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Morphological studies on rumen development in West African Dwarf goats (*Capra hircus*)

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Abstract

We studied the gross and light microscopic structures of rumen in fetal, neonatal and adult West African Dwarf (WAD) goats obtained from Nsukka and Igboeze South Local Government Areas (L.G.A) of Enugu State. After euthanasia the rumen was ligated, dissected out and the volume determined by flotation and displacement method. For histological studies pieces of rumen were fixed in Bouin`s fluid for 24hrs, processed and routinely stained with H & E. The volume of rumen was 7.25 ± 1.62, 14.3 ± 2.1, 211.6 ± 36.0 and 1620.3 ± 46.5 ml for gestation day 87, full term fetuses, neonates and adult goats respectively. The rumen volume body mass indices were 18.03 ± 3.45, 10.75 ± 4.29, 87.08 ± 6.50 and 108.02 ± 10.65 for gestation day 87, full term fetuses, neonates and adults respectively. Grossly, the mucosal surface was smooth and beige in fetuses, velvety and greenish brown in neonates and adults. Microscopically, the mucosa was lined by stratified squamous epithelium which was divided into larger lighter luminal and darker basal zones in fetuses and early neonates. The dark basal zone had finger-like projections into the lighter zone- proprial papillae. The papillae were tiny and covered by thin keratin layer in 4- week-old neonates. They were very tall especially in the ventral ruminal sac and the epithelium covered by thick keratin in adult goats. These results provide baseline data on rumen development in WAD goats.

Key words: Age, Goats, Morphology, Rumen.

Introduction

The energy and nutrient requirements of the ruminants increase as they transit from fetal through neonatal (milk) to herbivorous mode of nutrition. The digestive organs increase their functions in order to meet this increase in energy and nutrient requirements. This increase in function is accompanied by morphological changes in the digestive organs. Literature on development and growth of rumen in exotic ruminants abound (Huh *et al.*, 1994, Trahair *et al.*, 1997; Poole, 2001; Heinrichs and Jones, 2003; Franco *et al.*, 2004). However these research findings cannot easily be adapted or applied to our local breeds due to variations in genetic makeup, climate, vegetation, and feeding regimen. Ruminants in developing countries feed mainly on poor quality plant materials, natural rangeland or pastures as well as on bushes, trees and crop residues whose availability are highly seasonal (Mcmillan, 1996). The rate of growth and development of rumen in our local ruminants could differ from those of exotic breeds since growth has been shown to be influenced in utero and postnatally by nutrition (Trahair *et al.*, 1997; Heinrichs and Jones, 2003).

In Nigeria, the goat is numerically the most abundant ruminant (Maina, 2002; Dubeuf *et al.*, 2004). The economic importance includes its meat, milk and hides production potentials (Zakari *et al.*, 1988; Egwu *et al.*, 1995; Chibuzo *et al.*, 1997). The studies on development of the gastrointestinal organs in our local breeds especially goats are rare. There is the need for biological and anatomical data on these important breeds. We reported on the development of omasum in West African Dwarf (WAD) goats (Nwaogu and Ezeasor, 2008). The rumen development was not studied in our previous work. The objective of this work, therefore, is to study the gross and light microscopic features and compare the morphometric measurements of rumen in fetal, neonatal and adult WAD goats.

Materials and Methods

Ten adult and ten neonatal WAD goats used in this study were obtained from Obukpa village and Nkwor Ibagwa market in Nsukka and Igboeze South Local Government Areas of Enugu State respectively. Fifty two fetuses were obtained from does slaughtered at Nsukka and Obollo Afor abattoirs in Enugu State. The ages of the adult and neonatal goats were determined by dentition (Dyce *et al.*, 2002; Chibuzo, 2006). The fetal ages were estimated by age prediction formula X = (Y + 17) 2.1 where x is the age in days and y the crown - rump length in centimeters (Arthur *et al.*, 1996) as modified by Nwaogu and Ezeasor (2008). The fetuses were divided into two groups (gestation day 87 and full term) based on their ages. The estimated fetal ages were confirmed by breeding of adult goats obtained from the above sources.

The animals were brought out to graze in the field during the day and kept in pens in the night. The forage browsing was supplemented with maize and sorghum chaff as well as banana and yam peels once a day. The animals were bred in the farm, Faculty of Veterinary Medicine, University of Nigeria, Nsukka (UNN) after 4 weeks of acclimatization. Fertile bucks were used to detect does exhibiting estrus. Estrus detection was carried

out twice daily at 9.00am and 6.00pm. Animals exhibiting estrus by allowing mounting were separated and kept together with the buck until they were out of heat. The animals were bred between April and September. The mated does were suspected pregnant, if they did not return to heat after one month. This was confirmed by ultrasound pregnancy test in Veterinary Teaching Hospital, UNN. The crown – rump lengths of fetuses with known gestational ages were measured by ultrasound according to Russel and Goddard (1995). The actual fetal ages and their crown rump lengths were used to validate those of the abattoir fetuses.

The animals were euthanized by intravenous injection of saturated aqueous solution (1:1) of Magnesium sulphate (5ml for neonates and 10ml for adults) in conformity with UNN ethics on animal handling and research. The rumen was ligated, dissected out and the volume measured by floatation and displacement method as previously described (Nwaogu and Ezeasor, 2008). The rumen volume body mass indices were calculated by dividing the rumen volume with the body mass of each animal.

For histological studies, pieces of rumen were fixed by immersion in Bouins fluid for 24 hrs, processed and routinely stained with H & E. Sections were studied and images captured with a digital camera, Moticam 1000 1.3M Pixel USB 2.0 attached to a computer. The height and width of rumen papillae were measured with stage and ocular micrometer gauge. The height of the papillae was taken as the distance from tip to base for the neonates and adults. The distance from the tip of the proprial papillae to luminal epithelial surface was measured and negative value taken for the fetuses as previously described (Nwaogu and Ezeasor, 2008). The width was measured from one outer epithelial edge to the other at mid -height. The obtained values were analyzed statistically by one-way Analysis of variance and Duncan's New Multiple Range Test using SPSS windows version 9.0.

Results

The WAD goat fetuses weighed 0.40 ± 0.365kg and 1.33± 0.22kg at gestation day (GD) 87 and full term respectively. The neonates at 4 weeks of age weighed 2.43± 0.43kg and 1 year old adults weighed 15.00 ± 3.22kg (Figure 1). The body mass increased significantly ($P < 0.01$) with the age of the animals (Figure 1). The volume of rumen was 7.25 ± 1.62, 14.3 ± 2.1, 211.6 ± 36.0 and 1620.3 ± 46.5 ml for GD 87, full term fetuses, neonates and adult goats respectively (Figure 2). The rumen volume body mass indices decreased significantly ($P < 0.01$) from GD 87 (18.03 ± 3.45) to full term (10.75 ± 4.29) but they increased very significantly ($P < 0.01$) in the neonates (87.08 ± 6.50) and adults (108.02 ± 10.65) (Figure 3).

The mucosal surface of rumen was smooth and beige in color in GD 87 fetuses. Microscopically the rumen wall comprised stratified squamous epithelium which was divided into larger lighter luminal and smaller darker basal zones (Figure 4). The lamina propria - submucosa was made of primitive mesenchymal cells. The tunica muscularis had inner circular and outer longitudinal layers covered externally by tunica serosa. The dark basal epithelial zone had finger-like profiles extending into the light luminal epithelial zone- proprial papillae in full term fetuses (Figure 5). These profiles approached the luminal wavy surface with shallow grooves demarcating tips of the future papillae. The tunica muscularis appeared thicker than that of gestation day 87 fetuses. The height and width of rumen papillae were -192.1 ± 2.0 and 59.0 ± 5.1µm respectively for full term fetuses (Figure 6).

The rumen contained small pieces of swallowed grass in 2 week old neonates. It was filled with grass ingests in 4 week old neonates. The color was light gray in early neonates and later turned greenish brown in late neonates. By 4 weeks of age the surface was covered with tiny papillae. Histologically, a thin layer of keratin covered the stratified squamous epithelium (Figures 7 & 8). Both the inner and outer longitudinal muscular layers had increased in thickness in 4 week old neonates. The height and width of rumen papillae were 358.0 ± 11.4 and 210.5 ± 14.3µm respectively (Figure 6).

The greenish brown intensity of the rumen mucosa increased in adult goats. The rumen epithelium of adult goats was covered with thick keratin. The papillae were very tall especially in the ventral rumen sac and tunica muscularis had increased thickness (Figures. 9 & 10). The dorsal rumen sac contained short but wider rumen papillae when compared with those of the ventral sac (Fig. 11). The height and width of rumen papillae were 1630.0 ± 19.5µm and 283.0 ± 30.0µm respectively (Figure 6); and these significantly ($p < 0.01$) increased with the age of the goats.

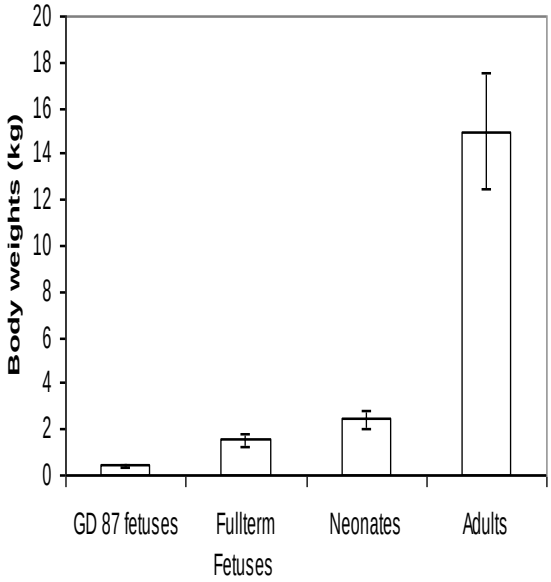

Figure 1: Comparison of body weights of different age groups (Mean±SD)

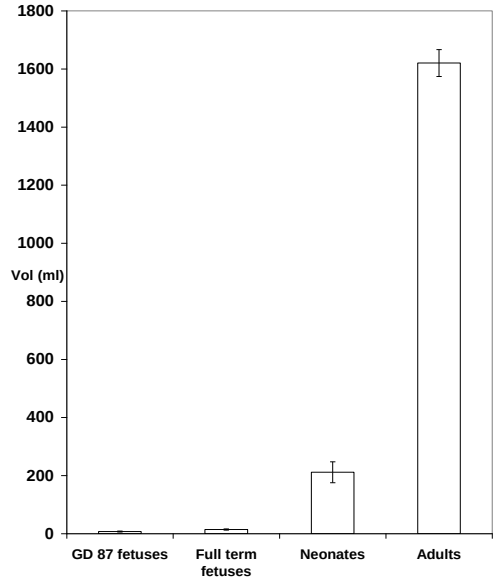

Figure 2: Comparison of rumen volume of different age groups (Mean±SD)

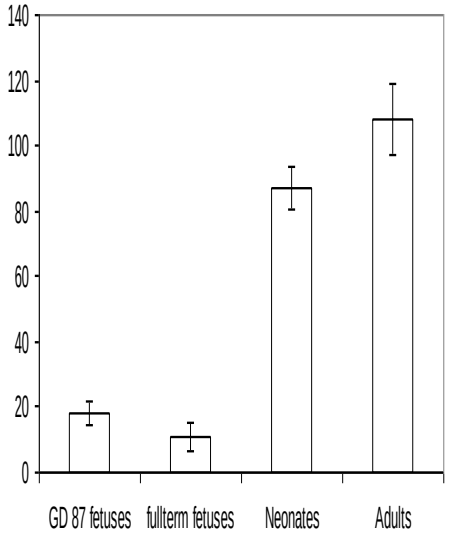

Figure 3: Comparison of rumen volume body mass indices of different age groups (Mean±SD)

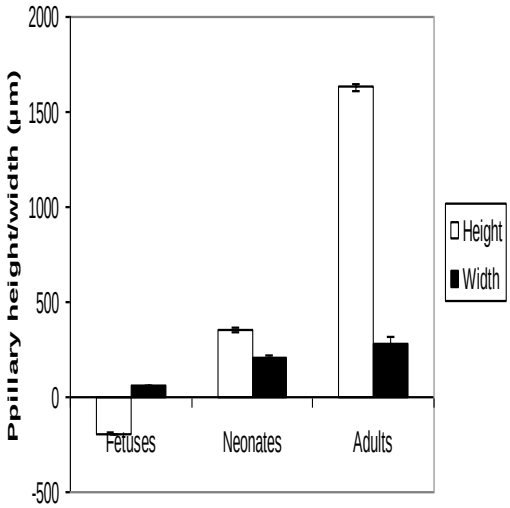

Figure 4: Comparison of papillary length/width of different age groups (Mean±SD)

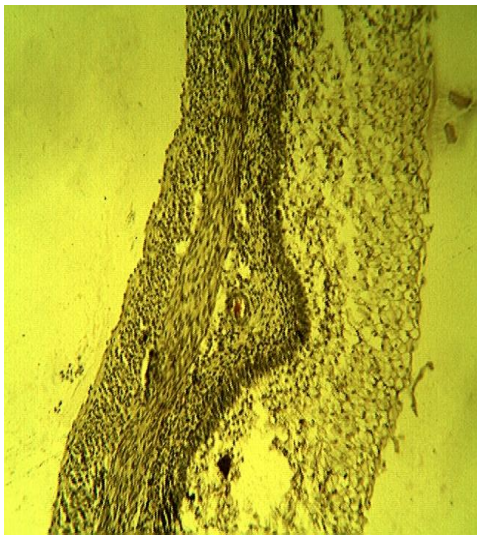

Plate 1: Section of fetal rumen GD 87.

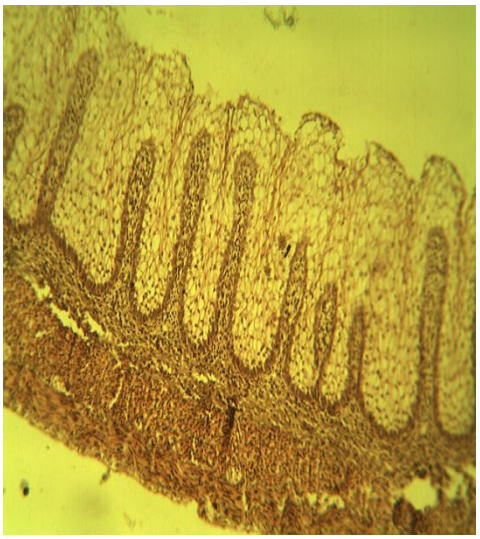

Plate 2: Section of fetal rumen 146 days.

Plates 1 and 2 are sections of fetal rumen showing stratified squamous epithelium (EP), proprial papillae (CP), lamina propria - submucosa ((LP), blood vessel (BV), inner circular layer (CL), outer longitudinal layer (LL) and serosa (SE).

Plate 3: Section of neonatal rumen (2 weeks)

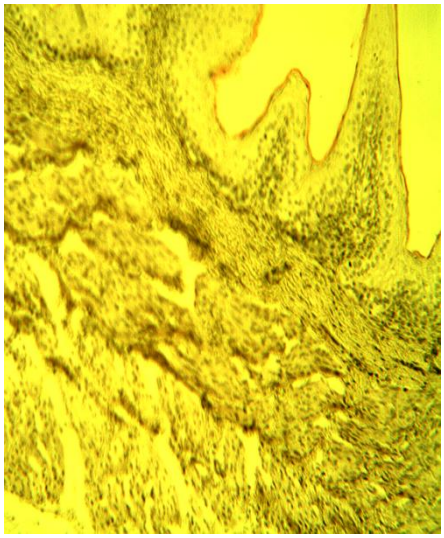

Plate 4: Section of neonatal rumen (4 weeks)

Plates 3 and 4 are sections of neonatal rumen showing papillae (P), keratin (K), stratified squamous epithelium (EP), proprial papillae (CP), lamina propria- submucosa (LP), circular layer (CL) and longitudinal layer ((LL).

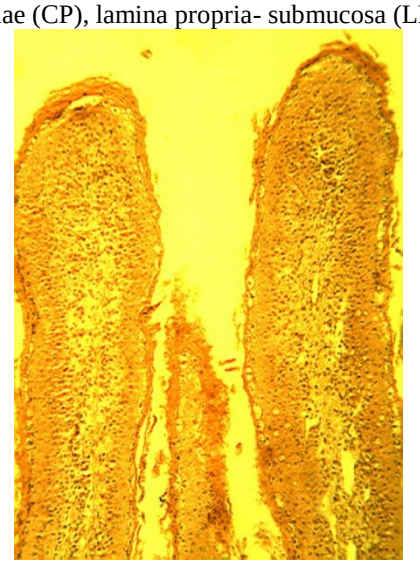

Plate 5: Section of adult rumen (ventral sac)

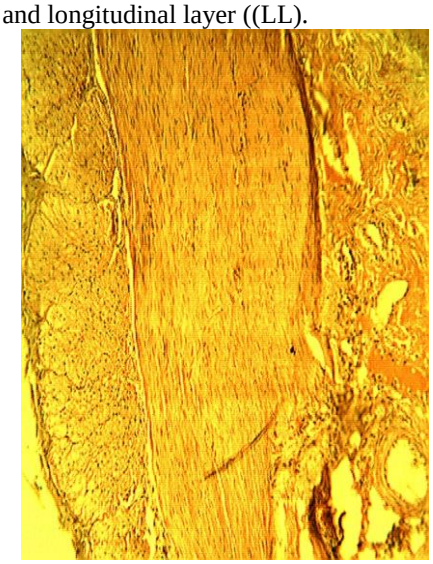

Plate 6: Section of adult rumen (ventral sac)

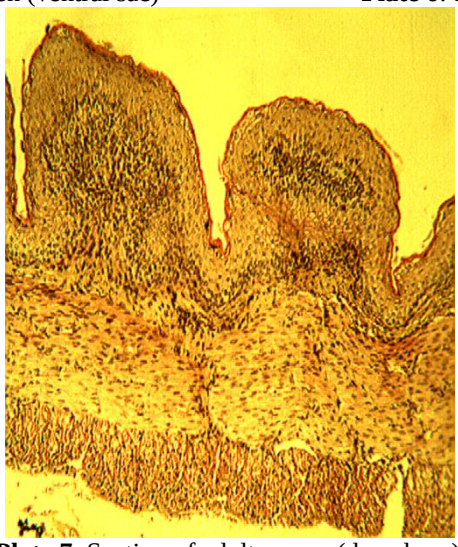

Plate 7: Section of adult rumen (dorsal sac)

Plates 5, 6 and 7 are sections of adult rumen showing keratin (K), papillae (P), stratified squamous epithelium (EP), lamina propria (LP), submucosa (SM), blood vessel(BV), circular layer(CL), longitudinal layer(LL) and serosa (SE)

Discussion

The result of this study provides baseline data on rumen development in WAD goats. The rumen volume body mass indices decreased significantly ($P < 0.01$) from gestation day 87 to full term but they increased very significantly ($P < 0.01$) in the neonates. This suggests that the body grew faster than the rumen in the fetuses. However the rumen grew faster than the body in the neonates when compared with the fetuses probably because it begins to perform its function as a fermentation vat within this period. This observation is supported by the report that the rumen is small and flaccid at birth but grows rapidly with increase in age and roughage intake in calves (Heinrichs and Jones, 2003). The adult rumen

volume body mass indices increased significantly when compared with those of the neonates. This may be due to increase in function and the need to meet the energy and nutritional requirements of the adult goats.

The observed mean fetal, birth, neonatal and adult WAD goat weights corroborate with those previously reported by other workers on this breed (Sumberg and Mack, 1985; Osuagwuh and Aire, 1986; Gall, 1996). The gross and histomorphological features observed in the rumen of fetal WAD goats corroborate with previous reports on fetal rumen in sheep (Wardrop, 1961; Franco *et al.*, 1993), cattle (Arias *et al.*, 1980), Korean native goats (Huh *et al.*, 1994) and Iberian red deer (Franco *et al.*, 2004).

The rumen mucosa was greenish brown in color and had tiny papillae covering the surface in neonates. The rumen ingesta of two week old kids contained pieces of grass. This indicates that they nibbled grass within this period thus suggesting early establishment of rumen fermentation. The goats were reared between April and September when there was abundance of grass in Nigeria. In consonance with this observation is the suggestion that papillary development is enhanced by products of rumen fermentation (Mcmillan, 1996; Mentschel *et al.*, 2002; Baldwin *et al.*, 2004). The thickened tunica muscularis in the neonates when compared with that of the fetuses suggests higher muscular activity. This observation is supported by reports that early rumination (rumen wall contraction) has been observed in 2-3 week-old calves (Ghezzi *et al.*, 2000).

The mucosa had velvety appearance due to presence of papillae in adult goats. Histologically, the stratified squamous epithelium was covered by thick keratin layer. The high keratinization may be protective mechanism hence the papillae are subject to mechanical and chemical wear from the ingesta and their fermentation products. Poole (2001) suggested that extent of keratinization of epithelial layer is determined by amount of mechanical wear that occurs against the papillae in sheep. The rumen papillae of adult goats were significantly taller especially in the ventral sac which is always in contact with the digesta. These papillae provide wider surface area for absorption of short chain volatile fatty acids. This corroborates with previous reports that rumen mucosa is thickly studded with papillae which vary in size and shape with the tallest in the ventral sacs where the most absorption occurs (Dyce *et al.*, 2002; Dehority, 2002).

In conclusion, this study shows that the rumen volume body mass indices decreased significantly from gestation day 87 to full term in WAD goats. The indices increased significantly in neonates and adults. Rumen papillae are at the precursor stage in fetuses, rudimentary in neonates and well developed in adult WAD goats.

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