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# Effect of Dietary Niacin Supplementation on Growth Performance, Nutrient Digestibility, Hematology, and Lipoprotein Concentrations of Young Turkeys, *Meleagris gallopavo*

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The growth performance, nutrient digestibility, hematology, serum chemistry, and lipoprotein concentrations of turkey (*Meleagris gallopavo*) poults fed diets supplemented with high or recommended concentrations of niacin were investigated in this study. A total of 120 four-week-old turkey poults were randomly divided into three treatment groups with five replicates of eight birds in each group. The poult diets were supplemented with 0.0, 60, and 180 mg/kg niacin in the three treatments, termed control, recommended niacin supplementation (RNS), and high niacin supplementation (HNS), respectively. The study lasted for four weeks. The results showed that the HNS treatment reduced the feed intake and increased the body weight gain of poults. The apparent, nitrogen-corrected, and true metabolizable energy contents were the highest in the HNS-group turkey poults ($P < 0.05$). The red and white blood cell counts and hemoglobin concentration of the turkeys improved with increasing niacin supplementation ($P < 0.01$). The serum constituents, including the serum protein and globulin, were significantly increased ($P < 0.05$), while the uric acid and creatinine contents were significantly reduced in the HNS-group turkeys. Similarly, the HNS-group turkeys exhibited significantly reduced alanine aminotransferase (ALT) and alkaline phosphatase (ALP) contents, while the RNS-group turkeys had the least aspartate aminotransferase (AST) content. In addition, the HNS-group turkeys had the least serum low-density lipoprotein (LDL), triglyceride, and total cholesterol concentrations and the highest serum high-density lipoprotein (HDL) ($P < 0.01$) concentrations. In conclusion, the supplementation of 180 mg/kg niacin in the diet reduced the feed intake and serum ALT, ALP, LDL, triglyceride, and cholesterol contents and increased the body weight gain, metabolizable energy, and HDL concentration in turkeys. This study showed that niacin supplementation could reduce the fat content without compromising the body weight gain and increase stress resistance in turkey poults.

**Key words**: body weight gain, hematology, metabolizable energy, niacin, turkeys

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## Introduction

Niacin is a dietary precursor for the synthesis of nicotinamide adenine dinucleotide ($NAD^+$) and its phosphorylated derivative $NADP^+$, which are the essential coenzymes for the metabolism of nutrients in the body (Bogan and Brenner 2008). NAD (NADH) is extensively used in the catabolism of carbohydrates, fats, proteins, and alcohol to produce energy (Gille *et al*., 2008). Thus, niacin could be essential for the improvement of growth performance and fat reduction in animals (Yang *et al*., 2016). Ruiz and Harms (1988) found that the turkey poults fed a corn-soybean meal diet without supplemental niacin showed depressed growth and high incidence of leg abnormalities. The physiological effects of niacin on nutrient utilization and lipid metabolism have been variable to a great degree among animal studies (Grewal *et al*., 2014; Matte *et al*., 2016). In addition, Maurice

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*et al*. (1990) reported that the modern genetic lines of turkeys seem to require higher niacin supplementation to meet their increasing body needs. Therefore, niacin supplementation might be essential for turkey poults in the reduction of accumulated fat, to meet the expected high growth rates, and to bridge the gap between the demand and availability of balanced nutrition (Lala *et al*., 2015). However, it is not clear whether the high or recommended niacin supplementation could improve the productive performance and lipid metabolism in rapid growing young turkeys. Thus, the aim of this study was to determine the effect of dietary high or recommended supplementation of niacin on the growth performance, nutrient digestibility, hematological indices, serum chemistry, and blood lipoprotein concentrations of turkey toms.

## Materials and Methods

### *Experimental Materials and Design*

The study was carried out at the Turkey Experimental Unit of the Federal University of Agriculture, Abeokuta, Nigeria. The experimental procedures were conducted in accordance with the guidelines of the Animal Care Committee of the Federal University of Agriculture, Abeokuta Nigeria. The feed-grade niacin used in this study was purchased from a commercial company (Bio-Organics Nutrient Systems Limited Lagos State, Nigeria). Three experimental diets were formulated for this study. The formulated diet (Table 1) was supplemented with three different concentrations (0, 60, and 180 mg/kg) of the feed-grade niacin in the treatments termed as control, recommended niacin supplementation (RNS) and high niacin supplementation (HNS), respectively. The supplemental level of niacin used in this study was based on the minimum requirement of niacin for turkeys (NRC 1994). Similarly, all diets were formulated to meet the minimum specification for other macro- and micro-nutrients as recommended (NRC, 1994). The niacin content of the three diets were analyzed in triplicate (Control (26.40 mg/kg), RNS (85.96 mg/kg), and HNS diet (206.42 mg/kg)) (method NO. 981.16) (AOAC 2000).

Table 1. **Composition of basal diet for turkey toms**

| Items | |
|---|---|
| Ingredients (g/kg) | |
| Maize | 45.30 |
| Soybean meal | 40.00 |
| Fishmeal | 7.30 |
| Bone meal | 4.50 |
| Oyster shell | 2.00 |
| Premix* | 0.50 |
| Salt | 0.25 |
| DL-methionine | 0.30 |
| Lysine | 0.10 |
| ***Determined Analysis*** | |
| ME (MJ/Kg) | 11.91 |
| CP (%) | 26.00 |
| CF (%) | 3.90 |
| FAT (%) | 3.76 |
| **Calculated Analysis** | |
| Basal niacin (mg/kg) | 26.50 |
| Ca (g/kg) | 19.30 |
| P (g/kg) | 10.70 |

* Each 1.25 kg of vitamin premix contains: 10,000,000 IU vitamin A; 2,200,000 IU vitamin $D_3$; 10,000 mg vitamin E; 2000 mg vitamin $K_3$; 1500 mg vitamin $B_1$; 5000 mg vitamin $B_2$; 1500 mg vitamin $B_6$; 10 mg vitamin $B_{12}$; 15,000 mg niacin; 20 mg biotin; 125,000 mg anti-oxidant; 500 mg folic acid; 5000 mg calpan; CP = crude protein; CF = crude fiber; EE = ether extract

### *Experimental Birds and Management*

One-hundred-and-fifty one-day-old male BUT turkey poults (Aviagen Turkeys, Tattenhall, Cheshire, UK) were purchased from a commercial hatchery (Obasanjo Farms Ltd, Ibadan, Nigeria). The poults were brooded (deep litter system of management) for 4 weeks. The commercial diets based on the maize-soybean meal were provided to the poults before the start of the experiment (metabolizable energy (ME) = 11.79 MJ/kg, crude protein (CP) = 278 g/kg); these diets met the National Research Council (NRC) (1994) nutritional requirements of the poults. The brooding temperature was maintained close to the body requirements of poults.

During brooding, the temperature was maintained at 35.5 ℃ for the first 0 to 2 d and then gradually reduced by 1.5℃ per week to a final temperature of 29.5℃ at 28 d. On Day 29, 120 poults were selected from the purchased flock and allotted to dietary treatments on weight equalization basis. Each experimental treatment was replicated five times with eight poults per replicate. Feed and water were provided *ad libitum*. The experiment lasted for 4 weeks.

### *Growth Performance*

The feed intake and body weight gain were measured at weekly intervals. Feed intake was obtained as the difference between the feed offered and leftovers. The feed-to-gain ratio was calculated as the ratio of the feed consumed to the gain in body weight.

### *Nutrient Digestibility and Metabolizable Energy*

The determination of nutrient digestibility and metabolizable energy were conducted at day 56 of the experiment as described previously (Oke *et al*., 2017). One turkey per replicate was randomly selected and housed separately in an appropriate metabolic cage fitted with an individual feed trough and a facility for separate excreta collection. The turkeys were acclimatized for 2 d prior to the commencement of the 4-d collection period. The excreta collected per turkey per day was oven-dried (60℃) and then used for analysis. The proximate compositions of the feed and dried excreta samples were analyzed for the dry matter, crude fibre, fat, ash, and crude protein contents using the standard methods (AOAC 2000). At the expiration of the metabolic trial, the left-over feed was withdrawn from the turkeys, but unrestricted access to clean water was provided for 24 h during which the excreta voided were discarded. After the expiration of the 24-h feed withdrawal, each turkey was dosed with 50 mL of warm glucose solution to reduce stress and was deprived of feed for another 24 h, making it a total of 48-h starvation period. The total amount of excreta collected per turkey during the last (24 h) phase of feed withdrawal was used for the estimation of endogenous losses.

The gross energies of the excreta samples (starved turkeys) were estimated using the adiabatic bomb calorimeter (Model 1261; Parr Instrument Co., Moline, IL, US). The apparent metabolizable energy (AME), nitrogen-corrected AME (AMEn), true metabolizable energy (TME), and nitrogen-corrected TME (TMEn) were computed using the equations described previously (Sibbald and Wolynetz 1989).

***Blood Sample Collection***

On day 28 of the study, a turkey per pen was selected at random, and the blood samples (3 mL each) from the brachial wing veins were collected in the vials containing EDTA for the determination of hematological indices. Another set of blood samples were collected into plain vials (without EDTA), centrifuged (2500 × g for 15 min at 8℃), and used for serum chemistry analysis.

***Hematological Indices***

The hemoglobin concentration (Hb) was estimated using the cyanmethemoglobin method (Cannan 1958). The packed cell volume (PCV) and red blood cell (RBC) and white blood cell (WBC) counts were determined using a Wintrobe hematocrit tube according to the method of Schalm *et al.* (1975). The differential leucocyte counts (heterophils, lymphocytes, basophils, eosinophils, and monocytes) were determined using the blood smears stained with the May-Grunwald-Giemsa stain.

***Serum Chemistry***

The total serum protein and serum uric acid concentrations were measured according to the standard procedures (Wootton and Powell 1964; Varley *et al*., 1980). The concentrations of the serum enzymes, such as alkaline phosphatase (ALP), aspartate aminotransferase (AST), and alanine aminotransferase (ALT), were determined (Bergmeyer 1983) with the aid of commercial kits (Roche COBAS testing Kits, Roche, Basel, Switzerland).

***Plasma Lipid***

The harvested plasma was used for the lipid profile analysis. The concentrations of the total cholesterol (TC), triglyceride (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) were measured using the commercial analytical kits (Randox diagnostic kit; GPO-PAP Method; Randox Laboratory, Antrim, Northern Ireland) and automatic blood biochemical analyzer (Roche). All procedures were conducted according to the manufacturers' guidelines.

***Statistical Analysis***

The data obtained from this study were subjected to one-way analysis of variance (ANOVA) in a completely randomized design, followed by the post-hoc Tukey's test, when the F-values were significant (SAS 1999). The pen was used as the experimental unit for statistical analysis Significant differences were considered at $P < 0.05$.

## Results

***Growth Performance***

The body weight gain increased significantly ($p < 0.01$) with increasing niacin supplementation. The turkey poults in the control group showed the highest ($p < 0.01$) feed intake, highest feed-to-gain ratio, least ($p < 0.001$) final body weight and body weight gain, whereas the HNS-group turkeys (180 mg/kg niacin) showed the highest final live weight and least ($p < 0.01$) feed intake (Table 2). The feed conversion ratio improved significantly ($p < 0.05$) in the turkey poults fed with the diets supplemented with niacin, being the best in the HNS-group turkeys ($p < 0.01$).

***Nutrient Digestibility and Apparent Metabolizable Energy (AME)***

The nutrient digestibility and AME values of the turkey toms fed diets supplemented with niacin are shown in Table 3. The dry matter, fat, and ash contents were not significantly ($p > 0.05$) affected. The HNS-group turkeys showed increased crude fibre and crude protein digestibility ($p < 0.05$) as compared to the other group turkeys.

The HNS-group turkeys had the highest nitrogen-free extract (NFE) ($P < 0.05$), AME ($P < 0.01$), $AME_n$ ($P < 0.01$), TME ($P < 0.01$), and $TME_n$ values ($P < 0.01$).

***Hematological Parameters***

Table 4 shows the hematological parameters of the 8-week-old turkey toms. The HNS-group turkeys had the highest red blood cell count ($p < 0.001$) and the least hemoglobin content ($P < 0.05$). The lymphocyte content increased as niacin supplementation increased from 0 to 60 mg/kg (RNS), but decreased with a further increase in niacin supplementation to 180 mg/kg niacin. However, the heterophil content in the blood of turkeys increased linearly, and the white blood cell count ($p < 0.05$) decreased with an increase in niacin supplementation. The highest monocyte count was obtained

Table 2. **Growth performance of 8-week-old toms fed with a diet supplemented with niacin**

| Parameters | Control | RNS | HNS | SEM | $P < 0.05$ |
|---|---|---|---|---|---|
| Initial weight (g/bird) | 940.30 | 940.20 | 940.15 | 4.50 | 0.11 |
| Final weight (g/bird) | 2280.20$^{b}$ | 2300.15$^{b}$ | 2450.20$^{a}$ | 27.40 | 0.02 |
| Feed intake (g/bird) | 4760.20$^{a}$ | 4380.20$^{b}$ | 4270.10$^{c}$ | 68.10 | 0.001 |
| BWG (g/bird) | 1339.90$^{b}$ | 1359.95$^{b}$ | 1510.05$^{a}$ | 28.20 | 0.001 |
| Feed/gain ratio | 3.60$^{a}$ | 3.22$^{b}$ | 2.83$^{c}$ | 0.05 | 0.001 |

[abc] Means in the same row having different superscripts are significantly different ($P < 0.05$), BWG = body weight gain, Control = 0 mg/kg, RNS = recommended niacin supplementation (60 mg/kg), HNS = high niacin supplementation (180 mg/kg)

Table 3. **Effect of niacin supplementation on nutrient retention and metabolizable energy values of 8-week-old toms**

| Parameter (g/kg) | Control | RNS | HNS | SEM | $P<0.05$ |
|---|---|---|---|---|---|
| DM | 78.00 | 77.50 | 77.50 | 0.82 | 0.46 |
| Fat | 55.20 | 54.60 | 56.60 | 2.32 | 0.45 |
| Ash | 57.60 | 55.00 | 53.70 | 1.03 | 0.05 |
| CF | 58.00[c] | 65.00[b] | 67.00[a] | 2.42 | 0.02 |
| CP | 69.50[c] | 75.00[b] | 78.00[a] | 1.79 | 0.001 |
| NFE | 53.00[c] | 72.00[b] | 79.00[a] | 1.47 | 0.03 |
| AME | 15.80[c] | 16.76[b] | 18.34[a] | 1.22 | 0.001 |
| $AME_n$ | 15.71[c] | 16.52[b] | 18.25[a] | 0.88 | 0.001 |
| TME | 16.50[c] | 17.36[b] | 19.38[a] | 0.16 | 0.001 |
| $TME_n$ | 16.35[c] | 17.14[b] | 19.22[a] | 0.18 | 0.001 |

[abc] Means in the same row having different superscripts are significantly different ($P<0.05$). Control=0 mg/kg, RNS=recommended niacin supplementation (60 mg/kg), HNS=high niacin supplementation (180 mg/kg), DM=dry matter, CF=crude fibre, CP=crude protein, NFE=nitrogen free extract, AME=apparent metabolizable energy, $AME_n$=nitrogen-corrected apparent metabolizable energy, TME=true metabolizable energy $TME_n$=nitrogen-corrected true metabolizable energy

Table 4. **Effect of niacin supplementation on the hematology of 8-week-old toms**

| Parameter | Control | RNS | HNS | SEM | $P<0.05$ |
|---|---|---|---|---|---|
| PCV (%) | 37.70 | 39.00 | 38.40 | 0.86 | 0.06 |
| Hemoglobin (g/dL) | 8.73[b] | 9.71[a] | 9.72[a] | 0.25 | 0.004 |
| RBC (X $10^{12}$/L) | 2.90[b] | 3.20[a] | 3.21[a] | 0.05 | 0.001 |
| WBC (X $10^{9}$/L) | 25.32[a] | 21.22[b] | 20.13[c] | 1.06 | 0.003 |
| Het/lym ratio (%) | 0.87[c] | 1.07[a] | 1.02[b] | 0.09 | 0.002 |
| Heterophil (%) | 40.20[b] | 41.70[a] | 43.50[a] | 2.00 | 0.001 |
| Lymphocytes (%) | 46.00[a] | 39.00[c] | 42.50[b] | 3.39 | 0.001 |
| Basophils (%) | 0.50 | 2.50 | 0.00 | 0.50 | 0.001 |
| Eosinophil (%) | 2.23[a`] | 2.20[a] | 1.80[b] | 0.25 | 0.001 |
| Monocyte (%) | 0.50[b] | 0.50[b] | 1.00[a] | 0.11 | 0.001 |

[abc] Means in the same row having different superscripts are significantly different ($P<0.05$), Control=0 mg/kg, RNS=recommended niacin supplementation (60 mg/kg), HNS=high niacin supplementation (180 mg/kg), PCV=packed cell volume, RBC=red blood cell, WBC=white blood cell, Het/lym=Heterophil/lymphocyte

Table 5. **Effect of niacin supplementation on the serum chemistry and lipids concentration of 8-week-old toms**

| Parameters | Control | RNS | HNS | SEM | $P<0.05$ |
|---|---|---|---|---|---|
| Protein (g/L) | 43.07[c] | 52.75[b] | 57.90[a] | 0.75 | 0.03 |
| Albumin (g/L) | 20.97 | 20.85 | 22.40 | 0.50 | 0.35 |
| Globulin (g/L) | 22.10[b] | 21.90[b] | 25.70[a] | 0.52 | 0.02 |
| Uric acid (mg/dL) | 5.40[a] | 4.60[b] | 4.30[c] | 0.12 | 0.001 |
| Creatinine (mg/dL) | 1.60[a] | 1.10[b] | 1.00[b] | 0.10 | 0.001 |
| AST (U/L) | 176.20[a] | 136.07[c] | 144.50[b] | 4.20 | 0.007 |
| ALT (U/L) | 30.10[a] | 26.28[b] | 23.50[c] | 0.88 | 0.004 |
| ALP (U/L) | 191.40[a] | 180.40[b] | 121.50[c] | 8.93 | 0.023 |
| **Plasma Lipids** | | | | | |
| Cholesterol (mg/dL) | 144.93[a] | 140.40[b] | 130.40[c] | 0.66 | 0.01 |
| Triglyceride (mg/dL) | 121.00[a] | 103.70[b] | 100.00[c] | 2.38 | 0.001 |
| HDL (mg/dL) | 37.30[c] | 39.30[b] | 40.75[a] | 0.19 | 0.03 |
| LDL (mg/dL) | 83.50[a] | 82.80[b] | 78.55[c] | 0.54 | 0.002 |

[abc] Means in the same row having different superscripts are significantly different ($P<0.05$), Control=0 mg/kg, RNS=recommended niacin supplementation (60 mg/kg), HNS=high niacin supplementation (180 mg/kg), AST=aspartate aminotransaminase, ALT=alanine aminotransaminase, ALP=alkaline phosphatase, HDL=high-density lipoprotein, LDL=low-density lipoprotein

in the HNS-group turkeys. Dietary niacin supplementation moderately increased the heterophil/lymphocyte ratio in the HNS-group turkeys. The packed cell volume was not significantly affected by the dietary treatments.

***Serum Chemistry and Lipids (Plasma)***

The effect of niacin supplementation on the serum chemistry of the 8-week-old turkeys is shown in Table 5. The HNS treatment significantly increased the total serum protein and globulin ($P < 0.05$) in the plasma of turkeys. The serum uric acid was significantly increased in the control-group turkeys. The blood albumin was not significantly affected by the dietary treatments. Niacin supplementation significantly reduced the ALT and ALP concentrations in the serum of turkeys ($p < 0.05$) at day 56. In addition, the plasma cholesterol, triglyceride, and low-density lipoprotein concentrations were significantly reduced ($p < 0.05$), while the plasma HDL concentration was significantly increased ($p < 0.05$) in the HNS-group turkeys.

## Discussion

***Growth Performance***

The observed increase in body weight gain of turkeys with increasing niacin supplementation showed that niacin is essential for body weight gain in poultry. The improved body weight gain with increased niacin supplementation indicates that the commercial turkeys might require niacin at concentrations higher than those generally recommended. However, previous studies have reported variable effects of niacin supplementation on growth performance in poultry. Ouart *et al*. (1987) found no effect of niacin supplementation on feed conversion ratio and egg production in laying hens, while Waldroup *et al*. (1985) reported that the growing broiler chickens fed diets supplemented with niacin at 66 to 100 mg/kg showed an increase in body weight gain and feed conversion ratio. Furthermore, the addition of niacin (50 mg/L) into the drinking water of chicks was reported to be beneficial in the early stage, but not in the last stage (Celik *et al*., 2003). In contrast, Oh *et al*. (1972) reported that diet supplementation with 60 mg/kg niacin reduced feed consumption and improved feed conversion ratio in white leghorn chicks for the complete growth period. Our results confirmed that the modern genetic lines of turkeys might require relatively high niacin supplementation for optimum performance (Maurice *et al*., 1990). The feed intake of turkeys was improved with dietary supplementation of niacin at the recommended dose of 60 mg/kg (RNS), but the feed efficiency and body weight gain were increased with niacin supplementation at a relatively high dose of 180 mg/kg. Variations in the effect of niacin on the growth performance of animals could be attributed to the variation in the species and age of animals and the concentration of niacin used in different studies.

***Nutrient Digestibility***

The high AME values indicate improved digestive functions in turkeys (Oso *et al*., 2017). The high $AME_n$ and $TME_n$ values of the HNS-group turkeys indicated an improvement in the nutrient metabolism of turkeys (Zuber and Rodehutscord 2017).

Hence, the nutrient availability seems to increase with dietary niacin supplementation in turkeys. The insignificant effect of niacin on the dry matter, fat, and ash contents in this study agrees with the previous study that reported the effect of niacin supplementation on dry matter digestibility in vitro (Hannah and Stern 1985). The type of diet, level of added niacin, and experimental animals might influence the results of the nutrient digestibility studies (Flachowsky 1993). In this study, the level of added niacin increases the digestibility of crude protein and crude fiber. Maurice *et al*. (1990) concluded that the modern turkeys might require relatively high niacin supplementation for improved nutrient metabolism. The availability of the niacin present in cereals (including corn) is limited to humans and some animal species (Carpenter 1983). Thus, it might be prudent to agree that niacin supplementation, especially in corn-based diets, is essential for improved nutrient digestibility in young animals.

***Hematological Indices***

Red blood cells are the principal means of delivering oxygen to body tissues in vertebrates. The depletion of tissue oxygen could lead to stress and deterioration of systemic health in poultry, suggesting that dietary niacin supplementation increases the availability of oxygen to body tissues, thereby preventing the deterioration of the systemic health in turkeys.

Furthermore, the white and red blood cell counts have been reported as an index for measuring health status (McKenzie *et al*., 2005). The white blood cell (heterophil) is the immediate response of the body to antigens (Levinas *et al*., 2012). An elevation in white blood cell (WBC) count is recorded under the conditions of disease, infection, or immune system disorder (Makkar *et al*., 2016). Our results showed decreased WBC count and a moderately increased heterophil count in the starter turkeys fed diets supplemented with high concentrations of niacin. This suggests that the potential of niacin to improve the health status of turkeys could be increased with an increase in its supplementation. The reason for this could be attributed to the higher nutrient requirements of turkeys during their growing phase.

It has been reported earlier that the modern breeds of turkeys seem to require supplementation with niacin concentrations higher than those recommended by the NRC (1994) (60 mg/kg). Similarly, Whitehead (2001) stated that the niacin requirement of broilers is 20 mg/kg higher than the NRC recommendation; however, in this study, at a concentration higher than that recommended by both NRC (60 mg/kg niacin) and Whitehead (80 mg/kg niacin), the measured health markers were improved. The mechanism by which niacin improves the WBC and RBC counts could be related to the reported stability conferred by dietary niacin on the bone marrow cells (cells responsible for WBC and RBC production) (Boyonoski *et al*., 2002; Kirkland 2012).

Zulkifli (2003) reported that the heterophil/lymphocyte (H/L) ratio is a reliable indicator of avian stress, and it increases significantly under stress (Ilori *et al*., 2011). In this study, the moderate increase in the H/L ratio of the turkeys fed niacin-supplemented diet suggests that niacin supplementation might in itself function as a moderate stressor, which, in turn, might help in regulating stress responses in turkeys. This agrees with the report that a moderate increase in the heterophil/lymphocyte ratio could indicate a positive modulation of the immune system in turkeys (Huff *et al*., 2010). Furthermore, Li *et al*. (2016) found that niacin supplementation positively contributes to the immune status and stress resistance of aquatic animals. This implies that niacin supplementation could increase stress resistance in turkeys.

Moreover, Ilori *et al*. (2011) showed that the number of heterophils per unit of blood increases, whereas the number of lymphocytes decreases in birds under stress, but the ratio of these cell types is less variable. However, the H/L ratios without reference to the total white blood cell counts (TWBC) and cellular atypia appear to lack the potential for the realistic assessment of stress status in avian species (Cotter 2015). This suggests that the collective effect of niacin supplementation on turkeys could have important implications during the periods of stress. The hematological constituents reflect the physiological responsiveness of an animal to its internal and external environments (Esonu *et al*., 2001). The packed cell volume in poultry birds is associated with protein synthesis, immune functionality, and balanced blood levels (Denli *et al*., 2009). The improved performance of the turkeys fed niacin supplemented diets could be associated with an improvement in PCV.

***Serum Chemistry***

In the present study, the increased total serum protein and globulin of the turkeys fed diets supplemented with niacin indicate improved tissue growth which could be associated with the increased body weight gain in the supplemented groups. An increase in the level of total serum protein has been reported to indicate improved dietary protein utilization (Eggum *et al*., 1990). This finding differs from that of (Bulku *et al*., 2010), who reported that niacin did not affect the serum proteins of rats. A reduction in total serum protein concentration indicates low dietary protein utilization (Schalm *et al*., 1975); however, the dietary protein seems to be adequately utilized in the turkeys fed diets supplemented with high concentrations of niacin due to the improved body weight gain. The serum enzymes AST, ALP, and ALT are used as diagnostic markers for liver and muscle damage. In normal healthy animals, the serum enzymes exist at low concentrations, but increase under stressful or hepatotoxic conditions, which are usually accompanied by the inhibition of protein synthesis (Schalm *et al*., 1975; Grunwaldt *et al*., 2005). The serum enzyme (ALT and ALP) concentration was the lowest ($P<0.01$) in the birds fed diets supplemented with niacin, showing that niacin posed no adverse effect on the liver and muscle functions of the poults.In addition, the reduced serum uric acid of the HNS-group turkey poults in this study corroborated with the previous findings that dietary niacin supplementation reduced the serum uric acid levels (Tornvall and Walldius 1991; Yuvaraj *et al*., 2009). This could be associated with efficient utilization of crude protein and other nutrients in the supplemented diets. Serum uric acid has been shown to be an important indicator of protein catabolism and utilization in poultry (Oduguwa 1995; Sun *et al*., 2009).

***Plasma Lipids***

The reduced low-density lipoprotein, cholesterol, and triglyceride concentrations in the plasma of the HNS-group turkey poults as compared to the other treatment-group poults agreed with the previous studies (Jiang *et al*., 2014; Kamanna *et al*., 2013), which showed that niacin is effective in reducing the levels of plasma cholesterol and low-density lipoproteins. At physiological doses, niacin might exert profound effects on the plasma cholesterol and lipoprotein concentrations (Artemeva *et al*., 2015). Several mechanisms by which niacin reduces plasma cholesterol and lipoprotein concentrations have been proposed.

Niacin inhibits the peripheral mobilization of free fatty acids (Wu and Zhao 2009), which decreases the amount of substrate available for the hepatic synthesis of triglycerides and very low-density lipoprotein (VLDL) particles (Grundy *et al*., 1981). This, in turn, reduces the hepatic conversion of VLDL particles to LDL particles or decreases the secretion of VLDL (Kamanna and Kashyap 2008). In addition, niacin appears to interfere directly with the enzymatic conversion of VLDL-C to LDL-C and decreases triglyceride synthesis and hepatic lipoprotein secretion via inhibition of diacylglycerol acyltransferase-2 (Ganji *et al*., 2004). Consequently, the increased plasma HDL removes the cholesterol from the plasma by promoting the transport of cholesterol from the peripheral blood to the liver (Grummer and Carroll 1988). Interestingly, the plasma HDL was also significantly increased with niacin supplementation in this study. The increase in HDL values might be attributed to the fact that the effect of niacin on HDL-C levels is mediated in part by the reduction in LDL-C levels, since the reduced availability of this lipoprotein limits cholesterol transfer from HDL-C to LDL-C, thereby increasing the serum HDL-C levels (Natarajan *et al*., 2010).

This study justified that niacin supplementation affects the plasma lipid metabolism in turkeys without compromising their body weight gain and provided evidence for the possible role of niacin in stress resistance.

## Conclusion

The present study demonstrated that the supplementation of 180 mg/kg Niacin (HNS) in the diet of young turkeys reduces the accumulation of serum lipids without compromising body weight gain. Furthermore, this study confirms the notion that niacin supplementation could be an effective strategy to mitigate stress in young animals. Such a strategy could be warranted in the situations in which the production or environmental conditions might increase stress and consequently reduce the production performance of turkeys. The improved digestive and immune functions of toms in this study warrant further studies to determine the influence of niacin on intestinal functions and oxidative stress in growing animals.

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## Conflicts of interest

The authors declare no conflict of interest.

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