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Evaluation of Serum Antioxidant Markers and Stress Oxidative Indices of Goat Bucks Raised Under Tropical Conditions with Different Ages and Seasons

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ABSTRACT

This study assessed the oxidative stress markers of 63 goat bucks of different breeds - Kalahari Red (KR), West African dwarf (WAD) and Kalawad (KW)] with 21 animals each. They were assigned to three age groups -– 7≤1,>1≤2 and, >2≤3 and >3≤4 years and evaluated across four seasons (early/late rainy and early/late dry) in a 23 × 3 × 4 factorial design. Animals were managed under uniform nutritional conditions for one year. On Bbimonthly basis, repeated blood samples on the same 63 animals (24 samples/animal over 12 months blood samples were collected to analyze serum antioxidant biomarkers and stress indicator. Three-way ANOVA was used for data analysis in SAS (1999). All determined serum antioxidant indices except malondialdehyde had significant (p <0.05) impact by breed. Glutathione and glutathione peroxidase were not statistically (p >0.05) modified by age. Every parameter considered was significantly (p <0.05) influenced by months of sampling (MOS) and season. All parameters considered were significantly (p <0.05) impacted by the interaction of breed/season, or age/season, age/MOS and breed/MOS. Age, breed, MOS and season exert significant but variable influences on serum antioxidant markers and malondialdehyde in KR, WAD and KW bucks under tropical conditions. These results indicated the importance of physiological monitoring for managing health, reproductive performance and provide reference values for selection and clinical assessments in heat-stressed environments.

Keywords: WAD, Kalahari, Kalawad, serum antioxidants, stress biomarkers

INTRODUCTION

The body responds to stress when it encounters stimuli that interrupt equilibrium. These stimuli may be thermal, pharmacological, or dietary. Knowing that fluctuations occur in environmental temperatures which have resultant effects on animal production and reproduction, further attention should be paid to these stimuli especially thermal stress (Leite et al. 2022; Salama et al. 2014; Nardone et al. 2010). Consequent upon inevitability of animal species being exposed to more stressful environment globally, the consequences have gotten worse in recent years as a result of climate change.

Goats are more resilient to various environmental factors than other livestock animals, including shortage of resources (Stone et al., 2020), restricted roughages (Sejian et al., 2021), illnesses (Pal and Chakravarty, 2020), and environmental changes (Nair et al., 2021). In response to oxidative stress, the body produces excessive amounts of pro-oxidants, which harms biological substances and throws the antioxidant defense systems out of balance (Habashy et al. 2019; Giorgio et al., 2020; Juan et al., 2021). Reactive oxygen metabolites (ROM) are free radicals that comprise one to two percent of the body and facilitate a number of vital processes, including egg drop (egg release), nidation (embryology), blastula formation, corpus luteum regression, perforatorium reactions, syngamy (impregnation), luteal maintenance during pregnancy, phospho-signaling, cellular differentiation, programmed cell death, oogenesis, steroidogenesis, and cell-mediated immunity (Celi et al., 2012).

According to Castillo et al. (2003), organisms typically possess adequate antioxidant reserves to handle the generation of free radicals. However, oxidative stress can occur when the availability of the generation of oxygen free radicals and free radical scavengers are out of balance. However, in some pathological circumstances, including changes in the environment, dietary regimes, age, or physiological state, their levels rise. These circumstances can also alter normal metabolism and physiology and disrupt biological macromolecules (Trevisan et al., 2001; Gupta and Mondal, 2021).

The antioxidant system's constituents are divided into two categories: chain-breaking and preventative antioxidants. Antioxidant enzymes include glutathione peroxidase (GSHPx) and catalase (CAT) (Davies, 2000; Kohen and Nyska, 2002; Miller et al., 1993). After a chain reaction is initiated, the chain-breaking antioxidants start working. Water-soluble ascorbate (Baydar et al., 2018) and decreased lipid soluble vitamin E (Ozkul et al., 2002) are examples of this family of antioxidants. Oxidative stress can have a direct or indirect negative impact on health because it causes the gradual oxidative degradation of additional life-sustaining substances, including proteins, fatty acids, and the blueprint – genetic materials, whenever the balance between ROS and antioxidants is upset (Miller et al., 1993; Davies, 2000; Baydar et al., 2018). Indirect alterations include impacts in the outermost layers of cells along with constituents, altering the mechanisms of metabolism thereby leading to changes in physiological functions, whereas immediate consequences comprise major fatty acids along with large molecules breakdown from the oxidation process (Castillo et al., 2003).

Livestock may experience heat stress as a result of elevated environmental temperatures as well as increased relative humidity (Belhadj et al., 2016; Silanikove, 2000). Whenever the actual environmental temperature surpasses the livestock's tolerance level, heat stress results (Al-Tamimi, 2007; Srikandakumar et al., 2003). In tropical regions in particular, oxidative stress is caused by a decreased antioxidant system and/or rapid generation of ROS and free radicals, that impacts many biological traits in farm animals (Celi, 2011a; Sordillo and Aitken, 2009). The disconnect between the generation of oxygen radicals and a biological system's capacity to either eliminate the radicals or rebuilding the harm they cause is regarded to as redox imbalance or cellular oxidative stress (Celi, 2011b). Intense with extended physical exertion during grazing can cause lipids and proteins in the contractile muscle fibers to sustain damage due to oxidation (Powers and Jackson, 2008; Radovanović et al., 2004). Oxidative stress causes multiple health problems and metabolic conditions in ruminants like acidemia, acetonemia, septicaemia, mammae infection, gastroenteritis, pneumonitis and pulmonary diseases are consequent of cellular oxidative stress (Celi, 2010, Huang et al., 2021, Ayemele et al., 2021). Quick meltdown of glaciers with long-lasting drought or famine are two detrimental effects of global warming, especially in tropical regions across the globe, which have resulted in notable drops in the development of agriculture. (Ullah et al., 2021), unsustainable management (Ahmed et al., 2022); which consequently results to food insecurity and loss of biodiversity (Hirwa et al., 2022).

A typical goat breed that originated in South Africa is the Kalahari Red. The reddish pigmentation of the coat and location - Kalahari Desert, which has a mean summer temperature of 27 °C and winter temperature of 18 °C, correspondingly, are the sources of their name. However, severe temperatures may differ from 3 °C during the winter to 36 °C when the peak of summer (Kotze et al., 2004). The term "kalawad" describes the progeny that are produced when a West African dwarf (WAD) doe and a Kalahari Red buck mate. It was developed in 2013 by the Animal Scientists at the IFSERAR, Federal University of Agriculture, Abeokuta, Ogun State. They are sturdy and resistant to trypanosomiasis, they typically weigh 2.2 kg at birth for twins and 3.2 kg for singletons, together with live weights of 45–60 kg and 40–50 kg at maturity for males and females respectively. They are medium in size in comparison to West African dwarf and Kalahari Red goats (Odeyemi et al., 2024). However, the WAD goats are Nigerian indigenous breed, highly trypanotolreant [they have capacity to resist infections by *Trypanosoma*], drought resilient {thrive under harsh environmental conditions with feed/nutritional shortage] and haemonchotolerant [possess strong resistance against infections caused by the gastrointestinal parasite nematode - *Haemonchus contortus*]; these attributes position them to be more effective than other breeds of domestic goat in the region (Chiejina et al., 2015).

There is information on blood oxidative stress biomarkers for each of the three phases of pregnancy in WAD goat does. The reference values are accessible. However, there is a lack of data about the serum oxidative record during distinct times of year and age(s) in WAD goat bucks. It becomes imperative that this study be carried out to establish the serum antioxidant status of WAD, Kalahari Red and *Kalawad* bucks under Nigeria conditions at different ages. The present study aimed to assess breed, age and season impact on indigenous goats (WAD), exotic breed (KR) and the crossbred (*Kalawad*) which emerged between WAD does and KR bucks; to determine the degree of stress antioxidant indices such as malondialdehyde, CAT, GSH, GSHPx and Superoxide dismutase of these goats. Based on advance comprehension of the team, research focused on the antioxidant traits of WAD, Kalahari and *Kalawad* bucks in all the seasons are not available in the literature. Hence, the need for the study and the results obtained can be useful in comprehending how these antioxidant variables impact the ecological biodiversity of the tropical zone; thereby, remedies by administering or supplementing antioxidant nutrients capable of reducing or limiting the impact of ROS could be adopted for efficiency and consequently, improving the general physiologic and reproductive development of these animals under tropical climate.

MATERIALS AND METHODS

Study Locations

The study was carried out at the Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR) goat farm; Department of Animal Physiology and veterinary Teaching Hospital Laboratories at Federal University of Agriculture, Abeokuta (FUNAAB). The location is 76 meters above sea level and lies within the following latitude and longitude coordinates: 7o 13' 49'' N and 3o 26' 12'' E (Google Earth, 2023). The region in Nigeria has a humid climate. The downpour pattern in Abeokuta is bimodal, with a typical peak around July and September with 2 - 3-weeks relaxation in August. In the harmattan period, which runs from December - February, the lowest overnight temperature is about 24°C. At the time of the rainy months, the daytime temperatures usually range from 28 - 30°C while in the dry months, they range from 30 - 34°C. Relative humidity rises during the rainy months (between 63% – 96%) compared to 55% - 84% during the dry months (FUNAAB, 2020).

Animals and their Management

The total number of sixty-three (63) male goats were randomly selected from the herds using farm data; with 21 each of WAD, KR and KW goat bucks. The animals were categorized under three (3) various age groups: bucks aged 7 months to 1 year (≤1 year), bucks aged 13 months - 2 years (>1≤ 2 years), and bucks aged 2 - 3 years (>2≤3) at the start of the trial, with a body weight of about (10 – 15kg, 18 – 21kg and 22 – 25kg), (35 – 40kg, 45 – 55kg and 60 – 80kg) and (25 – 30kg, 35 – 45kg and 45 – 55kg) respectively. There were 7 animals in each group. With typical body weights of roughly 18–22 kg, 22–26, and 26–28 kg; 45–58 kg, 62–84 kg and 85–88 kg and 35–45 kg, 45–55 kg, and 55–60 kg accordingly, the original categorization has been adjusted to the following arrangement at the close of the study - >1≤ 2 years, >2≤ 3 years and >3≤ 4 years. Apparently healthy bucks were used for this study. Consistent health regimen management were performed. The animals were given prophylactic intra-muscular treatment of 1ml/bodyweight of the buck. Additionally, the animals received Ivomec® treatment for skin related diseases (mange) along with various parasitic organisms and were drenched with albendazole for combating intestinal parasites. WAD is an indigenous breed in Nigeria; KR is an exotic but indigenous breed of South Africa imported to Nigeria for the purpose of improving the meat and milk quality of the indigenous breeds. KW is the cross breed emerged from crossing KR buck and WAD doe. The bucks were housed in a visible, air-circulated environment under semi-intensive management. The goat house consists 12 pens of 10 x 8f each with the flooring made of concrete that is exposed to natural lighting and kept up with a consistent and regular nutrition.

Animals were allowed to graze on paddocks exclusively established with Stylosanthes hamata, Brachiaria ruzizensis, and Chloris gayana without restriction; and augmented with supplementary diet at two percent total body weight dry matter. The feed contained 15% Corn, 5% SBM (soybean meal), 4% GNC (groundnut cake), 23.5% PKC (palm kernel cake), 50% WO (wheat offal), 1% BM (bone meal), 1% salt, 0.5% premix, 16.45% CP (crude protein), 88.14% DM (dry matter), 2.48% EE (ether extract), 27.50% crude fibre, 10.98% ash , 41.74% NFE (nitrogen free extract), 89.06% (organic matter) and 12.27 MJ/kg DM ME (metabolisable energy). Water was also provided without restriction. The experiment lasted for twelve (12) months.

Experimental Design

A 3 × 3 x 4 factorial arrangement was used as the experimental layout for this investigation; where 3 indicate 3 goat breeds, 3 depicts 3 various age groups and 4 implies 4 distinct seasons using breed, age and season as distinct factors and serum antioxidant markers as dependent components.

$$Y_{ijklm} = \mu + J_i + K_j + L_k + M_l + JK_{ij} + JL_{ik} + JM_{il} + KL_{jk} + KM_{kl} + JKLM_{ijk} + \mathcal{E}_{ijklm}$$

Where:
Yijkl = Value of relevant indices
μ = The whole mean
Ji = ith age effect (i=1, 2, 3)
Kj = jth breed effect (j=1, 2, 3)
Lk = kth season effect (k=1, 2, 3, 4)
Ml = lth Months of sampling (m = 1,2, 3,….12)
JKij = ijth interactive effect of age and breed
JLik =ikth interactive impact of age and season
KLjk = jkth interactive effect of breed and season
JMil = JMil interactive effect age and months of sampling
KMjl = KMjl interactive effect age and months of sampling
JKLMijkl = ijklth interactive effect between age, breed, season and months of sampling
Ɛijklm = Residual error

The Climate and Temperature Humidity Index (THI) Calculation

According to Akinseye et al. (2012), the two major seasons were divided into two - the early/late for both rainy and dry seasons. April through June correspond to the early rainy season; July through September is considered the late rainy season. October to December is regarded as the early dry season while January through March is considered as the late dry season. Daily meteorological data of the experimental location were obtained at the Agrometrological Station FUNAAB and analysed which comprise mean temperature, atmospheric temperature (dry), adiabatic saturation temperature (wet) and relative humidity. The procedure developed for ruminants was used to determine the temperature humidity index (THI); THI = $(0.8 \times Tdb) + [(Rh/100) \times (Tdb-14.4)] + 46.4)$. Detail information is presented in Table 1. The Armstrong, 1994 method could be employed to assess whether the animals were under heat stress; in this case, various stress levels can be deduced: <72 denotes little or no, 72–78 suggests mild, 79–88 implies moderate and 89–98 represents extreme stress. Relative humidity and ambient temperature are combined to form THI. This helps to evaluate the thermal harm.

Table 1. Meteorological observations during the study

Seasons	MT (°C)	DBT (°C)	WBT (°C)	RH (%)	THI
Early rainy	28.63 ± 0.16^{b}	27.23 ± 0.21^{c}	23.67 ± 0.31^{b}	70.71 ± 1.24^{b}	77.26 ± 0.52^{c}
Late rainy	29.52 ± 0.16^{a}	28.89 ± 0.17^{b}	24.85 ± 0.24^{a}	71.18 ± 1.22^{b}	79.83 ± 0.33^{b}
Early dry	28.38 ± 0.14^{b}	30.42 ± 0.33^{a}	24.99 ± 0.12^{a}	72.07 ± 1.71^{b}	82.28 ± 0.47^{a}
Late dry	26.38 ± 0.15^{c}	28.53 ± 0.36^{b}	23.78 ± 0.09^{b}	81.36 ± 0.89^{a}	80.72 ± 0.61^{a}

Note: ^{ab} Means in the same row with different superscript vary significantly ($p < 0.05$)
MT = Mean Temperature, DBT = Dry bulb Temperature, WBT = Wet bulb Temperature, RH = Relative humidity

Stress serum antioxidant markers analysis

All animals were sampled (blood collection) twice every month for the duration of the experiment. The goats' jugular vein was used to extract five (5) milliliters of blood using a vacutainer needle and tubes. The blood samples were appropriately labeled, put in a cooler bag with ice and transported to the lab within an hour of collection. For the purpose of separating the sera, blood samples were spun using a centrifuge for 20 minutes. Sera were kept at -20°C in 1.5 ml plastic containers (Eppendorf®) until they were analysed for serum stress antioxidant markers were performed in duplicate using a breed-specific standardized kits. The following serum antioxidant markers – catalase (Upingbio catalog number - YPW-EG775504), glutathione (MyBioSource catalog number - YP_004524833.1), glutathione peroxidase (MyBioSource catalog number - MBS260284) and superoxide dismutase (FineTest catalogue number · EG0028) were determined while procedures provided by the respective kits were strictly followed. However, malondialdehyde determination followed thiobarbituric acid-reactive substances (TBARS) procedure for serum analysis which involved preparation of serum, incubating it with thiobarbituric acid (TBA) at high temperature (95°C) for 60 minutes to produce a red-pink chromophore, and then measured the absorbance at 532 nm to quantify lipid peroxidation).

Statistical analysis

Using statistical analysis software (SAS) 1999 package; version 9.0, the data were examined by the least squares analysis of variance technique. Tukey's HSD (Honestly Significant Difference) was used to compare the means. This was to specify the relationship between dependent and independent variables.

RESULTS AND DISCUSSION

Effects of breed, age and season on serum stress antioxidant indices of goat bucks

The least square means showing the main effects of breed, age and season on serum stress antioxidant indices of West African dwarf (WAD) and Kalahari Red (KR) goats and their crossbred - Kalawad (KW) is shown in Table 2. Results indicated that all determined serum antioxidant indices except MDA were statistically ($p < 0.05$) affected by breed. WAD bucks had the highest values in CAT, GSH and SOD (4.40±0.03 μg/mL, 7.22±0.06 ng/mL and 3.90±0.04 μg/mL) respectively. KR bucks had the least values of 5.41±0.07 ng/mL and 179.82±1.93 nmol/min/mL for GSH and GSHPx respectively while the least value (3.10±0.03 μg/mL) for CAT was recorded in KW bucks.

The GSH and GSHPx were not statistically (p >0.05) influenced by age while other determined parameters were influenced by age (p <0.05). The results revealed increase in age with rise in serum antioxidant indices.

All parameters considered were significantly (p <0.05) influenced by season. During early rainy season, the CAT, MDA and SOD had the least values which was closely followed by late rainy season but CAT and SOD had the highest values in late dry season. The GSH and GSHPx had peak values (8.12±0.05 µg/mL and 229.17±0.80 nmol/min/mL) respectively during the late rainy season while the least values were recorded during the late dry season.

Table 2: Least square means indicating the effects of breed, age and season on serum antioxidant indices of goat bucks

		BREED			
Parameter	**Kalahari**	**WAD**	**Kalawad**	**P value**	
CAT (*)	3.58±0.04[b]	4.40±0.03[a]	3.10±0.03[c]	0.0001	
MDA (#)	1.07±0.03	1.03±0.03	1.05±0.03	0.6206	
GSH (#)	5.41±0.07[c]	7.22±0.06[a]	6.41±0.07[b]	0.0001	
GSHPx (**)	179.82±1.93[c]	185.55±1.93[b]	192.22±1.92[a]	0.0001	
SOD (*)	3.06±0.04[b]	3.90±0.04[a]	2.72±0.03[c]	0.0001	
		AGE (Months)			
	7 – 24	25 – 36	37 – 48	P value	
CAT (*)	3.40±0.04[c]	3.69±0.05[b]	3.99±0.06[a]	0.0001	
MDA (#)	0.79±0.02[c]	1.05±0.03[b]	1.31±0.03[a]	0.0001	
GSH (#)	6.32±0.08	6.25±0.08	6.46±0.08	0.1799	
GSHPx (**)	185.63±1.94	185.94±1.96	186.01±1.94	0.9894	
SOD (*)	2.94±0.04[a]	3.23±0.05[b]	3.53±0.06[a]	0.0001	
			SEASON		
	ER	LR	ED	LD	P value
CAT (*)	2.94±0.04[d]	3.13±0.03[c]	3.98±0.04[b]	4.74±0.05[a]	0.0001
MDA (#)	0.58±0.01[d]	0.77±0.01[c]	1.58±0.02[a]	1.27±0.04[b]	0.0001
GSH (#)	7.03±0.05[b]	8.12±0.05[a]	5.48±0.04[c]	4.75±0.04[d]	0.0001
GSHPx (**)	207.35±0.97[b]	229.17±0.80[a]	168.67±0.47[c]	138.25±0.43[d]	0.0001
SOD (*)	2.47±0.03[d]	2.66±0.03[c]	3.51±0.40[b]	4.28±0.05[a]	0.0001

Note: [abc...] Means in the same row with different superscript differs significantly (P <0.05)
WAD = West African dwarf, CAT = catalase, MDA = Malondialdehyde, GSH = Glutathione, GSHPx = glutathione peroxidase, SOD = Superoxide dismutase, * = µg/mL, # = ng/mL, ** = nmol/min/mL, ER = Early rainy, LR = Late rainy, ED = Early dry, LD = Late dry

Effects of months of sampling on serum stress antioxidant indices of goat bucks

The least square means showing the main effects of breed, age and season on serum stress antioxidant indices of West African dwarf (WAD) and Kalahari Red (KR) goats and their crossbred - Kalawad (KW) is shown in Table 3. Results indicated that all determined serum antioxidant indices were significantly ($p < 0.05$) affected by months of sampling. The highest value (4.98 µg/mL) for CAT was recorded in March while the least values were observed from April – July. The CAT, MDA and SOD had the least values from April – July but the highest mean were noted in March, December and March respectively. The GSH was highest (8.17±0.07 ng/mL and 8.22±0.09 ng/mL) in August and September while the least value (4.54±0.07ng/mL) was recorded in January. The least values ($p > 0.05$) for GSHPx were observed from January – March but highest values were recorded in July and August.

Table 3: Least square means indicating the effects of months of sampling on serum antioxidant indices of goat bucks

Months of sampling	**CAT (µg/mL)**	**MDA (ng/mL)**	**GSH (ng/mL)**	**GSHPx (nmol/min/mL)**	**SOD (µg/mL)**
April	$2.93{\pm}0.06^{h}$	$0.55{\pm}0.02^{g}$	$7.05{\pm}0.08^{c}$	$203.13{\pm}1.54^{d}$	$2.46{\pm}0.06^{h}$
May	$2.96{\pm}0.06^{h}$	$0.60{\pm}0.03^{g}$	$7.08{\pm}0.08^{c}$	$209.98{\pm}1.68^{c}$	$2.49{\pm}0.06^{h}$
June	$2.92{\pm}0.06^{h}$	$0.57{\pm}0.02^{g}$	$6.95{\pm}0.08^{c}$	$208.94{\pm}1.76^{c}$	$2.46{\pm}0.06^{h}$
July	$2.94{\pm}0.06^{h}$	$0.59{\pm}0.02^{g}$	$7.96{\pm}0.08^{b}$	$231.81{\pm}1.40^{a}$	$2.47{\pm}0.06^{h}$
August	$3.15{\pm}0.05^{g}$	$0.79{\pm}0.01^{f}$	$8.17{\pm}0.07^{ab}$	$230.87{\pm}1.65^{a}$	$2.68{\pm}0.05^{g}$
September	$3.29{\pm}0.05^{g}$	$0.94{\pm}0.01^{e}$	$8.22{\pm}0.09^{a}$	$224.84{\pm}0.91^{b}$	$2.83{\pm}0.05^{g}$
October	$3.76{\pm}0.06^{f}$	$1.39{\pm}0.02^{c}$	$5.47{\pm}0.08^{d}$	$166.99{\pm}0.89^{e}$	$3.29{\pm}0.06^{f}$
November	$3.97{\pm}0.06^{e}$	$1.59{\pm}0.03^{b}$	$5.41{\pm}0.08^{d}$	$168.71{\pm}0.76^{e}$	$3.50{\pm}0.06^{e}$
December	$4.20{\pm}0.07^{d}$	$1.77{\pm}0.04^{a}$	$5.56{\pm}0.08^{d}$	$170.31{\pm}0.74^{e}$	$3.74{\pm}0.06^{d}$
January	$4.48{\pm}0.07^{c}$	$1.66{\pm}0.04^{b}$	$4.54{\pm}0.07^{f}$	$138.30{\pm}0.68^{f}$	$4.01{\pm}0.07^{c}$
February	$4.77{\pm}0.08^{b}$	$1.12{\pm}0.05^{d}$	$4.78{\pm}0.07^{e}$	$138.38{\pm}0.78^{f}$	$4.30{\pm}0.08^{b}$
March	$4.98{\pm}0.09^{a}$	$1.03{\pm}0.07^{de}$	$4.92{\pm}0.08^{e}$	$138.06{\pm}0.75^{f}$	$4.51{\pm}0.09^{a}$
P value	0.0001	0.0001	0.0001	0.0001	0.0001

Note: $^{abc...}$ Means in the same column with different superscript differs significantly ($P < 0.05$)
CAT = catalase, MDA = Malondialdehyde, GSH = Glutathione, GSHPx = glutathione peroxidase, SOD = Superoxide dismutase,

Influences of breed and age on serum stress antioxidant markers of goat bucks

The interactive influence of breed and age on serum stress antioxidant indices of goat bucks is shown in Table 4. The results indicated that each parameter considered was significantly ($p < 0.05$) affected consequent upon interaction between breed and age. Results also indicated that the values of all the parameters considered increased in each breed as age increased except GSH which did not follow the trend. The values of GSH irrespective of age were not significantly ($p > 0.05$) influenced within a breed.

Table 4: Interactive effects of breed with age on serum antioxidant indices of goat bucks

AGE (Months)	BREED	CAT (µg/mL)	MDA (ng/mL)	GSH (ng/mL)	GSHPx (nmol/min/mL)	SOD (µg/mL)
7 – 24	KR	3.29±0.05^{fg}	0.81±0.04^{c}	5.38±0.12^{c}	179.59±3.33^{b}	2.77±0.05^{f}
	WAD	4.11±0.04^{c}	0.77±0.04^{c}	7.19±0.12^{a}	185.32±3.32^{ab}	3.61±0.04^{c}
	Kalawad	2.81±0.05^{h}	0.79±0.03^{c}	6.37±0.12^{b}	191.99±3.33^{a}	2.43±0.05^{g}
25 – 36	KR	3.58±0.08^{e}	1.07±0.05^{b}	5.32±0.12^{c}	179.91±3.37^{b}	3.06±0.08^{e}
	WAD	4.41±0.07^{b}	1.03±0.04^{b}	7.13±0.12^{a}	185.63±3.37^{ab}	3.91±0.07^{b}
	Kalawad	3.11±0.08^{g}	1.05±0.05^{b}	6.31±0.12^{b}	192.30±3.38^{a}	2.72±0.08^{f}
37 – 48	KR	3.88±0.08^{d}	1.33±0.04^{a}	5.53±0.12^{c}	179.96±3.34^{b}	3.36±0.08^{d}
	WAD	4.70±0.07^{a}	1.29±0.05^{a}	7.34±0.12^{a}	185.69±3.33^{ab}	4.20±0.07^{a}
	Kalawad	3.40±0.09^{ef}	1.31±0.05^{a}	6.52±0.12^{b}	192.36±3.34^{a}	3.02±0.07^{e}
	P value	<0.0001	<0.0001	<0.0001	0.0086	<0.0001

Note: $^{abcd...}$ Means in the same column with different superscript differs significantly ($P < 0.05$)
KR = Kalahari Red, WAD = West African dwarf, CAT = catalase, MDA = Malondialdehyde, GSH = Glutathione, GSHPx = glutathione peroxidase, SOD = Superoxide dismutase

Effects of breed and season on serum stress antioxidant markers of goat bucks

Presented in Table 5 is the interactive effects of breed and season on serum stress antioxidant markers of KR, WAD and crossbred between KR and WAD - KW goat bucks. All parameters considered were statistically ($p < 0.05$) impacted by breed and season. The highest means (5.45±0.06 µg/mL and 4.95±0.03 µg/mL) for CAT and SOD were recorded in WAD during late dry season while the least values (3.64±0.02 µg/mL and 3.14±0.06 µg/mL) were observed during early rainy season and similar trend is recorded in both KR and KW bucks. The MDA was at peak ($p > 0.05$) in all the breeds during early dry season and the lowest values were obtained during the early rainy season. GSH had highest value (8.99±0.03ng/mL) obtained in WAD bucks at late raining season but least value (3.82±0.03) was recorded during late dry season in KR bucks. In late dry season, GSHPx had the least (p <0.05) value (132.20±0.51 nmol/min/mL) in KR followed by WAD (137.93±0.52 nmol/min/mL) and KW (144.60±0.51 nmol/min/mL) while the highest value (235.53±1.28 nmol/min/mL) was obtained in KW during the late rainy season.

Table 5: Interactive effects of breed with season on serum antioxidant indices of goat bucks

Breed	Season	CAT (μg/mL)	MDA (ng/mL)	GSH (ng/mL)	GSHPx (nmol/min/mL)	SOD (μg/mL)
KR	Early Rainy	2.82±0.02^{h}	0.59±0.03^{d}	6.09±0.02^{g}	201.31±1.61^{f}	2.30±0.03^{h}
	Late Rainy	3.01±0.02^{g}	0.79±0.02^{c}	7.18±0.04^{d}	223.13±1.29^{c}	2.49±0.02^{g}
	Early Dry	3.86±0.03^{d}	1.60±0.03^{a}	4.55±0.02^{k}	162.62±0.63^{i}	3.35±0.02^{d}
	Late Dry	4.63±0.06^{b}	1.29±0.06^{b}	3.82±0.03^{l}	132.20±0.51^{l}	4.11±0.03^{b}
WAD	Early Rainy	3.64±0.02^{e}	0.56±0.03^{d}	7.90±0.02^{c}	207.04±1.60^{e}	3.14±0.06^{e}
	Late Rainy	3.83±0.02^{d}	0.75±0.02^{c}	8.99±0.03^{a}	228.86±1.29^{b}	3.33±0.02^{d}
	Early Dry	4.69±0.03^{b}	1.56±0.03^{a}	6.35±0.02^{f}	168.35±0.61^{h}	4.18±0.02^{b}
	Late Dry	5.45±0.06^{a}	1.25±0.06^{b}	5.63±0.02^{h}	137.93±0.52^{k}	4.95±0.03^{a}
Kalawad	Early Rainy	2.34±0.02^{j}	0.58±0.02^{d}	7.08±0.02^{e}	213.71±1.60^{d}	1.96±0.06^{j}
	Late Rainy	2.53±0.02^{i}	0.77±0.02^{c}	8.17±0.04^{b}	235.53±1.28^{a}	2.15±0.02^{i}
	Early Dry	3.39±0.03^{f}	1.58±0.03^{a}	5.54±0.02^{i}	175.02±0.60^{g}	3.01±0.03^{f}
	Late Dry	4.15±0.06^{c}	1.27±0.06^{b}	4.81±0.03^{j}	144.60±0.51^{j}	3.76±0.06^{c}
	P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Note: $^{abcde...}$ Means in the same column with different superscript(s) differ(s) significantly (P<0.05)
KR = Kalahari Red, WAD = West African dwarf, CAT = catalase, MDA = Malondialdehyde, GSH = Glutathione, GSHPx = glutathione peroxidase, SOD = Superoxide dismutase

Age and season influence on serum stress antioxidant markers of goat bucks

Interactive effects of age and season on serum antioxidant indices of KR, WAD and their crossbred – KW goat bucks are shown in Table 6. Results indicated that each parameter considered was significantly (p <0.05) influenced by age and season. Results also showed that the values of CAT, MDA and SOD irrespective of the age were increased (p <0.05) in dry seasons in contrast with rainy seasons. GSH and GSPx had highest values (P >0.05) at age >1≤2 and >2≤3 in late rainy season but lowest values were obtained in late dry season irrespective of age.

The CAT and SOD had the highest values (5.74 μg/mL and 5.28 μg/mL) at age 36 – 47 months in March and followed closely by bucks aged 35 – 46 months in February (p <0.05). The CAT concentration remained constant in each corresponding age from April – July and similar trend (p <0.05) was observed from August – March.

Table 6: Interactive effects of age with season on serum antioxidant indices of goat bucks

AGE (Months)	SEASON	CAT (µg/mL)	MDA (ng/mL)	GSH (ng/mL)	GSHPx (nmol/min/mL)	SOD (µg/mL)
7 – 15	Early Rainy	2.79±0.05^{h}	0.43±0.01^{h}	6.89±0.08^{c}	205.75±1.39^{b}	2.32±0.06^{h}
10 – 18	Late Rainy	3.11±0.06^{fg}	0.74±0.02^{fg}	8.12±0.08^{a}	229.91±1.37^{a}	2.63±0.05^{fg}
13 – 21	Early Dry	3.67±0.05^{e}	1.28±0.01^{d}	5.55±0.08^{d}	168.97±0.88^{c}	3.20±0.06^{e}
16 - 24	Late Dry	4.06±0.05^{d}	0.69±0.06^{g}	4.69±0.08^{f}	137.89±0.76^{d}	3.59±0.04^{d}
13 – 27	Early Rainy	2.85±0.06^{h}	0.48±0.03^{h}	6.95±0.08^{c}	208.59±1.99^{b}	2.39±0.05^{h}
16 – 30	Late Rainy	3.04±0.06^{g}	0.68±0.02^{g}	8.06±0.08^{a}	228.16±1.30^{a}	2.57±0.06^{g}
19 – 33	Early Dry	4.03±0.06^{d}	1.63±0.02^{c}	5.28±0.08^{e}	169.47±0.79^{c}	3.57±0.05^{d}
22 – 36	Late Dry	4.84±0.07^{b}	1.40±0.05^{c}	4.72±0.08^{f}	137.54±0.76^{d}	4.38±0.03^{b}
25 – 39	Early Rainy	3.17±0.06^{fg}	0.81±0.01^{f}	7.23±0.08^{b}	207.72±1.62^{b}	2.69±0.06^{fg}
28 – 42	Late Rainy	3.24±0.05^{f}	0.89±0.01^{f}	8.18±0.09^{a}	229.44±1.49^{a}	2.78±0.05^{f}
31 – 45	Early Dry	4.23±0.06^{c}	1.83±0.03^{a}	5.60±0.08^{d}	167.56±0.74^{c}	3.77±0.04^{c}
34 - 48	Late Dry	5.33±0.07^{a}	1.71±0.03^{b}	4.83±0.08^{f}	139.31±0.69^{d}	4.86±0.07^{a}
	P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Note: $^{abcdef...}$ Means in the same column with different superscript(s) differ(s) significantly (P <0.05)

CAT = catalase, MDA = Malondialdehyde, GSH = Glutathione, GSHPx = glutathione peroxidase, SOD = Superoxide dismutase

Bucks aged 7 – 24, 9 – 26 and 10 – 27 months had the lowest MDA values in April, June and July respectively but highest value (2.10 ng/mL) was recorded in December among bucks aged 33 – 44 months. The GSH maintained similar concentration (p>0.05) in bucks aged 7 – 38 and 16 - 47 from April - June and January – March respectively while the highest values were recorded in July and September. The GSHPx was at peak in July and August among bucks aged 10 – 40 months but the least values were recorded from January – March in bucks aged 16 – 47 months. SOD had steady but fluctuated mean values (p <0.05) from April – September.

Breed and months of sampling on serum stress antioxidant markers of goat bucks

Interactive effects of breed and months of sampling on serum antioxidant indices of KR, WAD and their crossbred – KW goat bucks are shown in Table 8.

Table 7: Interactive effects of age with months of sampling on serum antioxidant indices of goat bucks

Months of sampling	AGE (Months)	CAT (µg/mL)	MDA (ng/mL)	GSH (ng/mL)	GSHPx (nmol/min/mL)	SOD (µg/mL)
April	7 - 12	2.83^{n}	0.46^{no}	6.95^{cd}	202.29^{i}	2.37^{op}
	13 - 24	2.85^{mn}	0.45^{no}	6.97^{cd}	194.95^{j}	2.38^{op}
	25 - 36	3.10^{lmn}	0.75^{jk}	7.22^{cd}	212.16^{efg}	2.64^{mno}
May	8 - 13	2.76^{n}	0.41^{o}	6.88^{d}	209.36^{fgh}	2.29^{p}
	14 - 25	2.88^{mn}	0.53^{mn}	6.99^{cd}	213.59^{ef}	2.41^{nop}
	26 - 37	3.23^{lm}	0.88^{hi}	7.35^{cd}	206.99^{ghi}	2.76^{m}
June	9 - 14	2.78^{n}	0.42^{no}	6.86^{d}	205.58^{hi}	2.31^{p}
	15 - 26	2.83^{n}	0.48^{no}	6.88^{d}	217.23^{e}	2.36^{op}
	27 - 38	3.16^{lm}	0.80^{ij}	7.11^{cd}	203.99^{hi}	2.71^{m}
July	10 - 15	2.83^{n}	0.47^{no}	7.85^{b}	232.39^{a}	2.36^{op}
	17 - 27	2.81^{n}	0.45^{no}	7.83^{b}	230.86^{abc}	2.34^{op}
	28 - 39	3.18^{lm}	0.83^{ij}	8.20^{ab}	232.17^{a}	2.72^{m}
August	11 - 16	3.17^{lm}	0.82^{ij}	8.19^{ab}	231.98^{ab}	2.70^{mn}
	17 - 28	3.05^{lmn}	0.69^{kl}	8.07^{ab}	229.18^{abcd}	2.58^{mnop}
	29 - 40	3.23^{kl}	0.88^{hi}	8.25^{ab}	231.43^{ab}	2.77^{m}
September	12 - 17	3.31^{kl}	0.94^{h}	8.32^{a}	225.35^{bcd}	2.83^{lm}
	18 - 29	3.25^{kl}	0.90^{hi}	8.27^{ab}	224.44^{d}	2.79^{lm}
	30 - 41	3.32^{kl}	0.97^{h}	8.07^{ab}	224.71^{cd}	2.86^{lm}
October	13 - 18	3.54^{jk}	1.17^{g}	5.49^{efg}	168.34^{k}	3.08^{kl}
	19 - 30	3.78^{hij}	1.41^{de}	5.29^{efgh}	166.78^{k}	3.31^{ijk}
	31 - 42	3.96^{ghi}	1.58^{c}	5.63^{e}	165.84^{k}	3.49^{hij}
November	14 - 19	3.69^{ij}	1.30^{f}	5.53^{ef}	167.78^{k}	3.23^{jk}
	20 - 31	4.02^{fghi}	1.64^{c}	5.14^{fghi}	170.61^{k}	3.55^{ghi}
	32 - 43	4.20^{fg}	1.82^{b}	5.54^{ef}	167.74^{k}	3.73^{gh}
December	15 - 20	3.76^{hij}	1.35^{ef}	5.63^{e}	170.78^{k}	3.29^{ijk}
	21 - 32	4.29^{ef}	1.86^{b}	5.41^{efg}	171.02^{k}	3.83^{fg}
	33 - 44	4.54^{de}	2.10^{a}	5.63^{e}	169.12^{k}	4.08^{ef}
January	16 - 21	3.99^{fghi}	1.31^{ef}	4.56^{k}	136.90^{l}	3.53^{ghi}
	22 - 33	4.59^{de}	1.79^{b}	4.52^{k}	138.81^{l}	4.13^{de}
	34 - 45	4.85^{cd}	1.89^{b}	4.55^{k}	139.20^{l}	4.38^{cd}
February	17 - 22	4.06^{fgh}	0.61^{lm}	4.67^{jk}	139.12^{l}	3.59^{cd}
	23 - 34	4.85^{cd}	1.29^{f}	4.78^{ijk}	136.86^{l}	4.39^{cd}
	35 - 46	5.39^{b}	1.45^{d}	4.88^{hijk}	139.16^{l}	4.93^{b}
March	18 - 23	4.11^{fg}	1.17^{g}	4.85^{hijk}	137.66^{l}	3.65^{gh}
	24 - 35	5.08^{c}	1.13^{g}	4.86^{hijk}	136.93^{l}	4.61^{c}
	36 - 47	5.74^{a}	1.81^{b}	5.06^{ghij}	139.56^{l}	5.27^{a}
SEM		0.03	0.02	0.05	1.12	0.02
P value		0.0001	0.0001	0.0001	0.0001	0.0001

Note: $^{abcde...}$ Means in the same column with different superscript(s) differ(s) significantly (P <0.05)

CAT = catalase, MDA = Malondialdehyde, GSH = Glutathione, GSHPx = glutathione peroxidase, SOD = Superoxide dismutase

Table 8: Interactive effects of breed with months of sampling on serum antioxidant indices of goat bucks

Months of sampling	BREED	CAT (μg/mL)	MDA (ng/mL)	GSH (ng/mL)	GSHPx (nmol/min/mL)	SOD (μg/mL)
April	KR	2.81^{l}	0.57^{k}	6.12^{k}	197.09^{i}	2.29^{r}
	WAD	3.63^{i}	0.53^{k}	7.93^{de}	202.82^{h}	3.14^{no}
	Kalawad	2.34^{n}	0.55^{k}	7.11^{gh}	209.49^{f}	1.96^{s}
May	KR	2.84^{l}	0.62^{ijk}	6.14^{k}	203.94^{gh}	2.32^{r}
	WAD	3.66^{i}	0.58^{jk}	7.95^{de}	209.67^{f}	3.16^{lmno}
	Kalawad	2.36^{n}	0.60^{ijk}	7.13^{gh}	216.34^{e}	1.98^{s}
June	KR	2.81^{l}	0.59^{k}	6.02^{k}	202.89^{h}	2.29^{r}
	WAD	3.63^{i}	0.55^{k}	7.82^{e}	208.63^{fg}	3.13^{no}
	Kalawad	2.33^{n}	0.57^{k}	7.01^{h}	215.29^{e}	1.95^{s}
July	KR	2.82^{l}	0.61^{ijk}	7.03^{h}	225.76^{cd}	2.31^{r}
	WAD	3.64^{i}	0.56^{k}	8.84^{b}	231.49^{b}	3.15^{mno}
	Kalawad	2.34^{n}	0.58^{k}	8.02^{d}	238.16^{a}	1.97^{s}
August	KR	3.04^{k}	0.82^{h}	7.24^{fg}	224.82^{d}	2.52^{q}
	WAD	3.86^{h}	0.78^{hij}	9.05^{a}	230.55^{bc}	3.36^{kl}
	Kalawad	2.56^{m}	0.79^{hi}	8.23^{c}	237.22^{a}	2.18^{r}
September	KR	3.17^{k}	0.96^{gh}	7.28^{f}	218.79^{e}	2.66^{pq}
	WAD	3.99^{gh}	0.92^{gh}	9.09^{a}	224.52^{d}	3.49^{jk}
	Kalawad	2.69^{lm}	0.94^{gh}	8.28^{c}	231.19^{bc}	2.32^{r}
October	KR	3.65^{i}	1.41^{cde}	4.54^{qr}	160.94^{p}	3.13^{no}
	WAD	4.47^{f}	1.37^{e}	6.35^{ij}	166.67^{mno}	3.97^{ghi}
	Kalawad	3.17^{k}	1.39^{de}	5.53^{mn}	173.34^{jkl}	2.79^{p}
November	KR	3.86^{h}	1.61^{ab}	4.47^{r}	162.67^{op}	3.34^{klm}
	WAD	4.68^{e}	1.56^{bcd}	6.28^{j}	168.39^{lmn}	4.18^{ef}
	Kalawad	3.38^{j}	1.59^{abc}	5.46^{n}	175.07^{jk}	2.99^{o}
December	KR	4.09^{g}	1.79^{a}	4.62^{q}	164.26^{nop}	3.57^{j}
	WAD	4.91^{d}	1.75^{ab}	6.44^{i}	169.99^{klm}	4.41^{d}
	Kalawad	3.61^{i}	1.76^{ab}	5.62^{m}	176.66^{j}	3.23^{lmn}
January	KR	4.37^{f}	1.68^{ab}	3.61^{u}	132.26^{rs}	3.85^{hi}
	WAD	5.19^{c}	1.64^{ab}	5.42^{n}	137.99^{r}	4.69^{c}
	Kalawad	3.89^{h}	1.65^{ab}	4.60^{qr}	144.66^{q}	3.51^{jk}
February	KR	4.66^{e}	1.14^{f}	3.85^{t}	132.34^{rs}	4.14^{fg}
	WAD	5.48^{b}	1.09^{fg}	5.66^{m}	138.07^{r}	4.98^{b}
	Kalawad	4.18^{g}	1.12^{fg}	4.83^{p}	144.74^{q}	3.80^{i}
March	KR	4.86^{d}	1.05^{fg}	3.99^{s}	132.01^{s}	4.34^{de}
	WAD	5.68^{a}	1.01^{fg}	5.79^{l}	137.74^{r}	5.18^{a}
	Kalawad	4.38^{f}	1.03^{fg}	4.98^{o}	144.41^{q}	4.00^{fgh}
SEM		0.03	0.02	0.05	1.12	0.05
P value		0.0001	0.0001	0.0001	0.0001	0.0001

Note: $^{abcde...}$ Means in the same column with different superscript(s) differ(s) significantly (P <0.05)

KR = Kalahari Red, WAD = West African dwarf, CAT = catalase, MDA = Malondialdehyde, GSH = Glutathione, GSHPx = glutathione peroxidase, SOD = Superoxide dismutase

Results indicated that each parameter considered was significantly ($p < 0.05$) influenced by breed and months of sampling. All parameters considered were significantly influenced by the interaction of breed and months of sampling. The CAT concentration remained constant in each breed and KW recorded the least value in April – July while WAD had the highest concentration in March. All the breeds were able to keep the MDA at lowest values ($p > 0.05$) in April – July but the highest values were recorded in November – January.

KR recorded the lowest value (3.85 ng/mL) of GSH ($p<0.05$) in February while WAD had the highest concentration (9.05 ng/mL and 9.09 ng/mL) was obtained in August and September. GSHPx was highest (238.16; 237.22 nmol/min/mL) in KW ($p < 0.05$) and closely followed by WAD (231.49; 230.55 nmol/min/mL) during July and August respectively. KW maintained the lowest concentration ($p>0.05$) of SOD during April – July but WAD obtained the highest concentration (5.18 μg/mL) in March.

DISCUSSION

An unbalanced ratio of antioxidants to oxidants occurs when oxidant activity surpasses antioxidants' ability to neutralize it, leading to oxidative stress. Multiple medical conditions may have oxidative stress as a contributory component or disease conditions both in humans and animals, especially ruminants, including those that affect the animals' overall welfare and reproductive efficiency.

The results in this study reveal how successfully the breeds of goats have adjusted to and are associated with any of the blood stress antioxidant biomarkers under evaluation. Variations in CAT, GSH, GSHPx, and SOD were observed in the bucks. The results of Amal et al. (2018), who found that multiple-bearing goats had low CAT and SOD, are in contradiction to this finding. However, Cetin et al. (2021) found no differences in SOD, GSH, or GSHPx across the various phases of pregnancy. The discrepancies in the results may be due to variances in the animals' sex and physiological conditions, which necessitate different dietary requirements for maximum effectiveness.

In line with Chaturvedi and Kataria (2013), who discovered that Marwari goats' levels of some antioxidant compounds varied depending on their age and gender at various ambient temperatures, the antioxidant defense of goat bucks in this study increased as age increased up to four years and also increased steadily from early rainy season to late dry season. This increase in reactive oxygen species (ROS) predisposes the animals to oxidative stress. Furthermore, the study found that goats' antioxidant levels increased with age, but that male goats had higher levels of antioxidant substances than female goats. This could be because aging tissues and organs accumulate more ROS.

The SOD activities usually increase hydrogen peroxide generation and it is regarded the first barrier against pro-oxidants according to Celia et al., (2023), thus the protection from ROS could only occur when glutathione availability, catalase, and glutathione peroxidase activities all rise concurrently (Celi, 2011a) and vice-versa. This is in accordance with the result of this study, because an increase in SOD was accompanied by a resultant increase in glutathione peroxidase and catalase activities as the bucks increased in age; and partly in agreement because a decrease in SOD resulted in decrease in glutathione peroxidase and catalase activities during the dry seasons and vice-versa during rainy seasons. The decrease in glutathione peroxidase during the dry seasons indicating that the bucks could have possibly gone through or been subjected to oxidative stress to a certain extent. This agreed with Celi et al. 2008, Celi et al. 2011a) who reported decrease in blood glutathione peroxidase of dairy goats during postpatrtum period. The noticeable reduction in the activity of antioxidant enzymes (GSHPx) from early dry season to late dry season may result from the antioxidants' exhaustion or from their mobilization to meet increased physiological demands such as maintenance of homeostasis and immunity; since GSHPx is specifically intended to eliminate hydrogen peroxide produced when free radicals dismutate. However, Castillo et al. (2005) identified the quick loss of antioxidants in milk being the cause of the significant decline in antioxidant enzyme activity as lactation continued.

One particular indicator of lipid peroxidation is malondialdehyde (MDA). In this study, an increase in MDA was observed in late dry season. This finding is at variance with Yusuf et al. (2017) who reported increased value for MDA during early rainy season with no increase in SOD. This could be linked to the TBARS assay's precision and specificity since SOD was higher during this period - late dry season. This implies that bucks were adequately fed because prostanoids, polysaccharides, and both saturated and unsaturated non-functional alkanal could all interact with MDA which might have an impact on its stability according to Alessio (2000). In addition, increased levels of oxidative stress throughout pregnancy were reported to raise the level of MDA in the blood (Bhale et al., 2014; Bhuyar and Shamsudden, 2014) but Cetin et al., 2021 reported that blood antioxidant state and MDA status (SOD, GSH, GSHPx) remained unchanged during any stage of goats' pregnancy. Variations observed can be attributed to oxidants-antioxidants balanced or unbalanced mechanism maintenance consequent upon adequate/inadequate feeding under favorable or unfavorable environmental conditions.

The greater concentrations of glutathione noted in all breeds of goat bucks in this study during the rainy seasons compares well with the discovery of Yusuf et al. (2017) during early rainy season. This may be related to satisfactory forage of good quality, together with adequate added concentrates, which sufficiently meet nutrient requirement of the goats. Allowing the goat bucks to graze using semi-intensive management systems could also be responsible for the results, thereby allow the animals to exhibit their natural behaviour as browsers with regular exercise which consequently improves the overall physiological performances of the bucks.

The results in this study indicated high antioxidant defense during either early or late rainy seasons in all the breeds with high antioxidant production but low pro-oxidants production. Also, an increase in SOD and CAT was not accompanied with resultant increase in glutathione peroxidase activities of the bucks during the early and late dry seasons. This implies that both ROS and antioxidants have important physiological functions in every aspect of the goat buck's reproduction at all the seasons. It is also an indication that the bucks were undergoing high level of oxidative stress during the dry seasons because SOD and CAT were decreasing and used up rapidly for the demanding physiological processes to maintain homeostasis with increase in MDA. This is in line to Karapehlivan et al. (2012) who reported that goats in the early stages of lactation have lower antioxidant potential and higher levels of oxidative stress. Additionally, animals may be more susceptible to metabolic alterations brought on by oxidative stress if vital antioxidant defense components in their tissues are depleted. Nonetheless, the reproductive process reaches its peak during the period of adequate and quality forage production with moderate environmental cues (rainy seasons) when the ROS generation decreases with the physiological demands due to sufficient nutrients for the sustenance of cells, tissues, organs and systems. Also, during the periods that is marked with high seasonal variations coupled with low quality and availability of forages (dry seasons) which can also be categorized as a time for significant energy deficiency and drastic metabolic alterations, particularly with regard to the fats or proteins metabolism, ROS and nitrogen metabolites are usually produced in excess. Therefore, certain tissues or organs are prioritized in the distribution of available substances. This compares well with the report of Van Saum et al. (1989) who emphasized the homeorhesis principle which asserts that the uterus is prioritized over other organs in the late-prepartum female's body when it comes to the absorption of certain substances.

This study provides reference values for serum stress antioxidant markers in Kalahari Red, West African dwarf and crossbred between KR and WAD – Kalawad goat bucks at different ages and seasons indicating level of oxidative stress. The antioxidant status of the ruminant animals particularly bucks at different physiological stages should be taken into consideration and sustained at the appropriate periods alongside with the adjustments to the energy, protein and mineral balance for optimal ruminant production/reproduction, especially when concentration is based on the nutritional or environmental variables to enhance reproduction. This implies that in addition to the metabolic profile, assessment of oxidative stress - MDA status and different serum antioxidant activity, is required when performing dietary, physiological or biochemical investigations in animals. The impact of antioxidant supplementation on the functionality and resilience of reproductive accessories or organs due to oxidation in goat bucks of these or other breeds and ages should be the subject of future research.

CONCLUSION

The study concluded that the CAT, GSH, GSHPx and SOD were influenced by age, breed and season.

The MDA concentration was not a breed specific.

The average values of every parameter considered increased for every breed as age increased except GSH which did not follow the trend.

The mean values of CAT, MDA and SOD irrespective of the age increased during dry seasons in contrast to rainy seasons.

The means for CAT, MDA, GSH, SOD and GSHPx formed a similar fluctuated patterns in respect to breed and age at each season

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