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NANO ZINC OXIDE SUPPLEMENTATION IMPROVES GROWTH PERFORMANCE AND HEALTH OF WEST AFRICAN DWARF GOATS

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SUMMARY

This study investigated the influence of nano zinc oxide (nZnO) supplementation on growth performance and health of West African dwarf goats. A total of twenty-four (24) West African Dwarf (WAD) goats averaged 7.2±0.54kg were used for the experiment. The twenty-four (24) WAD goats were divided into three (3) treatment groups of eight (8) animals per group on weight equalization bases. Each group was randomly allotted to the three (3) experimental diets (0, 300 and 600mg/kg nano zinc oxide) in a completely randomized design (CRD). Data were collected for growth performance characteristics, hematology and serum chemistry and analyzed using one way analysis of variance while Tukey's test was used to separate significantly different means as in Statistical Analyst System software. Results indicated that significantly ($p<0.05$) higher total weight gain, average weight gain, total dry matter intake and average dry matter intake in goats fed 600mg/kg nZnO while similar in the control and those offered 300mg/kg nZnO. Hematological and serum parameter documented at the onset of the experiment were statistically ($p>0.05$) similar. The control diet and 600mg/kg nZnO elevated the packed cell volume, white blood cell, neutrophils, monocytes and mean corpuscular volume at the zenith of the experiment when compared to those offered 300mg/kg nZnO. However, nZnO supplementation at 300mg/kg gave increased total protein, globulin and total cholesterol concentration as compared to the control and 600mg/kg nZnO groups. Despite these divergences in function of nZnO, it was noted that it has no negative influence or toxicity noted or recorded. Thus, it can be concluded that nZnO supplementation can be adopted in goat feeding to improve growth and for strong immunity.

Keywords: Goats, performance, nano zinc, blood status

INTRODUCTION

West African Dwarf (WAD) goat is the predominant breed of goats in South Western part of Nigeria though its productivity is adversely affected due to poor genetic and nutritional factors (Amole *et al*., 2014). Irrespective of the environment in which they are kept, they are efficient converters of low-quality forage feeds to highly desired animal products of high biological value for the benefit of man (Oshineye, 2011).

Their nutritional needs are deterred by unfavorable weather conditions that affect the nutritional quality of the forages. Hence, there is need to supplement this poor-quality feed with other rich nutrient sources minerals (Salem and Nefzaoui, 2003). Minerals (such as copper, calcium and zinc) play an essential role in the nutrition and health of animals (Soetan *et al*., 2010). Inclusion of one or more minerals to ruminant diets has been reported to enhance immune functions and support health maintenance (Spears, 2003).

Zinc as a mineral component of many enzymes elements, plays vital roles in nutrient metabolism of ruminant animals most especially in goat (Swain *et al.*, 2016), it is one of the most abundant essential elements that cannot be stored in animal body for system balance (Zalewski *et al.*, 2005). Zinc dietary intake is essential for building the physiological function and augmentation of the immune system (Zhao *et al.*, 2014, Parashuramulu *et al.*, 2015).

The dietary zinc toxicity expresses itself as an increase in the number of immune systems such as Neutrophils, Eosinophils and Basophils and reduces the prevalence number of lymphocytes, implying the diversity in occurrence of white blood cell (Someye *et al.*, 2007). Serum Alkaline Phosphatase is a Zn metalloenzyme that decreases in Zn deficiency and its activity is used as an indicator of animal Zn status (Viveros *et al.*, 2002). Often times, the levels of Aspartate aminotransferase alongside with serum Alkaline Phosphatase is evaluated to determine the functioning of the liver (Najafzadeh *et al.*, 2013).

Zinc may be supplemented in form of feed inorganic, organic or nano source and the nanometer dimension for zinc is term nanozinc (nZn; Swain *et al.*, 2019).

Nano form of supplementation increases the surface area that would increase mineral absorption (Desai *et al.*, 1997). These nano zinc as a particle of Zinc Oxide can adequately be synthesized by using chemical, physiological or biological methods (Swain *et al.*, 2015) and there is higher potential in Nano particles than their conventional Zn sources (Sri Sindhura *et al.*, 2014).

Apart from being highly bioavailable, reports have pointed out the antibacterial, immuno-modulatory and many other beneficial effects of nZnO. The potential hazard of high concentrations of nZnO is still unknown and their toxicological data are essentially unknown, therefore, the possible toxicological effect on hematology and blood serum quality along with the toxic doses needs to be studied (Swain *et al.,* 2016). Hence, this study focused on the possible effects of supplementing varying level of nano zinc oxide (nZnO) in diet of West African Dwarf goats.

MATERIALS AND METHODS

Site description:

The experiment was carried out at the Small ruminant Unit of the Directorate of University Farms (DUFARM), Federal University of Agriculture, Abeokuta, Nigeria with latitude 7o 13' 48N, longitude 3o 26' 14E and 348m above sea level. It lies within the humid lowland rain forest region with two distinctive seasons (Google Earth, 2019).

Experimental animals, management and treatment arrangement:

Twenty-four (24) West African Dwarf (WAD) goats averaged 7.2±0.54kg were sourced from a smallholder goat farm close to the University environment. Prior to the arrival of the experimental goats, pens were cleaned, washed and disinfected with Dettol and Izal solution. The goats were given prophylactic treatments consisting of intra-muscular injection of oxytetracycline (1ml/10kg BW) and multivitamins to ensure good health of the animals. The goats were also dewormed with Albendanzole and injected with 1ml/50kg body weight of Ivermectin to get rid of internal and external parasites, respectively during the four weeks period of acclimatization in the experimental pens to ensure sound health and stability before the commencement of the research. The goats were adapted to pen environment for 28 days and after which experimental data were collected for 84 days. After adaptation period, the goats were randomly allotted to three (3) dietary treatment groups (on weight equalization) of eight (8) goats each per treatment. The animals were allotted to a 1m2pen, meanwhile, they were fed *Megathyrsus maximus* (*ad-libitum*) in the morning and experimental concentrate (3% body weight) in the afternoon. Clean cool water was provided *ad-libitum* throughout the experimental period.

***Experimental diets*:**

Nano zinc oxide was purchased from a reputable veterinary outlet in Abeokuta. Concentrate diets were formulated with ingredients such as maize bran, wheat offal, palm kernel cake, zinc free premix, bone meal and salt. Nano zinc was added to the diet daily at the rate of 0mg/kg, 300mg/kg and 600mg/kg of feed. (Table 1).

Table 1. Gross composition of the experimental diets

	nZnO	**Inclusion**	**Levels**
Ingredients (%)	0mg/kg	300mg/kg	600mg/kg
Maize bran	40.00	40.00	40.00
Wheat offal	24.50	24.50	24.50
Palm kernel cake	30.00	30.00	30.00
Bone meal	5.00	5.00	5.00
Salt (NaCl)	0.50	0.50	0.50
Total	100	100	100
Determined Analysis (%)			
Dry Matter	92.45	93.01	92.19
Crude Protein	14.6	15.48	15.75
Ash	11.2	8.3	9.05
Fibre fraction	32.8	35.2	35
Ether Extract	3.9	4.4	4.1
Zinc (mg/kg)	28.11	108.39	229.65
Metabolizable Energy (MJ/Kg DM)	27.12	26.24	26.84

NOTE: Nano zinc was added as a supplement and not an inclusion in the diet

Experimental design:

The twenty-four (24) WAD goats were divided into three (3) treatment groups of eight (8) animals per group on weight equalization bases. Each group was randomly allotted to the three (3) experimental diets in a completely randomized design (CRD). The animals were housed singly in a feeding pen.

Data collection:

Chemical analysis:

Feed samples were ground to pass a 1-mm sieve screen using laboratory blender and were analyzed for crude protein, ether extract, and ash contents as enunciated by AOAC, (2005). Neutral detergent fibre (NDF) was analyzed by a method of Van Soest*et al*. (1991). Acid detergent fibre (ADF) was analysed sequentially on the same sample by a method of

AOAC (2000). Zn was estimated in an air-acetylene flame on an atomic absorption spectrophotometer

Growth performance characteristics:

The weight changes were monitored using 0-25kg digital hanging scale at the commencement of the research and at 7-days interval throughout the research period. Feed intake was documented as the difference of feed offered and feed refusal. Feed conversion ratio was estimated as the ratio of the total feed intake to that of weight gain.

Bloodanalysis:

Blood samples were collected before the animals are placed on experimental diets and on the 84th day of the experiment. All experimental goats were selected from each treatment. Before collecting the blood sample, the point of blood collection was cleaned with swab in order to disinfect the region to make the vein notable. Blood samples (5ml each) were collected through the jugular vein-puncture of the goats using purple top and red top vacutainer tubes for haematological and blood biochemical analysis, respectively

The purple top vacutainer tubes were analyzed for packed cell volume (PCV); which is the ratio of volume of cells to volume of plasma, haemoglobin (Hb) concentration, red blood cells (RBC), white blood cells (WBC), lymphocyte, neutrophils, eosinophils, basophils and monocytes. Serum minerals (such calcium, phosphorus, zinc, iron and cupper) and metabolites such as glucose, globulin, creatinine, cholesterol, Alkaline phosphatase (ALP), Alanine aminotransferase (ALT) and Aspartate aminotransferase (AST) were estimated from the supernatant of the coagulated blood from the red top vacutainer tubes.

The packed cell volume was measured from each ethyl diamine tetra acetic acid (EDTA) anticoagulant samples within 24hr of collection using the micro haematocrit method. Haemoglobin concentration was also measured in fresh EDTA anticoagulant samples using the Sahl's (acid haematin) method (c, 1978). RBC was measured in fresh EDTA with the aid of Neubauer counting chamber (haemocytometer). Blood smear was for total WBC counts and WBC differential relative and absolute counts (Tevares-Dias *et al*., 2008). Differential relative and absolute counts were classified as lymphocyte, neutrophils, eosinophils, basophils and monocytes and were determined by Giemsa's stain method (Coles, 1986). Mean corpuscular haemoglobin (MCH) and Mean corpuscular haemoglobin concentration (MCHC) values were calculated from PCV, Hb and RBC values (Jain, 1986).

Total serum protein was measured in Serum for individual goat using biuret method. Serum Alanine aminotransferase and Serum Aspartate aminotransferase were analyzed spectrophotometrically by using commercially available diagnostic kits (Randox Test kits). Serum globulin was measured using bromocresol purple method of Varley *et al.* (1980). Serum total cholesterol was determined spectrophotometrically by Randox kit according to the method of Allain*et al.* (1974). Serum glucose was determined spectrophotometrically by using Randox kit following the method of Barham and Trinder (1972).

Statistical analysis

Data obtained were subjected to one way analysis of variance in a completely randomized design. Tukey's test was used to separate significantly different means (SAS, 2004). The model for the experimental design is

$Y_{ii} = \mu + T_i + e_{ij}$

Where;

Y_{ii}= Observed value;

μ =The overall mean;

T_i =Nano zinc effect; and

e_{ij} =Random residual error.

RESULT AND DISCUSSION

RESULT

Table 2 highlights the effect of varying levels of nano zinc oxide (nZnO) supplementation on average dry matter intake, average weight gain and feed conversion ratio of West African Dwarf goats. Nano Zinc supplementation significantly influenced most parameters under consideration except metabolic weight, initial and final weight with similar values across the treatment groups.

Total weight gain, average weight gain, total dry matter intake and average dry matter intake were observed to be higher in goats fed 600mg/kg nZnO while the control and 300mg/kg nZnO groups had the least values. Value for FCR in 600mg/kg nZnO supplemented group was best result with the least value obtained in the control group.

Haematological parameters of West African Dwarf goats supplemented with nZnO at day 0, day 84 and the difference between the day 84 and day 0 of the experiment is shown on table 3. The haematological parameters were found to be similar ($P>0.05$) across the treatments at the onset of the experiment. Nano zinc oxide supplementation significantly ($p<0.05$) affected most haematological parameters at the culmination of the experiment. Haemoglobin concentration, red blood cell count, eosinophils and mean corpuscular haemoglobin concentration were similar across the treatment groups. It was observed that the packed cell volume, white blood cell, neutrophils, monocytes and mean corpuscular volume at the zenith of the experiment were elevated in the control group and goats offered 600mg/kg nZnO than those offered 300mg/kg nZnO. The lymphocyte and mean corpuscular haemoglobin concentration were observed to be higher in goats fed 300mg/kg nZnO while those fed 600mg/kg nZnO and control group had the least values. Basophil concentration was higher in the supplemented groups when compared to control diet.

Table 2. Effect of Nano Zinc Oxide Supplementation on Growth Performance of West African Dwarf Goats

Parameters	0mg/kg nZnO	300mg/kg nZnO	600mg/kg nZnO	SEM
Average dry matter intake (g/day)	355.89[b]	358.35[b]	398.27[a]	12.23
Initial weight (kg)	8.02	7.98	7.93	0.31
Final weight (kg)	9.90	9.97	10.39	0.43
Total weight gain (kg)	1.89[b]	1.99[b]	2.46[a]	0.25
Metabolic weight (kg)	5.56	5.60	5.77	0.18
Average weight gain (g/day)	22.54[b]	23.63[b]	29.25[a]	2.92
Feed Conversion Ratio	15.78[a]	15.18[a]	13.63[b]	3.16

a,b,c Means on the same row having different superscripts are significantly (P<0.05) different
SEM: Standard error of mean; nZnO: Nano Zinc Oxide.

Table 3. Effect of Nano Zinc Oxide Supplementation on Haematological Parameters of West African Dwarf Goats

Parameters	Reference values*	Day	0mg/kg nZnO	300mg/kg nZnO	600mg/kg nZnO	SEM
		0	22.00	23.67	29.00	2.09
PCV (%)	22-38	84	31.83[a]	29.33[b]	32.00[a]	0.48
		**	10.00[a]	5.67[ab]	3.00[b]	2.01
		0	8.83	8.17	8.63	0.29
Haemoglobin (g/dl)	8-12	84	10.50	10.57	10.90	0.10
		**	1.17	2.40	2.27	0.34
		0	13.60	14.03	13.83	0.22
Red blood cell (×106/L)	8-18	84	11.47	11.57	11.53	0.13
		**	-2.13	-2.47	-2.30	0.26
		0	5.93	6.40	7.30	0.42
White blood cell(×103/L)	4-13	84	5.63[a]	4.87[b]	5.70[a]	0.11
		**	-0.30[b]	-1.53[a]	-1.60[a]	0.42
		0	29.67	33.33	27.33	1.60
Neutrophils (%)	30-48	84	29.67[a]	26.33[b]	29.33[a]	0.63
		**	0.00	-7.00	2.00	2.26
		0	67.00	63.33	69.33	1.72
Lymphocyte (%)	50-70	84	66.67[b]	71.00[a]	68.00[b]	0.64
		**	-0.33	7.67	-1.33	2.48
		0	1.33	1.00	1.00	0.26
Eosinophils (%)	1-8	84	1.67	1.00	1.00	0.15
		**	0.33	0.00	0.00	3.55
		0	1.00	1.00	0.67	0.26
Basophil (%)		84	0.33[b]	1.00[a]	0.67[ab]	0.11
		**	-0.67	0.00	0.00	0.22
		0	1.00	1.33	1.33	0.32
Monocytes (%)	0-4	84	1.67[a]	0.67[b]	1.00[ab]	0.16
		**	0.67	-0.67	-0.33	0.46
		0	16.01	16.86	20.84	1.29
MCV (fl)	16-25	84	27.96[a]	25.22[b]	27.74[a]	0.38
		**	11.95	8.36	6.90	1.40
		0	6.50	5.82	6.24	0.19
MCH (pg)	5.2-8	84	9.21	9.16	9.46	0.08
		**	2.71	3.33	3.22	0.29
		0	41.68	34.46	30.72	2.37
MCHC (g/dl)	30-36	84	32.90[b]	36.48[a]	34.12[b]	0.53
		**	-8.79[a]	2.01[b]	3.38[b]	2.58

a,b,c Means on the same row having different superscripts are significantly (P<0.05) different. *Merck (2011),
**= difference between 84th day and day 0: SEM: Standard error of mean; Mean corpuscular volume (MCV):Mean corpuscular haemoglobin (MCH), Mean corpuscular haemoglobin concentration (MCHC): Packed cell volume (PCV).

Table 4 presents the serum biochemical properties of the experimental animals supplemented with nano zinc oxide at day 0, day 84 and the difference between the day 84 and day 0 of the experiment. Comparable (P>0.05) results were recorded for all serum biochemical parameters across the treatment groups at the beginning of the experiment. At the end of the experiment, nZnO supplementation significantly (P<0.05) influenced all parameters considered. Nano ZnO supplementation at 300mg/kg resulted in increased total protein, globulin and total cholesterol concentration while the control and 600mg/kg groups had the least values. Serum Aspartate aminotransferase concentration was higher in the control and 600mg/kg groups. Glucose and alkaline phosphatase mean values were recorded to be highest in 300mg/kg nZnO group while goats in 600mg/kg nZnO group had the least values. Serum creatinine concentration was highest in 600mg/kg nZnO with the least value observed in control group.

Table 4 Effect of nano Zinc Oxide supplementation on serum biochemical constiuents of West African Dwarf goats

Parameters	Reference Values*	Days	0mg/kg nZnO	300mg/kg nZnO	600mg/kg nZnO	SME
		0	9.07	7.27	7.07	0.72
Total Protein (g/dl)	6.1-7.5	84	6.63^{b}	7.57^{a}	6.20b	0.19
		**	-2.43^{a}	0.60^{b}	-0.87b	0.69
		0	1.80	3.13	2.10	0.29
Globulin (g/dl)	2.7-4.4	84	3.27^{b}	4.17^{a}	3.33b	0.12
		**	1.47	1.03	1.23	0.23
		0	92.83	73.40	81.83	3.83
Aspartate aminotransferase(U/L)	66-230	84	74.33^{a}	66.33^{b}	71.33^{a}	1.01
		**	-18.50^{a}	-7.07^{b}	-10.50^{ab}	2.76
		0	16.67	14.60	16.83	0.78
Alanine aminotransferase(U/L)	15-52	84	16.00^{b}	15.33^{c}	18.00^{a}	0.29
		**	-0.67	0.73	1.17	1.14
		0	66.93	75.23	62.87	4.06
Total Cholesterol (mg/dl)	65-136	84	71.83^{b}	95.73^{a}	76.13^{b}	2.67
		**	4.90^{c}	20.50^{a}	13.27^{b}	6.62
		0	2.07	1.30	2.43	0.36
Creatinine (mg/dl)	0.7-1.5	84	0.67^{c}	1.07^{b}	1.43^{a}	0.10
		**	-1.40	-0.23	-0.90	0.41
		0	80.90	85.93	80.07	4.54
Alkaline phosphatase (U/L)	61-283	84	70.20^{b}	79.47^{a}	66.70^{c}	1.36
		**	-10.70	-6.47	-13.37	5.05
		0	59.17	50.87	54.97	7.22
Glucose (mg/dl)	48-76	84	56.43^{b}	74.13^{a}	49.70^{c}	2.76
		**	-2.73^{b}	23.27^{a}	-5.27^{b}	9.64

a,b,c Means on the same row having different superscripts are significantly (P<0.05) different *= Merck (2011), **= difference between 84th day and day 0 SEM: Standard error of mean; nZnO: Nano Zinc Oxide;

DISCUSSION

The observed increase in growth performance of West African dwarf (WAD) goat fed varying levels of nano zinc oxide (nZnO) is in line with the study of Osineye, (2011) who reported the highest weight gain for WAD goats fed 134 ppm dietary zinc inclusion and Mohamed, (2001) who documented high weight gain in Nubian goats fed diets with zinc inclusion compared to the control. This result contradicted that of Elamin *et al*. (2013) who recorded similar weight gain in Nubian goats fed Zn (at 33mg/kg) and those in the control group. The high weight gain revealed for goats in 600mg/kg nZnO group may be linked to the increase in feed intake of the goats in that group, and to the high bioavailability of nano form of ZnO and its associated function in protein synthesis which in turn contributes to weight gain and overall improved growth of the goats.

Total and average dry matter intake in this study shows linear increase as nZnO inclusion level increases and the varying levels of nano zinc oxide (nZnO) supplementation significantly improved dry matter intake in West African dwarf (WAD) and this

is in agreement with Jia et al., (2009) who reported that dry matter intake of Angora goats increases but was unaffected by Zn supplementation and Salama Ahmed (2003) found that supplementation of Zn to a basal diet containing more than 25mg Zn/kg dm had no effect on dry matter intake in dairy goats. It has been reported that a low level of dietary Zn could lead to reduced food intake and growth performance (Jia *et al*., 2008). Goats in 600mg/kg nZnO had the highest dry matter intake which can be attributed to the higher availability of Zn in the diet. Mohamed (2001) reported similarly higher value for dry matter intake in all zinc supplemented Nubian goats. Zaboli *et al (*2013) also recorded similar high value of dry matter intake for Markhoz goats fed 40mg/kg of nZnO inclusion level. On the contrary, Osineye, (2011) reported low dry matter intake for goats fed high level (294mg/kg) of zinc. Kincaid *et al*. (1997) did not identify any effect on calves for 300 ppm Zn in terms of dry matter intake.

The FCR was improved as nZnO inclusion level increases. Consistent with this result, Garg*et al*. (2008) and Fadayifar *et al*. (2012) observed improved feed efficiency in finishing lambs fed organic Zn as compared to lambs fed the control diet. Jia *et al.* (2008) also identified a decrease in feed conversion ratio when 15-45 mg Zn/kg DM was supplemented to a basal diet in Liaoning Cashmere goats. In contrast, observation in WAD goats (Osineye, 2011) and Nubian goats (Elamin*et al*., 2013) shows that diets with Zn supplementation had a lesser feed efficiency when compared to the control.

The packed cell volume (PCV) obtained in the present study was within the normal reference range for goats as per few reported by Daramola (2005), Merck (2011) and Feldman *et al*. (2002). Estimates for PCV in this study were similar to Sobhanirad and Naserian (2012) who indicated higher values for PCV in the Zn-Met than control and ZnSO4 supplemented group after supplementing 500 mg Zn/kg DM from either ZnSO4.H2O or ZnMet in Holstein cows in crossbred calves after supplementing 35 mg/kg of Zn.

However, and contrary to this result, Mandal and Das (2010) and Swain *et al.* (2019) reported similar PCV in crossbred calves after supplementing 35 mg/kg of Zn as zinc sulphate or zinc propionate and in goats fed 25 and 50mg/kg nano zinc respectively.

Similar finding observed by Elamin*et al* (2013) reported an increase in WBC of goat kids fed 33mg/kg ZnSO4 as against the control were not significantly affected by treatment differences, which is in agreement with findings in this study, while Kegley*et al*., (2001) and Swain *et al.* (2019) reported no significant difference in total WBC and lymphocyte when 360 mg Zn/d of ZnSO4 or Zn-amino acid complex was supplemented in beef calves and 25 to 50mg/kg nano zinc fed to goats, respectively. White blood cell values observed in this study was found to be at par with those reported by Daramola (2005) and Merck (2011). Lymphocyte values (%) in 600mg/kg nZnO and control groups (68.00 and 66.67 % respectively) are in range (50 to70%) with Feldman *et al*., (2002), whereas animals in 300mg/kg nZnO group (71.00%) recorded slightly higher values than the reported values. The result obtained in this present study indicates that animal in both the supplemented and control groups were free of infection.

Neutrophil concentration values which were below reference range reported Daramola (2005). Our results are in agreement with the report of Swain *et al.* (2019), who reported significant difference in neutrophil level with higher concentration in control group than the supplemented groups that received 25 to 50mg/kg nanoZin. In concordance to this study, Someya*et al.* (2007) reported that dietary Zinc deficiency increased the number of eosinophil and neutrophils and decreased the number of lymphocytes, suggesting a change in white blood cell distribution. Monocyte values in this study are in range with Merck (2011). Higher monocyte values observed in the control group is in contrast to the study of Swain *et al.* (2019) who reported a lower value than the control group when compared to the supplemented groups.

Mandal and Das (2010) reported similar mean corpuscular volume (MCV) in crossbred calves after supplementing 35 mg/kg of Zn as zinc sulphate or zinc propionate to the basal diet (32.5 mg Zn/kg DM). This is in disparity with the report of this study, where significant difference was observed between the control group and the supplemented groups. Corresponding to this study, Sobhanirad and Naserian (2012) reported higher number of mean corpuscular haemoglobin concentration in the Zn-Met than control and ZnSO4 supplemented group after supplementing 500 mg Zn/kg DM from either ZnSO4.H2O and ZnMet in Holstein cows. On the other hand, Kegley*et al*. (2001) observed higher concentration of mean corpuscular haemoglobin concentration in control diet when compared with 360 mg Zn/d either as ZnSO4 or Zn-amino acid complex supplemented diet fed to beef calves and heifers.

The elevated total protein (g/dL) levels recorded in nZnO supplemented at 300 mg/kg is similar to the work of Daghash and Mousa (1999) and Swain *et al.* (2019) who observed increased protein levels due to zinc supplementation in buffalo calves and goats. However, Nagalakshmi *et al*. (2009) observed similar protein levels in lambs fed inorganic or organic zinc sources at 30 ppm. Huerta *et al*. (2002) did not find any change in plasma protein in beef steers with zinc supplementation even at 200 ppm. Similarly, Hassan *et al*. (2011) working with adult, Bakri sheep found similar serum total protein. High total protein observed in this study can be traced to the nano Zinc Oxide supplementation, the high absorbing trait of nano zinc made it more available to serve its function in increasing protein synthesis and makes protein more available in the blood.

Nagalakshmi *et al*. (2009) and Swain *et al.* (2019) observed increased globulin levels in lambs fed organic zinc sources at 30 ppm and goats fed 50mg/kg nano zinc, respectively. This is in line with the result of this study where higher globulin level was observed for group supplemented with 300mg/kg nano Zinc Oxide. Higher level of globulin recorded in this study is as a result of Zn supplementation which has a stimulatory effect on immune system in ruminants (Chen *et al.,* 2009). This indicated that supplementation of nano zinc at the rate of 300mg/kg to goats resulted in better immune system balancing and/or normative immune functions than the control group, as reflected in the globulin level in this study.

In ruminants, aspartate aminotransferase (AST) is often tested along with alkaline phosphatase (ALP) to evaluate whether the liver is damaged or diseased. When the liver is in dysfunction, the levels of the above enzymes will rise (Najafzadeh*et al.,* 2013). The observed lower values of AST and ALP in the supplemented group (600 mg/kg nZnO) when compared to control diet in this study is in agreement with Najafzadeh*et al.* (2013). The reduced AST level in nZnO supplemented group is an indication of nano Zinc Oxide bioavailability as increased availability of zinc reduces AST activities (Yousef, *et al.,* 2002). Gaafar *et al*., (2011) report was in support of the present study as they reported decrease in ALP and AST values due to supplementation of graded levels of zinc from organic sources. Contrary to the present findings obtained in the study, Jia*et al*., (2009) in Cashmere goats and Nagalakshmi*et al*., (2009) in Nellore lambs documented an increase in ALP with different levels and sources of supplemented zinc. Serum ALP is a Zn metalloenzyme that decreases in Zn deficiency and serum ALP activity is used as an indicator of animal Zn status (Viveros*et al.,* 2002), hence, Zn deficiency was not observed in the present study. This is an indication that the zinc level in the control and supplemented group diet was not deficient enough to bring the changes in serum ALP level and are in normal reference range as reported by Daramola (2005) and Merck (2011).

Alanine aminotransferase (ALT) is an important indicator for liver cell activities (Evans and Duncan, 2011). Swain *et al.* (2019) reported a decrease in ALT levels as nano zinc inclusion increase which is contradictory to the result obtained in this study where higher values in 600mg/kg Nano Zinc Oxide supplemented group was recorded with other group (300mg/kg nano Zinc Oxide) lower than the control group. Although ALT level of 300mg/kg nZnO group was lower at the onset of the study with a much higher value recorded after the experiment. Therefore, the administration of nano Zinc Oxide increases ALT production. Meanwhile, Najafzadeh *et al.* (2013) reported that inclusion of nano Zinc Oxide in lambs 'diet did not significantly elevate ALT activities. The effects of dietary treatments on blood concentrations of glucose and total cholesterol did not have obvious trends among the experimental treatments, but generally are within the normal reference range for goats as reported by Merck (2011) and there was a favorable effect in 300mg/kg nZnO treatment group in relation to the control and other supplemented group. Similar to this result, Mohamed *et al. (*2017) reported that ewes supplemented with nano zinc at different days intervals had a favorablecompared to other groups. High level of cholesterol was reported by Daghash and Mousa (1999) buffalo calves and Waziri *et al*. (2010) on Sahel goats, whereas low level was depicted by Kwari *et al*. (2011).

Creatinine is an indicator for kidney function. If kidney function falls, creatinine level rises (Najafzadeh *et al.,* 2013). Thus, significant increase in creatinine level in the nano Zinc Oxide groups in this study may not suggest kidney dysfunction because when compared to the values at day-1 of experiment, the final creatinine values were lesser and within reference range (Daramola, 2005) while the control is below the reference range.

It can be concluded that nano zinc supplementation brought about a balanced creatinine secretion for proper kidney function. In contrary to this study, Hassan *et al*., (2011), found in adult Bakri sheep, similar creatinine values in chelated zinc supplemented groups and the control groups whereas, Swain *et al.* (2019) reported increase in creatinine level of goats with increasing level of nano zinc supplementation in their ration.

CONCLUSION

Conclusively, feeding nZnO up to 600mg/kg aided the maintenance of health and immune stability of West African dwarf goats. Thus, nano Zinc oxide supplementation may be adopted in ruminant feeding with no alteration in their physiological functions.

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إضافة نانو أكسيد الزنك تُحسن أداء النمو وصحة الماعز القزمية في غرب أفريقيا

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أجري البحث لدراسة تأثير إضافة النانو أكسيد الزنك علي أداء النمو وصحة الماعز القزمية بغرب أفريقيا .استخدم في التجربه ٢٤ ماعز قزمية متوسط وزنها ٧,٢±٥٤, كجم قسمت الي ٣ مجموعات متساوية من حيث وزن الجسم .وزعت الثلاث مجموعات عشوائيا علي ثلاث معاملات تجريبية وهي إضافة صفر أو ٣٠٠ أو٦٠٠ مجم نانو أكسيد زنك لكل كجم عليقة في تصميم عشوائي كامل .تم نسجيل بيانات عن خصائص النمو وصفات الدم وكيمياء السبرم ثم حللت البيبانات باستخدام نموذج احصائي في اتجاه واحد واستخدم إختبار Tukey للمقارنة الإحصائية للمتوسطات.

أشارت النتائج إلي أن إضافة ٦٠٠ مجم نانو أكسيد الزنك /كجم عليقة أدت إلي زيادة معنوية ($P\leq0.05$)في الوزن الكلي للجسم ومعدل الزيادة الوزنية والمادة الجافة المأكولة يوميا بينما كانت تلك الصفات متساوية بين صفر إضافة و ٣٠٠ مجم نانو أكسيد الزنك .كانت صفات الدم والسيرم متساوية إحصائيا في جميع المعاملات عند بدء التجربة أدت إضافة ٦٠٠ مجم نانو أكسيد الزنك إلي زيادة , packed cell volume white blood cells , neutrophils, monocytes, corpuscular في نهاية التجربة بالمفارنة مع إضافة صفر أو ٣٠٠ مجم نانو أكسيد الزنك .كما أدت إضافة ٣٠٠ مجم نانو أكسيد الزنك إلي زيادة تركيزات البروتين الكلي والجلوبيولين والكوليسترول بالمقارنة بمجموعة ٦٠ مجم نانو اكسيد الزنك .بالرغم من تفاوت تأثير إضافة النانو أكسيد زنك فلم يكن له تأثير سلبي علي السمية وبالتالي يمكن تطبيق إضافة النانو أكسيد الزنك إلي علائق الماعز لتحسين أداء النمو وتقوية المناعة.