Effects of dietary inclusion of turmeric (*Curcuma longa* L.) powder on oxidative stress and cortisol concentration in goats during pregnancy and onset of postpartum

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Abstract

Oxidative stress is a chemical stress caused by imbalance between the production of free radicals and the ability of organisms to absorb their excess. It is extremely dangerous because affected animals may not exhibit physical symptom(s). It induces a stress with cellular damage that if not adequately restored by antioxidant makes the organism sensitive to serious degenerative disorders. Against this background, a study on oxidative stress in Kalahari Red (KR), West African Dwarf (WAD) and KalaWAD goats fed graded levels of turmeric (*Curcuma longa* L.) powder (TP) during pregnancy and after kidding was evaluated. Forty five goats comprising of 15 goats/breed and divided into five goats per/breed/treatment were used. Dietary treatments which included concentrate diet (CD) as TM-0; CD+2g/kg TP as TM-2; and CD+5g/kg TP as TM-5 were fed for 162days. Blood samples were collected from the goats at the beginning of the experiment; 1st and 2nd trimesters; and within 24hrs after kidding for determination of antioxidant enzymes activities like Superoxide dismutase (SOD); Glutathione peroxidase (GSH-Px); Glutathione (GSH); Thiobarbituric reactive substances (TBARS) and Cortisol spectrophotometrically. Results obtained revealed that WAD goats had highest ($p<0.05$) reduction by 3.57u/mL for TBARS. The KR goats had increment ($p<0.05$) by 1.56u/mL for GSH-Px and decrease ($p<0.05$) by 1.78ng/mL for cortisol concentration. SOD was increased ($p<0.05$) by 0.50u/ml for KalaWAD goats. TP inclusion at 2g/kg improved ($p<0.05$) values for SOD (1.21u/mL) and GSH-Px (0.85u/mL), while GSH (2.28u/mL) was improved by TP inclusion at 5g/kg. KalaWAD goats fed TM-2 had highest ($p<0.05$) reduction in TBARS value by 2.70u/mL, whereas KalaWAD goats fed TM-5 had improved ($p<0.05$) value for SOD (1.91u/mL). KR goats fed TM-2 and TM-5 had improvement and reduction in the values of GSH-Px by 5.41u/mL and cortisol concentration by 2.93ng/mL respectively. It is concluded that breeds of goat, turmeric powder inclusion and their interaction influenced oxidative stress and cortisol concentration.

Keywords: Superoxide dismutase; Glutathione peroxidase; Thiobarbituric reactive substances; Kalahari Red; KalaWAD; West African Dwarf

Effets de l'inclusion alimentaire de poudre de curcuma (*Curcuma longa* L.) sur le stress oxydatif et la concentration de cortisol chez les chèvres pendant la gestation et le début du post-partum

Résumé

*Le stress oxydatif est un stress chimique causé par un déséquilibre entre la production de radicaux libres et la capacité des organismes à absorber leur excès. C'est extrêmement dangereux car les animaux affectés peuvent ne pas présenter de symptôme(s) physique(s). Il induit un stress avec des dommages cellulaires qui, s'il n'est pas correctement restauré par des antioxydants, rend l'organisme sensible à de graves troubles dégénératifs. Dans ce contexte, une étude sur le stress oxydatif chez les chèvres Kalahari Red (KR), West African Dwarf (WAD) et Kala WAD nourries à des niveaux gradués de poudre de curcuma (*Curcuma longa* L.) (TP) pendant la grossesse et après la mise bas a été évaluée. Quarante-cinq chèvres comprenant 15 chèvres/race et divisées en cinq chèvres par/race/traitement ont été utilisées. Traitements diététiques qui comprenaient un régime concentré (RC) en tant que TM-0 ; CD+2g/kg TP comme TM-2 ; et CD+5g/kg de TP sous forme de TM-5 ont été nourris pendant 162 jours. Des échantillons de sang ont été prélevés sur les chèvres au début de l'expérience; 1er et 2e trimestres ; et dans les 24 heures après la blague pour la détermination des activités des enzymes antioxydantes comme le superoxyde dismutase (SOD) ; Glutathion peroxydase (GSH-Px); glutathion (GSH); Substances réactives thiobarbituriques (TBARS) et cortisol par spectrophotométrie. Les résultats obtenus ont révélé que les chèvres WAD présentaient la réduction la plus élevée ($p<0,05$) de 3,57u/mL pour les TBARS. Les chèvres KR ont augmenté ($p<0,05$) de 1,56u/mL pour le GSH-Px et diminué ($p<0,05$) de 1,78ng/mL pour la concentration de cortisol. La SOD a été augmentée ($p<0,05$) de 0,50 u/ml pour les chèvres KalaWAD. L'inclusion de TP à 2g/kg a amélioré ($p<0,05$) les valeurs de SOD (1,21u/mL) et de GSH-Px (0,85u/mL), tandis que le GSH (2,28u/mL) a été amélioré par l'inclusion de TP à 5g/kg. Les chèvres KalaWAD nourries au TM-2 présentaient la réduction la plus élevée ($p<0,05$) de la valeur TBARS de 2,70u/mL, tandis que les chèvres KalaWAD nourries au TM-5 avaient une valeur améliorée ($p<0,05$) pour la SOD (1,91u/mL). Les chèvres KR nourries avec TM-2 et TM-5 ont eu une amélioration et une réduction des valeurs de GSH-Px de 5,41u/mL et de la concentration de cortisol de 2,93ng/mL respectivement. Il est conclu que les races de chèvres, l'inclusion de poudre de curcuma et leur interaction ont influencé le stress oxydatif et la concentration de cortisol.*

Mots clés : Superoxyde dismutase ; Glutathion peroxydase ; Substances réactives thiobarbituriques; Rouge Kalahari ; KalaWAD ; West African Dwarf

Introduction

Ruminants largely depend on forages as these are essential to maintain their health and production at various stages of their growth and development. In developed countries, sufficient grazing land is available, so ruminants can get adequate amount of green grasses during grazing seasons and when it is not possible in other

seasons they are supplied with silage and other high quality conserved forages. Conversely, green forages are not abundantly available and are seasonal in some developing countries like Nigeria, so ruminants are mainly supplied with low quality forages and cereal straws. During the course of foraging on these low quality and poor feed resources, the animals are stressed due to long distance trekking,

picking of many pathogens together with their eggs, and the animals suffer directly or indirectly from adverse effects of climate change. Supplementation is another tool to improve the quality of these forages, straws and other feed resources by adding nutrients that otherwise are low/deficient in these forages (Khandaker *et al.*, 1998; Muetzel *et al.*, 2003; Chaudhry, 2008), it can also come in form of some materials that can aid digestion or better feed utilisation by the animals. Supplements increase the utilization of low quality forages, but the requirement for these supplements is more than their availability in many developing countries (Devendra and Sevilla, 2002). As the demand for animal protein continue to increase, global animal production faces several challenges in order to meet these demands because of environmental challenges (global warming and climate change). Furthermore, the intensification of animal production systems might compromise animal health and welfare; and consequently increase the incidence of the metabolic diseases. Ruminant health and production is crucial for a sustainable animal production system, and this area of research is now attracting international interest, especially the mechanisms by which antioxidant supplementation may influence metabolism and health. Oxidants play a central role in normal cellular function, providing an important feedback loop between metabolic activity and regulation of cellular functions. Oxidative stress (OS) arises due to an imbalance between pro-oxidants and antioxidants, which can occur under circumstances of increased antioxidant utilisation or immune function. In ruminant health and production, the study of redox homeostasis is contributing to the understanding of important pathways involved in metabolic disorders. Indeed, OS seems to play a central role in the regulation of the metabolic activity of some organs and

productivity in farm animals (Celi, 2011). For example, during the last trimester of pregnancy and at the beginning of lactation the rapid foetal growth and the production of large amounts of colostrum and milk, an increase in both maternal and foetal metabolism result in increased reactive oxygen species production during late gestation and early lactation and increased requirements for micronutrients, including antioxidants (Pedernera *et al.*, 2010). Therefore manipulation of micronutrients and antioxidants has the potential to control the effects of oxidative damage, such as occurs during the transition period (Lean *et al.*, 2014). This period is characterised by extremely high levels of nutrient utilisation due to the growing foetus and then lactation diverts micronutrients and antioxidants from the animal to the mammary gland. The relationship between OS, diseases and metabolic disorders is further demonstrated by lowered antioxidant status during mastitis, retained placenta, acidosis, ketosis and milk fever (Celi, 2011).

Cortisol is considered one of the main hormones involved in stress response, and its main function is to favour protein metabolism to convert protein into amino acids, supporting gluconeogenesis. The cortisol synthesized by the adrenal cortex stimulates the degradation and release of glucose (Ribeiro *et al.*, 2018), amino acid, and fat in the liver, muscle and adipose tissue (Sejian *et al.*, 2010). It is also associated with inflammation (Sjaastad *et al.*, 2003). Concentrations of cortisol can vary according to several factors, such as season, photoperiod and diet composition. Stress which could be as a result of external and internal forces (stressors) is a disruptive event accompanied by predictable biochemical, physiological, cognitive and behavioural changes that are directed either toward altering the stressful event or accommodating to its effects (Taylor, 2008). Stressors are classified as

physical/environmental or psychologic/perceived (Gruys *et al.*, 1998). These stressors influence activation of the hypothalamic pituitary adrenal axis followed by synthesis of corticotrophin or adrenocorticotrophic hormone by the anterior pituitary. This stimulates adrenal cortical secretion of glucocorticoids leading to increased circulating concentration of cortisol. Psychological and physical factors like anxiety and pain influence the activation of the hypothalamic–pituitary–adrenal axis leading to cortisol release; a core mediator of stress response (Desborough, 2000) which in turn promotes glycogenolysis and gluconeogenesis resulting in hyperglycaemia. The stress induced cortisol secretion exists so that the body can handle and recuperate after an injury, physical activity or physiological strain (Desborough, 2000). Spices which have long been safely used for human consumption could be tested as alternative supplements to enhance forage utilization, reduce nutrient wastage, alleviate stress emanating from adverse climate change and anti-oxidant imbalance, promote growth, as antibiotics, to improve overall performances and health of animals in ruminant livestock production. Turmeric (*Curcuma longa* L.) possesses antioxidant properties which function as free radical scavengers that protect the body defence system against excessively produced free radicals thereby stabilizing the health status of the animal (Sivakumar *et al.*, 2010). Oxidants are compounds capable of oxidising target molecules. According to Lykkesfeldt and Svendsen (2007), this can take place by one of three actions i.e. abstraction of a hydrogen atom; abstraction of an electron; or the addition of oxygen. The study was therefore conducted to

evaluate oxidative stress and cortisol concentration in Kalahari Red, West African Dwarf and KalaWAD goats fed graded levels of turmeric powder intensively during pregnancy and shortly after kidding in South-western Nigeria.

Materials and methods

Preparation of turmeric (Curcuma longa L.) powder

Turmeric rhizome was sourced from a market in Ibadan, Oyo State, Nigeria, and was prepared according to the procedure of Oderinwale *et al.* (2020) as outlined in Figure 1.

Description of the experimental site

The study was conducted at the Kalahari Red Goats Unit under Livestock Production and Research Programme of Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR), Federal University of Agriculture Abeokuta, Ogun State, Nigeria. The region is 76m above the sea level and falls within Latitude 7°13'47.41"N and Longitude 3°23'43.48"E. The climate is humid and located in the forest zone of South-Western Nigeria.

Source of experimental animals

The Kalahari Red, KalaWAD and West African Dwarf goats used for the study were sourced from IFSERAR, Federal University of Agriculture Abeokuta, Nigeria.

Atmospheric data collection

The ambient temperature taken in the morning (8:00am) and afternoon (1:00pm) on daily basis using atmospheric thermometer during the course of the study is presented in Figure 2. The mean annual precipitation of the experimental site was 1,330mm with an average relative humidity of 80% throughout the year.

Figure 1: Flow chart showing preparation of turmeric powder

Figure 2: Monthly ambient temperature (°C) of the experimental site

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Animal management procedure

A total of 45 mature primiparous non-pregnant and non-lactating goats of about two years old were used. These included 15 Kalahari Red (KR), 15 KalaWAD and 15 West African Dwarf (WAD) goats. The goats were balanced for weight, tagged and randomly allotted to three treatment groups comprising of five goats as replicates per treatment. Each goat was housed in an individual cubicle measuring 1.2x1.4m². Flock treatment was done prior to mating to control infection from insect vectors and disease causing organisms. Oxytetracycline 20% (Oxytetracycline 200mg/ml as dihydrate) was administered intramuscularly at 1ml per 20kg body weight, while multivitamin injection was administered intramuscularly at 1ml per

10kg body weight as vitamin supplement and anti-stress. Ivermectin (Ivermectin Injection 10mg/ml) was administered subcutaneously at 1mL per 50kg body weight to control gastro-intestinal worms, fly larvae, lice, ticks and mites.

Experimental diets

1.TM-0: Basal concentrate diet (as control);

2.TM-2: Basal concentrate diet + 2g/kg Turmeric powder;

3.TM-5: Basal concentrate diet + 5g/kg Turmeric powder.

The composition of basal concentrate diet is presented in Table 1.

The dietary treatments were used for flushing of the goats two weeks before mating and throughout the experimental period. The dietary treatments were fed at the rate of 5% bodyweight of the goats.

Table 1: Gross compositions (%) of basal experimental concentrate diet

Ingredients	% Inclusion
Maize	15.0
Wheat Offal	42.0
Palm Kernel Cake	30.0
Soybean Meal	4.0
Groundnut Cake	3.0
Bone Meal	3.0
Limestone	1.5
Common Salt	1.0
†Premix	0.5
Total (kg)	100

†contains Vitamin A (I.U.) 10,000,000; Vitamin D₂ (I.U.) 2,000,000; Vitamin E (I.U) 20,000; Vitamin K (mg) 2,250; Riboflavin (mg) 5000; Pyridoxine (mg) 275; Biotin (mg) 50; Pantothenic acid (mg) 7500; Vitamin B₁ (mg) 175; Vitamin B₁₂ (mg) 15.0; Niacin (mg) 27,500; Folic acid (mg) 7500. Choline Chloride (mg) 400; Antioxidant (mg) 125; Fe (g) 20.0; Zn (g) 50.0; Mn (g) 80.0; Cu (g) 5.0g; I (g) 12.0; Co (mg) 200; Se (mg) 200.

Oestrous synchronisation, mating and scanning

Goats used for the study were synchronized during the flushing period with first intramuscular injection of DinoprostTriomethamine (5mg/mL). Second injection was given to the goats 10 days after first injection at same dosage

according to the procedure of Heise (2012). Thereafter, mating of the synchronized goats was done by introducing six (i.e. two bucks per breed of goat) proven KR bucks of similar weight and age range into pens where the experimental goats were housed for six hours/day (between 4:00pm to 7:00pm; and 7:00am to 10:00am) for one

week. Proper observation was done to ensure successful mating of each goat by the selected KR bucks in terms of intromission and ejaculation before data collection commenced. After 30 days of successful mating, the goats were scanned by ultrasonography method using 3.5MHz linear array probe (Kaikin, China) and ultra-sound scanning machine (DraminskiAnimal Profi Ultrasound Scanner NimH 12V; 3.8Ah; 45°C). All the goats that did not conceive after the scanning went through the synchronization and mating cycle again.

Feeding trial

The pregnant goats were fed for 24 weeks (162 days) until all the goats kidded. The experimental diets were administered to the goats at 5% of their body weight twice a day throughout the feeding trial. The goats were fed concentrate diet on daily basis in the morning by 8:00, while stall-feeding was done using Congo grass (*Brachiaria ruziziensis*) in the evening by 4:00. Concentrate and grass refused each day are recorded before fresh ones are offered the following day. Cool and clean drinkable water was supplied to the goats *ad libitum*.

Determination of antioxidant enzyme activities (oxidative stress markers)

Blood samples were collected at the beginning of the experiment (before flushing), at 1st trimester (50 days), 2nd trimester (100 days) and within 24hrs after kidding. The blood samples were collected via the external jugular vein with new 5ml hypodermic syringes from each animal into a well labelled plain bottle, centrifuged for serum collection and kept at -4°C for subsequent use for the determination of oxidative stress markers and cortisol concentration with spectrophotometer in the Department of Veterinary Physiology and Pharmacology Laboratory, Federal University of Agriculture Abeokuta, Nigeria.

Oxidative stress markers assayed included

Superoxide Dismutase (SOD) according to the procedure of Misra and Fridovich (1972); Glutathione Peroxidase (GSH-Px) and Glutathione (GSH) were determined according to the procedure of Ellman (1995); while serum lipid peroxidation was determined as Thiobarbituric Reactive Substances (TBARS) according to the procedure of Ohkawa *et al.* (1979).

Proximate and fibre analysis of concentrate, turmeric powder and grass fed

Samples were taken from the dietary concentrate, milled turmeric powder and *Brachiaria ruziziensis* forage. The samples were milled, and kept until when needed for proximate composition according to the procedure of A.O.A.C. (2005), while fibre fractions were determined according to the procedure of Van Soest *et al.* (1991).

Statistical analysis

Data obtained were arranged in a 3x3 factorial layout in a completely randomized design, while one-way analysis of variance was done using the procedures of Statistical Analysis System, SAS (2004). Significance level was taken at 5% probability, while significant means were separated using Duncan's multiple range test of the same statistical package.

Experiment factors included:

Factor A: Goat Breeds (Kalahari Red, KalaWAD and West African Dwarf goats)

Factor B: Experimental concentrate diets (TM-0; TM-2; and TM-5)

Statistical model

$$Y_{ijkl} = \mu + T_i + R_j + (TR)_{ij} + \Sigma_{ijkl}$$

Where:

Y_{ijkl} = Observed performance indices

μ = Goats' population mean

T_i = Effects of goat breeds

R_j = Effects of experimental concentrate diets

$(TR)_{ij}$ = Interactive effects of breeds and diets

Σ_{ijkl} = Residual Effect/Error term

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Experimental formulae

Organic Matter (%) = 100 - Ash
Hemicellulose (%) = Neutral detergent fibre
– Acid detergent fibre
Cellulose (%) = Acid detergent fibre - Acid
detergent lignin
Weight Gain (kg) = Final weight (kg) -
Initial weight (kg)
ME (MJ/kg DM) = 12.86 + 0.0265EE +
0.0056ADF + 0.0153ASH -
0.0253ADL

Where: ME = Metabolisable
energy, DM = Dry matter, EE = Ether
extract,

ADF = Acid detergent
fibre, ADL = Acid detergent lignin

Results and discussion

Table 2 shows the proximate and fibre

fraction compositions of basal experimental concentrate diet fed to the goats. Dry matter (DM) contents of the dietary concentrates was 88.19%, while crude protein (CP) content of 16.49% was obtained. The CP value indicated that the concentrate diet had sufficient CP to meet the nutrient need of the pregnant goats in terms of CP. This is corroborated by the report of National Research Council (2007) which recommended CP of 9-10% and 13-14% for early and late gestations respectively for goats. The metabolisable energy of the diet was 12.27MJ/kg DM, the value which was sufficient compared to 11.30MJ/kg DM recommended by Agricultural and Food Research Council (1998) for pregnant goats.

Table 2: Proximate and fibre fraction compositions of basal experimental concentrate diet

Parameters (%)	TM-0
Dry Matter	88.19
Crude Protein	16.49
Ether Extract	2.48
Crude Fibre	27.50
Ash	10.98
Nitrogen Free Extract	41.74
Organic Matter	89.02
Neutral Detergent Fibre	62.67
Acid Detergent Fibre	38.00
Acid Detergent Lignin	10.67
Hemicellulose	24.67
Cellulose	27.33
†ME (MJ/kg DM)	12.27

ME is Metabolisable Energy

†Calculated using De Boever *et al.*(1997) equation

The proximate composition, fibre fractions and some vitamins assay of Congo grass (*Brachiaria ruziziensis*) and turmeric (*Curcuma longa* L.) powder is presented in Table 3. The results obtained for proximate

composition of turmeric powder revealed that the DM was 86.36%. The value, which was close to that of Feedipedia (2020) which reported DM content of turmeric to be 89.50%. The values reported by other

researchers were slightly higher than what was obtained for the study. Youssef *et al.* (2014) reported DM content of 93.40%, while 91.00% was reported by Ahamefula *et al.* (2014). Crude protein of 13.27% was obtained for turmeric, whereas lower CP content ranging from 4.6 to 9.40% was reported in other studies (Ahamefula *et al.*, 2014; Youssef *et al.*, 2014; Feedipedia, 2020). Variations in the values for CP might be due to processing methods, soil nutrient composition and effect of location. Crude fibre content obtained for the study was 24.21% which was close to 38.40% reported by Feedipedia (2020) compared to lower values of 4.02% and 4.60% as reported by Youssef *et al.* (2014) and Ahamefula *et al.* (2014) respectively. Values obtained for ash content, ether extract (EE) and nitrogen free extract (NFE) were 5.07%, 2.74% and 46.15% respectively. Proportions of fibre fractions such as neutral detergent fibre (NDF) were 66.67%; acid detergent fibre (ADF) was 38.67%; acid detergent lignin (ADL) was 8.00%; hemicellulose was 28%; and cellulose was 30.67%. The values obtained for these fibre fractions were similar to that

reported by Feedipedia (2020). Energy content of 12.44 MJ/kg DM was obtained, the value which was lower than 18.00 MJ/kg DM reported by Feedipedia (2020). The variation might be due to the procedures/formulae employed in estimating the energy content. The DM which was 89.12% for the Congo grass was similar to that reported by Feedipedia (2020), while the CP was 8.01% which was higher than 4.60% that was reported by Feedipedia (2020). The variation in the CP content might be due to various factors ranging from soil nutrients, part(s) of the plant used for analysis, season of harvest and geographical location. The values for EE, crude fibre (CF), ash, NFE and organic matter (OM) were 2.41, 24.54, 7.78, 54.17 and 92.22 percent respectively. These values contradict the results obtained by Maia *et al.* (2014) and Feedipedia (2020). These variations might be due to part(s) of the plant used for analysis, season of harvest and geographical location. Fibre fraction analysis for Congo grass revealed that NDF was 65.33%; ADF was 45.33%; ADL was 13.33%; hemicellulose was 20%; and cellulose was 32%.

Table 3: Proximate composition, fibre fractions and some vitamins assay of *Brachiaria ruziziensis* and turmeric powder

Parameters (%)	<i>Brachiaria ruziziensis</i>	Turmeric Powder
Dry Matter	89.12	86.36
Crude Protein	8.01	13.27
Ether Extract	2.41	2.74
Crude Fibre	24.54	24.21
Ash	7.78	5.07
Nitrogen Free Extract	54.17	46.15
Organic Matter	92.22	94.93
Neutral Detergent Fibre	65.33	66.67
Acid Detergent Fibre	45.33	38.67
Acid Detergent Lignin	13.33	8.00
Hemicellulose	20.00	28.00
Cellulose	32.00	30.67
†ME (MJ/kg DM)	12.21	12.44
Vitamins Assay (mg/kg)		
A	ND	18.98
C	ND	1.40
E	ND	5.59

ME is Metabolisable energy

ND is Not determined

†Calculated using De Boever *et al.* (1997) equation

Effects of dietary inclusion of turmeric (*Curcuma longa* L.) powder

The effects of goat breeds on oxidative stress markers and cortisol concentrations during pregnancy and after kidding are presented in Table 4. Breeds of goat had effects on oxidative stress markers and cortisol concentrations from mating till after kidding. Results obtained for breed were not in a particular order. The difference between thiobarbituric reacting substances (TBARS) within 24hrs post-kidding and before mating revealed that West African Dwarf (WAD) had the highest reduction in the value of TBARS while Kalahari Red (KRD) had the least reduction for same parameter. This indicated that KRD had heightened oxidative stress

during the course of pregnancy than others. On the other hand, KalaWAD had the least reduction in the difference of superoxide dismutase (SOD) than other breeds used. This indicates that KalaWAD had reduced oxidative stress than other breeds used. Glutathione peroxidase (GSH-Px) difference was least for KRD, whereas least reduction in value of glutathione (GSH) was obtained for KalaWAD. WAD experienced an increased value at the end of the study for cortisol concentration compared to other breeds used which may be due to stubborn nature of WAD goats and being the most active compared to other breeds of goat used.

Table 4: Effects of goat breeds on oxidative stress markers and cortisol concentrations during pregnancy and after kidding

		Breeds of goat			
Parameters	Kalahari Red	KalaWAD	WAD	SEM	
TBARS (u/mL)					
Before mating	6.14 ^b	7.62 ^a	7.23 ^a		0.33
1 st Trimester (day 50)	8.35	8.36	7.63		0.16
2 nd Trimester (day 100)	9.68 ^a	9.32 ^a	8.03 ^b		0.24
Within 24hrs post-kidding	12.93 ^a	12.57 ^a	10.80 ^b		0.48
Difference	6.79 ^a	4.95 ^b	3.57 ^b		0.41
SOD (u/mL)					
Before mating	42.10 ^a	27.60 ^c	33.36 ^b		1.34
1 st Trimester (day 50)	40.08 ^a	30.97 ^b	38.76 ^a		1.06
2 nd Trimester (day 100)	41.43 ^a	33.17 ^b	36.82 ^b		1.03
Within 24hrs post-kidding	35.65 ^a	28.10 ^b	29.35 ^b		0.93
Difference	-6.44 ^b	0.50 ^a	-4.01 ^b		0.97
GSH-Px (u/mL)					
Before mating	40.79	43.71	43.90		0.82
1 st Trimester (day 50)	40.49 ^b	47.35 ^a	49.29 ^a		1.18
2 nd Trimester (day 100)	40.63 ^b	46.26 ^a	47.54 ^a		1.05
Within 24hrs post-kidding	39.24	41.19	37.83		0.91
Difference	-1.56	-2.52	-6.07		1.14
GSH (u/mL)					
Before mating	25.21	21.23	22.93		0.80
1 st Trimester (day 50)	26.50	23.58	28.08		0.97
2 nd Trimester (day 100)	27.71	24.99	28.16		0.88
Within 24hrs post-kidding	24.58	20.83	23.61		0.77
Difference	-0.63	-0.40	0.68		0.81
Cortisol (ng/mL)					
Before mating	6.80 ^a	6.98 ^a	5.82 ^b		0.17
1 st Trimester (day 50)	8.00 ^b	8.29 ^b	9.39 ^a		0.21
2 nd Trimester (day 100)	10.02	10.24	10.78		0.21
Within 24hrs post-kidding	5.02 ^b	5.54 ^b	6.42 ^a		0.16
Difference	-1.78 ^b	-1.45 ^b	0.60 ^a		0.28

^{abc}Means on the same row having different superscripts are significantly different (p<0.05)

WAD =West African Dwarf, SEM =Standard Error of Means, Difference is Values within 24hrs post-kidding less before mating, TBARS =Thiobarbituric Acid Reactive Substance, SOD= Superoxide Dismutase, GSH-Px=Glutathione Peroxidase, GSH=Glutathione

The trends on applying nutritional antioxidants in order to prevent oxidative stress have gained immense interest. Herbal plants such as turmeric are known to exert their health effects by scavenging free radicals and modulating antioxidant defence system (Azza *et al.*, 2011). Curcuminoids such as curcumin, demethoxycurcumin and bisdemethoxycurcumin contained in turmeric have been reported (Cousins *et al.*, 2007) to have anti-oxidative activities. Curcumin is a potent quencher of singlet oxygen species (Das and Das, 2002) and the major anti-oxidative component of turmeric. It has the ability to inhibit lipid peroxidation and scavenge the superoxide anion and hydroxyl radicals (Motterlini *et al.*, 2000). Table 5 shows the effects of levels of turmeric powder inclusion on oxidative stress markers and cortisol concentrations of goat during pregnancy and after kidding. The results obtained revealed anti-oxidant property of turmeric in the goats by reducing the TBARS and improving the values of SOD, GSH-Px and GSH. Inclusion of turmeric powder at 2g/kg exerted the greatest effect on the oxidative stress markers as revealed by the study. Dingfa *et al.* (2015) reported that Wenchang broilers fed diets supplemented with 300g/100kg of turmeric powder improved the antioxidant capacity of the birds by increasing SOD and GSH-Px activities and decreasing serum malondialdehyde (MDA) concentrations of the birds. Similarly, results obtained by Bucaka *et al.* (2010) revealed that Angora goats' semen supplemented with curcumin had effect on some oxidative stress markers of the goat, where he reported that MDA was reduced, while SOD and GSH-Px were increased by the curcumin supplementation. In another research conducted by Alagawany *et al.* (2016) on the liver of New Zealand White rabbits revealed that supplementation of turmeric

at 6g/kg recorded the highest values for GSH-Px and GSH with 220 mmol/min/ml and 9.90ng/g tissue respectively, while it also recorded least value for MDA (2.83nmol/ml). Goats fed diets containing turmeric powder at 5g/kg exerted greatest effect on the reduction of cortisol level than the control with least reduction for same parameter.

The effects of goat breeds and levels of turmeric powder inclusion on oxidative stress markers and cortisol during pregnancy and after kidding (Table 6) revealed that TBARS was highest for KalaWAD placed under TM-2 before mating and at 1st trimester. KRd fed TM-5 had the highest value at 2nd trimester, whereas the value for TBARS was highest for KalaWAD fed TM-0 within 24hrs of kidding. The difference in the values of TBARS within 24hrs of kidding and before mating showed that KalaWAD fed TM-2 had the least value of 2.70u/mL, which indicated that the goats had a decrease in the value of TBARS by 2.70u/mL from mating till kidding. Other goats fed turmeric powder, especially at 2g/kg inclusion experienced a reduction in the value of TBARS compared to the control diet. The reduction in the value of TBARS which is the major indicator of oxidative stress (i.e. pro-oxidant) could be attributed to ability of turmeric powder inclusion especially at 2g/kg to alleviate oxidative stress. The differences in the values obtained for endogenous antioxidants like SOD, GSH-Px and GSH within 24hrs of kidding and before mating were not in a particular order, but it was observed that goats fed diets containing turmeric powder had improvement in the values of the antioxidants compared to the control groups with resultant reduction in the values of TBARS. This corroborates the report of Wojdyło *et al.* (2007) that turmeric plant possessed high antioxidant contents. KalaWAD fed TM-5 had least value for the

Effects of dietary inclusion of turmeric (Curcuma longa L.) powder

Table 5: Effects of levels of turmeric powder inclusion on oxidative stress markers and cortisol concentrations of goat during pregnancy and after kidding

Parameters	Levels of turmeric powder inclusion			SEM
	TM-0	TM-2	TM-5	
TBARS (u/mL)				
Before mating	6.71	7.12	7.17	0.19
1 st Trimester (day 50)	8.38	7.91	8.05	0.16
2 nd Trimester (day 100)	8.35	9.18	9.50	0.24
Within 24hrs post-kidding	12.63	11.18	12.48	0.33
Difference	5.92	4.07	5.32	0.41
SOD (u/mL)				
Before mating	36.62	33.47	32.97	1.35
1 st Trimester (day 50)	34.63	39.47	35.72	1.06
2 nd Trimester (day 100)	38.52	37.22	35.68	1.03
Within 24hrs post-kidding	29.63	32.26	31.22	0.92
Difference	-6.99 ^b	-1.21 ^a	-1.76 ^a	0.97
GSH-Px (u/mL)				
Before mating	44.54	41.14	42.72	0.82
1 st Trimester (day 50)	45.53	43.90	47.71	1.18
2 nd Trimester (day 100)	45.37	42.73	46.32	1.05
Within 24hrs post-kidding	36.48 ^b	40.29 ^{ab}	41.48 ^a	0.91
Difference	-8.06 ^b	-0.85 ^a	-1.24 ^a	1.14
GSH (u/mL)				
Before mating	24.16 ^a	24.96 ^a	20.25 ^b	0.80
1 st Trimester (day 50)	26.43 ^{ab}	29.37 ^a	22.37 ^b	0.97
2 nd Trimester (day 100)	27.83 ^a	29.76 ^a	23.26 ^b	0.88
Within 24hrs post-kidding	20.31 ^b	26.18 ^a	22.53 ^b	0.77
Difference	-3.85 ^b	1.22 ^a	2.28 ^a	0.81
Cortisol (ng/mL)				
Before mating	6.25	6.55	6.80	0.15
1 st Trimester (day 50)	8.91	8.64	8.13	0.21
2 nd Trimester (day 100)	10.50	10.68	9.85	0.22
Within 24hrs post-kidding	6.00	5.40	5.57	0.17
Difference	-0.25	-1.15	-1.23	0.20

^{ab}Means on the same row having different superscripts are significantly different (p<0.05)

SEM = Standard Error of Means, **Difference** = Values within 24hrs post-kidding less before mating
TM-0 = without Turmeric, **TM-2** = 2g/kg Turmeric Powder Inclusion, **TM-5** = 5g/kg Turmeric Powder Inclusion

difference in the values of cortisol taken within 24hrs of kidding and before mating, the Goats had a decrease in the value of

cortisol by 2.93ng/ml during pregnancy compared to WAD Goats with increase in

Table 6: Effects of breeds of goat and levels of turmeric powder inclusion on oxidative stress markers and cortisol during pregnancy and after kidding

Parameters	Kalahari Red			KalaWAD			West African Dwarf			SEM
	TM-0	TM-2	TM-5	TM-0	TM-2	TM-5	TM-0	TM-2	TM-5	
Thiobarbituric Acid Reactive Substance (TBARS, u/ml)										
Before mating	5.93 ^{bc}	5.55 ^c	6.95 ^{ab}	7.15 ^{ab}	8.15 ^a	7.55 ^a	7.05 ^{ab}	7.65 ^a	7.00 ^{ab}	0.19
1 st Trimester (day 50)	8.30 ^{abc}	7.76 ^{bcd}	8.99 ^a	8.20 ^{abc}	9.00 ^a	7.86 ^{bcd}	8.65 ^{ab}	6.95 ^d	7.30 ^{cd}	0.16
2 nd Trimester (day 100)	8.75 ^{abc}	9.70 ^{ab}	10.60 ^a	8.55 ^{bc}	10.20 ^{ab}	9.20 ^{abc}	7.75 ^c	7.65 ^c	8.70 ^{bc}	0.24
Within 24hrs PK	13.10 ^{abc}	12.15 ^{abc}	13.55 ^{ab}	13.80 ^a	10.85 ^c	13.05 ^{abc}	11.00 ^{bc}	10.55 ^c	10.85 ^c	0.33
Difference	7.17 ^a	6.60 ^{ab}	6.60 ^{ab}	6.65 ^{ab}	2.70 ^c	5.50 ^{abc}	3.95 ^{bc}	2.90 ^c	3.85 ^{bc}	0.41
Superoxide Dismutase (SOD, u/ml)										
Before mating	44.58 ^a	44.05 ^a	37.65 ^b	27.81 ^c	27.68 ^c	27.31 ^c	37.46 ^b	28.67 ^c	33.96 ^b	1.35
1 st Trimester (day 50)	37.46 ^b	44.56 ^a	38.24 ^b	27.52 ^d	35.03 ^{bc}	30.35 ^{cd}	38.91 ^b	38.82 ^b	38.56 ^b	1.06
2 nd Trimester (day 100)	39.68 ^{abc}	45.55 ^a	39.05 ^{bc}	33.57 ^{cd}	32.02 ^d	33.93 ^{cd}	42.32 ^{ab}	34.08 ^{cd}	34.06 ^{cd}	1.03
Within 24hrs PK	31.43 ^{bc}	39.73 ^a	35.79 ^{ab}	27.06 ^c	28.02 ^c	29.22 ^c	30.39 ^{bc}	29.03 ^c	28.63 ^c	0.93
Difference	-13.15 ^e	-4.32 ^{bcd}	-1.85 ^{abc}	-0.75 ^{abc}	0.33 ^{ab}	1.91 ^a	-7.07 ^d	0.36 ^{ab}	-5.33 ^{cd}	0.97
Glutathione Peroxidase (GSH-Px, u/ml)										
Before mating	44.04	38.18	40.15	44.85	42.40	43.88	44.71	42.84	44.13	0.82
1 st Trimester (day 50)	36.90 ^c	38.86 ^{de}	45.72 ^{bcd}	46.41 ^{abc}	49.68 ^{abc}	45.95 ^{bcd}	53.29 ^a	43.15 ^{cde}	51.44 ^{ab}	1.18
2 nd Trimester (day 100)	37.07 ^c	40.09 ^{bc}	44.72 ^{abc}	47.84 ^{ab}	45.02 ^{abc}	45.91 ^{ab}	51.20 ^a	43.08 ^{abc}	48.34 ^{ab}	1.05
Within 24hrs PK	32.13 ^b	43.59 ^a	41.98 ^a	40.73 ^a	41.09 ^a	41.76 ^a	36.57 ^{ab}	36.20 ^{ab}	40.70 ^a	0.91
Difference	-11.91 ^d	5.41 ^a	-1.83 ^{ab}	-4.12 ^{bc}	-1.31 ^{abc}	-2.12 ^{bc}	-8.14 ^{cd}	-6.64 ^{cd}	-3.43 ^{bc}	1.14
Glutathione (GSH, u/ml)										
Before mating	25.43 ^{ab}	30.36 ^a	19.85 ^b	22.39 ^b	21.89 ^b	19.40 ^b	24.66 ^{ab}	22.62 ^b	21.50 ^b	0.80
1 st Trimester (day 50)	27.03 ^{abc}	31.67 ^a	20.79 ^c	22.61 ^{bc}	26.95 ^{abc}	21.18 ^c	29.64 ^{ab}	29.47 ^{ab}	25.13 ^{abc}	0.97
2 nd Trimester (day 100)	26.70 ^{bc}	33.36 ^a	23.05 ^c	23.30 ^c	29.14 ^{ab}	22.52 ^c	33.49 ^a	26.78 ^{bc}	24.20 ^c	0.88
Within 24hrs PK	19.51 ^{cd}	31.21 ^a	23.02 ^{bc}	18.78 ^d	24.32 ^b	19.38 ^{cd}	22.66 ^{bc}	23.00 ^{bc}	25.18 ^b	0.77
Difference	-5.92 ^c	0.85 ^{ab}	3.17 ^a	-3.61 ^{bc}	2.43 ^{ab}	-0.02 ^{abc}	-2.00 ^{abc}	0.38 ^{abc}	3.67 ^a	0.81
Cortisol (ng/ml)										
Before mating	6.45 ^{abc}	6.45 ^{abc}	7.50 ^a	6.90 ^{ab}	6.85 ^{ab}	7.20 ^a	5.40 ^c	6.35 ^{abc}	5.70 ^{bc}	0.17
1 st Trimester (day 50)	8.00 ^{bc}	8.20 ^{bc}	7.80 ^{bc}	8.74 ^{abc}	8.95 ^{ab}	7.19 ^c	10.00 ^a	8.77 ^{abc}	9.39 ^{ab}	0.21
2 nd Trimester (day 100)	10.15	9.90	10.00	10.66	10.35	9.70	10.70	11.80	9.85	0.22
Within 24hrs PK	5.60 ^{abc}	4.90 ^{bc}	4.57 ^c	5.75 ^{abc}	5.26 ^{bc}	5.60 ^{abc}	6.65 ^a	6.05 ^{ab}	6.55 ^a	0.17
Difference	-0.85 ^b	-1.55 ^{bc}	-2.93 ^c	-1.15 ^b	-1.59 ^{bc}	-1.60 ^{bc}	1.25 ^a	-0.30 ^{ab}	0.85 ^a	0.87
Means on the same row having different superscripts are significantly different (p<0.05) Difference is Values within 24hrs post-kidding less before mating PK										

abcde

Means on the same row having different superscripts are significantly different ($p < 0.05$)

Post-Kidding

SEM is Standard Error of Means TM-0 is without Turmeric TM-2 is 2g/kg Turmeric Powder Inclusion TM-5 is 5g/kg Turmeric Powder Inclusion

PK is

Difference is Values within 24hrs post-kidding less before mating

Conclusions

Breeds of goat and turmeric powder inclusion at different levels exerted notable effects on oxidative stress and cortisol concentration. For breed effects, West African Dwarf (WAD) goats had the lowest and highest values for Thiobarbituric Acid Reactive Substance (TBARS) and Glutathione (GSH), respectively. KalaWAD goats recorded the highest value for Superoxide Dismutase (SOD); KalaWAD and WAD goats had the highest values for Glutathione Peroxidase (GSH-Px), whereas Kalahari Red (KR) goats had the highest reduction for cortisol concentration. Turmeric powder inclusions at 2g/kg (TM-2) and 5g/kg (TM-5) had the least reductions in the values of SOD and GSH-Px. Similarly, TM-2 and TM-5 had highest values for GSH. For interaction effects, KalaWAD and WAD goats fed TM-2 had the highest reduction for TBARS; KalaWAD goats fed TM-5 had the best value for SOD; KR goats fed TM-2 had the best value for GSH-Px; KR and WAD goats fed TM-5 had the best values for GSH; and cortisol concentration was lowest for KR goats fed TM-5.

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Statement of animal rights and welfare

The authors confirm that ethical policies were adhered to with respect to the guidelines as approved by the Animal Care

and Use Review Committee (ANCURC) of the College of Animal Science and Livestock Production, Federal University of Agriculture Abeokuta, Ogun State, Nigeria for this study.

Conflict of interest/Competing interests:

The authors declare that they have no conflict of interest in the conduct of the study.

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