Hematological and serum biochemical profile of farm emus (Dromaius novaehollandiae) at the onset of their breeding season. Poul Sci. 92: 935–944.
Mushi EZ, Binta GM, Chabo RG, Isa JFW, Kapaata RW. 1999. Selected hematologic values of farmed ostriches (Struthio camelus) in Botswana. J Vet Diagn Invest Davis. 11: 372–374.
Okotie-Eboh G, Bailey CA, Hicks KD, Kubena LF. 1992. Reference serum biochemical values for emus and ostriches. Am J Vet Res. 53:1765–1768.
Qiu XW, Wang JH, Fang XW, Gong ZY, Li ZQ, Yi ZH. 2005. Anti-inflammatory activity and healing-promoting effects of topical application of emu oil on wounds in scalded rats. Acad J First Med Coll PLA. 25:407–410.
Rajman M, Juráni M, Lamosov AD, Sediakov AM, Kost ALL, Jezov AD, Vyboh P. 2006. The effects of feed restriction on plasma biochemistry in growing meat type chickens (Gallus gallus). Com Biochem Physiol Part A. 145:363–371.
Samour JH, Markham J, Nieva O. 1984. Sexing ratite birds by cloacal examination. Vet Rec. 115:167–169.
Schmidt EMS, Locatelli-Dittrich R, Santin E, Paulillo AC. 2007. Patologia clinica em aves de produccion – Uma ferramenta para monitorar a sanidade avicola – revisao. Arch Vet Sci. 12:9–20.
Siegel HS. 1995. Stress strains and resistance. Br Poul Sci. 36:3–22.
Tully TN, Shane SM. 1996a. Ratite management medicine and surgery. Malabar, FL: Krieger Publishing Company; p. 105–113.
Tully TN, Shane SM. 1996b. Husbandry practices as related to infections and parasitic diseases of farmed ratites. Rev Sci Tech Paris. 15:73–89.
Uhart M, Aprile G, Beldomenico P, Solís G, Marull C, Beade M, Carminati A, Moreno D. 2006. Evaluation of the health of free-ranging greater rheas (Rhea americana) in Argentina. Vet Rec. 158:297–303.
Yoganathan S, Nicolosi R, Wilson T, Handelman G, Scollin P, Tao R, Binford P, Orthoefer F. 2003. Antagonism of croton oil inflammation by topical emu oil in CD-1 mice. Lipids. 38:603–607.
Zemstov A, Gaddis M, Montalvo-Lugo VM. 1996. Moisturizing and cosmetic properties of emu oil: a pilot double blind study. Australas J Dermatol. 37:159–161.