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Gross Adaptive Morphologic Changes Occurring in the Gastrointestinal Tract Components of Ostriches Fed Ration Including or Excluding Grit in Botswana

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Abstract: This study investigated the gross changes occurring in the luminal surface and structural anatomy of some Gastrointestinal Tract (GIT) components of ostriches with access to grit and of ostriches without access to grit. Fourteen ostrich chicks age ten weeks were raised on concrete without access to grit were randomly assigned to two feeding groups. Each feeding group had seven birds raised in a pen 30 meters long by 6 meters wide. All ostriches were fed and watered *ad libitum*. One group had access to grit through out the study while the other group did not have access to grits. From week 24 an ostrich from each group was slaughtered monthly. Gastrointestinal components were dissected and weights with and without contents recorded. The length of tubular components was measured. Digital photographs were taken of the external morphology and of the luminal surfaces of proventriculus and ventriculus (gizzard). Measurements were taken of the height of proventricular mucosal folds and the thickness of the ventricular muscle. The volume of the proventriculus and of the ventriculus was determined by measuring the volume of water displaced by the organs. The data was analyzed using the student-t test at $p < 0.05$. The proventricular mucosal folds of the grit group were significantly lower (0.49 ± 0.09 cm) than the proventricular mucosal folds (1.06 ± 0.09 cm) of the no grit group. This change in the mucosal fold does alter surface area of the proventricular mucosa in contact with ingester and could therefore positively affect digestion in the no grit group. There was no significant difference between percent body weight (0.85 ± 0.07) of and the volume of water displaced (810.71 ± 62.01 mL) by the proventriculus of the no grit group and percent body weight (0.94 ± 0.07) and volume of water displaced (692.43 ± 62.01 mL) by the proventriculus of the grit group. Ventricular percent body weight (0.96 ± 0.07) of the no grit group and percent body weight (1.12 ± 0.07) of the grit group were not significantly different. However there was a significant difference between the volume of water displaced (817.14 ± 40.47 mL) by the ventriculus of the no grit group and the volume displaced (1045.86 ± 40.47 mL) by the ventriculus of the grit group. There was similarly a significant difference between the muscle thickness (4.88 ± 0.23 cm) of the ventriculus of the no grit group and the muscle thickness (6.27 ± 0.23 cm) of the ventriculus of the grit group. Digital photography revealed more eroded luminal folds of both proventriculus and ventriculus of the grit group compared to those of the no grit group. The stark contrast in size of the ventriculus of the two treatment groups of birds was also demonstrated with digital photography. There was no significant difference between the percent body weight (0.98 ± 0.03) and length (611.14 ± 30.30 cm) of the small intestines of the no grit group and the percent body weight (1.01 ± 0.03) and the length (704.14 ± 30.30 cm) of the small intestines of the grit group. No significant difference was found between percent body wt (0.23 ± 0.01) of the caecum of the no grit group and the percent body weight (0.20 ± 0.01) of that of the grit group. However the caecal length (70.42 ± 1.67 cm) of the no grit group was significantly different from the caecal length (82.28 ± 1.67 cm) of the grit group. The percent body weight (1.27 ± 0.05) and the length (938.57 ± 51.11 cm) of the large intestines for the no grit group was not significantly different from the percent body weight (1.34 ± 0.05) and the length (941.17 ± 51.11 cm) of the large intestines for the grit group. Access to grits lead to a significant hypertrophy of the tunica muscularis of the gizzard and should thus increase the grinding power of the organ and its digestive efficiency. The significant erosion of the proventricular mucosal folds in birds with access to grit compared to the proventricular mucosal folds of the no grit group is likely to reduce digestive efficiency of this organ in the grit group of ostriches. The presence of grits had no significant impact on the parameters examined for the large and small intestines. This is in contrast to the caecum, which showed a significant increase in length in the birds exposed to grits.

Key words: Ostrich, gastrointestinal, adaptation, grit

Introduction

Ostriches (*Struthio camelus*) are large, flightless birds and are members of the family of birds known as Ratitae or the running bird. One feeding characteristic of this bird

in the wild is the deliberate swallowing of stone and sand or grit believed to assist the gizzard in grinding the food into smaller particles. Kreibich and Sommer, 1995 stated that in domesticated rearing situations where the

bird has no access to grit, it must be fed to the ostrich). Although grit assisted gastric grinding is not an absolute essential for digestion it does increase dry matter digestibility and efficiency of digestion (Mackie, 2002). Aganga *et al.* (2000) suggested that grit offered to ostriches could lead to gastric damage if care was not taken to select rounded, non-angular stones. Mushi *et al.* (1997) have reported impaction of the proventriculus and ventriculus (gizzard) of ostriches associated with excessive engorgement with grit by the birds.

Grit is a useful aid to digestion (Mackie, 2002) especially in situations where the ostrich gathers its feed from the wild or is fed unprocessed feeds. The present practice to make stones and sand available to ostriches as an aid to digestion (Mushi *et al.*, 1997) does seem to mimic the situation in the wild. However, the fact that the domesticated birds are fed highly processed feeds begs the question as to whether the feeding of stones and sand is still necessary.

It has been established that diet type will influence the development of structure and capacity of the gastrointestinal tract of an animal (Chivers and Hladik, 1980). As such animals that eat high fiber diets, such as ruminants, will evolve large capacity stomachs (Starck, 1999). Histological features of an organ such as the epithelium of the ruminant stomach changes as the nature of the contents of the GIT changes along the tract (Dellmann and Brown, 1976). Strack (1999) demonstrated rapid and reversible changes in the size of the avian gizzard in response to changes in dietary fiber content. Thus nature provides the gastrointestinal tract most suited to the diet and foraging habits of the animal. The objective of this paper was to examine the gross phenotypic changes that occur in components of the gastrointestinal tract and also examine changes in the luminal surface of the proventriculus and gizzard of ostriches exposed to grit and of ostriches not exposed to grit.

Materials and Methods

The study was conducted at Botswana College of Agriculture Notwane Farm located northeast of the capitol city of Gaborone. The altitude of the area is 3256 ft and the coordinates are S24°34.832 and E025°58.394. The global positioning system marketed by Garmin was used to obtain this information. Fourteen six month old ostriches of both sexes were used for this study. The Ostrich chicks were acquired from an intensive ostrich production system, Maradu Farm, Lobatse located south of the city of Gaborone, Botswana. All ostrich chicks were identified by the neck tags. The fourteen birds were randomly assigned to two treatment groups using a complete randomized design and were reared intensively. One group was provided with grit on a normal earth floor and the other group reared without grit

on a concrete floor. Accommodation, feeding, watering and supplementation was as described by Waugh *et al.* (2006). The duration of the study was 7 months.

From six month of age one ostrich from each treatment group was humanely slaughtered monthly using a captive bolt stunner to the head. The head was then removed by means of carving knives and transported to the poultry abattoir, Botswana College of Agriculture. The birds were then plucked by hand using leather gloves and skinned following normal abattoir procedure. The dead bird was held in a dorsal recumbent position on a steel table. The legs were disarticulated at the hip joint and a midline incision made from the neck to the anus. The sternum was severed with a rib cutter and the thoracic and abdominal wall reflected dorsally to reveal the thoracic and abdominal organs.

The proventriculus, gizzard and the tubular small and large intestinal tract were carefully dissected from the body and separated. The Proventriculus and gizzard were transacted using scalpel and forceps to expose the luminal epithelium. The ingester was gently washed from the epithelial surface with tap water. The height of the proventricular epithelial folds and the thickness of the gizzard muscle were measured using a vernia caliper. Digital photographs were taken to show the epithelium of both organs and the muscle of the gizzard. The volume of the proventriculus and gizzard was determined by floating each organ in a graduated beaker with water. The volume of water displaced was taken as the volume of the organ. A dry surgical towel was used to remove excess water and the fresh weight of the organ components determined with a digital scale. For ease of comparison the weight of each organ component was expressed as a ratio of the live body weight of the ostrich from which they were dissected. The lengths of small and large intestines were measured with a metric steel ruler. Statistical analysis was conducted using the Student T test to compare the means for each parameter of the grit group and the no grit group.

Results and Discussion

Proventriculus: The evidence indicates that the presence of grit in the proventriculus does exert some erosive effects on the luminal epithelium (Photo 1 and 2 and Table 1) thus significantly ($p < 0.05$) reducing the height of mucosal folds (0.49 ± 0.09) of the grit group compared to the height of mucosal folds (1.06 ± 0.09) in the no grit group. The increase in height of the mucosal fold of the proventriculus of the no grit group would naturally augment the surface area in contact with the ingester and could therefore increase the efficiency of the digestive/absorptive process in this organ. In fact in the first few months of life, the growth rate of ostriches not exposed to grit was found to be superior compared to those of young ostriches exposed to grits



Photo 1: From a 9-month-old ostrich of the no-grit group showing 'A' gizzard and 'B' proventricular epithelium

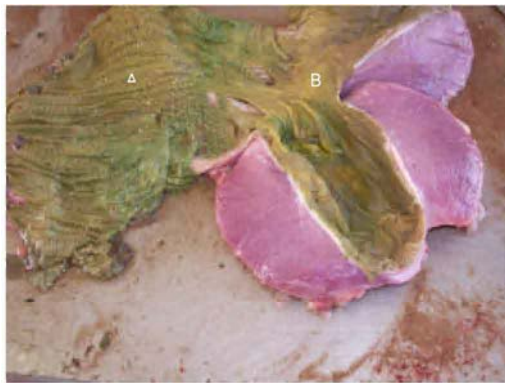


Photo 2: From a 9 month old ostrich of the grit group with 'A' showing proventricular and 'B' showing gizzard epithelium

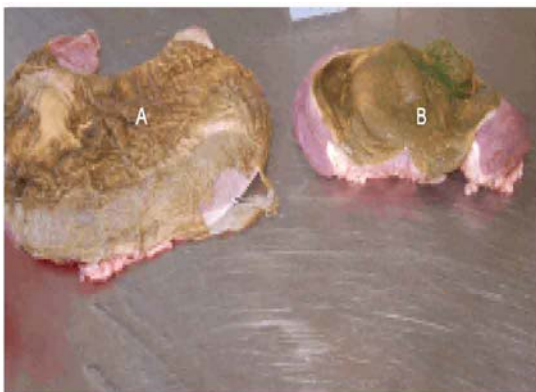


Photo 3: From 9-month-old ostriches of similar weight showing the relative size of transacted gizzards 'A' from the grit group and 'B' from the no-grit group

(Waugh *et al.*, 2006). There were no significant differences between percent body weight (0.85 ± 0.07) of

and the volume of water (810.71 ± 62.01) displaced by the proventriculus of the no grit group and percent body weight (0.94 ± 0.07) and volume of water displaced (692.43 ± 62.01) by the proventriculus of the grit group. However there is a notable trend for a more voluminous proventriculus of the no grit group of ostriches. This could be due to a chronic build up of larger volumes of feed in the proventriculus caused by a rate of feed consumption that exceeded the rate of passage of feed through the gizzard in the no grit group. In fact ostriches with no access to grit showed a higher rate of feed intake (Waugh *et al.*, 2006).

Gizzard: The presence of grit lead to a significant ($p < 0.05$) hypertrophic response of the gizzard muscle (Photo 1 and 2) as evidenced by the relatively higher muscle thickness (6.27 ± 0.23) of the gizzard of the grit group compared to that (4.88 ± 0.23) of the no grit group. This response is most probably due to the stimulus of the increased load on this muscle thus providing the power for the feed grinding process that occurs in this organ (Mackie, 2002). There was correspondingly a significant difference between the volume of water displaced (817.14 ± 40.47) by the ventriculus of the no grit group, and the volume displaced (1045.86 ± 40.47) by the ventriculus of the grit group. These findings are in parallel with those of Starck (1999) who observed phenotypic changes in the gizzard of the Japanese quail which were directly related to the load and level of non-digestible fiber in the diet. Exposure to grit did not significantly influence the ventricular percent body weight (0.96 ± 0.07) of the no grit group and that (1.12 ± 0.07) of the grit group. Where as the grinding influence of grit in the gizzard increases digestive efficiency (Gionfriddo and Best, 1995) of the ostrich, exposure to grit also leads to an obvious increase in net size and luminal capacity of the gizzard thus reducing the amount of feed needed to be temporarily stored in the proventriculus of the grit group. This could help to explain the tendency toward an increase in proventricular size due to greater need for temporary food retention in this organ of the no grit group. The remarkable diminution of gizzard muscle (Table 1) and also of the overall size of the gizzard (Photo 3) of the no grit group does lend credence to this view. This is in contrast to the findings of Riddell (2005) who found no relationship between the hypertrophy of gizzard muscle and the presence of grit in the organ. The photographic evidence also shows (Photo 2) the gizzard mucosal surface of the grit group to be eroded and relatively smooth with the apparent absence of epithelial folds in some areas. The gizzard mucosal surface of the no grit group consistently showed a more remarkable degree of folding of the mucosa (Photo 1). However given the physical role of the gizzard in the digestive process of the birds the mucosal changes in this organ may be of little consequence.

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Table 1: Mean, standard error of the mean and coefficient of variation of measurements for tissues taken from ostriches of the no grit group (Treat. 1) and the grit group (Treat. 2)

Variables						
Treat	gizzard% body wt.	Gizzard volume (mL)	Gizzard muscle thickness (cm)	Proventriculus% body wt.	Proventriculus volume (ml)	Proventriculus fold ht. (cm)
1	0.96	817.14	4.88	0.94	810.71	1.06
2	1.12	1045.86	6.27	0.85	692.43	0.49
SEM	0.07	40.47	0.23	0.07	62.01	0.09
CV (%)	17.83	11.49	10.69	20.21	21.83	30.78

Table 2: Mean, standard error of the mean and coefficient of variation of measurements for tissues taken from ostriches of the no grit group (Treat. 1) and the grit group (Treat. 2)

Variables						
Treat	Small Intest. % body wt.	Small intest. Length (cm)	Caecum% body wt.	Caecum length (cm)	Large instest.% body wt.	Large intest. Length (cm)
1	0.98	611.14	0.23	70.42	1.27	938.57
2	1.01	704.14	0.20	82.28	1.34	941.71
SEM	0.03	30.30	0.01	1.67	0.05	51.11
CV (%)	29.19	12.19	17.03	5.82	12.78	14.38

Small intestines: The data indicate no significant difference between the percent body weight (0.98 ± 0.03) of the small intestines of the no grit group and that (1.01 ± 0.03) of the grit group. There was no significant difference between the length of the small intestines of the no grit group (611.14 ± 30.30) and that of the grit group (704.14 ± 30.30). However, the trend was for longer small intestine in the grit group and raises the possibility of this being a factor in the superior growth and feed conversion rates in the later growth stage of ostriches exposed to grit (Waugh *et al.*, 2006).

Caecum: No significant difference was found in percent body wt (0.23 ± 0.01) of the caecum of no grit group and the percent body weight (0.20 ± 0.01) of that of the grit group. The caecal length (70.42 ± 1.67) in the ostrich of the no grit group was significantly different from the caecal length (82.28 ± 1.67) in the ostrich of the grit group. Given the importance of the caecus in the digestive process of the ostrich as a hindgut fermented this difference in caecal length could also be a factor in the superior performance of ostriches older than 6 months and exposed to grits (Waugh *et al.*, 2006).

Large intestines: The development of the large intestine as indicated by percent body weight (1.27 ± 0.05) of the no grit group and percent body weight (1.34 ± 0.05) of the grit group showed no significant difference. The length (938.57 ± 51.11) of the large intestines of the no grit group and the length of that (941.71 ± 51.11) of the grit group were not significantly ($p > 0.05$) different. Therefore exposure to grits did not affect the development of this segment of the gastrointestinal tract of the ostrich. The evidence suggested that development of the gastrointestinal tract components of the ostrich proceed normally whether or not the birds had access to grit. The

presence of grit however does lead to a hypertrophic response of the gizzard muscle most probably due to the stimulus of the increased load on grit on this muscle thus providing the power for the feed grinding process that occurred in the organ (Mushi *et al.*, 1997). The reduction in height in the proventricular mucosal folds and the diminution of the corrugations on the luminal surface of the gizzard were most likely due to the erosive effects of grit on these tissues. The erosive reduction of proventricular folds of ostriches exposed to grits would lead to a reduced luminal surface area in contact with ingester and could conceivably decrease the digestive effectiveness of this organ. Given the importance of the caecum in the digestive process of the ostrich (Bell and Freeman, 1971) the difference in caecal development could be a factor in the superior performance of older birds of the grit group.

It can be concluded therefore that exposure to grits does lead to gross adaptive changes in some components of the GIT in the ostrich, namely the proventriculus and the gizzard. These changes include morphological alterations in organ size and in the mucosal structure of the lumen.

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