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Original Research Article

COMPARISON OF THE ULTRASONOGRAPHIC TESTICULAR BLOOD FLOW IN THE RED SOKOTO AND KANO BROWN BUCKS

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ABSTRACT

The study was designed to compare the ultrasonograhic testicular blood flow of Red Sokoto and Kano Brown bucks of varying ages. Sixteen adult bucks comprising eight Red Sokoto and eight Kano Brown bucks with ages of one and three years for both breeds were grouped into four according to age and breed. Doppler ultrasonography was performed once weekly to obtain the haemodynamics (EDV, PSV, RI AND PI) of the testicular artery. Spectral Doppler measurement of the testicular artery demonstrated a monophasic and non-resistive waveforms pattern of blood flow indices similar for both testes, there were no breed differences in one year old Red Sokoto and Kano Brown bucks, but pronounced breed divergence emerges in 3 years old Red Sokoto and Kano Brown bucks, alongside age-dependent changes that vary by breed. The adult bucks showed average resistive index (RI) and Pulsatility index (PI) of 0.768 and 1.272 for Red Sokoto bucks and 0.867 and 1.537 for Kano Brown bucks respectively.

Keywords: Doppler ultrasonography, Kano Brown buck, Red Sokoto buck, Spectral Doppler, Testicular blood flow

INTRODUCTION

Small ruminants are important genetic resources and also play a predominant role in the sustenance of the livelihoods of impoverished families especially in the rural areas of tropical countries. Caprine species specifically goats play an important role in the social life of many Africans and supply human population with meat, milk, skin, manure and other products. The most important animal genetic resources in Nigeria include; poultry, goats, sheep, cattle and swine, with population figures of 305milliom, 84.5million, 48.7 million, 20.6 million and 8.9 million respectively (Rekwot *et al*., 2022).

Ultrasonography is non-invasive and provides the dimensions of the testicular parenchyma (length, width, height) in situ exclusive of any other tissues, some of the reasons that it has been promoted for assessment of dogs, boars and bulls (Pugh *et al*., 1990). Imaging is a very accurate tool for the identification of diseases in patients suspected of reproductive tract disorders. B mode ultrasonography allows for a detailed assessment of the inner structure whereas Doppler ultrasonography accurately characterizes the nature of blood flow and organ vasculature (Wojciech *et al*., 2020). Ultrasonographic doppler imaging is widely used as trans-abdominal and trans-rectal diagnostic imaging (Rubens *et al*., 2006) owing to its several advantages as a safe, non- invasive method to evaluate testicular parenchyma in rams (Camela *et al*., 2019) In men, diagnostic ultrasound has been used for the diagnosis of several types of testicular and epididymal lesions viz: occult neoplasms (Hendry *et al*., 1984), cystic lesions (Leung *et al*., 1984), epididymitis (Yin & Trainor, 2009) and orchitis (Bird & Rosenfield, 1984). It is also helpful to aid diagnosis in testicular torsion, cryptorchidism, scrotal hernia, varicocoele and follow-up of testicular microlithiasis (Karmazyn, 2010). In animal reproduction, it is almost exclusively used in the female for

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early pregnancy diagnosis (Anwar *et al*., 2008), monitoring morphological and physiological changes of the ovaries and tubular genital tract, and for the diagnosis of pathological lesions of these organs (Hinkeldey & Hopkins, 1996). Diagnostic ultrasound seems to be the best technique for the evaluation of scrotal contents, which are ideally suited for this type of examination because of their general superficial location. It is very useful in confirming the presence or absence of a mass, as the homogeneous echo pattern of the normal testis serves as a good background for the detection of small intratesticular focal lesions; the size of which can also be measured accurately. In many cases, it can give a specific diagnosis and it is also possible to differentiate between solid and cystic enlargements.

Triplex Doppler Ultrasound involves the simultaneous use of two-dimensional ultrasound, colour Doppler and pulsed Doppler, which allows the gathering of anatomical data of the vessels and functional data regarding blood flow, including its presence or absence, direction and speed, and is the method of choice for assessing the vascularity of various organs, including the testes (Souza *et al*., 2014).

The use of Doppler in Human Medicine for the evaluation of testicular perfusion is already well established (Dubinsky *et al*. 1998). In humans, it is used mainly for the diagnosis of diseases, including testicular torsion and varicocele (Schurich *et al*., 2009) and also to assist in the diagnosis of obstructive and non-obstructive azoospermia, which may reflect infertility problems (Foresta *et al*., 1998).

STUDY AREA

The study was carried out in Zaria, a town in Kaduna State, situated in North-western Nigeria, with the geographical coordinates of 110 4′ 0″ North and 70 42′ 0″ East (Anonymous, 2005). It has a total population of 408,198 based on the 2006 census (Anonymous, 2010).

ETHICAL APPROVAL

The Ahmadu Bello University committee for Animal use and care (ABUCAUC) provided ethical approval for this study with reference number: ABUCAUC/2024/041

EXPERIMENTAL ANIMALS

Sixteen (16) apparently healthy adult bucks consisting of 8 Red Sokoto and 8 Kano Brown bucks ranging from 1 – 3years were sourced locally from Makarfi market and transported to the Small ruminant's pen of the National Animal Production and Research Institute (NAPRI), Ahmadu Bello University Zaria, where they were kept for the duration of the research.

The animals were acclimatized for two (2) weeks during which general clinical examination was carried out on each of them. They were screened and treated against endo- and ecto- parasites during this period, the circulatory system of all the bucks were checked to get rid of bucks suffering from any cardiovascular problem that can influence the testicular blood flow measurements. Selected bucks showed normal ranges of pulse rate (60-90 beats/minutes) and capillary refilling time of (1-2 seconds) during the whole length of the study period (Pugh & Bairds, 2012) and were also vaccinated against commonly vaccine preventable diseases such as Peste des Petits Ruminants (PPR), Tetanus, and Orf). Feed and water were provided ad libitum.

EXPERIMENTAL DESIGN

The animals were grouped into four groups of varying breeds and ages, viz:

GROUP 1: Four (4) one year old Red Sokoto bucks with a mean live weight of 9.33Kg

GROUP 2: Four (4) one year old Kano Brown bucks with a mean live weight of 10.00Kg

GROUP 3: Four (4) three years old Red Sokoto bucks with a mean live weight of 16.83Kg

GROUP 4: Four (4) three years old Kano Brown bucks with a mean live weight of 16.67Kg

Age and body Measurements

Live body parameters such as age, body condition score (BCS), live weight (LW, Kg), and scrotal circumference (SC, cm) of each animal were examined and recorded. Body condition score was evaluated as per the method described by Okere *et al*., (2011). The scores ranged from 1 = emaciated, 2 = thin, 3 = ideal 4 = over weight to 5 = obese. The live weight (LW; kg) of each animal was measured using a portable balance and recorded in kilograms. Scrotal circumference (SC) was measured according to the method of Goyal and Memon (2007) using non-stretchable measuring tape.

ULTRASONOGRAPHIC MEASUREMENTS OF TESTICULAR ARTERY

Doppler ultrasound Scans using B mode color Doppler ultrasound was performed once a week throughout the period of the study to visualize the testicular artery in the region of the spermatic cord, and the procedure was repeated three (3) times to visualize the testicular artery in the marginal and intratesticular regions of the right and left testes for the Doppler velocimetry evaluation of the testicular artery (Souza *et al*. 2014). After locating the testicular artery, the evaluation was performed using pulsed Doppler, and the calliper positioned in the lumen of the vessel, assessing the graphical representation, as a

waveform, of the arterial blood flow. The 3 best waves of a cardiac cycle were measured to evaluate the following Doppler velocimetry parameters: peak systolic velocity (PSV), end diastolic velocity (EDV), resistance index (RI) and pulsatility index (PI). The angle of insonation used was (under 60o) and the same operator performed each examination. The colour gain was adjusted to reduce the excess of colour noise to observe slower blood flows.

Table I: Doppler indices Comparison between three years old Red Sokoto bucks and three years old Kano Brown bucks

Variable	t(df=10)	p-value	Mean (3 years old RSB)	Mean (3 years old KBB)	95% CI for Difference	Key Finding
PSV	-5.73	0.0002	12.63 cm/s	16.35 cm/s	-7.43 to -3.27	Significant: Higher PSV in Kano Brown (faster systolic flow).
EDV	1.15	0.277	2.92 cm/s	2.18 cm/s	-0.17 to 0.54	Non-significant: Similar diastolic flow.
RI	-4.06	0.0023	0.763 cm/s	0.867 cm/s	-0.152 to -0.044	Significant: Higher RI in Kano Brown (greater resistance).
PI	-4.14	0.0020	1.285 cm/s	1.537	-0.408 to -0.122	Significant: Higher PI in Kano Brown (greater pulsatility).

MANOVA Result: Pillai's trace = 0.995, F(4,7) = 353.25, p < 0.001 (highly significant).
Post-Hoc t-Tests (Bonferroni-adjusted p < 0.0125):
Key: PSV: Peak systolic velocity, EDV: End Diastolic Velocity, RI: Resistive index, PI: Pulsatility index

DATA ANALYSIS

The data collected were subjected to descriptive statistic and presented as mean and standard deviation. Comparison between the different ages and breeds of the bucks were performed using multivariance analysis of variance (Manova test) after verification of normality using Spiro-wilk test. Pearson correlation was established for the variables (RI, PI, EDV PSV, Volume and Motility). The value was considered statistically significant when P value is less than 0.05

RESULTS

Doppler indices Comparison between three years old Red Sokoto bucks and three years old Kano Brown bucks

The three year old Kano brown bucks (Group IV) exhibit markedly higher mean systolic velocities PSV of 16.3cn/s than the Red Sokoto bucks (Group III) which showed PSV of 12.63cm/s. Also the three year old Kano Brown bucks (Group IV) showed elevated vascular resistance with mean resistance index (RI) of 0.867cm/s and pulsatility (PI) of 1.537 (Figure I). While the three year old Red Sokoto bucks (Group III) showed a lower vascular resistance with a resistive index of (RI) of 0.763cm/s and pulsatility index (PI) of 1.285cm/s (Figure II). The comparison of the three year old Kano Brown and Red Sokoto bucks showed a P-value of 0.002, 0.277, 0.0023 and 0.0020 for PSV, EDV, RI and PI respectively (Table I).

Doppler indices Comparison between on year old Red Sokoto bucks and three years old Red Sokoto bucks

The comparison between Ages 1 and 3 years showed a modest multivariate shift in Red Sokoto bucks, but no univariate differences survive Bonferroni correction. The marginal EDV reduction suggests subtle age-related declines in diastolic flow. The one year old Red Sokoto bucks (Group I) showed a mean PSV of 11.00cm/s, Resistive index (RI) 0.768cm/s, Pulsatility index (PI) 1.272 (Figure II) while the three year old Red Sokoto bucks (group III) showed a PSV of 12.63cm/s, Resistive index (RI) 0.763cm/s, Pulsatility index (PI) 1.285cm/s (Figure II) with a P-value of 0.153, 0.859 and 0.883 for PSV, RI and PI respectively, indicating stable downstream resistance (Table II).

Table II: Doppler indices Comparison between on year old Red Sokoto bucks and three years old Red Sokoto bucks

Variable	t(df=10)	p-value	Mean (1 year old RSB)	Mean (3 years old RSB)	95% CI for Difference	Key Finding
PSV	1.55	0.153	11.00 cm/s	12.63 cm/s	-0.72 to 3.98	Non-significant: Slight PSV decline with age.
EDV	2.51	0.031	2.37 cm/s	2.92 cm/s	0.06 to 1.04	Non-significant (marginal): Lower EDV in large bucks.
RI	-0.18	0.859	0.768 cm/s	0.763 cm/s	-0.066 to 0.056	Non-significant: Stable RI.
PI	0.15	0.883	1.272 cm/s	1.285 cm/s	-0.183 to 0.209	Non-significant: Stable PI.

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MANOVA Result: Pillai's trace = 0.707, F(4,7) = 4.223, p = 0.047 (significant at p < 0.05).
Post-Hoc t-Tests (Bonferroni-adjusted p < 0.0125):
Key: PSV: Peak systolic velocity, EDV: End Diastolic Velocity, RI: Resistive index, PI: Pulsatility index

DOPPLER INDICES COMPARISON BETWEEN ONE YEARS OLD KANO BROWN BUCKS AND THREE YEARS OLD KANO BROWN BUCKS

The comparison between Ages 1 and 3 years showed aging significantly altered testicular hemodynamics in Kano Brown bucks. The one year old Kano Brown bucks (Group II) showed mean Peak systolic velocity (PSV) 13.23cm/s, mean End diastolic velocity (EDV) 2.5cm/s, Resistive index (RI) 0.790cm/s, and Pulsatility index (PI) 1.315cm/s while the three years old Kano Brown bucks (Group IV) showed a mean Peak systolic velocity (PSV) 16.35cm/s, mean End diastolic velocity (EDV) 2.18cm/s, Resistive index (RI) 0.869cm/s, and Pulsatility index (PI) 1.537cm/s with a P-value of 0.0011, 0.021, 0.0001 and 0.0001 for PSV, EDV, RI and PI respectively (Table III). Increased PSV (enhanced systolic drive) but also elevated RI and PI (greater resistance and pulsatility). EDV shows a marginal decline, consistent with reduced diastolic perfusion.

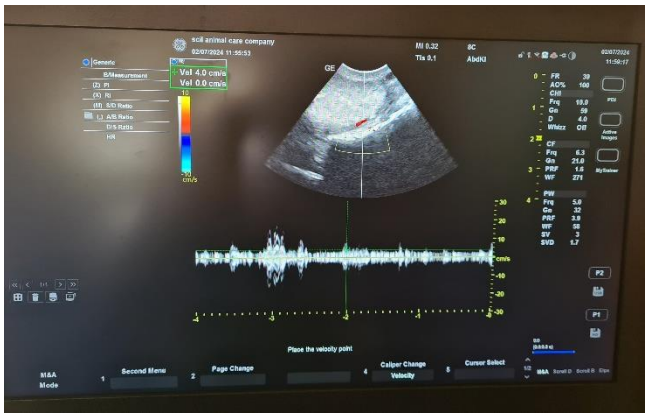

Figure I: Colour and spectra Doppler images of EDV in three years Kano Brown bucks

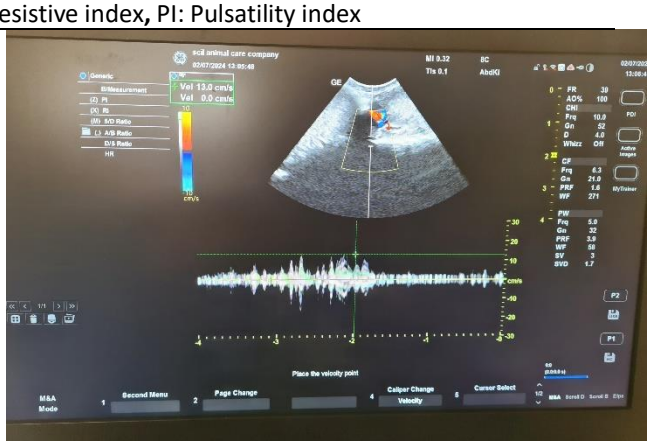

Figure II: Colour and spectra Doppler images of PSV in one year Red Sokoto bucks.

TABLE III: DOPPLER INDICES COMPARISON BETWEEN ONE YEARS OLD KANO BROWN BUCKS AND THREE YEARS OLD KANO BROWN BUCKS

Variable	t(df=10)	p-value	Mean (1 year old KBB)	Mean (3 years old KBB)	95% CI for Difference	Key Finding
PSV	-4.50	0.0011	13.23 cm/s	16.35 cm/s	-4.66 to -1.57	Significant: PSV increases with age.
EDV	2.75	0.021	2.58 cm/s	2.18 cm/s	0.08 to 0.72	Significant (marginal): EDV increases with age.
RI	-7.75	<0.0001	0.790 cm/s	0.867 cm/s	-0.099 to -0.055	Significant: RI increases with age.
PI	-8.10	<0.0001	1.315 cm/s	1.537 cm/s	-0.283 to -0.161	Significant: PI increases with age.

MANOVA Result: Pillai's trace = 0.907, F(4,7) = 17.021, p = 0.001 (highly significant).
Post-Hoc t-Tests (Bonferroni-adjusted p < 0.0125)
Key: PSV: Peak systolic velocity**,** EDV: End Diastolic Velocity**,** RI: Resistive index**,** PI: Pulsatility index

DISCUSSIONS

On pulsed-wave Doppler imaging, in our study, the testicular artery showed mostly monophasic and non-resistive waveforms pattern which is similar to that described in humans (Middleton *et al*., 1989), dogs (Zelli *et al*., 2013) as well as in rams (Batissaco *et al*., 2013). However, spectral Doppler imaging for the testicular artery in stallions exhibited resistive and biphasic waveforms (Pozor & McDonnell, 2004), which is in contrast to our study, these differences might be due, in part, to the vertical long axis of rams and bucks testes compared to the horizontal position of long axis of stallion testes.

Spectral Doppler measures obtained in this study demonstrated similar blood flow indices for both testes, which agreed with the results in rams (Batissaco *et al*., 2013; Camela *et al*., 2019), stallions (Pozor & McDonnell, 2002) and dogs (Zelli *et al*., 2013).

In the present findings, there were no breed differences at young ages (one year old Red Sokoto and Kano Brown bucks), but pronounced breed divergence emerges in adults (3 years old Red Sokoto and Kano Brown bucks), alongside age-dependent changes that varied by breed. The adult bucks showed average resistive index (RI) and Pulsatility index (PI) of (0.768 and 1.272) for Red Sokoto bucks and (0.867 and 1.537) for Kano Brown bucks respectively.

The result of the study was similar to those of Batissaco *et al*. (2013); and Camela *et al*. (2019). These authors recorded a range of 0.61 ± 0.10 and 1.1 ± 0.1 for RI and PI measures, respectively. However, results of the current study differ from that of Hedia *et al.* (2021) who reported average values of 0.44±0.02 and 0.64±0.04 for RI and PI in rams. This discrepancy might be attributed to the age, breed, geographical location as well as the expertise of the ultrasound operator.

In the adult bucks, Kano Brown bucks exhibited higher RI (0.867 vs. 0.768) and PI (1.537 vs. 1.272) than Red Sokoto bucks, indicating greater vascular resistance despite higher PSV. This suggests Kano Brown testes may experience more impedance to blood flow, potentially due to physiological adaptations such as hormonal influences on vasoconstriction. Conversely, Red Sokoto bucks' lower indices align with better downstream perfusion which could confer reproductive advantages like higher fertility rates-consistent with reports of Red Sokoto as a prolific breed in arid Nigerian environments. The lack of younger-group differences implies these breed traits manifest post-puberty, possibly triggered by maturation or environmental stressors.

The non-significant difference of doppler measurements observed between the one-year-old Red Sokoto bucks and three years old Red Sokoto bucks is in agreement with the work of El-kon (2004) who reported that there were non-significant (P 0.05) difference between the young and adult bucks in pulsatility index, resistive index and systolic diastolic ratio. Pozor & MacDonnel (2003) reported that, the differences between age groups were not significant for peak systolic whereas RI was significantly lower for the 11-15 year age than for the 16-22 years age group of stallion. Paltiel *et al*. (1994) and Wielgo *et al*. (1998) reported that RI values were lower in prepubertal than pubertal boys and were increased in aging men. In addition Patiel *et al*. (1994) suggested that larger volume of testes are associated with lower resistance index. Aging universally trends toward increased resistance in large bucks, but the pattern was breed-specific. Kano Brown showed clear age-related elevations in RI (+0.077) and PI (+0.222), coupled with higher PSV, suggesting compensatory systolic boosts against rising impedance. In Red Sokoto, age effects were subtler (non-significant for RI/PI), with stable resistance implying more resilient

hemodynamics. Marginal EDV declines across breeds hint at reduced basal flow with age, a common mammalian aging pattern, but without impacting RI/PI directly.

Elevated RI/PI in older Kano Brown bucks may signal suboptimal conditions for spermatogenesis, as high resistance can limit nutrient/oxygen delivery. This could explain anecdotal lower fertility in Kano Brown compared to Red Sokoto under similar management. PSV's role as a compensatory factor (higher in large Kano Brown) underscores its utility in Doppler assessments, though RI/PI remain the primary resistance metrics.

Studies conducted by Semiz *et al*. (2014) found that the spectral Doppler analysis is a noninvasive method which is able to provide valuable information for the diagnosis of hemodynamic changes and the testicular microcirculation status. Additionally, the Doppler velocimetric values of the testicular artery can be used as a complementary tool to indicate seminal quality or even for the prediction of fertility potential.

The current study provides important information about the validation of color and spectral Doppler techniques applied to testicular evaluation in goats, besides establishing reference values for healthy animals. In addition, it is important to evaluate the applicability of these imaging techniques to the diagnosis of testicular abnormalities in goats.

CONCLUSION

Doppler measurement of the testicular artery obtained demonstrated mostly a monophasic and non-resistive waveforms pattern of blood flow indices similar for both testes, there were no breed differences at young ages (one year old Red Sokoto and Kano Brown bucks), but pronounced breed divergence emerges in adults (3 years old Red Sokoto and Kano Brown bucks), alongside age-dependent changes that varied by breed. The adult bucks showed average resistive index (RI) and Pulsatility index (PI) of (0.768 and 1.272) for Red Sokoto bucks and (0.867 and 1.537) for Kano Brown bucks respectively. In the adult bucks, Kano Brown bucks exhibited higher RI (0.867 vs. 0.768) and PI (1.537 vs. 1.272) than Red Sokoto bucks, indicating greater vascular resistance, suggesting Kano Brown testes may experience more impedance to blood flow, Conversely, Red Sokoto bucks' lower indices align with better downstream perfusion which could confer reproductive advantages.

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