MORPHOMETRIC AND MASOMETRIC PARAMETERS OF THE OSTRICH (*STRUTHIO CAMELUS*) STOMACH IN POSTNATAL ONTOGENESIS

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Abstract
Stomach, as a part of the digestive canal, is important in the metabolic processes of the organism which affects the bird's general health condition, its growth and development, consequently also the increase of the body weight. The aim of the research was to find out the dynamics of weight, length, and area of the ostrich (*Struthio camelus*) stomach and its parts in postnatal ontogenesis from 4 to 12 months of age. The absolute weight of stomach, length of the greater curvature of the stomach glandular part, diameter of the muscular part, thickness of stomach wall was determined. To find out the differences of the mean values between various age groups, ANOVA and Post Hoch tests were used. The increase of the stomach absolute weight continued throughout the postnatal ontogenesis period, but the stomach weight in relation to the ostrich body weight decreased, especially rapidly at the age of 6 and 8 months. At the same time, proportions of the absolute and relative weight of the stomach glandular and muscular part changed. The length of the greater curvature of the stomach glandular part, length of the deep gland region and diameter of the stomach muscular part increased during the whole observed period of ontogenesis; moreover, these parameters increased more rapidly from 6 to 8 months of age. The area of the stomach glandular and muscular part mucosa increased throughout the observed period of ontogenesis. The area of the superficial gland region in all age groups was larger than the area of the deep gland region.
Key words: ostrich, stomach, growth, development.

Introduction

African ostrich *(Struthio camelus var. domesticus)* is the largest non-flying bird, which is raised in captivity mainly for meat production because it has a low fat and cholesterol content. The production yield depends on several factors, including digestive canal development, the stomach in particular. Stomach is important in the metabolic processes of the body, which, in its turn, affects the bird's general health condition, its growth and development, consequently also the increase of the body weight. In order to provide optimal conditions for ostrich keeping and feeding, further study is needed on development of separate parts of the digestive canal in postnatal ontogenesis.

The bird's stomach consists of two parts – glandular part (*proventriculus gastris; pars glandularis s. ventriculus glandularis*) and muscular part (*ventriculus gastris; pars muscularis s. ventriculus muscularis*) which are separated by a constriction (*isthmus gastris*) (Baumel, 1993; Rossi et al., 2005; Brūveris, 2007). The glandular part of the stomach in the ostrich is formed of two regions – the deep gland region and superficial gland region because of the different structure of their mucous membrane (Illanes et al., 2006; Порческу, 2007). The deep gland region (*regio glandularis*) is situated on the greater curvature of the glandular part, with a narrowed cranial end at the junction of esophagus (*oesophagus*) and with a widened rounded caudal end. The muscular part of the stomach is bilaterally curved with a complex structure. In most of the birds, it is developed from two layers of smooth musculature. A simpler structure of the muscular part is observed in the birds of prey and piscivorous birds. In the ostrich, the wall of the muscular part is thick, with a typical structure of herbivorous birds (Duke, 1997). The main caudodorsal and cranioventral thick muscle (*m. crassus caudodorsalis et m. crassus cranioventralis*) of the ostrich stomach are particularly well developed and 5.2-6.5 cm thick; in hens its thickness is 1.5-2.1 cm. Tendinous center (centrum tendineum) surfaces are joined (left/right) ventrolaterally and dorsolaterally, and divide the muscular part into cranial and caudal sack (*saccus cranialis et saccus caudalis*) (Baumel, 1993; Bezuidenhout, 1999; Sales, 2006; Порческу, 2007).

The aim of the study was to find out the dynamics of weight, length and area of the ostrich stomach and its parts in postnatal ontogenesis from 4 to 12 months of age.

Materials and Methods

In this research, 18 African ostriches of both sexes at the age of 4, 6, 8, and 12 months raised in Latvia on the farm Ozolini AB (Krustpils county Atasienes parish) and the farm Indrani (Sigulda county More parish) as well as in the premises of experimental animals of the Faculty of Veterinary Medicine, Latvia University of Agriculture were used. The temperature regime was maintained within the range of + 20 to 22 °C with air moisture of 43 - 50%, and light regime from 7 a.m. to 9 p.m. Ostrich chicks until two months of age were fed on the young birds feed Strus Premium – Strus 1, and over the further raising period, it was gradually changed to the wholesome young birds feed produced by the Latvian producer

Tukuma Straume, supplemented with oats and barley corn, barley meal, ground seashells, Dolfos D mineral substances, and vitamins. The feed, water and gravel stones were available ad libitum. After slaughtering, the body weight was determined, and necropsy performed for further examination. The absolute weight of the glandular and muscular part of the stomach was determined using scale Kern EW 420-3 NM (± 0.01 g), and the total and relative (in relation to the body weight) stomach weight were calculated. The stomach greater curvature length was estimated using a tape-measure (± 1 mm). The diameter of the muscular part and the thickness of the stomach wall in the deep gland region were measured with a digital slide gauge Limit-2000 (± 0.01 mm). By using the digital planimeter Sokkia KP-90N (± 0.1 cm), the total gastric mucosal area of the glandular part, area of the deep gland region and muscular part were estimated as well as their ratio was calculated. For the research data statistical processing SPSS 20.0 program was used. In each age group, the mean arithmetic value and standard error were calculated for all parameters. To find out the differences of the mean values between various age groups, a one-way variance analysis (ANOVA) and Post Hoch test were used.

Results and Discussion

The absolute ostrich stomach weight without its content increased ($p<0.001$) over the investigated period of ontogenesis; a significant increase was observed among 6, 8 and 12 months old ostriches ($p<0.001$). The absolute stomach weight with its content increased over the observed period of ontogenesis (see Tab. 1). However, the relative stomach weight with and without its content decreased ($p<0.001$) over the observed period of ontogenesis. A significant decrease of these parameters ($p<0.05$) was observed in 6 and 8 months old ostriches (see Tab. 2). Several researchers have noted that in ostriches at the age of 10 – 14 months the stomach relative weight with its content is 8.77 kg, i.e. 8.46%, but without the content it is 4.55 kg, i.e. 4.39% (Dijana et al., 2010). C.A. Moriss et al. (1995), in their turn, note that the relative stomach weight together with its content is lower – 5.8 kg, i.e. 6.05%. Even lower results have obtained K.D. Pollok et al. (1997) – 3.14 kg, i.e. 3.1%. P.A. Ilji and his colleagues (2003) have established that in younger birds the relative stomach weight is changing, namely, decreasing from 14.7% at the age of one month to 12.1% at the age of two months, but at 2.5 months of age the stomach relative weight has already increased to 15.1% (Ilji et al., 2003).

The absolute weight of the stomach glandular part increased ($p<0.001$) throughout the observed period of ontogenesis, but a more rapid increase ($p<0.05$) was observed in 6 and 8 months old ostriches, and in 8 and 12 months old birds (see Tab. 1). The relative weight of glandular part, in its turn, decreased with increasing of ostriches age ($p<0.001$). A significantly more rapid decrease of the relative weight ($p<0.05$) was observed from 4 to 6 months of age as well as in ostriches aged 6 and 8 months (see Tab. 2).

Table 1

Dynamics of the absolute weight of ostrich stomach and its parts from 4 to 12 months of age (g ± Standard error)

Age, month	Absolute weight of stomach glandular part	Absolute weight of stomach muscular part	Stomach absolute weight	Stomach absolute weight with its content	*Pars glandularis* and *pars muscularis* weight without their content
4	219.40±43.36	247.10±36.13	466.50±70.91	1218.55±220.99	1.20±0.15
6	274.50±36.83	422.75±43.98	697.25±68.88	1597.75±233.60	1.59±0.20
8	555.75±28.73	1605.75±61.53	2161.50±63.16	3691.00±385.37	2.92±0.20
12	785.00±62.81	2075.00±69.13	2860.00±112.84	5315.00±471.80	2.71±0.20

Table 2

Dynamics of the relative weight of ostrich stomach from 4 to 12 months of age (% ± Standard error)

Age, month	Stomach relative weight without content	Stomach relative weight with its content	Relative weight of stomach glandular part
4	7.92±0.77	20.52±2.78	3.71±0.58
6	6.44±0.64	14.66±2.20	2.51±0.29
8	4.28±0.35	7.15±0.34	1.09±0.05
12	3.84±0.63	7.27±1.50	1.07±0.22

Table 3

Dynamics of the ostrich stomach parts length and wall thickness form 4 to 12 months of age (mm ± Standard error)

Age, month	Length of *pars glandularis curvature major*	Diameter of *pars muscularis*	Wall thickness of *pars glandularis regio glandularis*	Wall thickness of *pars glandularis*	Wall thickness of *pars muscularis*	Length of *pars glandularis regio glandularis*
4	349.25±23.17	109.75±10.64	9.47±0.60	3.25±0.45	27.14±5.62	170.50±7.23
6	381.75±20.97	123.50±5.42	11.12±1.24	3.78±0.54	33.38±3.58	202.50±16.48
8	492.50±23.94	196.00±2.45	11.73±0.89	4.60±0.27	65.60±2.02	287.50±6.61
12	520.17±33.35	206.00±1.83	15.29±0.70	5.85±0.67	68.27±1.82	285.00±13.80

The absolute weight of the stomach muscular part increased ($p<0.001$) over the ontogenesis period studied, but a significant increase ($p<0.001$) was observed from 6 to 8 months of age, and in 8 to 12 months old ostriches (see Tab. 1). Although the ostrich stomach muscular part visually looks like a hen stomach muscular part, its weight without the content is even 12 times larger than that in a hen (52-81 g), and in an adult ostrich it reaches 960-1025 g (Порческу, 2007). The ratio between the absolute weight of stomach muscular part and glandular part increased from 1.19 ± 0.2 to 2.89 ± 0.2 throughout the observed period of ontogenesis ($p<0.001$), but significantly more rapid increase ($p<0.01$) was observed in 6 and 8 months old ostriches (from 1.59 ± 0.2 to 2.89 ± 0.2) (see Tab. 1).

The length of the greater curvature of the glandular part of the ostrich stomach increased ($p<0.01$) throughout the observed period of ontogenesis, but a significant increase of length ($p<0.05$) was observed in 6 and 8 months old ostriches (see Tab. 3). The wall thickness of the superficial gland region increased throughout the observed period of ontogenesis (see Tab. 3). Other scientists also have noted that in adult ostriches the wall thickness of the superficial gland region reaches 7–12 mm decreasing caudally to 1.2–1.5 mm (Порческу, 2007). The specific structure of the ostrich stomach with a relatively large glandular part and thin wall provides ability to intake a large amount of dry feed (Cho et al., 1984). It could be explained by the fact that in ostriches and emu, contrary to other bird species, there is no crop that is why its functions are carried out by the glandular part of the stomach. Consequently, the glandular part is large, because it is used as a reservoir for feed and water storage even up to 20 hours. In older birds and in larger young birds with a slower metabolism, these water reserves may be stored even for a longer time (Degen et al., 1994).

The length of the deep gland region of the glandular part of the stomach increased throughout the period of ontogenesis studied. A significant increase ($p<0.01$) was observed from 6 to 8 months of age (see Tab.3). The stomach wall thickness of the deep gland region increased throughout the investigated period of ontogenesis ($p<0.01$), but significantly more rapidly ($p<0.05$) this parameter increased from 8 to 12 months of age (see Tab.3). The obtained results on the length of the deep gland region and wall thickness changes in 12 months old ostriches correspond to the length of an adult ostrich gland region of glandular part, as indicated also by other authors – M.E. Fowler (1991) and G.S. Porchesku (Порческу, 2007). For instance, M.E. Fowler (1991) noted that the length of the deep gland region of glandular part was 240 mm, width – 4–7 mm, and wall thickness – 10 mm. According to G.S. Porchesku (Порческу, 2007) studies, the length of glandular part is 180–270 mm, width at the cranial end 45–60 mm, at the caudal end 70–130 mm, in the middle part 31–38 mm, and the maximal thickness is 15 mm. In this region of adult ostriches, around 750–1200 deep gland excretory ducts open (Порческу, 2007). The area of glandular part of ostriches differs from other ratites: in emu, the deep gland zone occupies all gastric mucosa of glandular part while in rhea only half of it (Fowler, 1991).

The diameter of the stomach muscular part increased throughout the observed period of ontogenesis ($p<0.001$), but a more rapid increase ($p<0.001$) was observed from 6 to 8 months of age (see Tab. 3). The wall thickness of the stomach muscular part increased ($p<0.01$) throughout the investigated period of ontogenesis, but significantly ($p<0.001$) it increased from 6 to 8 months of age (see Tab. 3). D. Swart and his colleagues (1993) indicated that the diameter of the ostrich stomach muscular part was 120±10 mm at 4 months of age, which was also proved by the present study results. The length of an adult ostrich stomach glandular part ranges from 141 to 155 mm, length 133–152 mm, and thickness is 79–92 mm (Порческу, 2007). M.E. Fowler (1991) observed 120–160 mm diameter of the muscular part in the adult ostrich while in emu and rhea it was larger than glandular part.

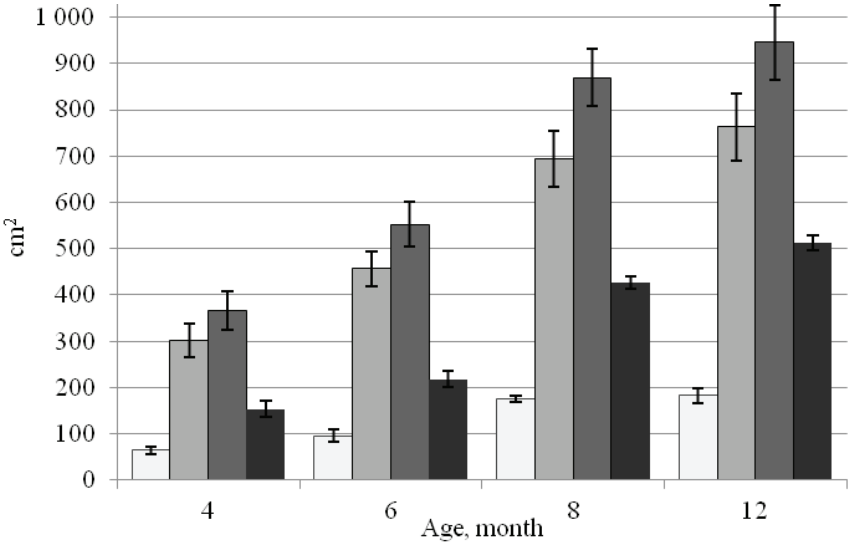

Figure 1. Dynamics of the area of ostrich gastric mucosa from 4 to 12 months of age:
□ Deep gland region of glandular part ▒ Superficial gland region of glandular part
■ Stomach glandular part ■ Stomach muscular part

The mucosal area in both stomach parts increased with advancing of ostrich age ($p<0.001$). The area of the deep gland region of the stomach glandular part and the total mucosal area of glandular part increased significantly ($p<0.01$) from the age of 6 to 8 months. In turn, mucosal area of the stomach muscular part increased significantly ($p<0.05$) with advancing of ostrich age throughout the observed period of ontogenesis (see Fig. 1).

The area of the superficial gland region of the stomach glandular part exceeds the deep gland regional area by 4–4.7 times with a tendency to decrease with advancing of ostrich age. In adult ostriches, the superficial gland region exceeds the deep gland region of mucosal surface area by 2 -3 times (Порческу, 2007).

The area of the deep gland region of glandular part made 17.22 ± 1.37 – 20.4 ± 1.35% out of the total mucosal surface of glandular part throughout the observed period of ontogenesis. The area ratio of the stomach muscular part to the glandular part area from 4 to 6 months of age had a tendency to decrease from 1:3.56 ± 0.2 to 1:2.85 ± 0.2. Although in the ostrich, contrary to other running birds, the area of stomach glandular part is proportionally larger than muscular part area, the relative area of the deep gland of stomach glandular part is less than in other birds, only 25% of the total mucosal surface area in the adult ostrich (Cho et al., 1984; Fowler, 1991; Bezuidenhout, 1999; Cooper and Mahroze, 2004; Sales, 2006; Порческу, 2007).

Conclusions

1. The increase of the ostrich stomach absolute weight continued throughout the postnatal ontogenesis, while the stomach weight ratio to the ostrich body weight decreased rapidly at 6 and 8 months of age in particular, which indicates a more rapid increase of the ostrich body weight at this age. At the same time, proportions of the absolute and relative weight of the stomach glandular part and muscular part changed. If at the age of 4 months the absolute weight of both stomach parts was almost equal, then starting from 6 months of age, weight of the stomach muscular part continued to increase until it reached ratio 1:2.92 at the age of 8 months.
2. The length of the greater curvature of the stomach glandular part, the length of the deep gland region and the diameter of the stomach muscular part increased throughout the observed period of ontogenesis; however, a more rapid increase of these parameters was observed from 6 to 8 months of age.
3. The mucosal area of the stomach glandular part and muscular part increased throughout the observed period of ontogenesis. The area of the stomach superficial gland region of glandular part was larger than the deep gland region in all age groups.

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