



## GENETIC VARIATION IN PHYSIOLOGICAL RESPONSES AND ADAPTATION OF DIFFERENT BREED OF DUCKS TO TROPICAL HEAT STRESS

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### ABSTRACT

The Study was conducted at the Poultry unit of the Teaching and Research Farm of Abubakar Tafawa Balewa University, Bauchi to determine the genetic variation on physiological and adaptation responses of three duck breeds. Data on physiological parameters: pulse rate (PR), respiratory rate (RR) and rectal temperature (RT) of twenty-five (25) matured ducks, comprising ten (five males and five females) each of Muscovy and Khaki Campbell and five (two males and three females) of White Pekin ducks were obtained and subjected to analysis of variance. Breed had significant ( $P<0.001$ ) effects on all the physiological parameters. White Pekin had the highest PR ( $186.80\pm0.39$  beat/minute), RR ( $31.43\pm0.19$  breath/minutes) and RT ( $41.79\pm0.10^{\circ}\text{C}$ ), while the least were recorded among Muscovy ducks ( $145.98\pm0.48$  beat/minute,  $23.61\pm0.16$  beat/minute, and  $41.34\pm0.71^{\circ}\text{C}$ , respectively). Similarly, all physiological parameters recorded were significantly affected ( $P<0.001$ ) by the period of the day. The highest responses were observed in the afternoon. Significant ( $P<0.001$ ) effects of sex on PR and RR were detected. Females exhibited higher responses than males. However, a non-significant influence of sex on RT was observed. A significant ( $P<0.001$ ) breed x period of the day and breed x sex interactions existed on all the parameters. The research has shown that Muscovy ducks were more tolerant to heat stress than Khaki Campbell and White Pekin. Adequate measures should be employed to alleviate heat stress on ducks during the hot season. This study could serve as a baseline for the genetic improvement of ducks in the tropics.

**Keywords:** Genetic variation; physiological responses; Adaptation; heat stress

### INTRODUCTION

Poultry, including chicken, duck, and turkey is significant source of protein in the form of meat and eggs for many people worldwide. However, various factors impact the production of poultry meat and eggs (Oluwagbenga and Fraley, 2023). In tropical environments, periods of high temperatures harm the health and performance of domestic animals. If the earth's temperature continues to rise further as predicted, the harmful effects of environmental stress on animal welfare and production could be a significant issue in the future (Bernabucci *et al.*, 2010). Thermal stress can lead to physiological and behavioral responses in an animal which changes their duration and intensity with respect to the genetic makeup and environmental factors (St-Pierre *et al.*, 2003). Poultry farming is no exception, and the stress caused by elevated temperatures can result in heavy economic losses from increased mortality and reduced productivity (Zerjal *et al.*, 2013). Poultry are more susceptible to heat stress (HS), especially due to their inability to sweat, thereby relying on panting to dissipate heat. The physiological responses to stress in poultry involve the activation of the sympathetic adreno-medullary pathway that releases catecholamines such as epinephrine and norepinephrine from the adrenal medulla (Li *et al.*, 2022). For birds to perform at their optimum capacity, they need to, among other factors, be in homeostasis with their environment through maintaining thermo-balance (Zerjal *et al.*, 2013). Birds, like mammals, are homoeothermic; they produce heat to maintain a relatively constant body temperature and may permit



certain variations within their temperature range without significant perturbation (Adedeji *et al.*, 2015). Using an adapted animal with lower productivity is better than infusing stress tolerance to non-adapted breeds (Gaughan and Smith, 2015). Adaptation is not only the tolerance level of the livestock to environmental stresses but also their ability to survive, grow, and reproduce under harsh living conditions (Hoffmann and Sgro, 2011). The adaptive mechanisms through which animals adapt to the changing climatic conditions include genetic or biological adaptation, phenotypic or physiological adaptation, acclimatization, acclimation and habituation (Gaughan, 2012).

Physiological parameters like respiratory rate (RR), pulse rate (PR) and rectal temperature (RT) give an immediate response to the climatic stress and, consequently, the level of discomfort/comfort to the animal. These responses have been used to measure an animal's comfort and adaptability to an adverse environment or as a sensitive physiological measure of environmental modification (Ganaie *et al.* 2012). Physiological (RT, PR and RR) responses reflect the degree of stress imposed on animals by climatic parameters. They also indicate the ability of an animal to withstand the rigors of climatic stress physiologically under warm conditions through changes in these parameters (Ganaie *et al.* 2012). Higher values of physiological parameters RR, RT, and PR have been reported under thermal stress compared to the thermo-neutral zone (Al-Tamimi, 2007).

Tropical and sub-tropical climates are blessed with high ambient temperatures, which is the primary cause of heat stress, leading to reduced productivity of animals raised in these environments. Heat stress is a significant problem which affects animal welfare (Abdelatif and Alameen, 2012). Heat stress negatively affects livability, production performance, immune functions, and disease susceptibility in poultry (Cahaner *et al.*, 2008; Mashaly *et al.*, 2004). Potential countermeasures to the adverse effects of heat stress have been suggested, such as the genetic selection for heat-tolerant genes (Mashaly, 2004) and tolerance induction by neonatal- or embryonic-age thermal conditioning (Piestun, *et al.*, 2012) or by feed restriction (Liew *et al.*, 2003; Zulkifi *et al.*, 2000). Most studies, however, have been conducted under conditions with fixed high environmental temperature. In contrast, very little information is available on the effects of the dynamic combination of temperature and relative humidity in actual tropical climates (Tirawattanawanich *et al.*, 2011).

Therefore, there is a need to assess the genetic variation on physiological and adaptation responses of different breeds of ducks to tropical heat stress under intensive system. A good understanding of how they respond to the high ambient temperature and relative humidity may offer a long-lasting solution in alleviating heat stress in the study area.

## **MATERIALS AND METHODS**

### **Description of the Study Area**

The study was conducted at the Poultry unit of the Teaching and Research Farm of Abubakar Tafawa Balewa University, Bauchi, Nigeria. The study area lies within Northern Guinea Savannah, located between latitudes 9° 30' and 12° 30' North of the equator and between the longitudes 8° 50' and 11° 0' East of the Greenwich meridian. The rainfall ranges between 1300 mm per annum in the South and only 700 mm in the extreme North (Muhammad, 2003). The average relative humidity, daily sunshine hours, and temperature values range between 35 - 94 % for February and August, 5.0 - 10.0 hours in August and November and 42– 12.8 °C during April and December, respectively (Saidu, 2001).

### **Experimental Birds and Management**

Twenty-five (25) mature ducks, comprising ten (five males and five females) each for Muscovy and Khaki Campbell and five (two males and three females) White Pekin ducks, were purchased from the local farmers. The birds were dewormed with albendazole and managed under an intensive system. Feed and water were given *ad libitum* throughout the study period.



### Data and Sample Collection

To measure the breed's physiological responses to heat stress, the following parameters were taken; Pulse rate (PR), Respiratory rate (RR), and Rectal temperature (RT). They were measured according to the methods described by Adedeji *et al.* (2015).

**Rectal Temperature:** This was measured using a digital clinical thermometer inserted into the vent and the readings were taken ( $T^{\circ}\text{C}$ ).

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

**Pulse Rate:** This was determined by placing the fingertips under the wing vein and counting the number of beats per minute using a stopwatch, which was recorded as beats/minute.

The above measurements were taken three times daily: morning at 6:00 AM, afternoon at 12:30 PM, and evening at 5:00 PM, thrice a week for three months (April, May, and June), for a total of 2700 observations.

### Temperature Humidity Index

Ambient temperature and relative humidity records for the study period were collected from the Bauchi State Meteorological Inspection office to determine the Temperature Humidity Index (THI) using the formula by Bianca (1962) as follows:

$$\text{THI}_2 = (0.35 \times T_{\text{db}} + 0.65 \times T_{\text{wb}}) \times 1.8 + 32$$

$T_{\text{db}}^{\circ}\text{C}$  = Dry bulb temperature and  $T_{\text{wb}}$  = Wet bulb temperature in celsius.

The estimated values of THI were classified as follows: 75 to 78 = Alarm, 79 to 83 = Danger and 84 & above Emergency.

**Table 1: Meteorological Data and Temperature Humidity Index for the Period of the Study**

Parameters	Months		
	April	May	June
Ambient temperature ( $^{\circ}\text{C}$ )	30.84	30.12	26.87
Relative humidity (%)	36.00	55.00	70.87
Wind speed (m/sec)	164.90	200.42	134.20
Temperature humidity index (THI)	77.08	78.56	77.36

For THI the values obtained indicate the following: 75 to 78 = Alarm, 79 to 83 = Danger and 84 and above = Emergency.

### Coefficients of Adaptability of the Animals

Rectal temperature and respiratory rates/minute were used to determine coefficients of adaptability (CA) according to the method of Bianca (1965) as follows;

$$\text{CA} = \frac{\text{Rectal Temperature}}{41} + \frac{\text{Respiratory rate per minute}}{22.5} = 2$$

Values that fall above and below 2 represent low and high heat adaptability than normal, respectively.

### Data Analysis

The generated data were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure of SPSS version 25 (2017). Significantly different means were compared using the Duncan multiple range test (DMRT). The model utilized was as follows:

$$Y_{ijkl} = \mu + B_i + S_j + T_k + BS_{ij} + BT_{ik} + e_{ijkl}$$

$Y_{ijkl}$  = Observation on independent variables

$\mu$  = Common Mean,  $B_i$  = effect of  $i^{\text{th}}$  breed,  $S_j$  = effect of  $j^{\text{th}}$  sex,  $T_k$  = effect of  $k^{\text{th}}$  period

$BS_{ij}$  = interaction effects of  $i^{\text{th}}$  breed and  $j^{\text{th}}$  sex,  $BT_{ik}$  = interaction effects of  $i^{\text{th}}$  breed and  $k^{\text{th}}$  period

$e_{ijkl}$  = random error term



## RESULTS AND DISCUSSION

### Breed Effect on Physiological Parameters

Significant ( $P < 0.001$ ) effect of breed on Pulse rate (PR), Respiratory rate (RR) and Rectal temperature (RT) was observed as presented in Table 2. White Pekin had the highest PR ( $186.80 \pm 0.39$  beat/minute), RR ( $31.43 \pm 0.19$  breath/minutes) and RT ( $41.79 \pm 0.10$  °C), while the lowest values were recorded among Muscovy ducks, being  $145.98 \pm 0.48$  beat/minute,  $23.61 \pm 0.16$  breath/minutes, and  $41.34 \pm 0.71$  °C, respectively. The higher values of physiological parameters observed in White Pekin ducks than that of Khaki Campbell and Muscovy ducks, indicated that the physiological responses of ducks to heat stress are genotype dependent. This is in agreement with the findings of Cardoso *et al.* (2015) that breed affects all physiological parameters. Several authors (Isidahomen *et al.*, 2012; Adedeji *et al.*, 2015; Mutibvu *et al.*, 2017) reported a significant effect of genotype on PR in chickens as well as on RR. The RT differed significantly among the breeds in this study is in line with the findings of Zerjal *et al.* (2013) in chickens and that of Eyarefe and Oguntunde (2012), who noted differences in values among Boran hybrid laying birds. However, the findings of Adedeji *et al.* (2015) and Mutibvu *et al.* (2017) contradict this observation. The authors reported that genotype had no influence on RT in chickens. Similarly, Oso *et al.* (2013) observed no significant effect of breed on this trait in turkey. Variation in physiological parameters among breeds of ducks may be attributed to inherent genetic differences, as Chineke *et al.* (2006) reported.

### Effect of Sex on Physiological Parameters

The effects of sex on physiological parameters are shown in Table 3. A significant ( $P < 0.001$ ) influence of sex on PR and RR was noticed. Females had higher values for PR ( $165.38 \pm 0.81$  beat/minute) and RR ( $26.35 \pm 0.16$  breath/minutes) than the males ( $173.28 \pm 0.34$  beat/minute,  $29.37 \pm 0.14$  breath/minutes, respectively). However, a non-significant influence of sex on RT was observed. The sexual difference in PR and RR is in accordance with the findings of Uzma *et al.* (2008). Similarly, Sayed and Scott (2008) and Adedeji *et al.* (2015) reported significant effect of sex on physiological parameters among pigeons and local chickens, respectively. The authors attributed this to hormonal differences between the two sexes. On the other hand, the report of Mutibvu *et al.* (2017) contradicts this finding. However, the absence of significant effect of sex on RT observed in the present study agrees with the reports of Adedeji *et al.* (2015) and Mutibvu *et al.* (2017).

**Table 2:** Effect of Breed on Physiological Parameters of Duck

Parameters	Overall mean	Breed			Sig. value
		Khaki Campbell	White Pekin	Muscovy duck	
<b>Vital</b>					
Pulse rate (beats/min.)	$169.50 \pm 0.47$	$184.37 \pm 0.53^b$	$186.80 \pm 0.39^a$	$145.98 \pm 0.48^c$	***
Respiratory rate (breath/min.)	$27.93 \pm 0.11$	$30.48 \pm 0.11^b$	$31.45 \pm 0.19^a$	$23.61 \pm 0.16^c$	***
Rectal Temperature (°C)	$41.58 \pm 0.05$	$41.71 \pm 0.87^a$	$41.79 \pm 0.10^a$	$41.34 \pm 0.71^b$	***

Means having different superscripts <sup>abc</sup> in the same row are significantly different \*\*\*  $p < 0.001$



**Table 3: Effect of sex on Physiological Parameters of Duck**

Parameters	Overall mean	Sex		Sig. value
		Males	Females	
Pulse rate (beats/min.)	169.50±0.47	165.38±0.81 <sup>b</sup>	173.28±0.34 <sup>a</sup>	***
Respiratory rate (breath/min.)	27.93±0.11	26.35±0.16 <sup>b</sup>	29.37±0.14 <sup>a</sup>	***
Rectal Temperature (°C)	41.58±0.05	41.55±0.06	41.61±0.08	NS

Means having different superscripts <sup>abc</sup> in the same row are significantly different \*\*\*  $p < 0.001$ , NS: Not significant.

#### Effect of Period of the Day on Physiological Parameters

The effect period of the day on physiological parameters is presented in Table 3. Significant ( $P < 0.001$ ) effect of the period of the day on PR, RR, RT was detected. The afternoon period had higher values for PR (175.54±0.69 beat/minute), RR (30.59±0.20 breath/minutes), and RT (42.06±0.08 °C) than the morning period, which had values of 164.51±0.99 beat/minute, 26.13±0.19 breath/minutes, and 41.14±0.08 °C, respectively.

The significant effect of a period of the day on physiological parameters observed in the present study agrees with the findings of Purswell *et al.* (2012) and Zahoor *et al.* (2016). The investigators reported higher values in the afternoon than morning and evening and attributed this to increase in ambient temperature. Furthermore, Cardoso *et al.* (2015) reported significant effect of period on RR with the afternoon having the highest value.

**Table 4: Effect of Period of the Day on Physiological Parameters of Duck**

Parameters	Overall mean	Period			Sig. value
		Morning	Afternoon	Evening	
PR (beats/min.)	169.50±0.47	164.51±0.99 <sup>c</sup>	175.54±0.69 <sup>a</sup>	168.44±0.71 <sup>b</sup>	***
RR (breath/min.)	27.93±0.11	26.13±0.19 <sup>c</sup>	30.59±0.20 <sup>a</sup>	27.07±0.14 <sup>b</sup>	***
RT (°C)	41.58±0.05	41.14±0.08 <sup>c</sup>	42.06±0.08 <sup>a</sup>	41.53±0.09 <sup>b</sup>	***

Means having different superscripts <sup>abc</sup> in the same row are significantly different \*\*\*  $p < 0.001$ . PR: Pulse rate, RR: Respiratory rate and RT: Rectal temperature

#### Effect of Breed x Sex Interaction on Physiological Parameters

The breed x sex interaction effect on physiological parameters is shown in Table 4. There was a significant breed x sex interaction effect on PR, RR, ( $P < 0.01$ ), RT and ( $P < 0.05$ ). Males and females of White Pekin had the highest PR values of 186.67±1.00 and 186.70±0.80 beat/minute, respectively, followed by males (184.36±0.63 beat/minute) and females (184.38±0.63 beat/minute) of Khaki Cambell while males Muscovy duck had the least (137.92±0.63 beat/minute). Similarly, value for RR was highest in males and females (31.45±0.28 breath/minutes) White Pekin, followed by the females Khaki Cambell (30.93±0.18 breath/minutes), while males Muscovy had the least (20.62±0.18 breath/minutes). For RT, the highest values recorded were 41.85±0.18, 41.81±0.11 and 41.75±0.14 °C in males White Pekin, males Khaki Cambell and females White Pekin, respectively, while the least was recorded in males Muscovy (41.15±0.11 °C).

The higher PR, RR and RT values observed in males and females White pekin ducks in the current study is in agreement with findings of Kavitha *et al.* (2016). The authors reported higher values in males and females White Pekin than local ducks. This indicates that the female birds were more stressed than the male and alleviating HS should be by sex within breed rather than across breeds only.





### **Effect of Breed x Period of the Day Interaction on Physiological Parameters**

Table 5 shows the effect of breed x period of the day interaction on physiological parameters. Significant ( $P < 0.001$ ) effect of breed x period of the day interaction on PR, RR and RT was observed. The highest PR ( $193.21 \pm 1.10$  beat/minute), RR ( $35.12 \pm 0.30$  breath/minutes) and RT ( $42.40 \pm 0.19$  °C) values were recorded among White Pekin in the afternoon period while Muscovy ducks had the least during morning hours with respective values of  $138.89 \pm 0.77$  beat/minute,  $22.64 \pm 0.21$  breath/minutes and  $41.03 \pm 0.13$  °C.

The observed higher PR, RR and RT in White Pekin during the afternoon period, followed by Khaki Campbell, revealed that they were more stressed in the afternoon than morning and evening, as indicated by their coefficient of adaptability 2.61 and 2.51 for White Pekin and Khaki Campbell in the afternoon, respectively. This may be attributed to genotype and environment (period of the day) interaction. This is in line with the findings of Marai and Habeeb (2010) that heat stress is cyclic, being generally at the peak in the mid-afternoon and cooling somewhat in the evening and early morning hours. Based on the present findings, White Pekin and Khaki Campbell ducks should be given special thermoregulatory consideration, especially in the afternoon.



**Table 5:** Breed x sex Interactions on Physiological Parameters of Khaki Campbell, White Peking and Muscovy Ducks

Parameters	Khaki Campbell		White Peking		Muscovy duck		Sig. value
	Males	Females	Males	Females	Males	Females	
PR (beats/min.)	41.81±0.11 <sup>a</sup>	41.60±0.11 <sup>ab</sup>	41.85±0.18 <sup>a</sup>	41.75±0.14 <sup>a</sup>	41.15±0.11 <sup>c</sup>	41.53±0.11 <sup>b</sup>	*
RR (breath/min.)	30.04±0.18 <sup>c</sup>	30.93±0.18 <sup>b</sup>	31.45±0.28 <sup>a</sup>	31.45±0.28 <sup>a</sup>	20.62±0.18 <sup>c</sup>	26.60±0.18 <sup>d</sup>	***
PR (°C)	184.36±0.63 <sup>b</sup>	184.38±0.63 <sup>b</sup>	186.67±1.00 <sup>a</sup>	186.70±0.81 <sup>a</sup>	137.92±0.63 <sup>d</sup>	154.04±0.63 <sup>c</sup>	***

Means having different superscripts <sup>abcde</sup> in the same row are significantly different \* p<0.05 and \*\*\* p<0.001. PR: Pulse rate, RR: Respiratory rate and RT: Rectal temperature

**Table 6:** Breed x Period of the Day Interactions on Physiological Parameters of Khaki Campbell, White Peking and Muscovy Ducks

Parameters	Khaki Campbell			White Peking			Muscovy duck			Sig. value
	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening	
PR (beats/min.)	181.43±0.77 <sup>d</sup>	189.03±0.77 <sup>b</sup>	182.64±0.77 <sup>d</sup>	181.90±1.10 <sup>d</sup>	193.21±1.10 <sup>a</sup>	185.28±1.10 <sup>c</sup>	138.89±0.77 <sup>g</sup>	153.22±0.77 <sup>e</sup>	145.84±0.77 <sup>f</sup>	***
RR(breath/min.)	28.23±0.21 <sup>c</sup>	33.62±0.21 <sup>b</sup>	29.60±0.21 <sup>d</sup>	28.91±0.30 <sup>d</sup>	35.12±0.30 <sup>a</sup>	30.33±0.30 <sup>c</sup>	22.64±0.21 <sup>g</sup>	25.29±0.21 <sup>f</sup>	22.91±0.21 <sup>g</sup>	***
RT (°C)	41.09±0.13 <sup>c</sup>	42.13±0.13 <sup>ab</sup>	41.90±0.13 <sup>b</sup>	41.47±0.19 <sup>bc</sup>	42.40±0.19 <sup>a</sup>	41.52±0.19 <sup>bc</sup>	41.03±0.13 <sup>c</sup>	41.83±0.13 <sup>b</sup>	41.17±0.13 <sup>c</sup>	***

Means having different superscripts <sup>abcdefg</sup> in the same row are significantly different \*\*\* p<0.001 . PR: Pulse rate, RR: Respiratory rate and RT: Rectal temperature



### **Coefficients of Adaptability of Ducks Based on Periods of the Day**

The coefficients of adaptability of Khaki Campbell, White Pekin and Muscovy ducks based on the period of the day are presented in Table 6. The results revealed that Muscovy ducks were more adapted in the morning, afternoon and evening periods with coefficients of adaptability of 2.02, 2.16 and 2.03, respectively, while the White Pekin breed exhibited the least adaptability with respective coefficients of 2.31, 2.61 and 2.46. Generally, the breeds showed better adaptability in the morning and evening periods than in the afternoon

### **CONCLUSION AND RECOMMENDATION**

The study has shown that Muscovy ducks exhibited the lowest physiological response to heat stress, indicating that of the three genotypes, it is the most suited for the study area in terms of adaptability. Therefore, Crossing of White Pekin and Khaki Campbell ducks with Muscovy breed should be encouraged to improve their adaptability to tropical heat stress.

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