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Influence of Preconception Body Weight and Pregnancy Types on Oxidative Stress Responses of Periparturient Tropical Goats, and Their Kids Body Weight During the Hot-dry Season

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ABSTRACT

The influence of preconception body weight and pregnancy types on the oxidative stress responses in periparturient tropical goats, and the effects on their kid's growth during the hot-dry season was evaluated. The goats were grouped based on climatic adaptation into Savannah climate-adapted (SCA) and humid climate-adapted (HCA) and further based on pregnancy types into singleton- and twin-bearing. Their body weight (BW), body mass index (BMI) and oxidative stress biomarkers were determined at preconception and once weekly peripartum. Malondialdehyde during the parturition was higher n singleton- and twin-bearing SCA than during the pre- and postpartum periods. Glutathione peroxidase was higher in twin-bearing HCA than singleton-bearing SCA goats at week 3 prepartum. In all pregnancy types, preconception BW and BMI positively correlated with the dam's BW at different periparturient stages. Preconception BW of the singleton-bearing SCA goats and the BW of the kids from birth until 3rd week postpartum positively correlated. Oxidative stress responses peaked during kidding in SCA goats regardless of the pregnancy type. The preconception BW and pregnancy type had no influence on the oxidative stress responses of the goats, however, the kids weight gain was positively influenced

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INTRODUCTION

Small ruminant production plays a vital role as an income-generating activity for the poor and small-holder farmers in many developing countries [1] and especially

Nigeria. In these regions, climate change and the resulting global warming have heightened the vulnerability of sheep and goats to environmental stressors, particularly thermal stress [2,3]. As the intensity of climate change increases, goats are expected to become even more susceptible to heat stress, raising serious concerns for their welfare [2,4]. High ambient temperatures (AT), especially during the hot-dry season, can trigger heat stress, most notably in goats that are not well adapted to such conditions [5].

Within the context of heat stress, female animals experience oxidative stress, which leads to several reproductive issues such as the production of poor-quality oocytes, lowered conception rates, embryonic and fetal losses, pregnancy loss due to abortion, still-birth, and other reproductive inefficiencies [6,7]. Physiological stages like pregnancy, parturition, and the onset of lactation further challenge the animal's homeostatic mechanisms by increasing metabolic activity, which raises reactive oxygen species (ROS) production and depletes natural body antioxidants, particularly during the transition period [8-10]. This effect is even more pronounced in twin-bearing pregnant animals, where accelerated metabolism, due to demands from the dam and multiple embryos, enhances ROS generation and further depletes antioxidants [4,11]. Increased ROS production and oxidative stress during gestation, attributed to heightened energy demand and oxygen requirements especially in the placental unit, have been linked to embryo resorption, placental degeneration, abnormal pregnancy, disrupted foeto-maternal exchanges, altered foetal growth, and still-birth [8,12]. The adverse effects of increased ROS generation during the hot-dry season are evident across various stages of gestation in does [13,14] and ewes [15,16]. Factors such as breed, adaptation level, nutrition quality, season and physiological status significantly influence ruminants' oxidative stress responses [16-18]. Several findings have been reported concerning biomarkers of lipoperoxidation in ruminants during the periparturient period, including evidence of their elevation during gestation [5,15] and reports showing minimal or insignificant effects [5,8,13,19].

Nigeria exemplifies this climatic diversity, having three distinct zones: the tropical rainforest in the South, the tropical Guinea savannah in the Central region, and the hot, semi-arid Sahel savannah in the North [20,21]. The country hosts three major indigenous goat breeds that are adapted to these zones: West African Dwarf (WAD) goats to the southern climate, and Red Sokoto (RSG) and Sahel (SHG) goats to the northern savannah [3,22]. Recent trends show the introduction of WAD goats to the Northern region; possibly due to their high fertility and resistance to parasites [23].

Despite this, there is limited information on the impacts of oxidative stress on periparturient SCA (RSG and SHG) and HCA (WAD) goats, as well as the influence of maternal factors on the kid weight variation from birth during the hot-dry season. The present study was designed to evaluate the influence of maternal factors of preconception BW and pregnancy types on the oxidative stress responses of the periparturient tropical goats, as well as on the on kids body weight during the hot-dry period. Findings from this study may reveal patterns in oxidative stress responses during and after kidding and may aid in anticipating and preventing metabolic disorders related to negative energy balance in dams, ultimately supporting the survivability and improved welfare of goat kids.

METHODS

Thermal environmental parameters

Using a hygrometer (Brannan®, UK) mounted on the pen's wall and 2.5 meters above the ground, wet and dry bulb temperatures were taken inside the pens in the morning, afternoon, and evening of the study period. Relative humidity (RH) values were extrapolated with the aid of tables of conversion of U.S. Weather Bureau Bulletin No. 1071 (1932) and the temperature-humidity index (THI) was obtained [24].

Experimental location and animal management

The research was carried out during the hot-dry season at the National Animal Production Research Institute, Shika-Zaria, Nigeria, on latitude 11º12'N, longitude 7 º33'E and an altitude of 610 m. The mean annual rainfall of the location is 1050 mm, while those of maximum and minimum ambient temperatures are 14 and 41 ºC. The mean yearly maximum and minimum RH are 85 and 17% [23]. Reared semi-intensively by returning to their shed from 12:00-15:00 h after morning grazing, the goats were housed independently in east-west orientated, adequately ventilated pens with respective lengths, widths, and heights of 61, 6.1, and 2.25 m. Zinc sheets were used to roof the shed and while the walls were built with blocks while concrete was used on the floor. The goats were supplemented with concentrate ration at 3% body weight per day, comprising of 40% wheat offal, 30% cotton seed cake, 20% maize, 5% bone meal and 5% salt, while maintaining *Digitaria smutsi* hay (composed of moisture, fibre, carbohydrates, proteins, lipids and ash at 3.50, 2.77, 89.85, 2.93, 1.85 and 1.87%, respectively) as their basal diet. They were given unrestricted access to cool clean water for drinking.

Experimental protocol

The experiment was performed in compliance with the international guidelines for animal welfare. The Ahmadu Bello University, Zaria, Nigeria, Committee on Animal Use and Care authorised the protocol with approval number ABUCAUC/2022/045. The study was conducted from December 2022 to May 2023 during the hot-dry season. The goats were grouped according to their climatic adaption into Savannah-climate adapted; SCA (RSG and SHG) and humid-climate adapted; HCA (WAD). They were oestrus synchronised in December with Cloprostenol® (0.263 mg/mL) by single intramuscular thigh injection. Goats on oestrus were bred with proven fertile bucks in the last week of December thereby ensuring the periparturient period, and kidding occurred at the summit of the hot-dry season (March and April). In the 4th week post-mating, the goats were pregnancy-diagnosed by non-return to oestrus and ultrasonography (Medison Ultrasound® V600S, Kruuse, Denmark) attached to a 3.5 MHz curvilinear probe. Sixteen (n = 16) goats were used for this study and grouped following kidding according to their parity into singleton-bearing and twin-bearing goats. The

SCA kidded eight singleton and four twin kids, while the humid-climate adapted goats had four twin kids. The fecundity of the goats was recorded as described by [25]. Samples of blood and thermal environmental values were recorded once weekly at preconception, gestation (prepartum weeks 3 and 1), parturition and lactation (postpartum weeks 1 and 3), respectively.

Determination of body weight and body mass index

A digital weighing balance (Camry®, Zhongshan, China) was used to weigh the goats at preconception, gestation (prepartum weeks three), parturition and lactation (postpartum weeks 1 and 3). The kids equally were weighed at birth before the first colostrum intake and once weekly until the third week after kidding. Body length (BL) and withers height (WH) were measured once at preconception using a measuring tape [26], and the values obtained were used to calculate the BMI of the dams [27]:

$$\text{gBMI} = \frac{\underline{\text{BW(kg)/WH(m)/BL(m)}}}{10}$$

Where: gBMI = goat's body mass index, BW = body weight, WH = height at withers, and BL = body length.

Blood sample collection

Blood (5 mL) was obtained from every doe via jugular venipuncture into sample bottles on the day of the oestrus (preconception) and subsequently once weekly during gestation (prepartum weeks three and one), parturition and lactation (postpartum weeks 1 and 3). The samples were centrifuged at 3000 × g for 10 minutes to extract the serum, which were kept at – 20 ℃ until analysis.

Determination of oxidative stress biomarkers

Colorimetric estimation of lipid peroxidation was performed by calculating concentration using the method of [28]. The principle of estimation was on the ability of MDA and thiobarbituric acid (TBA) to react to produce an MDA-TBA complex that was absorbed at 532 nm in a spectrophotometer (Rayto Microplate Reader, RT – 6000, Rayto Life and Analytical Science Co. Ltd., Shenzhen, China). The [29] method of measuring the consumption of H_2O_2 substrate at 240 nm was used to determine catalase activity (CAT). Based on the ability of glutathione peroxidase to catalyse the reduction of hydrogen peroxide to form oxidised glutathione, glutathione peroxidase activity (GPx) was determined according to [30]. The activity of the antioxidant enzyme, superoxide dismutase (SOD) was estimated using the method of [31] whose reaction was based on the monitoring the rate of auto-oxidation of haemoglobin.

Data Analyses

Mean ± SEM was used to present the data generated. Data were analysed using repeated-measures two-way ANOVA and the significance of the means was determined using Tukey's *post-hoc* test. Using Pearson's correlation, the relationship between preconception BW and BMI of the does with biomarkers and the kids BW changes was established. GraphPad Prism version 8.02

[GraphPad Software, San Diego, California, USA (www.graphpad.com)] for Windows (2007) was used for the analyses. Values of $p < 0.05$ were considered significant.

RESULTS

The highest ($p < 0.05$) AT (Fig. 1), THI (Fig. 3), and the least ($p < 0.05$) RH (Fig. 2) were recorded during afternoon compared to the morning hours, which had the lowest values of AT and THI. The RH was higher ($p < 0.05$) in the morning than at any other time of the day.

The overall preconception MDA concentration was higher ($p < 0.05$) than in other periparturient periods, irrespective of the pregnancy type. Regardless of the pregnancy type and stages, the overall MDA concentration was higher during parturition, compared to week 3 prepartum ($p < 0.0001$) and week 3 postpartum ($p < 0.05$; Table 1). The MDA concentration increased ($p < 0.01$) during parturition than 3 weeks pre- and postpartum in singleton. However, the value was lower ($p < 0.05$) during prepartum week 3 in twin-bearing SCA goats than during the preconception and parturition period (Table 1). The overall concentration of MDA was relatively higher ($p < 0.05$) in twin-bearing HCA goats, compared to the singleton twin-bearing SCA goats. There was no significant interaction between the pregnancy types and stages in MDA concentration, but the source of variation was due to the pregnancy stages ($p < 0.01$; Table 5).

The catalase activity maintained a relatively stable profile during the prepartum period in all groups (Table 2). Regardless of the pregnancy stage, the overall catalase activity was higher ($p < 0.05$) in the first week after kidding than at preconception, while the overall value was lower ($p < 0.05$) in singleton- than in twin-bearing SCA goats (Table 2). There was no significant interaction between the pregnancy types and stages in catalase activity, but the source of variation was due to the effect of both the pregnancy types ($p < 0.01$) and stages ($p < 0.01$; Table 5).

The overall GPx activity during parturition was lower ($p < 0.05$) than the values obtained during prepartum week 1 and postpartum week 3; whereas the preconception value was lower ($p < 0.05$) than the periparturient period. The GPx activity in twin-bearing SCA goats was lower ($p < 0.01$) during parturition than in the first week postpartum (Table 3), but the preconception GPx activity was lower ($p < 0.05$) than that recorded after kidding. Similarly, the GPx activity during prepartum week 3 was lower ($p < 0.05$), than postpartum values in singleton-bearing goats.

At prepartum weeks 3, the GPx activity in singleton- was lower ($p < 0.01$) than in twin-bearing HCA goats (Table 3). Similarly, overall activity of GPx was lower ($p < 0.05$) in singleton- than twin-bearing HCA goats. There was no significant interaction between the pregnancy types and stages in GPx activity. However, the source of variation in the GPx activity was due to the effect of both the pregnancy types ($p < 0.05$) and especially the stages ($p < 0.0001$; Table 5).

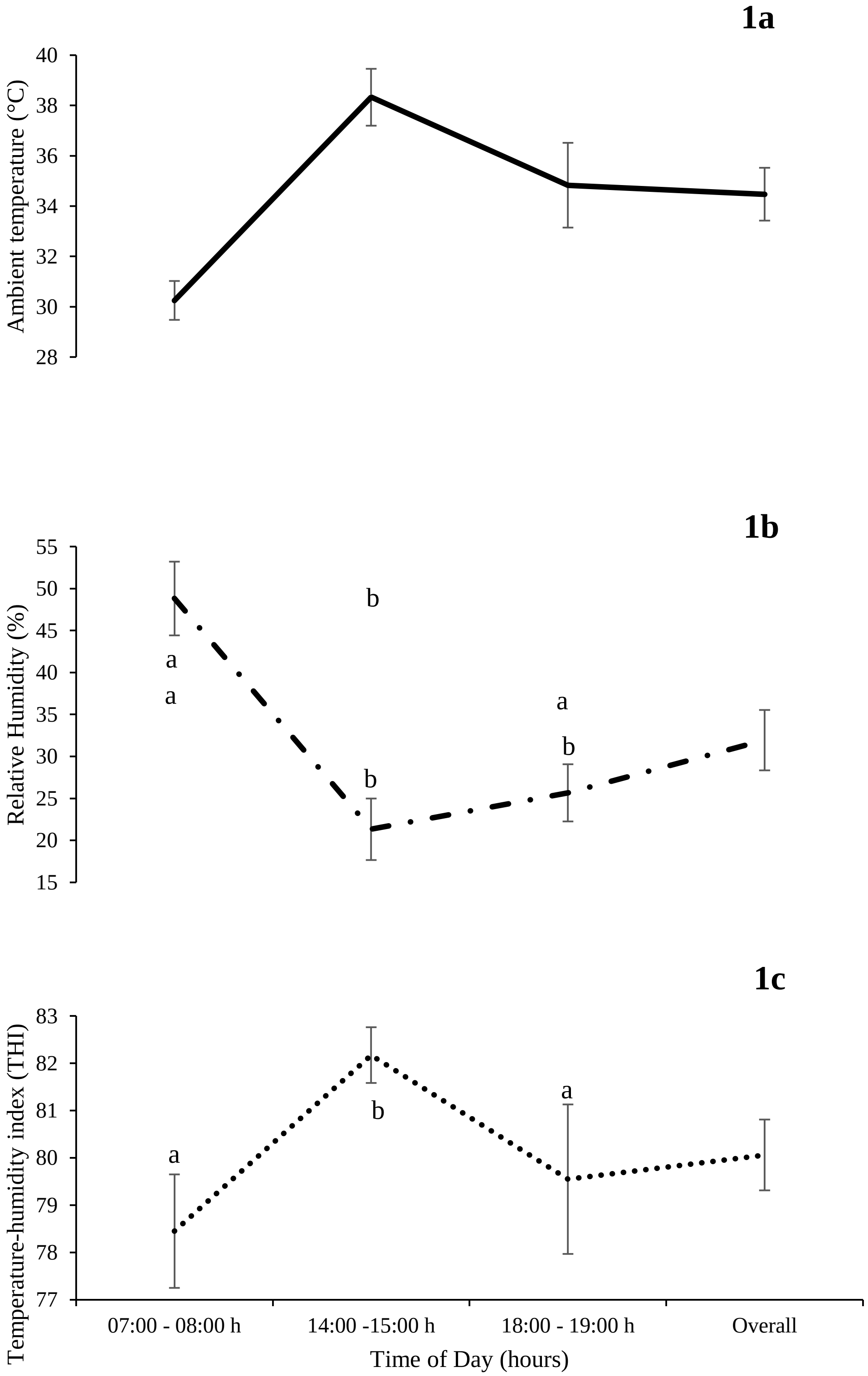

Fig. 1. Fluctuations in the ambient temperature **(1a)**, relative humidity **(1b)** and temperature-humidity index (1c) during the hot-dry season. **a,b** = Bars having different letters differ significantly ($P < 0.05$)

Table 1. Malondialdehyde concentration (µmol/L) in periparturient singleton and twin-bearing goats during the hot-dry season

Pregnancy period		Singleton (SCA)	Twin (SCA)	Twin (HCA)	Overall Mean
Pre-conception		12.10±2.60 (6.00-28.20)	16.79±2.97^{y} (8.50-30.60)	12.48±1.29 (5.70-17.80)	13.79±1.50^{x} (12.10-16.79)
Prepartum:	Week 3	4.14±0.84^{y} (1.50-8.90)	4.71±0.56^{x} (3.00-7.50)	8.10±1.90 (2.00-19.80)	5.65±1.24^{yz} (4.14-8.10)
	Week 1	9.35±1.94 (2.40-18.30)	16.08±3.71 (3.90-33.10)	14.50±2.95 (5.70-25.90)	13.31±2.03^{xz} (9.35-16.06)
Parturition		13.73±1.43^{x} (7.20-19.80)	13.31±1.57^{y} (8.20-19.20)	11.24±1.10 (4.80-14.50)	12.76±0.77^{xy} (11.24-13.73)
Postpartum:	Week 1	9.56±2.55 (1.10-20.70)	9.53±2.10 (2.50-18.50)	10.10±1.32 (5.70-15.20)	9.73±1.19 (9.53-10.10)
	Week 3	4.68±0.88^{y} (1.60-8.70)	5.96±1.37 (1.70-11.70)	11.31±2.73 (5.90-27.80)	7.32±2.03^{y} (4.68-11.31)
Overall Mean		8.93±1.53 (4.13-13.73)	11.06±1.58 (4.71-16.79)	11.29±0.88 (8.10-14.51)	

^{x,y,z} = Means differ significantly ($P < 0.05$) between periparturient periods; HCA = Humid climate-adapted; SCA = Savannah climate-adapted; n = 16

Table 2. Catalase activity (µmol/L) in periparturient singleton and twin-bearing during the hot-dry season

Pregnancy period		Singleton (SCA) n = 8	Twin (SCA) n = 4	Twin (HCA) n = 4	Overall Mean n = 16
Pre-conception		6.75±1.46 (2.90-13.20)	8.69±1.37 (4.10-14.40)	9.38±1.17 (6.30-15.60)	8.27±0.79^{x} (6.75-9.38)
Prepartum:	Week 3	7.51±1.08 (3.90-12.00)	10.95±1.52 (2.90-17.10)	9.74±1.32 (5.10-15.10)	9.40±1.01 (7.51-10.95)
	Week 1	9.19±1.29 (3.20-13.20)	12.45±0.75 (8.80-15.10)	10.66±1.65 (3.20-17.80)	10.77±0.94 (9.19-12.45)
Parturition		6.98±1.29 (2.70-12.20)	8.84±1.21 (2.90-13.20)	9.03±1.86 (2.00-17.30)	8.28±0.65 (6.98-9.03)
Postpartum:	Week 1	11.16±1.32 (5.90-17.10)	12.15±1.25 (4.40-15.40)	11.65±1.40 (4.10-16.60)	11.65±0.29^{y} (11.16-12.15)
	Week 3	8.125±1.15 (2.40-12.00)	8.1375±1.82 (2.00-15.60)	8.53±1.12 (4.40-14.10)	8.26±0.13 (8.13-8.53)
Overall Mean		8.29±0.68^{a} (6.75-11.16)	10.20±077^{b} (8.14-12.45)	9.83±0.47 (8.53-11.65)	

^{x,y,z} = Means differ significantly ($P < 0.05$) between periparturient periods; ^{a,b,c} = Means differ significantly ($P < 0.05$) between the pregnancy types; HCA = Humid climate-adapted; SCA = Savannah climate-adapted; n = 16.

Table 3. Glutathione peroxidase activity (μmol/L) in periparturient singleton and twin-bearing during the hot-dry season

Pregnancy period		Singleton (SCA)	Twin (SCA)	Twin (HCA)	Overall Mean
Pre-conception		6.28±2.06 (0.50-18.7)	5.89±1.11^{x} (1.50-9.90)	9.41±1.16^{y} (2.90-12.40)	7.19±1.12^{x} (5.88-9.41)
Prepartum:	Week 3	5.08±0.79^{ax} (2.10-7.80)	7.63±1.81 (1.10-15.50)	10.89±1.05^{b} (7.00-14.50)	7.86±1.68^{xy} (5.08-10.89)
	Week 1	10.44±1.20^{y} (6.00-17.40)	10.14±1.41 (3.90-17.70)	12.90±1.63 (7.00-19.20)	11.16±0.88^{y} (10.14-12.90)
Parturition		7.18±0.91 (4.20-11.70)	7.09±0.67^{xy} (4.60-9.90)	9.43±1.53 (3.10-15.30)	7.90±0.77^{x} (7.09-9.43)
Postpartum:	Week 1	9.38±0.83^{y} (6.00-13.20)	12.86±1.34^{yz} (9.10-21.00)	10.10±1.20 (6.50-14.80)	10.78±1.06^{yz} (9.38-12.86)
	Week 3	12.04±1.37^{y} (4.40-18.00)	11.60±1.28 ^{y} (8.00-18.00)	11.98±0.85 (8.50-15.30)	11.87±0.14^{z} (11.60-12.03)
Overall Mean		8.40±1.09^{a} (5.08-12.04)	9.20±1.13 (5.89-12.86)	10.78±0.58^{b} (9.41-12.90)	

^{x,y,z} = Means differ significantly ($P < 0.05$) between periparturient periods; ^{a,b,c} = Means differ significantly ($P < 0.05$) between the pregnancy types; HCA = Humid climate-adapted; SCA = Savannah climate-adapted; n = 16.

The SOD activity in twin-bearing HCA and twin-bearing SCA goats was lower ($p < 0.05$) a week after kidding than prepartum week 3 (Table 4). The activity was also lower ($p < 0.05$) during parturition in twin-bearing SCA goats, compared to 3 weeks prepartum. In contrast, singleton-bearing goats maintained relatively steady SOD activity, regardless of the pregnancy stages. Overall mean (± SEM) SOD activity was lower ($p < 0.05$) during parturition and the first week postpartum than during gestation (Table 4). There was no significant interaction between the pregnancy types and stages in SOD activity, but the source of variation in SOD activity was primarily due to the effect of pregnancy stages ($p < 0.001$) (Table 5).

Table 4. Superoxide dismutase activity (μmol/L) in periparturient singleton and twin-bearing during the hot-dry season

Pregnancy period		Singleton (SCA)	Twin (SCA)	Twin (HCA)	Overall Mean
Pre-conception		4.15±0.64 (1.20-6.60)	4.06±0.65 (0.90-6.10)	4.91±0.58 (1.10-6.20)	4.38±0.27 (4.06-4.91)
Prepartum:	Week 3	5.01±0.37 (2.90-6.10)	5.64±0.32^{x} (4.00-6.80)	5.10±0.20^{x} (4.50-6.10)	5.25±0.20^{x} (5.01-5.64)
	Week 1	5.09±0.38 (3.80-6.30)	4.89±0.46 (2.70-6.60)	5.31±0.34 (4.30-7.00)	5.10±0.12^{x} (4.89-5.31)
Parturition		4.58±0.51 (2.20-5.90)	3.30±0.38^{y} (1.90-4.70)	2.69±0.55 (0.40-4.50)	3.52±0.56^{y} (2.69-4.58)
Postpartum:	Week 1	4.34±0.44 (1.50-5.30)	3.78±0.37^{y} (2.30-5.40)	3.58±0.27^{y} (2.30-4.50)	3.90±0.23^{y} (3.58-4.34)
	Week 3	4.35±0.25 (3.005.40)	4.43±0.49 (2.10-6.30)	5.06±0.25 (4.2-5.70)	4.61±0.23 (4.35-5.06)
Overall Mean		4.59±0.56 (4.15-5.09)	4.35±0.34 (3.3-5.64)	4.44±0.43 (2.69-5.31)	

^{x,y,z} = Means differ significantly ($P < 0.05$) between periparturient periods; HCA = Humid climate-adapted; SCA = Savannah climate-adapted; n = 16

Table 5. Sources of variation in oxidative stress biomarkers between the pregnancy stages and types

Oxidative Biomarker	Percentage of Total Variation (%)		
	Pregnancy stage	Pregnancy type	Interaction (PS x PT)
MDA	22.15****	2.60^{ns}	7.08^{ns}
CAT	11.39*	4.37**	2.08^{ns}
GPx	20.01****	5.74*	7.05^{ns}
SOD	20.12***	0.51^{ns}	9.08^{ns}

MDA = malondialdehyde; CAT = catalase; GPx = glutathione peroxidase; SOD = superoxide dismutase; NS = not significant; PS = pregnancy stage; PT = pregnancy type (singleton- and twin-bearing goats); n = 16; Asterisk indicates significant correlation at * ($P < 0.05$); ** ($P < 0.01$); *** ($P < 0.001$); **** ($P < 0.0001$).

Correlation

There was a negative correlation between oxidative stress biomarkers and preconception BW and preconception BMI, regardless of the pregnancy type and the periparturient status of the does. In all the pregnancy types, the preconception BW and BMI were positively ($p < 0.01$) related with the BW of the dams at different stages of the peripartum (Table 6). There was a positive correlation ($p < 0.05$) between the preconception BW of the singleton-bearing does and that of kids from birth until the 3rd week postpartum; while in the twin-bearing HCA goats, the BMI correlated positively ($p < 0.05$) with the BW of the kids only at week 1 postpartum (r = 0.5639) (Table 7).

Table 6. Influence of maternal preconception body weight and body mass index on the body weight of the goats at different periparturient stages

Correlated Parameters		Body Weight of Dam			
		Prepartum 3	Prepartum 1	Postpartum 1	Postpartum 3
Singleton (SCA):	Preconception BW	0.995****	0.994****	0.997****	0.997****
	Preconception BMI	0.872**	0.854**	0.848**	0.858**
Twin (HCA):	Preconception BW	0.994****	0.927***	0.955***	0.992****
	Preconception BMI	0.910**	0.893**	0.930***	0.889**
Twin (SCA):	Preconception BW	0.988****	0.904**	0.893**	0.975****
	Preconception BMI	0.980****	0.899**	0.881**	0.949****

BW = body weight; BMI = body mass index; HCA = Humid climate-adapted; SCA = Savannah climate-adapted; n = 16; asterisk indicates significant correlation at * ($P < 0.05$); ** ($P < 0.01$); *** ($P < 0.001$); **** ($P < 0.0001$)

Table 7. Influence of the maternal preconception body weight and body mass index on the kid’s body weight

Correlated Parameters		Birth Weight	BW (Week 1)	BW (Week 2)	BW (Week 3)
Singleton (SCA):	Preconception BW	0.755*	0.760*	0.722*	0.723*
	Preconception BMI	0.688	0.703	0.585	0.590
Twin (HCA):	Preconception BW	0.578	0.628	0.528	0.501
	Preconception BMI	0.457	0.564*	0.433	0.349
Twin (SCA):	Preconception BW	0.028	-0.088	-0.247	-0.161
	Preconception BMI	0.0984	-0.003	-0.157	-0.097

BW = body weight; BMI = body mass index; HCA = Humid climate-adapted; SCA = Savannah climate-adapted; n = 16; asterisk indicates a significant correlation at * $P < 0.05$.

DISCUSSION

The result shows that MDA concentration increased during the parturition period in the twin-bearing goats, except in singleton-bearing goats. The finding of high and low MDA concentrations at pre- and postpartum in twin-bearing goats is in tandem with previous reports of high concentrations of MDA or thiobarbituric reactive substances (TBARS) during calving in cows [8,32]. Similarly, [10] reported increased MDA levels around kidding until the 2nd week post-kidding in peripartal Beetal goats. The high concentration of MDA during the parturition period might be due to an increased oxidative stress level, as reported in goats [10], sheep [5] and cows [8]. This finding may also be due to heat stress sequel to the increase in AT during the hot-dry season. Parity number significantly influences the oxidative status of pregnant animals [32] as recorded in this study, where the twin-bearing goats had higher MDA concentration than singleton-bearing goats. The result strongly suggests that as gestation advances, there was an accelerated demand for oxygen and increased metabolism, resulting in more generation of ROS until parturition. Thereafter, a decline due to an increase in antioxidant molecule production apparently occurred. Similar findings were obtained by [32] that gestation and parturition facilitate increased ROS production and decreased antioxidant capacity in lambs. The MDA concentration was relatively high in twin-bearing HCA goats during gestation, with a slight decline during lactation but a sharp decline in singleton- and twin-bearing SCA goats after parturition. The result suggests that the twin-bearing HCA breed was greatly influenced by the simultaneous effect of prevailing thermal environmental conditions and late-gestation stress, evidenced by increased lipoperoxidation. The result shows that the goats were subjected to oxidative stress sequel to the prevailing high AT and THI. The result demonstrated that in order to benefit maximally from the fecundity rate and to improve the productivity of HCA goats in the tropical Savannah climate, mitigative antistress measures must be adopted against extreme thermal environmental conditions. Physiological stress experienced by pregnant animals has been shown to have a negative influence on the offspring's behaviour, health, and productivity [14]; thus, good kidding management practices such as adequate nutrition, shedding and clean drinking water that would reduce periparturient stress should be instituted.

In the present study, the SOD activity was lower during and a week after parturition in both the twin-bearing goats. The finding suggests an increased generation of ROS and that the SOD activity was depleted as a result of ROS scavenging. Although SOD activity accentuates the production of H_2O_2, a simultaneous increase in activities of other important antioxidant enzymes including GPx and catalase were also apparently eminent to counteract the excess ROS generated during the last week of gestation and the first three weeks postpartum [13,14]. The increase was more evident in the singleton- and twin-bearing SCA goats as there was a simultaneous increase in antioxidant enzyme activities before and after parturition. [10] reported a similar finding of a corresponding decrease in antioxidant molecules around kidding in periparturient Beetal goats until the 2nd week postpartum. The GPx catalyzes oxidation-reduction reactions, resulting from the action of ROS by eliminating H_2O_2 molecules to protect cell-membrane integrity. [34] reported a decrease in GPx activity in dairy goats indicating that postpartum goats experience increased ROS production and lipid peroxidation. Catalase activity was higher in twin-bearing SCA than in singleton- and twin-bearing HCA goats. However, the overall GPx activity was higher in twin-bearing HCA than in singleton and twin-bearing SCA, thereby depicting a better oxidative stress response in HCA goats. Overall, the obtained result is similar to the reports of [18] that the depletion of antioxidants is the aftermath and not the cause of oxidative stress.

The preconception BW and BMI show a significant and positive relationship with the BW of the dams, regardless of the pregnancy type and periparturient status of the does, indicating that preconception BW and BMI are vital determinants of periparturient weight gain/loss in these breeds of goats. Furthermore, the correlation was stronger with preconception BMI than with BW. This finding is in consonant with that of [35] that the growth of kids before birth is modulated by nutrition and maternal genetic composition, and that postnatal growth of kids is influenced by weight at birth, birth type, sex, litter size, age, and of milk production of dams [36]. However, the findings of [37] in Kiko meat goats where the BW during breeding negatively correlated with the kids’ birth and weaning weight are contradictory to the findings of this study Similarly, the body condition score of the dam during breeding has been shown to have a higher positive impact on the birth weight and the kid’s body weight at weaning [37].

CONCLUSIONS

There was a heightened level of ROS generation during the parturition week with corresponding low activities of antioxidant enzymes in the singleton and twin-bearing SCA (RSG and SHG) goats, compared to twin-bearing HCA (WAD) goats. The activities of antioxidant enzymes were higher in HCA than in SCA goats, regardless of the pregnancy types. Furthermore, the oxidative stress responses were influenced by either the pregnancy types or stages rather than an interaction between them. The HCA goats showed lower oxidative stress responses during the study period as a function of either the pregnancy type or stage. The maternal factors of precondition BW and BMI did not influence the oxidative stress responses of the goats, except for the singleton-bearing kids that were influenced by the preconception BW of the dam. Maternal factors positively influenced the weight gain of the goat kids at birth. Further studies with larger sample sizes are recommended to explore the genetic basis of response and adaptation in multiple gestating goats under combined stressors of pregnancy and heat stress during the hot-dry season. Studies should also be carried out to evaluate the effects of quality of feed and season on the oxidative stress responses in the ewes.

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