Archives of Veterinary Science **ISSN 1517-784X**
v.27, n.1, p. 149-165, 2022 www.ser.ufpr.br/veterinary

COMPARATIVE NEUROCRANIAL MORPHOLOGY OF NIGERIAN BREEDS OF SHEEP

(Morfologia neurocraniana comparativa de raças nigerianas de ovinos)

Shaibu Mohammed Atabo[1], Abubakar Abubakar Umar[2], Sani Abdullahi Shehu[2], Adamu Abdul Abubakar[3]

[1]Department of Veterinary Anatomy, Bayero University, Kano, Nigeria; [2]Department of Veterinary Anatomy, Usmanu Danfodiyo University, Sokoto, Nigeria; [3] Department of Veterinary Surgery and Radiology, Usmanu Danfodiyo University, Sokoto, Nigeria.

*Corresponding author: mohakosh@yahoo.com

Editor: Rogério Amorim

ABSTRACT - This study established the morphology and variation of the neurocranium of Nigerian breeds of sheep. A total of 1,008 heads of abattoir-slaughtered Balami, Uda, and Yankasa breeds were used. The hot water maceration method was adopted in the skull preparation. The three breeds had 6 neurocranial bones. The occipital squama was extensive in Balami and Uda of the three breeds, it was concave in females and convex in males, in Balami and Uda, the external occipital protuberance was prominent in males though rudimentary in both sexes of Yankasa, among the three breeds, breed and sex polymorphism was observed in the median and nuchal crests, and rostral and muscular tubercles. The caudal part of the frontal bone of the breeds was more convex in females than in males, while the cranial part is depressed and roughly flattened in females and males respectively. The Crista Galli of the ethmoid was thicker in Balami than Uda and rudimentary in Yankasa. The interparietal bone was absent in both young and adult, the parietal was paired in the young but single in the adult. The bones of the neurocranium showed dimorphic and polymorphic variations with sex differences among the three breeds

Key words: Frontal; Occipital; Parietal; Balami; Uda; Yankasa.

RESUMO - Este estudo estabeleceu a morfologia e a variação do neurocrânio das raças nigerianas de ovelhas. Foram utilizadas 1.008 cabeças de raças Balami, Uda e Yankasa. O método de maceração de água quente foi adotado na preparação do crânio. As três raças tinham 6 ossos neurocraniais. O esqueleto occipital foi extenso em Balami e Uda das três raças, foi côncavo em fêmeas e convexo em machos, em Balami e Uda, a protuberância occipital externa foi proeminente em machos embora rudimentares em ambos os sexos de Yankasa, entre as três raças, raça e polimorfismo sexual foi observado nas cristas medianas e cristas nucal, e tubérculos rostral e muscular. A parte caudal do osso frontal das raças foi mais convexa em fêmeas do que em machos, enquanto a parte craniana é deprimida e aproximadamente achatada em fêmeas e machos, respectivamente. O Crista Galli do etmóide era mais espesso em Balami do que Uda e rudimentar em Yankasa. O osso interparietal estava ausente tanto em jovem quanto em adulto, o parietal foi emparelhado no jovem, mas solteiro no adulto. Os ossos do neurocranio apresentaram variações dimórficas e polimórficas com diferenças

Received in 05/04/2021
Approved in 12/14/2021

sexuais entre as três raças.

Palavras chave: Frontal; Occipital; Parietal; Balami; Uda; Yankasa.

INTRODUCTION

Typologic and phenotypic characteristics are commonly used in the identification and characterization of different breeds of animals (FAO, 2007). The head and the skull is the major part of the body and skeletal system respectively whose typology (craniomorphology and craniometry) has shown taxonomic affiliations and changes in animals as a result of selection (Popoola and Oseni, 2018). Several literatures (GÜndemir et al., 2020; Rodrigo et al., 2020) have adopted the craniometrical features of the skull to characterize different breeds of sheep. Popoola and Oseni (2018) classified Nigerian Balami, Uda, and Yankasa indigenous breeds of sheep based on their head conformation using multivariate analysis. However, studies on the morphological variability of skull especially in the Nigerian breeds of sheep is scanty. So, the study is aimed at establishing the morphological characteristics and variations of the neurocranium of the Nigerian breeds of sheep. The obtained result will aid comparative studies that can be useful in identifying the breeds of sheep, with a better description of sexual dimorphism, osteological investigation, radiographic interpretation, and estimation of landmarks for regional anaesthesia of the head.

MATERIAL AND METHODS

A cross-sectional design and purposive sampling method were used in this study. A total of one thousand and eight (1008) head samples; 336 each of Balami, Uda, and Yankasa breeds obtained from their naturally dominant geographical locations within four States of Nigeria were used for this study. The heads were obtained from slaughtered Uda breeds in the Sokoto metropolitan abattoir, Yankasa breed of sheep from Kaduna and Gusau abattoir, and Balami breeds from Gombe Township abattoir. All the samples were grouped as male and female, aged and sub-grouped into young (≤ 1year) and adult (>1 year) and transported in a nylon bag containing ice to the Veterinary Anatomy Laboratory, Department of Veterinary Anatomy, Usmanu Danfodiyo University Sokoto for further analysis.

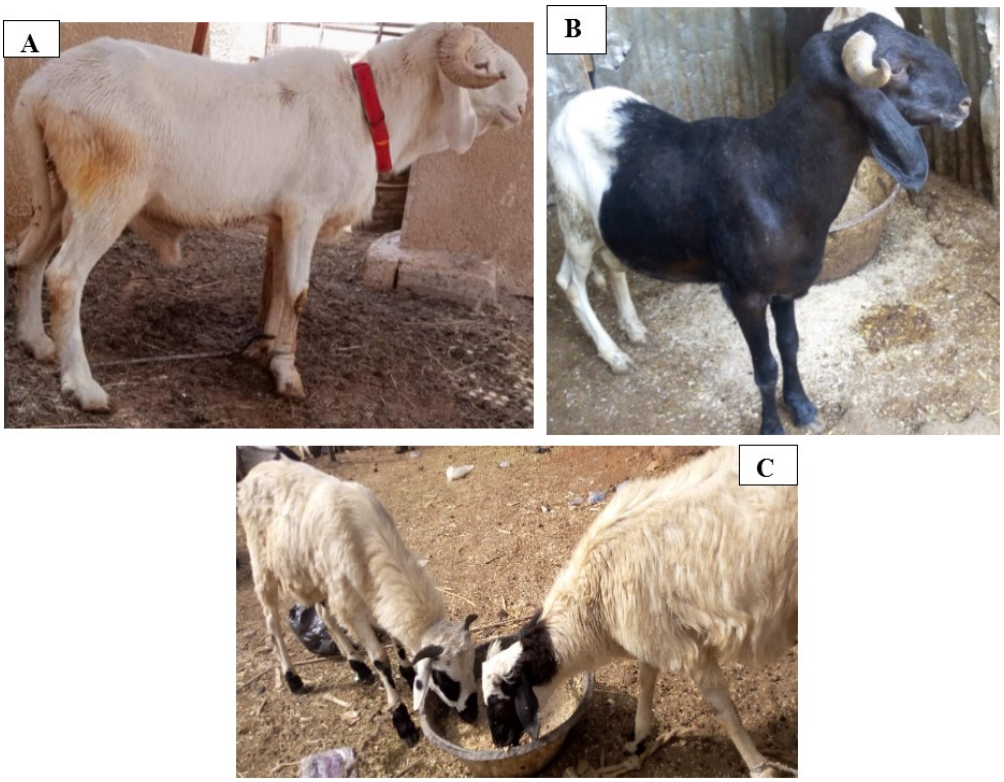


Figure 1- Nuchal surface of the skull in young female Balami (A), Uda (B), and male Yankasa (C) showing interparietal suture (1), small and circular bone (2), temporal crest (3) and Lambdoid sutures (LS).

Sample preparation

The male and female samples of the three breeds of sheep within the ages of <1 year to 3 (Table 3.3 and 3.5) were used for the study, the age of the animals were estimated through their dentition (Dyce et al., 2010). The heads were collected after slaughter from the abattoir, they were weighed and then macerated using the hot water technique to harvest the skull (Shawulu et al., 2011; Olopade, 2006). The skin and muscles of the head, eyes, tongue and nasal cartilages were removed. The brain was removed by filling the cranial cavity with water and stirred using long forceps or with vigorous shaking and pouring off through the foramen magnum with repetition till complete evacuation occurs. The bones were heated to over 80°C for 1 hour in a solution of crystallized hydrous carbonate of sodium (crystal soda) and anionic surfactant (detergent) in a metal drum. The remaining flesh on the boiled bones was separated with a knife and scalpel blade. The bones were left in the water containing detergent and crystal soda for 48 hours with the solution being changed twice after every 24 hours, after which the separation of remaining flesh and ligaments of the bones were carried out using sponges

and knives. The bones were then rinsed in running tap water and allowed to dry under the sun for 7 days.

Craniomorphology

The morphology of the adult (postnatal) skull bones was described and peculiar features and differences were noted among the three breeds and sexes.

RESULTS AND DISCUSSION

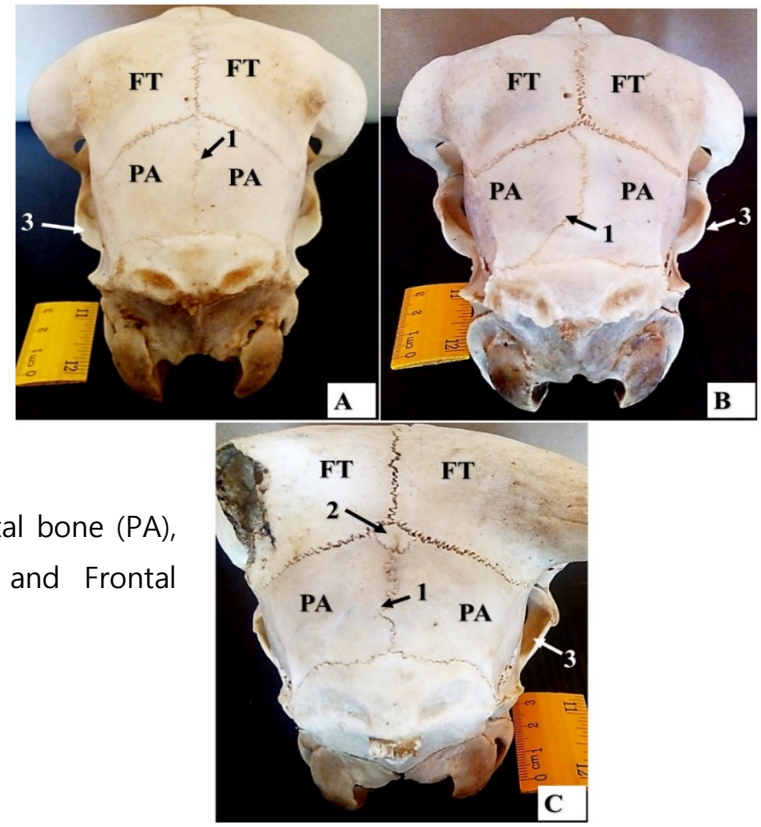
Neurocranial bones

The skull was roughly triangular in the three breeds of sheep. In Balami, Uda, and Yankasa the neurocranial bones were six (6) in number namely; the occipital, sphenoid, ethmoid, parietal, frontal, and temporal bones.

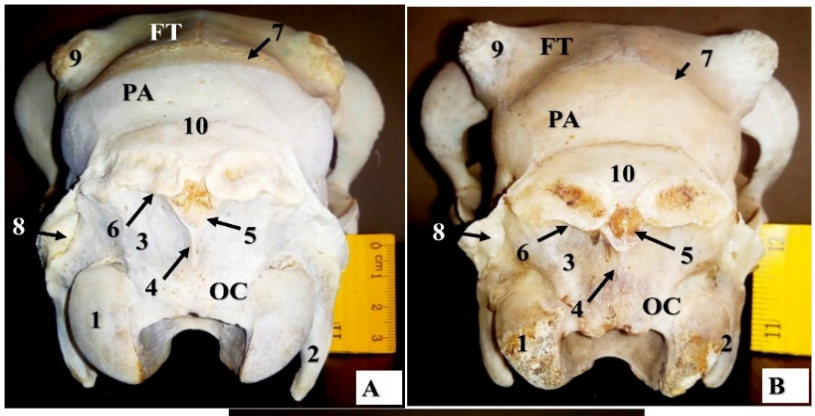
Parietal bone

The parietal bone in the three breeds was paired and they formed the dorsolateral wall of the cranial cavity in the young (Figure 1), this paired bone later fuses completely to a single bone in the adult (Figure 2). The parietal bone has a smooth, convex, and quadrilateral external surface and a rough concave inner surface. The parietal bone articulates anteriorly with the frontal bone forming the most serrated sutures of the skull (parieto-frontal/cornual suture). The fused single parietal bone has a smooth, convex, and quadrilateral external surface and a rough concave inner surface of the three breeds of sheep. The smooth and concave internal surface is to probably enables the bone to blend with the convolutions on the cerebral aspect of the brain. This agrees with Kumar (2017) and Choudhary and Singh (2016). Archana et al. (1998) studied parietal bones in yak skulls and reported that in the foetal skull, the paired parietals formed a 'C-shaped' structure over the interparietal and formed the caudodorsal and lateral walls of the cranium in the adult skull. In humans, each bone is roughly quadrilateral in form. In this study, the parietal bone was paired in the young and single in the adult sheep, this was due to the presence of interparietal suture in the young which later fuses in the adult. The presence of the interparietal (fibrous) suture in the young could be an indication that they are prone to cranial fracture in this region at a younger age, even though it was reported by Atabo (2021) that the parietal bone is best suited for craniotomy (surgical incision) in these breeds, midline craniotomy incision could affect the normal conformation of the neurocranium after healing and as such should be avoided in the

young. Similarly, stunning of these breeds at a younger age could also lead to complications such as fracture and brain rupture. According to Kumar (2017), Choudhary and Singh (2016), and Ramswarup (2011) the parietal bone is a paired bone in the skull of Zambian Gwembe dwarf and Indian blackbuck goats respectively, however, the details of their age groups were not provided. Occasionally the parietal bone is divided into two parts in humans, upper and lower, by an antero-posterior suture (Susan, 2015).



Bones: Paired parietal bone (PA), Parietal bone=PA, and Frontal bone=FT



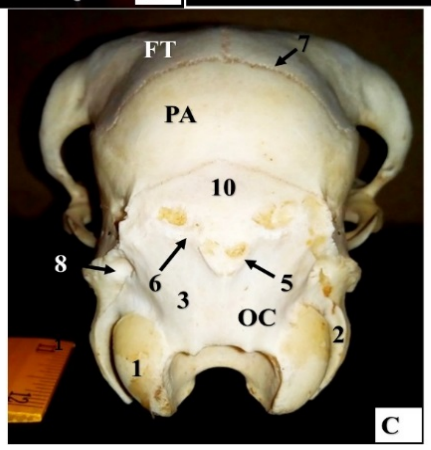


Figure 2- Nuchal surface of the skull in female Balami (A), Uda (B) and Yankasa (C) showing; Occipital bone (OC), Parietal bone (PA), and Frontal bone (FT), occipital condyles (1), paracondylar process (2), occipital squama (3), median crest (4), external occipital protuberance (5), nuchal line/crest (6), parietofrontal suture (7), mastoid foramen (8), cornual process (9), interparietal part of occipital bone (10).

Occipital bone

In the three breeds of sheep, the squamous part of the occipital bone (occipital squama) was quadrilateral in shape and extensive in Balami and Uda, they were concaved in females and convex in males. The median crest is well developed in female Balami and Uda, but rudimentary in their males, it is absent in male and female Yankasa. The left and right occipital condyles were transversely placed, thus, met ventrally forming a ''U'' shaped intercondyloid cleft and the paracondylar processes were curved latero-ventrally and tapered to a point. The interparietal part of the occipital bone was a small, single quadrilateral-shaped bone centrally placed between the parietal anteriolaterally and occipital squama posteriorly. It is smaller in the Uda and smallest in the Yankasa breed. In the young, it articulates with the parietal bone via the lambdoid suture (occipito-parietal suture), this suture fuses completely later in life as they ages. In Balami and Uda breeds, the external occipital protuberance was very prominent in males than in females, while the male and female Yankasa breeds both had a smaller external occipital protuberance. The nuchal line/crest of the occipital bone was prominent in both sexes in Balami, in the Uda, the nuchal line is prominent in females and rudimentary in males, whereas, in the Yankasa breeds, they were rudimentary in both sexes. A deep fossa (cerebella fossa) was

seen on the inner/endosteal surface of the occipital protuberance. The basilar part of the occipital bone of the three breeds of sheep was straight, short, and wide, they were bounded on the left and right sides by two pairs of muscular tubercles (caudal and rostral tubercles), and the rostral tubercles were larger compared to the caudal. They were farther apart from the median plan in Balami and Uda than in Yankasa. The muscular tubercle is well developed and curved medially in females and poorly developed in males of the Balami breeds. The reverse is the case in Uda breeds, where the tubercles were prominent in males and poorly developed in females. The male and female Yankasa breeds both had a rudimentary muscular tubercle (Figure 3).

The quadrilateral-shaped occipital squamous observed in the three breeds of sheep in this study is similar in camel (Yahaya et al., 2012; Singh, 1984), but differs from the pentagonal shaped occipital described by Singh and Patel (1984) in Indian goat. The squamous and basilar parts of the occipital bone of the three breeds of sheep in this study formed part of the nuchal and ventral surface as in the Mehraban Iranian breed of sheep (Karimi et al., 2012), Ecotypes of Sahelian breed goat (Shawulu et al., 2011), Red Sokoto and West African Dwarf Nigerian breeds of goat (Olopade, 2006). The result of this work revealed breed and sexual dimorphism in the occipital squamous of the three breeds. The external occipital protuberance present was similar to the findings in the Suffolk Down Chilean breed of sheep by Rodrigo et al. (2020). Whereas according to Sarma and Sarma (2002) absent in pigs. The presence of breed and sexual dimorphism in the external occipital protuberance of the three breeds of sheep agrees with the work of Shawulu et al. (2011) who noted that the external occipital protuberance was very obvious in females than the males of Sahel goat ecotypes. In addition to the occipital squamous and external occipital protuberance, the breed and sex differences were also noted on the nuchal crest, median crest, and muscular tubercles of the occipital bones of the three Nigerian breeds of sheep. These further agree with the work of Rogers (2005) who reported that occipital bone is frequently studied in procedures of sex determination in forensics or anthropology. The prominent nuchal crest noted in the occipital bone of the Balami and Uda is similar to that of the pig and horse (Sisson and Grossman, 1975), and tiger (Josh, 2004). The rudimentary nuchal crest in Yankasa is also similar to that of Indian blue bull (Kumar, 2017) and Indian blackbuck (Indian antelope) (Choudhary and Singh, 2016). The median crest was only present in female Balami and Uda. The median occipital crest was faint in local sheep of the Indian Jammu region (Sarma et al., 2007) and well developed in the Gwembe Valley Dwarf goat (Kataba, 2014) and Kagani goat (Sarma, 2006). The basilar part of the occipital bone of the three Nigerian breeds of

sheep was straight, short, and wide, they were bounded on the left and right sides by two pairs of muscular tubercles. In the Indian Kagani goat of the Jammu Region, the basilar part of the occipital bone also was straight, bound rostrocaudal by two pairs of muscular tubercles Sarma (2006). The basilar part of the occipital bone was short and wide in the ox and larger in horses (Raghavan, 1964). In the sloth bear, the basioccipital bone was comparatively shorter but wider Kalita and Kalita (2003b). Yankasa breeds both had a rudimentary muscular tubercle. The muscular tubercles were prominent and rough in the buffalo skull (Khatra, 1979).

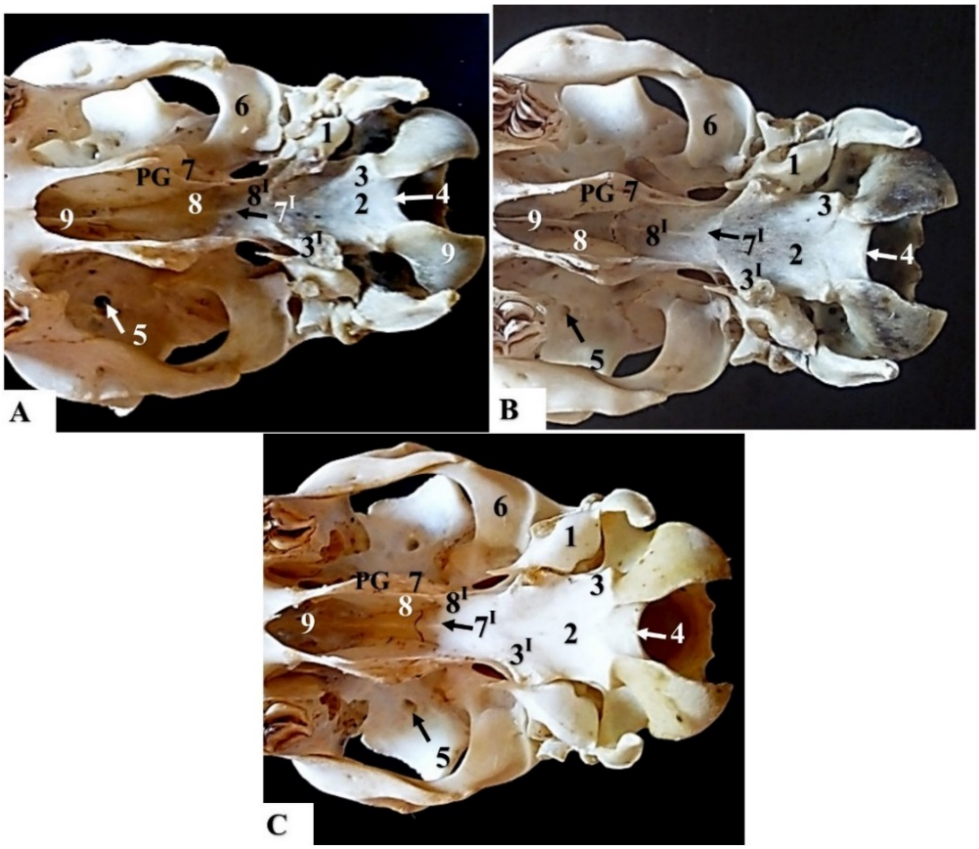


Figure 3- Basal view of the skull in male Balami (A), Uda (B), and Yankasa (C) showing; Pterygoid bone (PG) tympanic bulla (1), basilar part of the occipital (2), caudal muscular tubercles (3), Rostral muscular tubercles (3^{I}), intercondyloid cleft (4), supraorbital canal (5), articular surface (6), pterygoid process of basisphenoid (7), median ridge (7^{I}), presphenoid (8), basisphenoid (8^{I}), and Vomer (9)

Interparietal bone

The interparietal bone in both young and adult and males and females of the three breeds of sheep was absent (Figures 1-2). The. This suggests that the interparietal

bone which was observed at day-old Nigerian breeds of sheep by Atabo (2021) has probably fused completely with the parietal and occipital bones. This agrees with the work of Joshi (2004) who reported that the skull of a tiger has a single median interparietal bone which was completely fused with the occipital and parietal bones. Sisson and Grossman (1975) and Dhingra and Singh (1971) also observed the absence of interparietals in horse and goat respectively. Contrary to these findings, Miller et al. (1964) reported the presence of interparietal in ruminants and dogs, however, the details of their age were not provided.

Frontal bones

In the three breeds of sheep, the frontal bone is the largest of the neurocranial bones that formed the roof of the cranial cavity in the three breeds of sheep, it is paired and roughly pentagonal. The frontal bone is articulated with the nasal bone anteriorly at a ''V'' shaped frontonasal suture and posteriorly with the parietal bone at the parieto-frontal suture. The medial border of the left and right frontal bones is articulated at the interfrontal suture. In the three breeds, the posterior half of the interfrontal suture is serrated and the rostral half is straight. The bone has two parts; the caudal parts and the cranial parts. In all the males of the three breeds of sheep, the caudal part is moderately convex to form a lesser frontal eminence, while the cranial part is roughly flat. In the females of the three breeds, the caudal part is strongly convex to form a prominent/higher frontal eminence, while the cranial part is depressed. The frontal eminence is continuous with the cornual processes in both sexes across the three breeds of sheep, generally, the cornual process is well developed in males than in females and in most cases, it is completely absent in the females. Furthermore, the gross findings also showed that the cornual process is the smallest in the Yankasa and highly developed and largest in the Balami breeds of sheep. The supraorbital foramina were seen on the left and right dorsolateral aspect of the frontal bone, located at an equal distance from the interfrontal suture, approximately 1 cm away from the dorsal margin of the bony orbit in Balami, Uda and, Yankasa. The supraorbital foramina groove is deep in Balami than in Uda and Yankasa breeds of sheep. Accessory supraorbital foramina were seen in both sexes across the three breeds, although it was rare in Balami breeds. Small-sized ethmoid foramina were also observed on the wall of the orbit formed by the frontal bone on both sides of the skull.

The ethmoid foramen was situated in the centre of the orbit in Balami and Uda and ventral/lower end (6 O-clock) in Yankasa. Sarma (2006) reported that the frontal

bone of the skull of Kagani goat of the Jammu Region did not constitute the caudal part of the skull, but rather formed by the parietal bone unlike in other domestic animals, where the frontal bone extended up to the caudal part of the skull. The frontal eminence was present on the median line, in the middle of the frontals. The supraorbital foramina were single on either side, each lying at the dorsolateral aspect of a roughly quadrilateral depression. These foramina were located equidistant from the interfrontal suture, approximately 2 cm away from the dorsal rim of the bony orbit. According to Shawulu et al. (2011), sexual dimorphism was prominent in the concavity of the frontal bones in the Nigerian Sahel goat ecotypes. They also stated that the accentuated longitudinal convexity of the frontal bones between the horns in the male is probable that it corresponds to the location of the cranium and frontal sinuses in the buck. This coupled with the fact that males usually have stronger and larger horns than females (Dyce et. al., 2010) demands that careful consideration should be given to frontal bone morphology in captive-bolt stunning of male goats (Sivachelvan et al., 1995). Shawulu et al. (2011) stated that the ethmoid foramen was completely formed by the frontal bone within the orbit and the occurrence of accessory supraorbital foramina on the dorsofrontal surface of the skull was observed in Bones of the skull in Nigerian goats over 40% of Black and the black and White ecotype skulls, over 70% of Basic White and Basic Brown ecotypes. Such accessory foramina were seen in the Asam goats (Borthakur, 1990), but not reported in Kagani breeds of goat (Sarma, 2006), depicting variation within a species. The accessory foramina open into large foramen in most cases and others into a blind end. The numerous supraorbital and accessory foramina are indications of numerous nerve exits that innervate this region and the robust corneal processes in these ecotypes. This is important in regional anaesthesia and dehorning procedures in these Nigerian breeds of sheep. The architecture, shapes, and sizes of the cornual processes generally revealed breed and sex polymorphism. Clinically, considering the accentuated frontal sinus in the males and the architecture of the corneal processes, the captive-bolt stunning procedures in the goat could be done in between the horns at the back of the head at the position of the inter-parietal and parietal bones unlike that of the cow and pig where it is done on the frontal bone between the eyes (Dyce et al., 2010). Yahaya et al. (2012) reported that the frontal bones of the camel skull were situated on the limits of the cranium and face, between the parietals caudally and the nasal bones rostrally. The frontal bones were wider and join the caudal aspect of the nasal bones to form a nasofrontal suture which lies slightly rostral to the level of the orbit. These bones have a depressed central area that carries at least a pair of supraorbital foramina and two or more accessory

supraorbital foramina at various distances from the midline. The depression is well pronounced in the immature than the mature camels and also wider in the male than the female animals. The interfrontal suture was zigzag and the frontonasal suture appeared serrated and "V" shaped similar to what was reported in the Bardhoka Kosovo breed of (GÜndemir et al., 2020) and Kagani goat (Sarma, 2006). However, according to Dalga et al. (2018) and Karimi et al. (2011) the Western Iranian Mehraban sheep and the Turkish Hemshin breed of sheep skull had a ''U'' shaped frontonasal suture.

Temporal bone

In the three breeds of sheep, the temporal bones were paired and formed part of the lateral wall of the cranial cavity. Each pair consisted of two un-united segments, the squamous and petrous segments. The squamous segment was roughly flattened and larger in Balami and Uda than in the Yankasa, it comprised of a body and a zygomatic process. The body extends dorsally to articulate with the parietal bone in a wave-like fashion, while the zygomatic process of temporal bone extends cranially to form a temporal fossa, articular tubercle, a crest, and articulation with the temporal process of the zygomatic bone. The temporal fossa is deep and extensive in Balami and Uda but shallow and short in Yankasa. The temporal crest was prominent across the three breeds and extends caudolaterally. The petrous temporal bone comprised of the external auditory meatus, internal auditory meatus, tympanic bulla, and mastoid process which were larger in Balami than in Uda and Yankasa. The external auditory meatus protruded from the ventral notch of the squamous temporal bone. The tympanic bulla was oriented caudomedially with a styliform process projecting rostroventrally across the three breeds, but generally, they appeared larger in the males than in females. The mastoid process and foramen were present and appeared larger in Balami than in Uda and Yankasa, furthermore, the mastoid foramen was round in Balami and small and oval in Uda and Yankasa (Figure 2). Breed and sexual polymorphism were observed in findings of the temporal bones of the three Nigerian breeds of sheep.

The temporal bone was a paired bone that formed part of the lateral wall of the cranial cavity similar to Raghavan (1964) in the ox skull. The squamous segment was roughly flattened and perforated, it is larger in Balami and Uda than in the Yankasa, it is comprised of a body and a zygomatic process. The body extends dorsally to articulate with the parietal bone in a wave-like fashion, while the zygomatic process of temporal bone extends cranially to form a temporal fossa, articular tubercle, a crest, and articulation with the temporal process of the zygomatic bone. Choudhary and Singh

(2016) reported that the articular tubercle is absent in Indian Blackbuck (Indian antelope). The perforation seen on the squamous part of temporal bone concurs with that found in the ox and sheep (Sisson and Grossman, 1975). The squamous part of the temporal bone extended less rostral than that of the sheep (Sisson and Grossman, 1975). Raghavan (1964) revealed that in the ox skull, the zygomatic process of the temporal bone did not articulate with the zygomatic process of the frontal bone. Singh (1984) studied gross anatomical studies of the camel skull. He mentioned that there was no articulation between the zygomatic process of the temporal bone and the zygomatic process of the frontal bone. Sisson and Grossman (1975) cited that the zygomatic process of the temporal bone is articulated with the zygomatic process of the frontal bone in the horse. Sisson and Grossman (1975) also stated that in ruminants, the zygomatic process of temporal bone did not articulate with the zygomatic process of the frontal bone. The temporal fossa is deep and extensive in Balami and Uda but shallow and short in Yankasa and the mastoid process was larger in Balami than in Uda and Yankasa. The mastoid foramina were present and appeared larger in Balami than in Uda and Yankasa, furthermore, the mastoid foramen was round in Balami and small and oval in Uda and Yankasa. Karimi et al. (2011) studied the morphology of skulls of adult Mehraban native Iranian breed of sheep and reported that the temporal fossa was shallow and the facial crest was very prominent. Sarma et al. (2001) studied the skull of an adult leopard cat and observed the skull had a shallowed temporal fossa. Choudhary and Singh (2016) reported the mastoid process was absent in the Indian Blackbuck (Indian antelope). The tympanic bulla was oriented caudomedially with a styliform process projecting rostroventrally across the three breeds, but generally, they appeared larger in the males than in females. The tympanic bulla was large and oriented caudomedially, on the other hand, the petrous temporal bone was very small in the skull of the adult Mehraban sheep (Karimi et al., 2011). The petrous part of the temporal bone was relatively small in all ecotypes studied and was entirely within the cerebral cavity similar to the sheep as reported by Sisson and Grossman (1975). The tympanic bulla was compressed with blunt edges seen ventral to the squamous part and rostral to the large jugular processes of the occipital bone as reported by Sisson and Grossman (1975) in the sheep. Contrary to findings by Shawulu et al. (2011) reported that the styliform processes are very small and almost absent in all the Sahelian goat ecotypes.

Ethmoid bone

In the three breeds of sheep, the ethmoid was a single sponge-like bone placed between the nasal and cranial cavity, it was fused caudoventrally with the presphenoid, rostro-ventrally with vomer and palatine, and dorso-rostrally with frontal bones. It consists of four segments, a horizontal part, a vertical part, and two lateral masses. The horizontal part has a net-shaped cribriform plate that forms the anterior (nasal wall) of the cranial cavity, a deep fossa divided into two halves by a median crest (Crista Galli). The Crista Galli was thicker in Balami than Uda and very thin and sometimes rudimentary in Yankasa. The vertical part is the median perpendicular plate that forms part of the nasal septum. The two lateral masses were the labyrinths at the left and right sides of the bone. The ethmoid was a single sponge-like bone placed between the nasal and cranial cavity, it was fused caudoventrally with the presphenoid, rostro-ventrally with vomer and palatine, and dorso-rostrally with frontal bones similar to the report of Kumar (2017). The breed polymorphism observed in the Crista Galli agrees with the work of Shawulu et al. (2011) who mentioned that the Crista Galli of the ethmoid of the Sahel goat showed some size differences between ecotypes being thick and large in the Basic White ecotype, but are relatively thin in the Black and White ecotypes. According to Shawulu et al. (2011), the size of the cribriform plate in all Sahel goat ecotypes was most likely a direct correlation with the morphology and size of the olfactory bulbs. Hence, this means that the size of the olfactory region is directly related to the degree of development of the sense of smell which varies among species.

Table 1: Some comparison of the neurocranial bones in the three breeds of sheep

BONE	BALAMI	UDA	YANKASA
Parietal bone	Paired in the young and fused in the adult	Paired in the young and fused in the adult	Paired in the young & fused in the adult
Occipital bone	The occipital squama is extensive	The occipital squama is extensive	The occipital squama is less extensive
	The median crest is well developed in female Balami and Uda, but rudimentary in their males	The median crest is well developed in female Balami and Uda	The median crest is absent in male and female Yankasa.
	The external occipital protuberance was very prominent in males than in females	The external occipital protuberance was very prominent in males than in females	The external occipital protuberance was smaller in both sexes
	The nuchal line/crest was prominent in both sexes in Balami	The nuchal line is prominent in females and rudimentary in males	They were rudimentary in both sexes
	The muscular tubercle is well developed and curved medially in females and poorly developed in males	the tubercles were prominent in males and poorly developed in females.	The male and female Yankasa breeds both had a rudimentary muscular tubercle
Interparietal bone	Absent	Absent	Absent
Frontal bones	The supraorbital foramina groove is deep	Shallow	Shallow
	Rare	Consistent	Consistent
Temporal bone	The temporal fossa is deep and extensive in Balami and Uda	The temporal fossa is deep and extensive in Balami and Uda	shallow and short in Yankasa
	The mastoid foramen was round	small and oval in Uda	small and oval
Ethmoid bone	The Crista Galli was thickest	Less thickness	very thin and sometimes rudimentary

CONCLUSIONS

The gross craniomorphological studies of the postnatal skull showed that the face of the skull is triangular with a strongly convexed face in Balami than in Uda and a flat face in Yankasa. This could be responsible for the brachycephalic (short-headed) in the Balami and mesocephalic (medium-headed) in the Uda heads reported by (Popoola and Oseni, 2018). The pentagonal-shaped skull in camels reported by Yahaya et al. (2012) disagrees with our findings. The phenotypic appearance of the heads in animals depends strongly on the shape of the skull and the skull has also been used as a skeletal structure to determine taxonomic affiliations as it is subject to phenotypic changes because of selective breeding (Kunzel et al., 2014). The bones of the neurocranium showed dimorphic and polymorphic variations with sex differences among the three breeds.

RECOMMENDATION

Due to the presence of the interparietal suture in the young Nigerian breeds of sheep, we recommend that surgeons should avoid midline craniotomy incision since it could affect the normal fusion and conformation of the bone and or neurocranium after healing. Similarly, mechanical methods of stunning especially the use of captive bolt pistols in the young Nigerian breeds of sheep should also be avoided.

ETHICAL APPROVAL

This study was approved by the Institutional Animal Care and Use Committee of Usmanu Danfodiyo University Sokoto with reference no. UDUS/FAREC/2019/AUP-RO-17

REFERENCES

ARCHANA, S.; SUDHAKAR, L.S.; SHARMA, D.N. Anatomy of the parietal and interparietal bones of yak (Bos grunniens). Indian Journal Veterinary Anatomy, v10, n.1/2, p.26-30, 1998.

ATABO, S.M. Developmental comparative anatomy of the skull bones of Nigerian breeds of sheep (Ovis aries). 2021. Thesis (Ph.D. in Veterinary Anatomy) - Postgraduate Course in Veterinary Anatomy, Usmanu Danfodiyo University Sokoto, Nigeria.

BORTHAKUR, S. Post-natal study on the skull of Assam goat (Capra hircus) with an emphasis on sexual dimorphism. 1990. Thesis (Ph.D. in Veterinary Anatomy) - Postgraduate Course in Veterinary Anatomy, Assam Agricultural University, Guwahati, India,

CHOUDHARY, P.; SINGH, I. Morphological and radiographic studies on the skull of Indian blackbuck (Antilope cervicapra). International Journal of Morphology v.34, p.775-783, 2016.

DALGA, S.; ASLAN, K.; AKBULUT, Y. A Morphometrıc study on the skull of the Hemshin sheep. Van Veterinary Journal, v.29, n.3, p.125–129, 2018.

DHINGRA, L.D.; SINGH, Y. The interparietals of the goat. Journal of Research, v.1, n.4, p.90-92, 1971.

DYCE, K.M.; SACK, W.O.; WENSING, C.J.G. Textbook of Veterinary anatomy 4th edition Saunders Elsevier Inc. 3251 Riverport Lane St. Louis, Missouri 63043, 2010, p.644, 728-742.

Food and Agriculture Organization (FAO). Global Plan of Action for Animal Genetic Resources and Interlaken Declaration on Animal Genetic Resources, Rome, Italy, 2007.

GÜNDEMIR, O.; DURO, S.; JASHARI, T.; et al. A study on morphology and morphometric parameters on skull of the Bardhoka autochthonous sheep breed in Kosovo. Anatomia Histologia Embryologia, v.00: p.1-7, 2020.

JOSHI, H. "Gross anatomical studies of the skull of Indian tiger (Panthera tigris)." A Thesis submitted to College of Veterinary and Animal Science, RAU, Bikaner, 2004.

KALITA, P.C.; KALITA, H.C.; Anatomy of the skull of a Sloth bear (Melursus ursinus). XVIII IAVA Convention Souvenir and Abstracts, 26-28th December 2003. Gujarat Agricultural University, Anand Campus, Anand, 2003.

KARIMI, I.; HADIPOUR, M.; NIKBAKHT, P.; et al. 2012. The Lower Jawbone of Mehraban Sheep: A descriptive morphometric approach. World's Veterinary Journal, v.2, n.4, p.57-60.

KATABA, A. Biometric and Morphologic Characteristics of the Skull of the Gwembe Valley Dwarf Goat (Capra Hircus) Breed of Zambia. 2014. Dissertation (Master of Science in Veterinary Anatomy and Physiology) - Postgraduate Course in Veterinary Anatomy and Physiology, Biomedical Sciences Department, University of Zambia,

KHATRA, G.S. Anatomy of os occipitale of buffalo (Bubalus bubalis). Journal of Punjab Agricultural University v.16, n.2, p.242-245, 1979.

KUMAR, V. Gross Anatomical Studies on the Bones of Skull in Blue Bull (Boselaphus tragocamelus). 2017. Dissertation (Master of Science in Veterinary Anatomy and Histology) - Postgraduate Course in Veterinary Anatomy and Physiology, Rajasthan University of Veterinary and Animal Sciences, India,

KUNZEL, W.; BREIT, S.; OPPEL, M.; Morphometric investigations of breed specific features in feline skulls and considerations on their functional implications. Anatomia Histologia Embryoligia, v.32, n.4, p.218-23, 2014.

MILLER, M.S.; CHRISTENSEN, G.C.; EVANS, H.E. The skeletal system, skull; the respiratory system, Nasal cavity. In: Anatomy of Dog. W.B. Saunders Co., Philadelphia, p.6-49, 716-718, 1964.

OLOPADE, J.O. Morphometric analysis of the skull of three breeds of goats in Nigeria. 2006. Thesis (Ph.D. in Veterinary Anatomy) – Postgraduate Course in Veterinary Anatomy, University of Ibadan, Ibadan, Nigeria,

POPOOLA, M.A.; OSENI, S.O. Multifactorial Discriminant Analysis of Cephalic Morphology of Indigenous Breeds of Sheep in Nigeria. Slovak Journal of Animal Science, v.51, n.2 p.45–51, 2018.

POURLIS, A.; KATSOULOS, P.; CHATZIS, T. H. Metrical data of metapodial bones in female Karagouniko sheep and Hellenic goat. Revue de médecine vétérinaire, v.168, p.10-12, 2017.

RAGHAVAN, D. The skull, Nasal cavity. In: Anatomy of the ox, horse, and dog. Indian Council of Agricultural Research, New Delhi, 1964, p.49-94, 385-388.

RODRIGO, B.; CARVAJALA, A.M.; MARTÍNEZB, M.E.; Variability of cranial morphometrical traits in Suffolk Down Sheep. Australian Journal of Veterinary Science, v.52, p.25-31, 2020.

SARMA, K. Morphological and Craniometrical studies of the skull of Kagani Goats (Capra hircus) from the Jammu region. International Journal of Morphology, v.24 n.3, p.449-455, 2006.

SARMA, K., SARMA, M. Anatomy of the skull of dum pig of Assam. Indian Veterinary Journal, v.79, n.7, p.708-711, 2002.

SARMA, K.; NASHIVUDDULLAH, N.; ISLAM. S. Anatomy of the skull of a leopard cat (Felisbengalensis). Indian Journal of Animal Science, v.71, n.11, p.1011- 1013, 2001.

SARMA, K.; SUR, S.; KALITA, A. Gross anatomical studies on the skull of local sheep of Jammu region. Indian Journal of Animal Sciences, v.77, n.10: p999-1001, 2007.

SHAWULU, J.C.; KWARI, H.D.; Olopade, J.O. Morphology of the Bones of the Skull in the Sahel Ecotypes of Goats (Capra hircus) in Nigeria. Journal of Veterinary Anatomy, v.4, n.2, p.1-13, 2011.

SINGH, P. Gross Anatomical Studies on the Skull of Camel (Camelus dromedarius). 1984. Dissertation (Master in Veterinary Science) – Postgraduate Course in Veterinary Sciences, Hisar, Haryana Agriculture University,

SINGH, J.; PATEL, M. R. The osteology of skull of goat. Indian Journal of Veterinary Science Animal Husbandry, v.8, p80-90, 1984.

SISSON, S.; GROSSMAN, J.D. Ruminant osteology, anatomy of the domestic animals. Getty R. 5th ed. W.B. Sounder's Co., Philadelphia. 1975, p.762-774, 778-786.

SIVACHELVAN, M.N., HAJARA, B.U.; CHIBUZOR, G.A. Fetal development of the calvarium in Sahel goat: its post-natal significance. Tropical Veterinarian, v.13, n.3, p.109-118, 1995.

SUSAN, S. "Gray's Anatomy E-Book: The Anatomical Basis of Clinical Practice". Elsevier Health Sciences. 2015. p.150.

YAHAYA, A.; OLOPADE, J.O.; KWARI, H.D. et al. Osteometry of the skull of one-humped camels. Part I: immature animals. International Journal of Agricultural Economics, v.117, p23-33, 2012.