Effect of Feather Color on Heat Tolerance Traits and Growth Performance of Nigerian Indigenous Turkey

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ABSTRACT

Heat stress is considered to be one of the most important variables affecting the reproductive and productive performance of poultry in the tropics. Due to the common occurrence of environmental stressors worldwide, many studies have investigated the detrimental effects of heat stress on poultry production. The study was conducted to determine the effect of feather color on heat tolerance traits and growth performance of Nigerian indigenous turkey which are characterized with three main feather colors namely black, white, and lavender. A total of 270 poults consisting of ninety poults of each feather color were sourced and reared under intensive management system. Data were collected on growth parameters including body weight, body length, breast girth, shank length, keel length and thigh length. Adaptive parameters measured were rectal temperature, respiratory rate, pulse rate and heat stress index. Data collected were subjected to one-way analysis of variance (ANOVA) using the PROC GLM procedure of SAS using feather color as a factor.

Results indicated significant effect ($p<0.05$) of feather color on heat tolerance traits. No significant difference in rectal temperature was observed between black and white feather turkeys but was however significantly different from that obtained for lavender turkey in all the weeks. Rectal temperature ranged from 40.20^{O}C in lavender feather in week 3 to 40.45 black feather turkey in week 1. Higher respiratory rate was observed in black and lavender feather compared to the white feather color turkey. The black turkeys had higher heat stress index in all week which was significantly different from heat stress obtained for white and lavender turkeys. This suggested that the other lighter colors are better in their ability to control heat stress and will adapt better in hot tropical environment.

Growth performance of turkey with dark pigmentation were better than that of the white feather turkey. Black feather turkey consistently has better performance followed by the lavender color while the least was observed in white feather turkey suggesting that birds may be able to control their temperature and avoid being overheated by other mechanism rather than the structural colors and plumage pigmentation.

(Keywords: poultry production, heat stress, heat tolerance, growth performance, Nigerian indigenous turkey)

INTRODUCTION

Negative balance between the net amount of energy flowing from the animal's body to its surrounding environment and the amount of heat energy produced by the animal results in Heat stress. This negative imbalance as a result of heat stress may be caused by variations of a combination of environmental factors (e.g., sunlight, thermal irradiation, and air temperature, humidity and movement), and characteristics of the animal (e.g., species, metabolism rate, and thermoregulatory mechanisms).

Environmental stressors, such as heat stress, are particularly detrimental to animal agriculture (Nienaber and Hahn, 2007; Nardone et al., 2010; Renaudeau et al., 2012). Heat tolerance of organism is a strong determinant of the environmental conditions in which they inhabit. Hot ambient temperature above the zone neutral temperature for domestic poultry affects performance and overall adaptation to climate region. Birds will die from heat exhaustion, if heat produced is quite greater than heat loss. Heat stress is major welfare problem in the turkey industry (Ilori et al., 2011; Glatz and Rhoda, 2013).

Heat stress impairs overall poultry and egg production by modifying the bird's neuroendocrine profile both by decreased feed intake and by activation of the hypothalamic-pituitary-adrenal axis. Exposure of birds to high environmental temperature generates behavioral, physiological and immunological responses, which impose detrimental consequences to their productivity. Heat stress is considered to be one of the most important variables affecting feed intake, feed efficiency, egg production and quality body weight gain, mortality rate, and reduced profitability of poultry meat production, particularly in hot climate (Deeb and Cahaner 2001). It has also been reported to cause reduced dietary digestibility, decreased plasma protein and calcium levels (Mahmoud et al., 1996; Bonnet et al., 1997; Mashaly and Hendricks, 2004; Mohammed et al., 2014).

The feather color of birds provides a critical thermal buffer between the animal and its environment. Heat transfer through the feather occurs by several avenues, this includes: conduction, convention and radiation. Although feather color determines the fraction of incident solar radiation that is absorbed by the feather and generate heat, factors such as feather micro-optics and structure are critical determinants of radiation which penetrate into avian coat. Solar radiation had little effect on the changes in the body temperature and respiratory rate (Williams et al., 1960). Body temperature and respiratory rate are the most consistent physiological response studied and are more affected by solar radiation than by other weather influences.

Heat and nutritional stress are considered to influence both the productive and reproductive efficiency of animal. Also, the impaired metabolic and immune response of the animal finally results in a worsened health condition of the animal (Ratnakaran et al., 2017). A significant decrease in production potential and an increase in physiological responses are observed in those animals which are exposed to hot climate. It was noted that in order to cope with the extreme environmental conditions, an animal will undergo stress when it has to make extreme functional, behavioral, structural or immunological adjustments (Collier, 1982). Hot and humid conditions would cause heat stress among livestock including inducing metabolic and behavioral changes resulting in lower productivity.

The poultry sector is next to ruminants as a source of animal protein supply in Nigeria and accounts for almost 25% of local meat production (Ajala and Alli-Balogun, 2004) while turkey birds serve as one of the sources of animal protein in Nigeria which is suitable alternative for small- or large-scale producers considering the cost of production. Turkey occupies an important position next to chicken, duck, guinea fowl, and pigeon in contributing to the protein needs of our growing population. Turkeys have also been found to be of considerable economic and social significance in the tradition of Nigerians (Peters et al., 1997). Its importance in the national economy of developing countries and its role in improving the nutritional status and income of many small communities have been very significant.

The Nigerian indigenous turkey is adaptable to wide range of climatic conditions and can be raised successfully almost anywhere if they are well fed and protected against diseases, predators and adverse weather conditions (Ogundipe and Dafwang, 1980; Ilori et al., 2009, 2010). Turkey is an excellent insect forager and most crops that are troubled by insect population including vegetables are candidates for insect control by turkeys (Grimes et al., 2007). These turkeys have varying feather color ranging from black, lavender and white.

Growth in farm animals and especially poultry is a reflection of an intricate balance between a great number of endogenous (hormonal, immunological and genetic) and exogenous (environmental) factors. Though growth performance of an animal is a phenotypic attribute influenced by the environment, to a larger extent however, it is a manifestation of the genetic constitution of the animal (Kor et al.,

2016) in relation to environmental factors like feed, heat stress, and other management practices. There are many factors which can decrease the performance and increase abnormal behavior of poultry such as management, housing and heat stress (Mohammed et al., 2010; Ilori et al., 2011).

The concept of adaptive traits revolves around the developmental pattern of an organism which facilitates the survival and reproduction in a certain succession of environments (Walter et al., 2018). Poultry are particularly sensitive to temperature-related environmental challenges, especially heat stress. It has been suggested that modern poultry genotypes produce more body heat, due to their greater metabolic activity (Settar et al., 1999; Deeb and Cahaner, 2002).

Measures of rectal temperature (RT), pulse-rate (PR) and respiratory rate (RR) are some of the important determinants of the adaptive traits of poultry to its environment. They also, to a large extent, determine the profitability of the poultry enterprise (Ilori et al., 2011). Heat is produced by metabolism within the body, which includes maintenance, growth and egg production. During recent decades, fast-growing meat-type turkeys have shown significant improvements in growth performance, feed conversion and liveability (Havenstein et al., 2007), mainly as a result of progressive genetic selection. Low Turkey production is due to the sensitivity of this animal to infectious diseases and the difficulty to cope with difficult environment (Marchewka et al., 2013).

Structural colors are often produced by small particles or air pockets in the feather having dimension similar to wavelength of light and these cause the scattering of light. Structural colors may also arise from films having differed refraction qualities. They are probably the most complex integumentary appendages found in any avian species and they are certainly one of the most striking anatomical features of birds (Prum and Brush, 2002). And they also aid in flight, thermal insulation, and waterproofing (Prum and Brush, 2002).

The feather generates heat for the use of the birds whenever there is cold stress in the environment and also absorbs heat when there is sufficient heat supply. Birds that have much feather generate much heat compare to birds with fewer feathers which enhance the survival of Indigenous Turkey (Lehman, 2004).It has been postulated that the integument of black animals absorbs more of the visible and near infrared components of solar energy than does the integument of lighter-colored animals, and that this greater absorption may permit them to reduce their heat loss when ambient temperatures are below their lower critical temperature (Heppner, 1970). For example, a significant metabolic economy of white zebra finches (*Poephilu castanotis*) was observed over undyed birds when both were exposed to artificial sunlight in a moderately cold (10%) metabolism chamber (Hamilton and Heppner, 1970). They also submitted that the warming of the outer feathers of the black bird reduces the temperature gradient from the skin of the bird to the surface feathers, and thus slows the loss of metabolic heat to cold surroundings. On the other hand, it has been reported that it is the ‘unseen’ near-infrared (NIR) wavelengths light that confers thermal protection in birds and that the capacity to reflect solar radiation at NIR wavelengths may enable animals to control heat gain and remain within their critical thermal limits (Medina et al., 2018). They also reported using a continent-wide phylogenetic analysis of Australian birds, that species occupying hot, arid environments reflect more radiant energy in NIR wavelengths than species in thermally benign environments, even when controlling for variation in visible color.

The better an animal is able to cope in its environment, the better will be the level of production. Therefore, the objective of this study is to determine variations in the adaptive traits (pulse rate, respiratory rate, and rectal temperature) of Nigerian indigenous turkey based on feather color variation and examine the growth performance traits (body weight, body length, shank length, thigh length, keel length and breast girth) of Nigerian indigenous turkey.

MATERIALS AND METHODS

Experimental Site

The research work was carried out at the Turkey Breeding Unit of the Teaching and Research Farm of the College of Animal Science and Livestock Production, University of Agriculture, Alabata Road, Abeokuta, Nigeria. The University of Agriculture, Abeokuta is located on latitude 7°10'N and longitude 3°20'E and lies in the Southwestern part of Nigeria with a mean annual rainfall of about 1037 mm. The mean monthly ambient temperature ranges from 28°C in December to 36°C in February with a yearly average relative humidity of about 82%. The vegetation in the University represents an interphase between the tropical raining forest and the derived savannah (Ilori et al., 2017; Google Earth, 2018).

Experimental Birds and Management

A total of 270 Nigerian indigenous turkey poults consisting of 90 white, 90 black and 90 lavender feather color were sourced from a reputable hatchery in Ibadan, Nigeria and were raised under the intensive system of management (deep litter system). The birds were wing-tagged for proper identification and were subjected to the same management practices throughout the experimental period.

Brooding

On arrival on the farm, the turkey poults were placed in a pre-heated brooder house and given feed and water. Temperature was maintained at 35°C -37°C for the first two weeks and reduced gradually by 2°C till room temperature was attained at about eight weeks.

Housing

The experimental birds were raised under the intensive system of management on deep litters. They were all subjected to the same standard system of management. The housing consists of pens sub partitioned into different units. The floor was made up of concrete covered with wood shavings for easy cleaning of litters.

Feeding

On arrival of the experimental birds, they were given water containing anti-stress and multivitamins during the period of their acclimatization to stabilize their condition .Commercial feed was provided for the birds *ad libitum*. Starter mash containing 28% crude protein (CP), 2825 kcal/kgME, grower mash (24% CP), 2900 kcal/kgME, and finisher mash (20% CP), 3000 kcal/kgME was fed to the birds from 0 to 6, 7 to 16, and 17 to 20 weeks, respectively. Feeders and Drinkers were placed on the floor for easy access by chicks. As poults grows the feeders and drinkers was changed to fit their growth. Cool and clean water was supplied to the poults ad libitum. The water was mixed with multi-vitamin drugs to serve as an anti-stress during the period of the of their acclimatization to their condition

DATA COLLECTION

Growth Performance Parameters

Growth data was collected on a weekly basis for 20 weeks. Body measurements were taken as suggested by Gueye et al. (1998). On their arrival, the body weight of poults was measured using a sensitive scale (Metler balance).

Body Weight (BW): Weight of the live bird was measured using ATOM-A120 weighing scale of 0.005 g sensitivity.

Body Length (BL): was measured as the length of the body from the base of the neck to the base of the tail around the uropigial gland using measuring tape in cm.

Keel Length (KL): was measured as the length of the cartilaginous keel bone or metasternum using measuring tape in cm

Breast Girth (BG): was measured as the region of the largest breast expansion when the bird was positioned ventrally using measuring tape in cm.

Shank Length (SL): was measured as the hock joint to the tarsometarsus digit-3 joint using measuring tape in cm.

Thigh Length (TL): was measured as the distance between the hock joint and the pelvic joint using measuring tape in cm.

Physiological Parameters

Data for adaptive traits data were collected on a weekly basis. Parameters measured include:

Rectal Temperature (RT): This was measured using a clean clinical thermometer inserted into the vent for one (1) minute after which the readings were taken (T˚C).

Respiration Rate (RR): This was determined for each bird by counting the number of movements of the abdominal region for one minute using a stopwatch and recorded as breaths/minute.

Pulse Rate (PR): This was determined by placing the finger tips under the wing vein and counting the number of beats per minute using a stop watch and recorded as beats/minute.

Heat Stress Index (HSI): This was derived from the relationship between observed pulse and respiratory rate together with their normal values.

The formula is as follows:

H=AR/AP X NP/NR

Where:

H=Heat stress index

AR= Observed respiratory rate

AP= Observed pulse rate

NP= Normal pulse rate

NR= Normal respiratory rate.

RT, PR and RR of all the birds were measured early in the morning before sun rise and in the afternoon with the average recorded as described by Oladimeji et al. (1993).

Statistical Analysis

All data were subjected to analysis of variance using the PROC GLM procedure of SAS (2017). The model for the analysis is stated below:

$Yijk = \mu + Gi + \varepsilon ijk$

Where:

Yijk = Parameter of interest

μ = Overall mean for the parameter of interest

Gi = Effect of the ith color on growth or heat tolerance traits

εijk = Random Residual error

Significant differences were separated using Duncan multiple range tests implemented in SAS (2017).

RESULTS AND DISCUSSION

Effect of Feather Color on Heat Tolerance Traits

The animal and its environment make up an integrated system, where each act on the other. Stress response is mainly associated with the activation of hypothalamo pituitary-adrenal gland and orthosympathic nervous system, which aggravates the detrimental effect of high body temperature (Lin et al., 2006), and may compromise animal welfare (Blokhuis et al., 2010). The effect of feather color on heat tolerance traits is as shown in Table 1.

Turkey feather color had significant effect ($p<0.05$) on heat tolerance traits. No significant difference in rectal temperature was observed between black and white feather turkeys, but there performance however was significantly different from that obtained for lavender turkey in all the weeks. The result also indicated that, increase in growth also leads to increase in rectal temperature which could be attributed to increase in size and metabolic activities as the bird matures.

Feed intake tends to increase as growth increases which will lead to increase in metabolic and other physiological processes. Lack of significant difference in rectal temperature between black and white color feather turkeys suggests that solar radiation and absorption of heat in different plumage colors does not depend solely on structural and pigmentary colors of feathers. It has been reported that the ‘unseen’ near-infrared (NIR) wavelengths light confers thermal protection in birds and that the capacity to reflect solar radiation at NIR wavelengths may enable animals to control heat gain and remain within their critical thermal limits (Medina et al., 2018).

Heat Stress Index (HSI) is a method used to measure the impact of the thermal environment on an animal while high or low heat stress index to the normal range can pose thermal stress to animal and negatively affects its overall production (Beedee et al., 1983; Berman, 2005; Surej and Chaturvedi, 2013).

Table 1: Effect of Feather Color on Heat Tolerance Traits of Nigerian Indigenous Turkey.

Age in weeks	Color	Rectal temp (°c)	Respiratory rate (breaths/min)	Pulse rate (beats/min)	Heat stress Index
1	1	40.45±0.02[a]	67.92±0.67[a]	282.49±0.84[a]	1.57±0.16[a]
	2	40.43±0.02[a]	66.92±0.94[b]	290.03±6.12[a]	1.50±0.02[b]
	3	40.22±0.01[b]	68.47±0.98[a]	284.15±1.15[a]	1.48±0.02[b]
4	1	40.41±0.02[a]	56.98±0.72[b]	254.30±0.93[a]	1.56±0.02[a]
	2	40.39±0.01[a]	59.10±0.76[a]	256.41±1.40[a]	1.50±0.02[b]
	3	40.20±0.01[b]	59.00±1.10[a]	251.54±1.33[a]	1.51±0.29[b]
8	1	40.41±0.02[a]	43.07±0.65[a]	282.93±0.61[a]	1.48±0.01[a]
	2	40.39±0.01[a]	41.35±0.77[b]	280.45±1.24[a]	1.30±0.02[b]
	3	40.21±0.01[b]	43.12±1.10[a]	281.06±1.40[a]	1.30±0.03[b]
12	1	40.41±0.02[a]	50.40±0.56[b]	272.44±0.52[a]	1.30±0.10[a]
	2	40.39±0.01[a]	46.05±0.68[c]	273.60±0.70[a]	1.20±0.01[b]
	3	40.22±0.01[b]	54.56±0.67[a]	273.40±1.25[a]	1.210±0.02[b]
16	1	40.41±0.02[a]	35.05±0.40[b]	238.58±1.11[b]	0.96±0.01[a]
	2	40.40±0.01[a]	35.03±0.53[b]	241.13±1.01[a]	0.90±0.01[b]
	3	40.22±0.01[b]	37.23±0.88[a]	242.68±1.06[a]	0.91±0.02[b]
20	1	40.39±0.01[a]	34.60±0.56[b]	272.04±1.39[a]	0.83±0.01[a]
	2	40.36±0.01[a]	32.88±0.29[b]	277.13±1.00[a]	0.77±0.01[b]
	3	40.22±0.01[b]	38.21±1.48[a]	268.36±3.16[b]	0.79±0.03[b]

[abc] Means with same superscript in the same column for the same traits are not significant different ($p>0.05$)
1 = black feather turkey, 2 = white feather turkey 3 = lavender feather turkey

The black turkeys had higher heat stress index in all weeks and were significantly different from heat stress obtained for white and lavender turkey. This suggests that the other lighter colors are better in their ability to control heat stress and will adapt better in hot tropical environment.

Hamilton and Heppner, (1970) reported that the warming of the outer feathers of the black bird reduces the temperature gradient from the skin of the bird to the surface feathers, and thus slows the loss of metabolic heat to cold surroundings. When heat stress index is high, birds can experience severe dehydration and even death can result from over exposure to heat. Lin et al. (2005) also reported that high temperature in addition to changes in rectal temperature could lead to the disturbance of thermal balance of birds. These invariably can result to a stressor on an animal which in turn will affect the adaptability and productivity of such animal. However, the range of rectal temperature in this study are within the normal range of 40 – 41^{O}C in poultry (Daghir, 1995).

The differences observed in respiratory rate based on feather color in this study with higher values observed in black and lavender feather turkeys suggested that the darker the pigmentation or structural colors of the plumage the less the ability of the birds to dissipate heat quickly which will ultimately lead to increase in perspiration in order to bring down the temperature. There was also decrease in respiratory rate as birds mature which corroborated the report that the size of the animal also affects the respiratory rate, with reduction in breaths/min as age increases. As ambient temperature increases, birds start to pant to lose heat which is accompanied by increase in respiratory rate (Ilori et al., 2011).

The differences observed in pulse rate although not significant based on feather of all color types in this study is within the recommended range across all weeks and could be attributed to the fact that local turkeys of all color variants were well adapted to prevailing harsh environmental condition due to effect of natural selection (Lin et al., 2006; Ilori et al., 2010). Pulse rate of birds can increase for various reasons, for example during mating and excessive excitement.

Effect of Feather Color on Growth Performance

Heat stress is one of the most important environmental factors that determine the productivity of livestock especially in the tropics. The effect of feather color on body weight, body length, shank length, thigh length, keel length and breast girth are presented in Table 2.

Table 2: Effect of Feather Color on Growth Performance of Nigerian Indigenous Turkey.

Age in weeks	Color	BW	BL	SL	TL	KL	BG
1	1	99.45±27.44[a]	9.55±0.32[a]	3.52±0.19[a]	4.58±0.204[a]	2.88±0.17[a]	10.17±0.44[a]
	2	67.27±2.61[b]	9.14±0.30[a]	3.40±0.08[a]	4.52±0.11[a]	2.59±0.08[a]	10.01±0.22[a]
	3	70.23±2.76[b]	9.34±0.21[a]	3.37±0.12[a]	4.27±0.16[a]	2.86±0.01[a]	9.64±0.31[a]
4	1	303.11±10.02[a]	15.66±0.24[a]	5.81±0.10[a]	8.04±0.14[a]	5.28±0.09[a]	16.59±0.30[a]
	2	289.75±2.61[b]	15.51±0.39[a]	5.78±0.08[a]	8.52±0.26[a]	5.21±0.13[a]	16.29±0.30[a]
	3	302.91±2.76[a]	15.45±0.37[a]	6.02±0.19[a]	8.04±0.22[a]	5.32±0.16[a]	16.56±0.32[a]
8	1	1010.83±10.03[a]	26.44±0.35[a]	10.14±0.19[a]	12.32±0.18[a]	8.42±0.12[a]	25.26±0.26[a]
	2	940.94±45.02[b]	26.14±0.49[a]	10.49±9.69[a]	12.31±0.23[a]	8.04±0.18[b]	25.26±0.31[a]
	3	1002.00±44.03[a]	25.06±0.72[b]	10.73±10.04[a]	11.56±0.4[a]	8.55±0.59[a]	25.55±0.59[a]
12	1	1872.42±56.62[a]	32.42±0.27[a]	12.49±0.14[a]	15.16±0.15[a]	10.67±0.11[a]	31.77±0.46[a]
	2	1629.50±61.39[b]	32.53±11.60[a]	11.60±0.18[a]	14.08±0.75[b]	9.913±0.19[b]	30.31±0.55[b]
	3	1680.91±61.98[b]	32.57±12.33[a]	12.27±0.24[a]	14.98±0.33[a]	10.51±0.29[a]	31.65±0.62[a]
16	1	2313.56±45.78[a]	36.05±0.29[a]	14.07±0.14[a]	17.33±0.17[a]	12.37±0.02[a]	36.24±0.44[a]
	2	2172.5±7.997[b]	34.70±0.51[a]	13.16±0.21[b]	16.45±0.31[b]	12.19±34.26[a]	34.36±0.63[b]
	3	2262.82±95.87[a]	35.96±0.75[a]	13.79±0.21[b]	17.00±0.39[a]	12.09±0.31[a]	36.22±0.63[a]
20	1	2923.39±61.01[a]	39.49±0.35[a]	15.50±0.15[a]	18.89±0.12 [a]	13.80±0.13[a]	40.13±0.45[a]
	2	2735.69±77.6[b]	38.41±0.63[a]	14.71±0.35[b]	18.11±0.35[a]	13.24±1.54[a]	38.55±0.59[b]
	3	2888.82±127.31[a]	39.24±0.88[a]	15.23±0.22[a]	18.11±0.56[a]	13.61±0.33[a]	40.16±0.69[a]

[abc] Means with the superscript in the same column for the same traits are not significant different (p>0.05)
1 = black feather turkey, 2 = white feather turkey 3 = lavender feather turkey

Analysis of results showed significant effect ($p<0.05$) of color on all growth trait measured in the study. As expected growth performance increases as age increases in the turkey. Growth performance of turkey with dark pigmentation were better than that of the white feather turkey. Black feather turkey consistently has better performance followed by the lavender color while the least was observed in white feather turkey.

We expect white feather turkey to perform better than the dark feather turkey should heat absorption and radiation depend on structural color and pigmentation of feather alone. This suggests that apart from the visible feather colors there are some invisible colors that protect birds from heat and that birds may be able to control their temperature and avoid being overheated by reflecting near-infrared wavelengths of sunlight, regardless of their feather color (Medina *et al*., 2018).

The ability of animals to adapt to its environment differ between and within species, breeds and strains, as a result of genetic variation. Individual differences commonly arise through both heritable and non-heritable adaptive behavior. Adaptive traits such as pulse rate, respiratory rate and rectal temperature had been used to determine heat stress index of animals (Ilori *et al.,* 2011) and how it affects animals' physiology in such environment.

Our indigenous turkey was able to express its growth potential irrespective of feather color as they have been naturally selected for adaptation to harsh tropical environment over many generations. Our indigenous turkeys are endowed with rich genetic potentials and have developed adaptive measures to tropical environment through evolution over many generations.

CONCLUSIONS

Our analysis of feather color on heat tolerance traits and growth performance of Nigerian indigenous turkey showed that although feather color had effect on physiological traits measured, other factors apart from structural colors and plumage pigmentation are involved in the ability of turkey to withstand heat stress. The dark feather turkeys although had higher rectal temperature and heat stress index are better in their growth performance.

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