EFFECTS OF VITAMIN E SUPPLEMENTATION ON GROWTH, MORPHOMETRIC MEASUREMENTS, THYROID HORMONES AND HAEMATOBIOCHEMICAL INDICES OF SOKOTO RED GOATS

[1]Kehinde Matthias OKUKPE*,[2]Geetha Subramaniam, [3]Olayinka Ojo A., [1]Alli Oluwasayo Ibidapo, [1]Belewu, Moshood Adewale ,[3]Ogunsola Fisayo Oludele., [1]Salako Abiola Olayemi, [4]Oyeyemi Oladejo Osiyemi

[1]Department of Animal Production, Faculty of Agriculture, University of Ilorin, PMB 1515, Ilorin, Kwara State, Nigeria.
[2]Faculty of Health and Life Sciences, INTI International University, PersiaranPerdana BBN, Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia.
[3]Kwara State University, Malete, Nigeria
[4]Department of Animal Production, Sheffield Hallam University, UK.)
***Corresponding author:** okukpe.km@unilorin.edu.ng; +2348066716145;

Abstract

The study examined the effects of graded levels of vitamin E on growth performance, thyroid hormones, haematology and biochemical indices of Sokoto red goats. The objective therefore was to evaluate the effects of vitamin E on some growth morphometric measurement, thyroid hormones and haemato-biochemical indices of Sokoto red goats. A total of thirty growing Sokoto red goats of mixed sexes with an average weight of 16kg were used for the experiment. The animals were administered long acting Oxytetracycline against cold and pneumonia and ivermectin for endo- and ectoparasite control within the two weeks quarantine period before the commencement of the experiment. The animals were later allotted into five treatments (A, B, C, D, and E) with two replicates made up of three animals per replicate after they were balanced for body weight. It follows a completely randomized design. They were allowed access to feed and forages (Panicum maximum and Pennisetum purpureum), water was provided ad-libitum. The duration of the experiment was 3months. Daily feed offered and refusals were recorded along with body weights/ morphometric measurements which were taken forthnightly. Blood samples were collected into ethylene diamine tetracetic acid (EDTA) coated and plain bottles for haematology/ serum assay respectively by jugular venipuncture at the end of the experiment.The result of the study showed that vitamin E supplementation significantly ($p<0.05$) affected the morphometric measurements, thyroid hormones and blood indices. The rectal temperature (though within the standard temperature range for goats), red cell distribution width standard deviation (RDW-SD), red cell distribution width coefficient of variance (RDW-CV), mean platelet volume (MPV) and platelet distribution width (PDW) were not significantly affected. There were significant ($p<0.05$) reduction in ear length, scrotal circumference/length, packed cell volume (PCV), haemoglobin (Hb), red blood cell (RBC), creatinine, alkaline phosphatase (ALP) and sodium. All other parameters significantly increased($p<0.05$) with the supplementation of vitamin E. Vitamin E significantly increased thyroid hormone production as well as most of the blood parameters. It was concluded that the optimum performance was obtained with the 6g vitamin E per kg of feed inclusion.

KEYWORDS: Vitamin, Sokoto red goats, morphometric, haematology, serum, thyroid

INTRODUCTION

Globally, about 80% of goat production is confined to low-income countries, particularly in tropical Africa and Asia (Pragnan *et al.,* 2018). In developing countries of the world, small ruminants are described as 'village bank', while goats are known as the poor man's cow (Opara *et al.,* 2010). Promoting small-scale livestock ownership has been reported to be a potential way of reducing poverty and improving human nutrition in rural Africa (Azzarri *et al.,* 2015). The Sokoto red and Sahel goats are important breeds of goat that are widely distributed in the West Africa subcontinent. Sokoto red goats are indigenous to Niger Republic and the Savannah region of Nigeria (Otoikhian, 2012). Its survival in the humid rainforest and derived savannah region of Nigeria is often limited by cold, pneumonia and sometimes "kata or *petits des petit ruminante*" in endemic areas. In order to enhance its productivity, various avenues are explored necessitating the present study. High or low ambient temperatures as an aftermath of seasonal changes are well known to induce stress, with negative consequences on the physiology and productivity of livestock (Gaughan *et al.,* 2013). Over the years, scientists have put intense efforts into understanding how domestic animals respond to climate stressors. However, most of these studies were conducted in developed countries with a significant amount of data generated on adaptation and the impact of environmental stress on the production, reproduction and health of animals (Zhao *et al.,* 2013).

Physiological changes in blood cellular components, free radical biology, as well as endocrine, respiratory and cardiovascular systems have been used as important parameters to evaluate the adaptation of animals to a given geographical location (Sejian *et al.,* 2014; Ribeiro *et al.*, 2015). This may help in the selection of animals that are capable of producing satisfactorily in harsh environments and outside the zone of thermal comfort. Vertebrates respond to stressful and unpredictable environmental stimuli (*e.g.* food shortage, predation, adverse weather conditions, etc.) by activating a set of physiological and behavioural responses defined as a whole as the 'stress response' (Nardone *et al.,* 2010). One key component of the stress response is the activation of the hypothalamic-pituitary-adrenal axis, ultimately leading to the release of glucocorticoid hormones in the blood stream. Many years back, Das *et al.,* (2012) came up with the fact that if oxidative damage could be found to be responsible for the ever increasing incidence of various pathological conditions, then timely actions that could decrease or prevent occurrence would be therapeutically beneficial. It was then suggested that successful antioxidant treatment should be employed in the delay or prevention of onset of diseases induced by oxidative damage (Naziroğlu *et al.,* 2012). Since then, knowledge regarding the chemical nature and mechanism of action of antioxidants, especially endogenous antioxidant and their important role in disease prevention treatment has rapidly increased (Okukpe *et al.,* 2024). In view of this, much attention has been focused on the protective biochemical functions of naturally occurring antioxidants in biological system, and the mechanism of their actions. Moreover, research has shown that minerals and vitamin nutrition has an important role on animal performance, and the relationship between nutrition and physiology has played a key role in the recent years (El-Shabat *et al*, 2011).
Vitamin E, (Tocopherol) is a dietary essential which act as first line of defense in ruminants

against pro-oxidant. It is also a lipid soluble antioxidant which neutralizes free radicals; it plays important roles in animal growth, development and reproduction (Rooke *et al*., 2011; Idamokoro *et al.,* 2020). In the quality of beef and mutton, it was reported that supplementing feed with vitamin E enhanced the anti-oxidation and palatability characteristics, increased the total volatile fatty acid production and improved the growth of rumen microorganisms (Naziroğlu *et al.,* 2012; Hou *et al.,* 2013; Traber and Bruno, 2020). Supplementation of vitamin E was reported to affect the numbers of some immune cell types in the peripheral blood of suckling Japanese black calves (Otomaru *et al*., 2015). The objective of this work therefore is to evaluate the effects of vitamin E supplementation on morphometric measurements, thyroid hormone and haemato-biochemical parameters of Sokoto red goats in a humid derived savanna region of Nigeria.

Materials and Methods

Location of the Study: The experiment was carried out at the small ruminant unit of the University Teaching and Research Farm between the rainy months of April and July. The farm is located in the sub-humid tropical environment on latitude 8º 30' and 8º 50' N and longitude 4º20' and 4º35' E of the equator with an annual rainfall of 1,250 – 1500 mm and average maximum and minimum temperature readings of 19ºC and 33ºC respectively (14). It covers an approximate land mass of 5,000 hectares and about 500km from the Nigeria national capital (Abuja) and about 300km from the nation's economic capital (Lagos)(KWSG, 2017).

Experimental Materials: Vitamin E tablets were supplied by a pharmaceutical company in Nigeria for the experiment. It was ground into powder for inclusion in the feed at graded levels of 2, 4, 6 and 8g of vitamin E per kg basal feed after which they were thoroughly mixed and bagged every month. The control diet had no vitamin E inclusion.

Animal, Housing and Management: A total of thirty growing Sokoto red goats (16 males and 14 females) between 12 to 15 months of age with an average weight of 16kg were used for the experiment. The animals were administered long acting Oxytetracycline against cold and pneumonia and ivermectin for endo- and ectoparasite control within the two weeks quarantine period before the commencement of the experiment. The animals were later allotted into five treatments (A, B, C, D, and E) with two replicates made up of three animals per replicate after they were balanced for body weight. It follows a completely randomized design. The animals were given 300g of experimental diet (Table 1) daily with free access to forage (*Panicum maximum* and *Pennisetum purpureum*) and water. Cleaning of drinkers and pens were carried out daily. Weight, morphometric measurements and blood samples were collected at the beginning of the experiment and at every forth night for thyroid hormone assay, haematology and serum biochemical assessments respectively. The handling of animals and relevant protocols were carried out in accordance with the guidelines of the University of Ilorin Ethical review committee with an approval number UERC/ASN/2024/2790

Collection of samples and analyses:

Average daily feed intake for the individual goat was measured as the difference between the amount of feed offered and the amounts refused over 24hours during the collection period. Body weight measurements were recorded prior to early morning feeding on the first day of the 56-day feeding trial and subsequently at 14-day intervals. The difference between two consecutive measurements was used to estimate body weight gain over the interval period. Body weight and morphometric measurements were measured weekly with weighing scale and flexible measuring tape respectively. Blood samples were collected through the jugular vein from individual goats into ethylene diamineteracetic acid (EDTA) coated andplain bottles for haematology and serum biochemical and hormone assay, respectively. Blood in plain bottles were centrifuged at 1200xg for 20 minutes for serum using Minifuge RF, Heraeus, and Hannover, Germany. Separated serum was stored frozen at -4ºC until assayed. Hormone concentrations were measured by using an auto analyzer (Hitachi 747, Boehringer Mannheim, Madrid, Spain) which followed the principles of enzyme linked immunosorbent assay, ELISA kit (Lifespan Biosciences, Inc).

Data analysis: Empirical data were subjected to analysis of variance of a complete randomized designed experiment using Statistical Analysis Systems software package (2013). Differences between treatment mean was separated using Duncan`s Multiple Range Test of the same model.

Table 1: The composition of the experimental grower feed (Top feed[R])

INGREDIENTS	COMPOSITION(kg)
Maize	50.00
Soybean meal	12.50
Fishmeal	1.00
Wheat offal	11.45
Palm kernel cake	7.00
Corn bran	6.00
Groundnut cake	8.00
Bone meal	2.50
Oyster shell	1.00
Salt	0.30
Vitamin premix	0.25
TOTAL	100.00
Crude Protein (%)	18.40
MetabolizableEnergy (Kcal/Kg)	2810.67

Results

The morphometric parameters of Sokoto red goats supplemented with vitamin E is shown in Table 2. All the parameters studied were significantly different ($p<0.05$) except rectal temperature. There was a reduction in ear-length, scrotal-circumference and scrotal-length with increased inclusion of vitamin E supplement in the diets. Other parameters such as height, heart-girth, udder-length, udder-circumference and body length reduced after an initial increase as the levels of vitamin E in the diets were increased.

TABLE 2: Effects of vitamin E supplementation on morphometric parameters of Sokoto red

Goats

Parameters	A (0g E/kg feed)	B (2g E/kg feed)	C (4g E/kg feed)	D (6g E/kg feed)	E (8g E/kg feed)	± SEM

Ear-length	12..23^{a}	11.82^{ab}	10.75^{c}	11.09^{bc}	10.92^{c}	0.21
Height, cm	53.94^{a}	53.98^{a}	47.86^{b}	51.92^{ab}	51.65^{ab}	0.23
Heart –girth, cm	59.00^{ab}	62.13^{a}	55.28^{b}	57.125^{ab}	59.67^{ab}	0.3
Scrotal-circumference, cm	25.87^{a}	18.92^{bc}	18.23^{c}	17.99^{c}	19.96^{b}	0.21
Scrotal-length, cm	11.99^{a}	8.98^{c}	11.02^{b}	9.40^{c}	9.03^{c}	0.06
Udder-length, cm	9.08^{b}	12.23^{a}	7.78^{c}	7.26^{d}	7.16^{d}	0.03
Udder-circumference, cm	17.23^{d}	25.28^{a}	21.92^{bc}	21.38^{c}	23.42^{b}	0.34
Body-length, cm	75.42^{ab}	79.54^{a}	70.29^{b}	75.48^{ab}	75.35^{ab}	0.27
Rectal-temperature, ºC	38.00	38.57	38.58	38.17	38.65	0.02

$^{a, b, c, d}$ – mean on the same row with different superscripts are significantly different ($p<0.05$). SEM - Standard Error of Mean

The effects of vitamin E supplementation on selected thyroid hormones of Sokoto red goats are shown in Table 3. There were significant differences ($p<0.05$) in Triiodothyronine (T3) and Thyroxine (T4) levels in the goats. The increased supplementation of the diet with vitamin E resulted in a gradual increase in the thyroid homones.

Table 3: Selected Thyroid Hormones Levels in Sokoto Red Goats Supplemented With Vitamin E

Treatment	A	B	C	D	E	± SEM
T3 (Triiodothyronine)	15.79^{c}	23.87^{a}	17.88^{bc}	17.01^{bc}	19.46^{b}	0.55
T4 (Thyroxine)	82.91^{b}	63.51^{c}	66.73^{c}	119.22^{a}	83.69^{b}	0.99

^{a,b,c} means having different superscript along the same row are significantly different ($p<0.05$)

Table 4 showed the effects of vitamin E supplementation on haematology indices of Sokoto red goats. There were significant differences ($p<0.05$) in most of the haematology indices except Red Cell Distribution Width Standard Deviation (RDWSD), Red Blood Distribution width coefficient of variance (RDWCV), Mean Platelet Volume (MPV), Platelet Distribution Width (PDW) and LCDW. The supplementation of the goats feed with vitamin E resulted in an increase in Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC), White Blood Cell (WBC), Lymphocytes (LYM), Granulocyte (GRAN) and Platelet (PLT). It caused a reduction in the packed cell volume

(PCV), Haemoglobin (Hb) and red blood cell (RBC). There was a slight increase in Middle cell (MID),Platelet Larger Cell Ratio (P-LCR) and Procalcitonin (PCT) before it decreased with increase in vitamin E supplementation.

Table 4: Effects of vitamin E supplementation on haematology indices of Sokoto Red Goats

Parameters	A	B	C	D	E	±SEM
PCV, %	44.00[a]	13.70[d]	24.60[c]	34.30[b]	36.80[b]	2.90
Hb, g/dl	12.90[a]	3.60[d]	7.10[c]	10.60[b]	10.40[b]	0.87
RBC, x10$^{6/\mu l}$	2.90[a]	0.94[d]	1.71[c]	2.45[b]	2.33[b]	0.18
MCV, fl	152.00[b]	145.80[c]	140.80[d]	140.10[d]	157.36[a]	1.81
MCH, pg	44.40[a]	38.10[b]	40.40[b]	43.40[a]	44.50[a]	0.74
MCHC, g/dl	292.00[b]	261.00[c]	287.00[b]	310.00[a]	282.00[b]	4.51
WBC, x10$^{3/\mu l}$	2.60[b]	4.10[a]	3.00[ab]	3.30[ab]	3.00[ab]	0.21
LYM, %	71.26[c]	71.60[c]	88.26[a]	71.80[c]	75.50[b]	1.75
MID, %	17.90[a]	13.80[b]	9.20[c]	17.50[a]	15.80[ab]	0.89
GRAN, %	10.50[a]	9.70[a]	2.40[b]	10.70[a]	8.70[a]	0.85
LYM, %	80.00[a]	68.50[b]	66.70[b]	81.10[a]	78.50[a]	1.74
MID, %	20.00[a]	16.40[a]	6.90[b]	19.70[a]	16.40[a]	1.38
GRAN, %	11.80[a]	9.20[a]	1.90[b]	12.06[a]	9.20[a]	1.03
RDW-SD, %	35.76	33.80	32.50	32.00	34.40	0.67
RDW-CV, %	9.20	9.30	9.20	9.10	8.70	0.13
PLT, x10^{9k}	682.00[c]	1570.00[a]	1519.00[a]	1101.00[b]	1070.00[b]	87.75
MPV, fl	11.00	12.90	13.10	12.30	12.40	0.47
PDW, fl	9.00	5.90	6.10	7.50	7.40	0.47
P-LCR, %	53.70[c]	78.40[a]	78.00[a]	68.20[b]	53.70[c]	3.08
PCT, %	0.75[c]	2.03[a]	1.98[a]	1.36[b]	0.75[c]	0.15
LCDW, %	0.10	0.10	0.00	0.00	0.10	0.01

[a, b, c, d] Mean having different superscript along the same row are significantly different (p<0.05). SEM-Standard Error of Mean; WBC-White Blood Cell; LYM-Lymphocytes; MID-Middle cell; GRAN-Granulocyte; RBC-Red Blood Cell; Hb-Haemoglobin; PCV-Packed cell volume; MCV-Mean Corpuscular Volume; MCH-Mean Corpuscular Hemoglobin; MCHC-Mean Corpuscular Haemoglobin Concentration; RDWSD-Red Cell Distribution Width Standard Deviation; RDWCV- Red Blood Distribution width coefficient of variance; PLT-Platelet; MPV-Mean Platelet Volume; PDW-Platelet Distribution Width; P-LCR-Platelet Larger Cell Ratio; PCT-Procalcitonin; LCDW-

The effects of Vitamin E supplementation on Serum biochemical parameters of Sokoto red goats is shown in Table 5. There were significant differences ($p<0.05$) in all the serum biochemical parameters examined. The supplementation of the feed with vitamin E resulted in an increase in total protein, albumin, urea and aspartate aminotransferase (AST). Alanine aminotransferase

(ALT) and potassium levels were slightly reduced with initial supplementation but gradually increased as the inclusion of vitamin E increase. The levels of creatinine, alkaline phosphatase (ALP) and sodium were significantly reduced with increase vitamin E supplementation.

Table 5: Effects of Vitamin E supplementation on Serum biochemical parameters of Red Sokoto goats

Parameter	A	B	C	D	E	±SEM
Total protein, mg/dl	11.06^{b}	12.47^{a}	10.04^{c}	10.14^{c}	11.03^{b}	0.30
Albumin, mg/dl	8.28^{ab}	9.24^{a}	7.27^{b}	8.32^{ab}	7.27^{b}	0.26
Urea, mg/dl	1.03^{c}	1.60^{b}	1.52^{b}	1.72^{a}	1.75^{a}	0.087
Creatinine, mg/dl	2.60^{a}	2.03^{b}	0.69^{d}	0.69^{d}	1.09^{c}	0.25
Alkaline phosphatise, (U/I	93.17^{a}	82.25^{d}	88.38^{b}	86.75^{c}	92.04^{a}	1.31
Alanine aminotransferase, U/I	34.90^{a}	29.80^{b}	25.70^{c}	25.90^{c}	34.80^{a}	1.38
Aspartate aminotransferase, U/I	87.60^{b}	87.90^{b}	77.50^{c}	51.70^{d}	91.70^{a}	4.86
Sodium, ppm	17.13^{b}	15.15^{d}	18.15^{a}	13.98^{e}	15.95^{c}	0.49
Potassium, ppm	3.99^{a}	4.07^{a}	3.03^{b}	4.21^{a}	3.96^{a}	0.14

$^{a, b, c}$- Means within rows with different superscripts are significantly different at p<0.05;; SEM= Standard Error of means

Discussion

The Sokoto red goats are well adapted to the hot, dry savannah zones of Nigeria. It often succumb to cold or pneumonia when raised in the humid southern and sub-humid zones of Nigeria, hence about 70% of the sheep and goat populations in Nigeria are concentrated in the dry savannah zone or northern region (Gaughan *et al.,* 2013; Zhao *et al.,* 2013). Seasonal and climatic changes are a major factor that affects the distribution and production of ruminants in Nigeria (Silanikove, 2000; Sejian *et al.,* 2014). Vitamin E, a dietary essential fat-soluble vitamin has been used to regulate stress in animals (Ribeiro *et al.,* 2015) as it improves animal performance when provided in amounts above minimal requirements, due to the potent antioxidant properties of tocopherols.

The adverse impact of heat stress on growth performance can be attributed to the reduction in feed intake, digestibility and utilization efficiency (Popoola *et al*., 2014). Though goats have the capacity for adaptation to convert poor quality feeds to products in rangelands, still, if the heat stress prolongs for a longer duration, it can affect their growth performance. All the morphometric parameters studied were significantly different (p<0.05) except rectal temperature. There was a reduction in ear-length, scrotal-circumference, scrotal-length with increased inclusion of vitamin E supplement in the diets. Other parameters such as height, heart-girth, udder-length, udder-circumference and body length reduced after an initial increase as the levels of vitamin E in the diets were increased. The reports of Hassen *et al.* (2010) and Zergaw *et al.* (2016) showed that body length and heart-girth have a strong relationship in both sexes. Heart-girth and height at pelvic are selection criterion for goat populations in meat production in addition to body weight. Selecting animals for their heart-girth, body length and height at withers has been used for breeding soundness in goat population. Udder size and scrotal circumference are basis for selection criterion. According to Pérez-Cabal *et al.* (2013) and Cyrilla *et al*. (2015), Udder size has a positive relationship with milk production; Sperm production is associated with the number of sertoli cells that directly proportional to the testicular size which further enhances the productivity of Sokoto red goats. The rectal temperature results are inconsistent with the reports of Fahmy (1994) and Marai *et al*. (2007) that heat increases rectal temperatures in goats. The stability in rectal temperature might be a result of improved cellular activity as vitamin E is a major chain-breaking antioxidant that inhibits lipid peroxidation (Traber and Atkinson, 2007; Campbell, 2011). It's been reported by Altesman and Cole (1983) that vitamin E has antidepressant-like effect by playing a secondary role alongside antioxidants such as glutathione peroxidase and superoxide dismutase in reducing oxidant changes resulting from stress. Like vitamin C, vitamin E has antioxidant properties that help alleviate stress (McDowell *et al.*, 1996; Al-Sowayan & Almarzougi, 2024). Much nutrients is used by the body in stressful situations which creates free radicals and oxidative stress (Wang *et al.,* 2007; Lee *et al.,* 2022), hence the observed increase in morphometric growth and body weights of the animals. Vitamin E supplementation was reported by El-Shahat and Abdel Monem (2011) to increase the total number of lambs and the incidence of ewes bearing twin. Pragna *et al.* (2018) established the severity of heat stress on different growth variables in three indigenous Southern Indian goat breeds and observed a reduction of 11.0%, 8.0% and 6.0% of growth for Osmanabadi, Malabari and Salem Black breeds, respectively. Furthermore, heat stress reduces the daily weight gain that subsequently influences their allometric measurements (Das *et al.*, 2016). This reduction in heat-stress-associated growth variables could be due to the outcome of activation of hypothalamus–pituitary–adrenal axis (HPA) in response to heat stress. The activation of the HPA axis during heat stress directly influences the release of growth hormone (GH), which negatively influences growth in sub-optimal level (Popoola *et al.*, 2014). However, breed variations were observed for these mechanisms of HPA-axis-oriented heat stress impact on growth in the study conducted by Das *et al.* (2016). Besides being a threat to growth, heat stress acts as an aberrant effect on meat production and the goat's carcass characteristics. The productivity of goats is thus affected adversely by extreme climatic conditions. Depression of the feed intake and reduction in production are commonly observed in heat stressed goats. Proper understanding of how climatic factors affect the physiological responses of the goats provides a firm basis of improving their husbandry and health status (Abdelatif *et al.,* 2009).

There were significant differences ($p<0.05$) in Triiodothyronine (T3) and Thyroxine (T4) levels in the goats. The increased supplementation of the diet with vitamin E resulted in a gradual increase in the thyroid hormones. Physiological response of goats to environmental stress during the dry and wet season with their energy balance showed that seasonal heat and cold stress have profound effects on some thermoregulatory live bodyweight and physiological parameters which could be reduced by vitamin supplementation (Helal *et al*., 2010; Sanusi *et al*., 2010). Thus heat stress has generally been known to have effects on physiological equilibriums of goats and their various systems (nervous, endocrine and immune) have been implicated with specific responses and reciprocal regulatory influences (Castanheira *et al*., 2010). The high level of Triiodothyronine (T3) supports the findings of Collier *et al* (1982) that T3 concentration increased with prolonged heat stress. However, T3 plays a vital role in body's metabolic rate, heart and digestive functions, muscle control, brain development and functions, and the maintenance of bones, low level of T3 may indicate hypothyroidism or starvation or a condition of long-term illness (Collier *et al*., 1982). Thyroxine (T4) concentration decreased with prolonged heat stress. However thyroxine is the main hormone secreted in the blood stream by the thyroid gland that plays an important role in regulating body weight, body temperature, metabolic rate, weight gain and activity of the heart and muscle, low thyroxine level causes problems with development if it occurs in young animals, in adults, it lowers the metabolic rate, weight gain, memory problems, infertility, fatigue and muscle stiffness (Collier *et al.,* 1982). Although the experimental conditions varied, it has been previously shown in cattle that heat stress or high environmental temperature reduced plasma concentration of T4 (Magdub *et al*., 1982, Pereira *et al*., 2008) and T3 (Baccari *et al*., 1983; Nardone *et al.,* 1997) and decreased their total excretion from the body (Nardone *et al., 2010*). However detailed observations in pregnant Holstein cow have shown that prolonged heat stress decrease plasma T4 but increased plasma T3 concentration (Collier *et al.,* 1982). These data are in agreement with the suggestion that adaptation to heat stress in goats in its early stage, results in diminished secretions at both pituitary and thyroidal (T4) level (Baccari *et al.,* 1983).

Haematological studies are of ecological and physiological interest in helping to understand the relationship of blood characteristics to the environment (Ovuru & Ekweozor, 2014) and so could be useful in the selection of animals that are genetically resistant to certain diseases and environmental conditions (Isaac *et al.,* 2013). There were significant differences ($p<0.05$) in most of the haematology indices except Red Cell Distribution Width Standard Deviation (RDWSD), Red Blood Distribution width coefficient of variance (RDWCV), Mean Platelet Volume (MPV), Platelet Distribution Width (PDW) and large cell distribution width (LCDW). The supplementation of the goats feed with vitamin E resulted in an increase in Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC), White Blood Cell (WBC), Lymphocytes (LYM), Granulocyte (GRAN) and Platelet (PLT). It caused a reduction in the packed cell volume (PCV), Haemoglobin (Hb) and red blood cell (RBC). There was a slight increase in Middle cell (MID), Platelet Larger Cell Ratio (P-LCR) and Procalcitonin (PCT) before it decreased with increase in vitamin E supplementation. The reduction in the levels of PCV, RBC and Hb was contrary to the report of Al-Haidary et al. (2012) who found higher value of RBC in heat stress group ($8.4\times10^{3/\mu l}$) than in control group ($7.9\times10^{3/\mu l}$). Higher PCV values had been reported to be an adapted mechanism to provide water necessary for evaporative cooling process. However, this finding is consistent with the work of Sivakumar *et al.* (2010) that PCV was significantly decreased ($p<0.05$) in the heat stress group. The decrease in RBC levels could be due to either the antioxidant effect of Vitamin E which protects the cell membranes from damages by reactive oxidation or the increased size of the component cells as could be seen in the values of MCV, MCH and MCHC.MCV is an indication of the average size of an individual red blood cell. This was also reflected in the haemoglobin (Hb) levels, though contrary to the work of Al-Haidary *et al*. (2012) who found higher value of Hb in heat stress group. However, this finding is consistent with the work Sivakumar *et al.* (2010) who reported that Hb were significantly decreased ($p<0.05$) in the heat stress group. This decrease of Hb could be due to adequate nutrient availability for Hb synthesis as the animal consumes more feed or decreases voluntary intake under heat stress. Similarly, Biswas *et al*. (2000) and Pandey *et al*. (2005) recorded decreased Hb and marked leukopenia in experimentally induced toxicity in goats. Reduction of Hb might be due to interference in metabolism, suppression of granulopoietic activity of bone marrow by residual toxicants (Ianchev, 2001; Rana *et al*., 2008), increased rate of destruction or reduction in rate of formation of erythrocytes and altered cellular composition of blood leading to anaemia, anisocytosis, eosinophilia and leucopoenia and also due to impaired absorption of folic acid (Hardman and Limbird, 1996) and disruption of liver biosynthesis of heme (Woods and Fowler, 1986; Shittu *et al.,* 2016). The decreasing trend of Hb as observed in Vitamin E supplemented animals compared to control supports the findings of Patel *et al*. (2009) and Vaswani *et al*. (2010) in growing kids. The high levels of WBC, lymphocytes, granulocytes and platelets could be attributed to stress, exercise, and diurnal changes. This could be due to enhanced humoral stimulation for body defence and the stress modulating effect of vitamin E in body cells as reported by Makpol *et al.* (2010) and Okukpe *et al*. (2024). Several studies have demonstrated positive growth performance, improved humeral and cellular immune responses and protection against oxidative stress due to supplementation of animal diet with vitamin E (Koyuncu and Yerlikaya, 2007; Soliman, 2015). Tocopherols scavenge both the oxygen radicals attacking from outside the membrane and the lipid peroxyl radicals generated within the membrane and, as a result, terminate the free radical chain react ion (Surai, 2012). Das *et al.* (2012) further reported that dietary Vitamin E supplementation increased Leucocyte numbers and White Blood Cell counts while also significantly protecting Red Blood Cells against high levels of hydrogen peroxide induced stress. Platelets reduce loss of blood from injured vessels. By adhering to vessel walls and to each other in the area of the injury, platelets may form a plug upon which a thrombus (clot) forms to occlude the opening in the vessel and prevent further blood loss (Porth, 2000).

There were significant differences ($p<0.05$) in all the serum biochemical parameters examined. The supplementation of the feed with vitamin E resulted in an increase in total protein, albumin, urea and aspartate aminotransferase (AST). Alanine aminotransferase (ALT) and potassium levels were slightly reduced with initial supplementation but gradually increased as the inclusion of vitamin E increase. The levels of creatinine, alkaline phosphatase (ALP) and sodium were significantly reduced with increase vitamin E supplementation. The activities of ALT and AST reflect the integrity of hepatocytes and are often used as indicators of liver injuries/infarction (Lu *et al.,* 2014). This is because, when liver damages occur, there is leakage of some of these organ specific enzymes beyond the concentration expected in the blood. Although these enzymes are available in the blood at a level, undue increases could suggest a liver damage especially with ALT enzyme (Adegbeye *et al*., 2021).The observed increase in the serum total protein in this investigation supports the findings of Biswas *et al.* (2000) in goats, Uthus (2001) in rats and Wang *et al.* (2006) in pigs. Conversely, the present result differs from the findings of Das *et al.* (2012) in goats and Nandi *et al.* (2005) in rats who both reported decreased serum total protein as a result of Vitamin E supplementation. Hyperproteinaemia in Vitamin E supplemented animals observed in this study is likely to be due to marked increase in formation and secretion of parenchymatous tissues (Das *et al.,* 2012; Hyeldal *et al.,* 2017). The increase in total serum protein level observed could be attributed to various protective mechanisms of vitamin E which reduced nephrotoxicity and thereby reduced the urinary loss of protein from the serum. Furthermore, the increase in serum creatinine level after vitamin E supplementation is similar to the work of Nandi *et al.* (2005) who reported a significant in creatinine production. However, it disagrees with the findings of Wang *et al.* (2006) who reported significant depression in the serum level of creatinine after Vitamin E supplementation. Serum creatinine level is usually used to assess the proper functioning of the kidney since there are thresholds which must not be exceeded (Okunlola *et al.*, 2015). Values beyond this threshold indicate kidney stress and afflictions (Olafadehan, 2011). Thus, the increase in creatinine level could be indicative of renal stress due to exposure of goats to varying levels of vitamin E causing a problem with the globular filtration function of the kidney, the kidney loses its ability and functions to effectively filter and clear creatinine and urea nitrogen from the blood. Thus, this elevates their levels in the blood serum (Kaneko, 1980; Manning *et al.* 2004). A high level of serum urea has been attributed to excessive tissues protein catabolism associated with protein deficiency (Opara *et al.,* 2010). Furthermore, the antioxidant properties of Vitamin E could be responsible for the observed reduction in the serum urea level of Red Sokoto goats supplemented with Vitamin E.

In conclusion, vitamin E significantly increased growth performance and thyroid hormone production as well as most of the blood parameters. It is therefore recommended that 6g vitamin E per kg of feed inclusion should be used for optimum performance of Sokoto red goats in a humid environment.

References

Abdelatif, A. M., Ibrahim, M. Y., & Hassan, Y. Y. (2009).Seasonal variation in erythrocytic and leukocytic indices and serum proteins of female Nubian goats. *Middle-East Journal of Scientific Research, 4(3), 168–174.*

Adegbeye, M. J., Omotoso, O. B., Toye, C. O., Aderibigbe, A. M., Ajagun, P., Ajanaku, F., ... & Fajemisin, A. N. (2021). Comparative studies of nutrients intake and haemato-biochemical indices of bucks fed at three different times of the day. *Animal Research International*, *18*(3), 4176-4185.

Al - Haidary A.A., Aljumaah R.S., Alshaikh M.A., Abdoun K.A, Samara E.M., Okah A.B., AluraijiMM. (2012). Thermoregulatory and physiological responses of Najdi sheep exposed to environmental heat load prevailing in Saudi Arabia. *Pak. Vet. J., 32: 515–519*

Al-Haidary, A. (2004). Physiological responses of Naimey sheep to heat stress challenge under semi-arid environments. *International Journal of Agriculture and Biology* 2(6): 307 - 309

Al-Sowayan N.S. and Almarzougi R.A. (2024). Vitamin E reduces oxidative stress in brains of albino male rats undergoing immobilization. Saudi Journal of Biological Sciences 31(1): 103900 https://doi.org/10.1016/j.sjbs.2023.103900

Altesman R.I. and Cole J.O. (1983). Psychopharmacologic treatment of anxiety. *Journal of Clinical Psychiatry* 44: 12 – 18.

Azzarri, C., Zezza, A., Haile, B., & Cross, E. (2015). Does livestock ownership affect animal source foods consumption and child nutritional status? Evidence from rural Uganda. *Journal of Development Studies, 51(8), 1034–1059*. doi:10.1080/00220388.2015.1018905.

Baccari, F. J., Johnson, H. D., & Hahn, G. L. (1983). Environmental heat effects on growth, plasma T3, and post-heat compensatory effects on Holstein calves. *Proceedings of the Society for Experimental Biology and Medicine, 173(3), 312–318.* doi:10.3181/00379727-173-41648.

Biswas, U., S. Sarkar, M. K. Bhowmik, S. K. Samanta and S. Biswas. (2000). Chronic toxicity of arsenic in goats: clinicobiochemical changes, pathomorphology and tissue residues. *Small Ruminant Research,* 38:229-235.

Biswas, U., Sarkar, S., & Bhowmik, M.K. (1998). Clinicopathological profile of induced chronic arsenic toxicity in goats. *Indian Journal of Animal Sciences, 68(4), 320–323*.

Campbell I. (2011) Body Temperature and its Regulation. *Anaesth Intensive Care* Med. 12:240–244. doi: 10.1016/j.mpaic.2011.03.002

Castanheira, M., Jones, R. N., & Sader, H. S. (2010). Update of the in vitro activity of daptomycin tested against 6710 Gram-positive cocci isolated in North America (2008). *Diagnostic Microbiology and Infectious Disease, 68(1), 82–86*.

Collier, R. J., Doelger S.G., Head H. H., Thatcher W. W., Wilcox C. J. (1982). Effect of heat stress during pregnancy on maternal hormone concentrations, calf birth rate and postpartum milk yield of Holstein cows. *J Amin Sci* 309-19.

Cyrilla, L., B. P. Purwanto, A. Atabany, D. A. Astuti, & A. Sukmawati. (2015). Improving milk quality for dairy goat farm development. *Med. Pet.* 38:204–211. https://doi. org/10.5398/medpet.2015.38.3.204

Das, R., Sailo, L., Verma, N., Bharti, P., Saikia, J., Imtiwati, & Kumar, R. (2016).Impact of heat stress on health and performance of dairy animals – A review. *Veterinary World, 9(3), 260–268.*

Das, T.K., Mani, V., Kaur, H., Kewalramani, N. and Agarwal, A, (2012). Effect of Vitamin E Supplementation on Haematological and Plasma Biochemical Parameters during long term Exposure of Arsenic in Goats. *Asian-Australian Journal of Animal Science* 25(9): 1262-1268

El-Shahat K.H. and Abdel Monem U.M. (2011). Effects of Dietary supplementation with Vitamin E and/or Selenium on metabolic and reproductive performance of Egyptian Baladi Ewes under Sub-tropical conditions. *World Applied Sciences Journal* 12(9): 1492 - 1499

Fahmy, S. (1994). Effect of crossing Romanov with Rahmani sheep on some physiological and productive performance. *M. Sc. thesis. Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.*

Gaughan, J. B., Bonner, S., Loxton, I., Mader, T. L., Lisle, A., & Lawrence, R. (2013). Effect of shade on body temperature and respiration rate of beef cattle. *Journal of Animal Science, 91(11), 5488–5497.*

Hardman, J. G., & Limbird, L. E. (Eds.). (1996). Goodman & Gilman's The Pharmacological Basis of Therapeutics (9th ed.). McGraw-Hill.

Hassen, A., & El-Shaer, H. (2010). Impact of climate change on the distribution of plant species and their vegetation types in arid and semi-arid regions.In M. S. J. Simelton (Ed.), Climate Change and Variability.IntechOpen.

Hassen, H., S. Lababidi, B. Rischkowsky, M. Baum, & M. Tibbo. (2012). Molecular characterization of Ethiopian indigenous goat populations. *Trop. Anim. Health Prod.* 44: 1239–1246. https://doi.org/10.1007/s11250-011-0064-2

Helal A, Hashem ALS, Abdel-Fattah MS, El-Shaer HM. (2010). Effect of heat stress on coat characteristics and physiological responses of Balady and Damascus goats in Sinai, Egypt. *Am-Eurasian Journal of Agriculture Environmental Science*. 7:60–69.

Hou, C., Chen, L., Yang, L., & Ji, X. (2013). An insight into anti-inflammatory effects of natural polysaccharides. *International Journal of Biological Macromolecules, 99, 100-105.*

Hyelda1, A. J., M. M. Yahya, J. B. Abakura and R. J. Wafar (2017).Haematological and Biochemical Parameters ofRed Sokoto Goats Fed Desert Date (*Balanitesaegyptiaca*) Leaves as Supplement to Urea TreatedMaize Stover, *Journal of Advances in Biology & Biotechnology, 15(2): 1-7,*

Ianchev, I. (2001). Influence of some Geo-chemical ecological factors on some blood haematological characteristics in Sheep from Chiprovitei. *Zhivotnov dni Nauki* 38 (6): 41 - 43

Idamokoro E.M., Falowo A.B., Oyeagu C.E., Afolayan A.J. (2020). Multifunctional activity of vitamin E in animal and animal products: A review. *Animal Science Journal* 91: e13352

Isaac, L. J., Abah, G., Akpan, B., & Ekaette, I. U. (2013). Haematological properties of different breeds and sexes of rabbits (p.24-27). Proceedings of the 18th Annual Conference of Animal Science Association of Nigeria.

Kaneko, J. J. (1980). Clinical biochemistry of domestic animals. 3rd Edn. Academic press, NY, USA.

Koyumcu, I., & Yerlikaya, S. (2007). The effects of different drying methods on the nutrient composition of basil (Ocimum basilicum L.). *Journal of Food Quality, 30(4), 470-480*.

KWSG, 2017. Kwara State Government, (2017). Geography of Kwara State Available at https://kwarastate.gov.ng.

Lee A.R., Tariq A., Lau G., Tok N.W., Tam W.W., Ho C.S. (2022). Vitamin E, Alpha –Tocopherol, and Its Effects on Depression and Anxiety: A Systematic Review and Meta-Analysis. Nutrients 14 (3): 656. doi: 10.3390/nu14030656

Lu T., Harper A.F., Zhao J., Estienne M.J., Dalloul R.A. (2014). Supplementing antioxidants to pigs fed diets high in oxidants: I. Effects on growth performance, liver function, and oxidative status. *Journal of Animal Science* 92: 5455 – 5463.

Magdub A., Johnson H. D.., Belyea R. L. (1982). Effect of environmental heat and dietary fibre on thyroid physiology of lactating cows. *J Dairy Sci* 65:2323-31.

Makpol S., Zainuddin A., AbdulRahim N., YusofYAM., Ngah WZW. (2010). Alpha-tocopherol Modulates Hydrogen Peroxide-induced DNA Damage and Telomere Shortening of human Skin Fibroblasts Derived from differently Aged Individuals. *Planta Medica* 76(9): 869 – 875. doi: 10.1055/s-0029-1240812

Manning, P. J., W. H. F. Suther and R. J. Walker. (2004). Effect of high dose vitamin E on insulin resistance and associated parameters in overweight subjects. *Diabetes Care,* 27:2166.

Marai, I. F. M., Habeeb, A. A., Daader, A. H., & Yousef, H. M. (1997). Effects of diet supplementation and body cooling on Friesian calves reared in high ambient temperatures in the eastern desert of Egypt. *Tropical animal health and production*, *29*(4), 201-208.

Marai, I.F.M., El-Darawany, A.A., Fadiel, A. & Abdel-Hafez, M.A.M. 2007. Physiological traits as affected by heat stress in sheep – A review. *Small Ruminant Research* 71: 1-12

McDowell L.R., Williams S.N., Hidiroglou N., Njeru C.A., Hill G.M., Ochaa L., Wilkinson N.S. 1996. Vitamin E Supplementation for the ruminant. *Animal Feed Science and Technology* 60(3-4): 273 – 296. https://doi.org/10.1016/0377-8401(96)00982-0

Nandi, D., R. C. Patra and D. Swarup. (2005). Effect of cysteine, methionine, ascorbic acid and thiamine on arsenic induced oxidative stress and biochemical alterations in rats. *Toxicology,*211:26-35.

Nardone A., Lacetera N., Berbabucci U., Ronchi B. (1997). Composition of colostrums from dairy heifers exposed to high temperature during late pregnancy and early postpartum period. *Journal of Diary Science* 80: 838 - 844.

Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M.S. and Bernabucci, U. (2010). Effects of climate changes on animal production and sustainability of livestock systems. *Livestock Science*, 130:57–69.

Nazıroğlu, M., & Lückhoff, A. (2012).A review of TRP channels and oxidative stress. *Neurochemical Research, 37(6), 1311–1335*.

Okukpe K.M., Alli O.I., Olayinka O.A., Okeniyi F.A., Ajao B.H., Chimezie V.O., Familoni O.M. and Abdullahi M.A. (2024): Modulating Role of *Vernonia amygdalina* Leaf Meal on Spermatogenic and Steriodogenic Functions of West African Dwarf Bucks Testis. *Current Scientia 27* (02): 37 – 45. https://vjs.sljol.info/582/volume/25/issue/1

Okunlola D.O., Olorunnisomo O.A., Binuomote R.T., Amuda A.J., Agboola A.S. and Omole O.G. (2015). Heamatology and Serum Quality of Red Sokoto Goats FedBaobab

(*Adansoniadigitata* L.) Fruit Meal Supplement,*Journal of Natural Sciences Research*,5(17): 1-4

Olafadehan, O. A. (2011). Changes in haematological and biochemical diagnosticparameters of Red Sokoto goats fed tannin-rich *Pterocarpuserinaceus*forage diets.*Veterinary archives,* 81, 471-483.

Opara, M. N., N. Udevi, and I. C. Okoli. (2010) "Haematological parameters and blood chemistry of apparently healthy West African Dwarf (Wad) goats in Owerri, South Eastern Nigeria." *New York Science Journal* 3.8: 68-72.

Otomaru K., Saito S., Endo K., Kohiruimaki M. and Ohtsuka H. (2015). Effect of Supplemental Vitamin E on the Peripheral blood Leucocyte population in Japanese Black calves. *Journal of Veterinary Medicine Science* 77(8): 985 – 988. doi: 10.1292/jvms.15-0060

Ovuru, S. S., & Ekweozor, I. K. E. (2014). Haematological changes associated with crude oil ingestion in experimental rabbits. *African Journal of Biotechnology, 3*(6), 346-348.

Pandey, M. M., Rastogi, S., & Rawat, A. K. S. (2005). Indian herbal drug for general healthcare: An overview. *The Internet Journal of Alternative Medicine, 2(1).*

Patel, V. R., Patel, P. R., & Kajal, S. S. (2009). Antioxidant activity of some selected medicinal plants in western region of India. Advances in Biological Research, 4(2), 62-68.

Pereira A. M. F., Baccari F. Jr, Titto E. A. L., Almeida J. A. A. (2008). Effect of physiological parameters, feed intake and plasma thyroid hormones concentration in Alentejana, Mertolenga, Frisian and Limousine cattle breeds. *Int J Biometeorol* 52:199-208.

Pérez-Cabal, M. Á., E. Legaz, I. Cervantes, L. F. De La Fuente, R. Martínez, F. Goyache, & J. P. Gutiérrez. (2013). *Association between body and udder morphological traits and dairy performance in Spanish Assaf sheep. ArchivTierzucht 56:430–442. https://doi.org/10.7482/0003-9438-56-042*

Popoola, M. A., Bolarinwa, M. O., Yahaya, M. O., Adebisi, G. L., & Saka, A. A. (2014). Thermal comfort effects on physiological adaptations and growth performance of West African dwarf goats raised in Nigeria. *European Scientific Journal*.

Porth, C. M. (2000). Pathophysiology: Concepts of Altered Health States (6th ed.). Lippincott Williams & Wilkins.

Pragna, P., Sejian, V., Bagath, M., Krishnan, G., Archana, P. R., Soren, N. M., ... & Bhatta, R. (2018). Comparative assessment of growth performance of three different indigenous goat breeds exposed to summer heat stress. *Journal of animal physiology and animal nutrition*, *102*(4), 825-836.

Rana M.G., Katbamna R.V., Dudhrejiya A.V., Sheth N.R. (2008). Hepatoprotection of *Tecomella undulata* against experimentally induced liver injury in rats. *Pharmacology online* 3: 674 - 682

Ribeiro NL, PimentaFilho EC, Arandas JKG, Ribeiro MN, Saraiva EP, Bozzi R, Costa RG. (2015). Multivariate characterization of the adaptive profile in Brazilian and Italian goat population. *Small Rumin Res. 123:232–237. doi: 10.1016/j.smallrumres.2014.12.010 [Crossref], [Web of Science ®]*

Rooke, T. W., Hirsch, A. T., Misra, S., Sidawy, A. N., Beckman, J. A., Findeiss, L. K., Golzarian, J., Gornik, H. L., Halperin, J. L., Jaff, M. R., Moneta, G. L., Olin, J. W., Stanley, J. C., White, C. J., White, J. V., & Zierler, R. E. (2011). 2011 ACCF/AHA Focused Update of the Guideline for the Management of Patients With Peripheral Artery Disease (Updating the 2005 Guideline). *Circulation, 124(18), 2020–2045*.

Sanusi, A. O., Peters, S. O., Sonibare, A. O., & Ozojie, M. O. (2011). Effect of coat colour on heat stress among West African Dwarf sheep. *Nigerian Journal of Animal Production*, *38*(2), 28-36.

SAS. (2013). Statistical Analysis Systems for windows, version 9.4. Cary: SAS Institute Inc. 2013.

Sejian, V., Maurya, V. P., & Naqvi, S. M. (2010). Adaptability and growth of Malpura ewes subjected to thermal and nutritional stress. *Tropical Animal Health and Production*, *42*(8), 1763-1770.

Shittu, O. O., Amole, T. A., Okwelum, N., Odeyemi, J. A., Toviesi, D. P., Ojo, V. I. O., ... & Osinowo, O. A. (2016). Haematological and Serum Bio-Chemical Parameters of West African Dwarf and Kalahari Red Goats in the Humid Tropics. *Nigerian Journal of Animal Science*, *18*(2), 305-314.

Silanikove, N. (2000). The physiological basis of adaptation in goats to harsh environments. *Small Ruminant Research* 35(3), 181-193.

Sivakumar, A.V.N., Singh, G. and Varshney, V. P. (2010). Antioxidants Supplementation on Acid Base Balance during Heat Stress in Goats. *Asian-Australia Journal of Animal Science,* 23(11), 1462–1468.

Soliman, E.B. (2015).Dose-response of Vitamin E and Selenium Injection on growth performance, physiological and Immune Responses of Ossimi Lambs. Egyptian Journal of Sheep & Goat Sciences, 10(1): 27-40

Surai, P. F. (2012). The Antioxidant Systems in Poultry Biology: Superoxide Dismutase. *Journal of Agricultural Science and Technology, 2(1A), 9-15.*

Tambuwal, F. M., Agale, B. M., & Bangana, A. (2002).Haematological and serum biochemical values of apparently healthy Red Sokoto goats. *Proceedings of 27th Annual Conference of Nigerian Society of Animal Production*. p. 50-53

Traber M.G.; Atkinson J. (2007). Vitamin E, antioxidant and nothing more. *Free Radicals Biology and Medicine* 43: 4 – 15.

Traber, M.G. and Bruno, R.S. (2020). Vitamin E. In Marriott, B.P., Birt, D.F., Stallings, V.A. and Yates, A.A. (eds.). Present knowledge in nutrition Eleventh Edition, London, United Kingdom; Academic Press (Elsevier) pp. 115-136

Uthus, E. O. (2001). High dietary arsenic exacerbates copper deprivation in rats. *Journal of Trace Element and Experimental Medicine,*14:43-55.

Vaswani, P. R., Deshpande, S. S., & Dixit, M. P. (2010). Evaluation of in vitro anthelmintic activity of Leucas cephalotes leaves. *International Journal of Pharmaceutical Sciences and Research, 1(10), 120-124.*

Wang S., Wang G., Barton B.E., Murphy T.F., Huang H.F. (2007). Beneficial effects of vitamin E in sperm functions in the rat after spinal cord injury. *Journal of Andrology* 28: 334 – 341.

Woods, J. S., & Fowler, B. A. (1986). Alteration of mitochondrial structure and heme biosynthetic parameters in liver and kidney cells by bismuth. *Toxicology and Applied Pharmacology, 85(3), 462–472.*

Zergaw, N., Adugna, M., & Tadele, A. (2016). Evaluation of in vivo antidiabetic activity of Clerodendrum myricoides hydroalcoholic leaf extract in alloxan-induced diabetic mice. *Journal of Experimental Pharmacology, 8, 49–56.*

Zhao, F., Zhang, Z., Wang, C., Zhang, B., Yao, H., Li, S. and Xu, S. (2013). The role of heat shock proteins in inflammatory injury induced by cold stress in chicken hearts. Cell Stress Chaperones. 18:773-783.