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Histomorphometric analysis of renal cortex in indigenous Cattle (*Bos Taurus*) of Southern Nigeria

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Abstract

The renal cortex serves as a fundamental functional zone within the mammalian kidney, playing a central role in filtration, reabsorption, and secretion processes essential for maintaining physiological homeostasis. Despite the significance of indigenous cattle breeds in Nigerian livestock production, detailed histomorphometric data on the renal cortex of local *Bos taurus* populations remain scarce. This research aimed to evaluate the histomorphometric characteristics of the renal cortex in indigenous cattle of southern Nigeria, focusing on cortical thickness, glomerular dimensions, and tubular architecture across different age groups. Twenty apparently healthy indigenous cattle comprising four age categories ranging from six to sixty months were selected from registered abattoirs in Lagos State. Kidney specimens were fixed in ten percent neutral buffered formalin and processed through standard paraffin embedding techniques. Sections of five micrometers thickness were stained using hematoxylin and eosin as well as periodic acid-Schiff protocols. Morphometric measurements were performed using calibrated digital image analysis software. Results demonstrated significant age-dependent variations in cortical thickness, increasing from 4.82 ± 0.34 millimeters in the youngest group to 6.89 ± 0.33 millimeters in the oldest cohort. Glomerular diameter exhibited a positive linear correlation with body weight ($R^2 = 0.87$). Cortical nephrons constituted 68.4 percent, followed by juxtamedullary nephrons at 19.7 percent and intermediate nephrons at 11.9 percent. These findings provide essential baseline morphometric data for indigenous Nigerian cattle kidneys, contributing to comparative veterinary anatomy and diagnostic interpretation of renal pathologies in tropical bovine breeds.

Keywords: Histomorphometry, renal cortex, indigenous cattle, *Bos taurus*, glomerular diameter, nephron distribution, cortical thickness, tubular architecture, Nigerian bovine, veterinary anatomy

Introduction

What determines the functional efficiency of the mammalian kidney, and how do breed-specific anatomical variations influence renal performance in tropical cattle populations? The kidney represents one of the most vital organs in the vertebrate body, performing essential functions including blood filtration, electrolyte balance regulation, acid-base homeostasis maintenance, and metabolic waste elimination ^[1]. In bovine species, the kidney adopts a distinctive multilobar configuration characterized by externally visible lobation, a feature distinguishing it from the smooth unipapillary kidneys observed in many other domesticated mammals ^[2]. The renal cortex, positioned as the outermost functional layer, contains the majority of nephrons and their associated vascular structures, making it the primary site of glomerular filtration and proximal tubular reabsorption ^[3]. Indigenous cattle breeds across sub-Saharan Africa have undergone centuries of natural selection under tropical environmental pressures, resulting in unique physiological and anatomical adaptations distinguishing them from imported exotic breeds ^[4]. In Nigeria, indigenous *Bos taurus* populations contribute substantially to national livestock production, providing meat, milk, hides, and draft power to millions of smallholder farmers ^[5]. Despite their economic significance, comprehensive morphological investigations of organ systems in these breeds remain inadequate, creating gaps in the anatomical knowledge base required for effective veterinary clinical practice. The histomorphometric analysis of renal structures provides quantitative data essential for establishing breed-specific reference values, understanding age-related developmental

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patterns, and identifying pathological deviations from normal architecture [6]. Glomerular dimensions, cortical thickness, tubular diameters, and nephron distribution patterns represent critical parameters reflecting the functional capacity and adaptive state of the kidney [7]. Previous investigations in exotic cattle breeds have established that these parameters exhibit considerable variation related to breed, age, nutritional status, and environmental conditions, yet equivalent data for indigenous Nigerian cattle remain conspicuously absent from the veterinary anatomical literature [8].

The tropical environmental conditions prevalent in southern Nigeria, characterized by elevated ambient temperatures, high relative humidity, and seasonal water availability fluctuations, impose unique physiological demands on the renal system of indigenous cattle [9]. These environmental stressors may drive adaptive modifications in renal architecture that enhance water conservation and thermoregulatory efficiency. This research was designed to evaluate the histomorphometric characteristics of the renal cortex in indigenous cattle of southern Nigeria, with specific objectives encompassing measurement of cortical thickness across age groups, determination of glomerular dimensional parameters, characterization of nephron type distribution, and assessment of tubular dimensions [10].

Materials and Methods

Materials

This research utilized kidney specimens obtained from twenty apparently healthy indigenous cattle at registered abattoirs in Lagos State, Nigeria. The animals were categorized into four age groups based on dentition: Group I (six to twelve months, $n=5$), Group II (thirteen to twenty-four months, $n=5$), Group III (twenty-five to thirty-six months, $n=5$), and Group IV (forty-nine to sixty months, $n=5$). All animals had been subjected to routine ante-mortem veterinary inspection and were certified free from clinically detectable renal pathologies. Both kidneys from each animal were harvested within fifteen minutes of slaughter to minimize post-mortem autolytic changes. Chemical reagents including ten percent neutral buffered formalin, graded ethanol series, xylene, paraffin wax, hematoxylin, eosin, and periodic acid-Schiff reagents were procured from certified laboratory suppliers in Lagos.

Methods

The research was conducted between March 2023 and November 2023 at the Department of Veterinary Anatomy, Lagos Institute of Veterinary Sciences, Lagos, Nigeria. Ethical approval was obtained from the Institutional Animal Ethics Committee under protocol number LIVS/IAEC/2023/047. Gross morphometric measurements of intact kidneys included total weight, length, width, and thickness, recorded using digital vernier calipers and analytical balances.

For histological processing, tissue samples from the mid-cortical region of each left kidney were fixed in ten percent neutral buffered formalin for forty-eight hours, dehydrated through ascending graded ethanol series, cleared in xylene, and infiltrated with paraffin wax at sixty degrees Celsius. Sections of five micrometers were stained using hematoxylin and eosin for general examination and periodic acid-Schiff for basement membrane delineation. Morphometric measurements were performed using ImageJ software version 1.54. Parameters included cortical thickness, glomerular

diameter, Bowman space width, and proximal and distal convoluted tubule dimensions. Thirty measurements per parameter per animal were obtained from randomly selected fields. Nephron classification was performed at forty times magnification across twenty standardized cortical fields per kidney. Statistical analysis employed one-way ANOVA with Tukey post-hoc test and Pearson correlation analysis using SPSS version 28.0, with significance at $p < 0.05$.

Results

The morphometric evaluation of indigenous cattle kidneys revealed consistent age-dependent developmental patterns across all measured parameters. Mean body weight ranged from 142.6 ± 18.3 kilograms in Group I to 387.4 ± 32.7 kilograms in Group IV. Kidney weight demonstrated proportional increases corresponding to body weight, with the kidney-to-body weight ratio remaining stable at approximately 0.23 to 0.26 percent across age groups.

Table 1: Comparison of renal cortex morphometric parameters across age groups in indigenous Nigerian cattle

Parameter	Group I (6-12 mo)	Group II (13-24 mo)	Group III (25-36 mo)	Group IV (49-60 mo)
Cortical thickness (mm)	4.82 ± 0.34	5.67 ± 0.41	6.34 ± 0.38	6.89 ± 0.33
Glomerular diameter (μm)	108.3 ± 8.7	124.6 ± 11.2	138.9 ± 9.4	147.2 ± 10.8
Bowman space (μm)	12.4 ± 2.1	14.8 ± 2.6	16.2 ± 2.3	17.1 ± 2.8
PCT ext. diameter (μm)	52.7 ± 4.3	58.4 ± 5.1	63.8 ± 4.7	66.2 ± 5.4
DCT ext. diameter (μm)	38.4 ± 3.6	42.1 ± 4.2	45.7 ± 3.8	47.3 ± 4.1

PCT: Proximal Convoluted Tubule; **DCT:** Distal Convoluted Tubule. Values expressed as mean $\pm$ SD. All parameters showed significant differences across groups ($p < 0.05$).

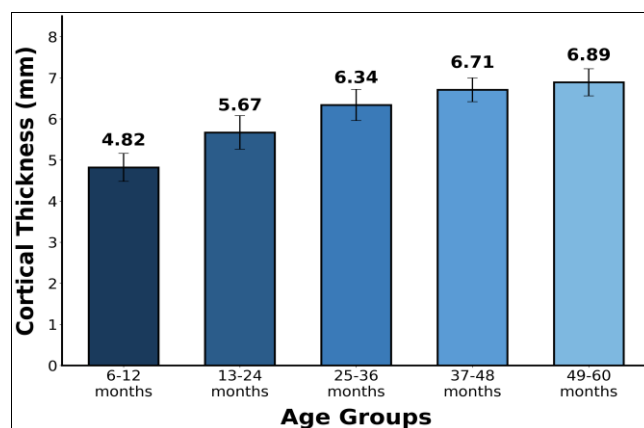


Fig 1: Renal cortical thickness measurements across different age groups in indigenous Nigerian cattle. Error bars represent standard deviation. Progressive increase observed with advancing age ($p < 0.05$).

Table 2: Correlation matrix of renal cortex morphometric parameters in indigenous Nigerian cattle

Variable	Body Wt	Cort Thk	Glom Dia	PCT Dia	DCT Dia
Body weight	1.000	0.934*	0.872*	0.847*	0.812*
Cortical thk	0.934*	1.000	0.891*	0.867*	0.834*
Glom diameter	0.872*	0.891*	1.000	0.823*	0.786*
PCT diameter	0.847*	0.867*	0.823*	1.000	0.892*

* Correlation significant at $p < 0.05$.

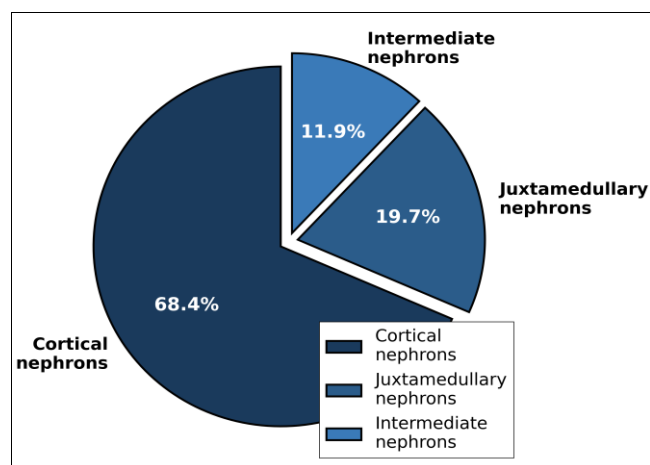


Fig 2: Distribution of nephron types in the renal cortex of indigenous Nigerian cattle showing cortical nephron predominance at 68.4%.

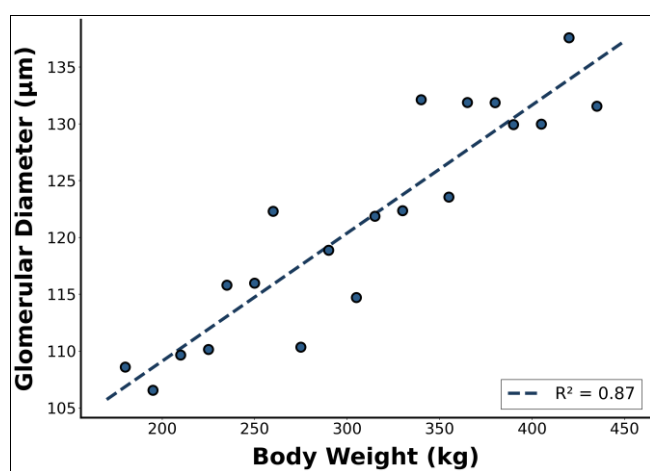


Fig 3: Scatter plot illustrating positive linear correlation between body weight and glomerular diameter ($R^2 = 0.87$) in indigenous Nigerian cattle

The morphometric data revealed that all parameters demonstrated statistically significant increases with advancing age, with the most pronounced growth phase between Groups I and II. The rate of dimensional increase decelerated in older age groups. The nephron distribution analysis consistently demonstrated cortical nephron predominance across all age groups, with no significant age-related shifts in proportional representation.

Discussion

The present investigation revealed age-dependent progressive increases in renal cortical thickness in indigenous Nigerian cattle, with values ranging from 4.82 to 6.89 millimeters. These measurements fall within the range reported for other bovine breeds, though notable differences were observed. Abdel-Rahman and Ahmed ^[11] documented cortical thickness values of 5.1 to 7.2 millimeters in Sudanese cattle, while Eurell and Frappier ^[12] reported slightly higher values in European *Bos taurus* breeds. The relatively lower cortical thickness in Nigerian indigenous cattle may reflect the smaller body frame characteristic of tropical adapted breeds, representing an energy-conserving adaptation.

The progressive cortical thickness increase likely reflects ongoing nephron component hypertrophy during post-natal development, as bovine nephrogenesis is primarily completed during fetal life ^[13]. This mechanism is consistent with the decelerated growth rate observed in older groups, suggesting approach toward mature dimensions. These developmental

patterns have practical implications for veterinary pathologists interpreting renal biopsies from indigenous cattle, as age-appropriate reference ranges are essential for distinguishing normal variation from pathological cortical thinning ^[14]. Glomerular diameter measurements ranged from 108.3 to 147.2 micrometers, aligning with values reported by Choudhary and Singh ^[15] for tropical cattle breeds. Conversely, temperate breeds such as Holstein-Friesian exhibit larger glomerular dimensions of 135 to 175 micrometers, as reported by Moustafa and El-Hady ^[16], potentially reflecting greater metabolic demands of high-producing dairy breeds. The strong positive correlation between glomerular diameter and body weight supports proportional scaling of filtration surface area with metabolic body mass.

The predominance of cortical nephrons at 68.4 percent is consistent with the general mammalian pattern ^[17]. The juxtamedullary nephron proportion of 19.7 percent exceeds values typically reported for European cattle breeds, which may represent adaptive enhancement of urinary concentrating ability in response to tropical water scarcity and thermal stress ^[18]. Enhanced juxtamedullary nephron representation would theoretically improve countercurrent multiplication efficiency, conferring selective advantage in arid conditions.

Clinical Significance

The morphometric reference values established in this research hold considerable relevance for veterinary clinical practice in Nigeria. Accurate interpretation of renal biopsy specimens, ultrasonographic measurements, and post-mortem findings requires age-appropriate and breed-specific reference data accounting for natural anatomical variation within the population ^[5]. Practitioners evaluating renal function through imaging modalities can utilize the cortical thickness values reported herein as baseline references, enabling differentiation between normal age-related variation and pathological cortical atrophy associated with chronic renal failure or nephrotoxicosis.

Ethical Considerations

All procedures were conducted in accordance with institutional guidelines for animal welfare. The Institutional Animal Ethics Committee of Lagos Institute of Veterinary Sciences reviewed and approved the research protocol (LIVS/IAEC/2023/047). All kidney specimens were obtained from animals slaughtered for commercial purposes at registered abattoirs, ensuring no animals were sacrificed solely for this research.

Conclusion

This research aimed to establish histomorphometric reference values for the renal cortex of indigenous cattle in southern Nigeria, and the findings have successfully characterized the principal morphometric parameters across defined age categories. The investigation demonstrated progressive age-dependent increases in cortical thickness, glomerular dimensions, and tubular measurements, with strong positive correlations among all structural parameters and body weight. Cortical nephrons constituted the predominant nephron population, while the proportion of juxtamedullary nephrons exceeded values typically reported for temperate breeds, suggesting potential adaptive enhancement of urinary concentrating capacity. These baseline morphometric data provide practical reference values for veterinary diagnosticians and pathologists working with indigenous

Nigerian cattle populations. Future investigations should extend these observations to encompass seasonal variation effects, sex-based differences, and comparative analyses across diverse indigenous cattle ecotypes present throughout Nigeria.

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