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Physiological Responses of Slow-Growing Chickens under Diurnally Cycling Temperature in a Hot Environment

ABSTRACT

Free-range chicken production has significantly increased in recent years and it often entails exposing birds to cyclic environmental conditions. The objective of the current study was to investigate the effect of bird strain and sex, and rearing system on the physiological responses of Potchefstroom Koekoek (PK), Ovambo (OV) and Naked Neck (NN) chickens reared in a hot environment. Body weight (BW), rectal temperature (RT), respiratory rate (RR) and heart rate (HR) were determined weekly for 4 weeks, in 3 slow-growing chicken strains under cyclic environmental conditions. A total of 288, 20-week old Potchefstroom Koekoek (PK), Ovambo (OV) and Naked Neck (NN) chickens were separated by sex and allocated to extensive and intensive rearing systems. Ambient temperature and relative humidity (RH) were used to compute a temperature humidity index (THI). A Proc MIXED model was used to analyze fixed effects and a linear regression model was fitted to test the relationship between THI and response parameters. All factors studied influenced ($p < 0.05$) BW while none affected ($p > 0.05$) RT. Higher BW ($p < 0.05$) were obtained with OV in both rearing systems. Sex influenced ($p = 0.0021$) HR but not RR ($p > 0.05$). Week and rearing system affected ($p > 0.05$) RR. THI showed significant correlation with RR and HR. THI was higher in intensive than extensive rearing. Physiological responses of PK, OV and NN are comparable under similar rearing conditions.

INTRODUCTION

Free-range chicken production is increasing due to increased awareness on animal welfare. In some parts of the world, there is widespread promotion of free-range and organic production of livestock. Conventional cage systems for laying hens were banned in the European Union (EU) as of January 2012, according to an EU Council Directive 1999/74/EC on the welfare of laying hens (Tactacan *et al.*, 2009). In the developing world, free-range production systems are predominant. Often, free-range systems entail the exposure of birds to high ambient temperature (T_a) and humidity. The climatic environment is one of the main limiting factors of production efficiency (Renaudeau *et al.*, 2011) and heat stress is amongst the most important environmental stressors, particularly in the hot regions of the world (Lara & Rostagno, 2013). It is vital to understand the effects of high temperatures on free-range chicken performance, in view of the anticipated increase in global average surface temperature by between 1.88°C and 4.08°C in the next 60 years (Renaudeau *et al.*, 2011). High T_a and RH are some of the direct meteorological factors affecting birds, and may cause severe heat stress (Ayo *et al.*, 2011).

High ambient temperatures have marked effects on the behavior, feed and water intake, heat production and body temperature of poultry.



Efforts to mitigate heat stress may improve animal health, general welfare and production efficiency (Purswell *et al.*, 2012). Chickens, as homeotherms, maintain constant body temperature within the thermoneutral zone (TNZ) of 18 to 24°C (Cahaner *et al.*, 2008; Soleimani *et al.*, 2008). This, however, requires the loss of excessive body heat and heat exchange could be assessed directly from physiological measurements, e.g. rectal and skin temperatures, respiratory rate, panting, heat production and growth rate. Rectal temperature, RR and HR can be used, in conjunction with temperature-humidity index (THI) as indices of heat stress in birds. The THI is an example of indices developed to assess the impact of the thermal environment on the thermoregulatory status of animals (Purswell *et al.*, 2012).

While slow-growing strains are known to be hardy, little is known of the effects of thermal stress on the homeostatic responses of free-range chicken breeds commonly reared in Southern Africa. Naked Neck, OV and PK chickens are closely associated with rural livelihoods in Southern Africa, where they are used to meet household nutritional and economic needs (Mapiye *et al.*, 2008). Naked Necks are a light-weight multi-coloured strain with white, red, and black feather combinations. They are known to be heat tolerant (Fathi *et al.*, 2013) and generally adapted to harsh environmental conditions. They carry a gene which results in reduced overall feather cover (Rajkumar *et al.*, 2010; Fathi *et al.*, 2013). This reduced feather cover is thought to be advantageous for thermoregulation and it is thought that the thermoregulatory ability of this strain at high temperature is slightly better than that of normally feathered birds (Rajkumar *et al.*, 2010; Fathi *et al.*, 2013). The OV is a predominantly dark coloured fairly heavy strain that attains sexual maturity at average weights of 2.16 kg for males and 1.54 kg for females at about 140 d of age (Nthimo *et al.*, 2004). It is generally regarded as adapted to high temperatures though the degree of thermal tolerance does not match NN owing to darker plumage color and fairly heavier body weight (BW). The PK is a composite strain developed by crossing Black Australorp cockerels with White Leghorn hens and the Plymouth Rock (Grobbelaar *et al.*, 2010). It is a heavy strain, with an average adult BW varying from 3-4 kg for males and 2.5-3.5 kg for females. Though bred to be adaptive and to survive under low input conditions, little is known about their adaptability to high T_a , particularly differences between sexes which exhibit clearly defined sexual dimorphism in plumage color intensity.

Investigating and comparing physiological responses of these strains is important for making decisions on appropriate genotypes to recommend for farmers in areas experiencing harsh environmental conditions. Fluctuations in environmental conditions have implications on productivity since birds are not able to maintain their body thermal equilibrium with the environment. This results in physiological and behavioural changes as chickens are particularly sensitive to heat stress (Renaudeau *et al.*, 2011; Fathi *et al.*, 2013; Lara & Rostagno, 2013) which could result in reduced performance (de Souza *et al.*, 2015). The current study was, therefore, designed to investigate the effect of genetic strain and sex, as well as rearing system on the physiological responses of PK, OV and NN chickens maintained in a hot environment.

MATERIALS AND METHODS

Animal ethics

The care, use and management of birds were according to internationally accepted standards for welfare and ethics of research animals (National Research Council, 2011). Specific approval was granted by the University of KwaZulu-Natal Animal Ethics Research Committee (Reference Number: 039/15/Animal).

Description of study site

The study was conducted between January and March, 2015 at Cedara College of Agriculture. The college is located in an upland savanna zone on latitude 29.53°S, longitude 30.27°E, and at an altitude 613 m, approximately 18 km north west of Pietermaritzburg, South Africa (SA). The area is characterized by a varied yet verdant climate owing to its diverse and complex topography. It is characterized by very warm summers and cold winters. The lowest temperatures are experienced between June and July, averaging 6°C, whereas the highest temperatures in the area occur between November and February, with 31°C on average. The minimum and maximum temperatures recorded over the trial period were 17°C and 39.7°C, respectively.

Treatments and experimental design

A total of 288, 20-week old dual purpose slow-growing chickens of the PK, OV and NN strains were used in the study. Birds were reared in intensive or extensive rearing systems with four pens each, with 12 males and 12 females of each strain per pen.



The pens of the extensive rearing system measured 900m² each and were demarcated by 2.2m high wire mesh reinforced by wooden and steel poles. *Chloris gayana* (Katambora Rhodes grass) was the dominant grass species on the extensive system. Similarly, in the intensive rearing system, males and females of the three tested strains were housed in 6.25 m² pens separated by wire mesh in a poultry house measuring 4 × 10m. The birds were weighed individually on a digital scale (model UME CCS-150K, S/N: NXC 100020) to determine initial body weights.

Bird management

Wooden cages measuring 2.5 × 2m were placed uniformly in one corner of each pen, under extensive rearing, to provide shelter for the birds. The stocking densities were 6.6 birds/m² and 3 birds/m² in the extensive and intensive systems, respectively. The cages, with slatted floors elevated 1m above the ground surface, had louvered walls approximately 2.2m above the floor. Cages were fitted with wire mesh doors to deter predators. Cage doors were left open during the day and closed at night after all birds had voluntarily climbed into the cages. Birds climbed into the cages between 1730 and 1830 h. The photoperiod during the observation period was approximately 10h long. A standard plastic drinker was placed under shade near each cage to provide cool clean water. The drinkers were inspected, washed and replenished at least twice a day to ensure *ad libitum* access to clean water.

The poultry house for intensive rearing was fitted with two roof air-vents and side curtains on both sides to enable adequate ventilation and had corrugated iron sheet roofing. Fluorescent lamps were used for lighting. Under intensive rearing, birds were raised on a deep litter system with wood shavings as bedding. The litter, which was regularly inspected for wetness, was maintained between 8 and 10 cm thick. Feed and potable tap water were supplied *ad libitum* through two standard plastic feeders and 2 standard 12L plastic drinkers, respectively.

Brooding, feeding and health management

Day-old chicks of OV, NN and PK strains were obtained from a parent flock kept at the Agricultural Research Council (ARC), Irene, Pretoria, SA. From d 1 to d 49 chicks of each strain were reared in 2 × 1.5m pens in a well ventilated 4 × 10m poultry house. The house floors were covered with an 8-10cm thick layer of wood shavings. Infrared lamps (75W) were used as a source of heat and light. Day-old chicks were

maintained at 32°C which was gradually reduced to 21°C by 21d old by adjusting the height of the infrared lamps from the floor.

Broiler starter mash and potable tap water were offered *ad libitum* from standard tube feeders and 4L plastic founts, respectively. Chicks were vaccinated against Newcastle disease (ND) at 10 and 35d of age. A foot bath drenched with disinfectant (Virukill®, Hygrotech South Africa (Pty) Ltd, Pretoria, SA) was placed at the entrance to the brooding house. From d 50, birds were given a grower meal feed. Feeds were supplied by Meadow Feeds, SA. The nutrient composition of the feeds is shown in Table 1.

Table 1 – Chemical composition (label values) of commercial broiler starter and grower feeds used in the study

Component	Composition (%)	
	Starter	Grower
Crude protein	20.0	18.0
Metabolisable energy (MJ/g)	12.0	13.0
Fat	2.5	2.5
Crude fibre	5.0	6.0
Moisture	12.0	12.0
Calcium	1.2	1.2
Phosphorus	0.6	0.6
Lysine	1.2	1.0

Feed supplied by Meadow Feeds, Pietermaritzburg, South Africa.

Data collection and measurements

Meteorological measurements

Meteorological measurements were recorded daily over the duration of the trial period. Ambient temperature (T_a , °C) and RH (%) were recorded automatically every 5 min throughout the trial period using HOBO data loggers (Onset Computer Corporation, Pocasset, MA, USA). Three data loggers were used per pen (outside) and one (inside) and these were placed on a platform approximately 30cm from the ground. The recorded temperature and RH values were used to estimate the temperature humidity index (THI) as follows;

$$THI = T_d - \left[0.55 \times \frac{RH}{100} \right] \times [T_d - 58]$$

(Spencer, 1995), where THI is the temperature humidity index; T_d is the ambient temperature and RH is the relative humidity.

Body weights

A total of 72 birds (36 males and 36 females) of three strains were randomly selected and weighed weekly on a digital scale to determine body weight



(BW). Three birds/strain were sampled per pen on each rearing system. Birds were weighed on the same day that physiological response parameters were measured to minimize handling. The birds were weighed weekly at 0900h throughout the study period.

Physiological responses

Heart rate (HR) in bpm, respiratory rate (RR) in breaths/min and rectal temperature (RT) in °C, were determined. Measurements were made immediately after weighing the birds. Heart rate was determined with the aid of a stethoscope (3M™ Littmann® Classic III™, USA) and a stop watch (model 870A, Century clock-timer) by counting the number of beats in 30s multiplied by two. The stethoscope was placed on the left side of the breast of an inverted bird after feathers were separated in order to expose as much skin as possible. Rectal temperature was measured using a digital clinical thermometer ($\pm 0.1^\circ\text{C}$ accuracy; model MC-246 Omron) inserted 3cm into the rectum and left until a constant reading followed by a repeated beeping tone was reached. The thermometer was wiped using fresh clean cotton wool moistened with methylated alcohol between subsequent measurements in order to prevent possible cross infection among birds. With the bird still in an inverted position, the abdominal region was observed to count respiratory movements within 1 min with the aid of a stopwatch to determine RR.

Statistical analyses

Data were subjected to analysis of variance using PROC GLM of SAS ver 9.3 (SAS, 2010). Means were generated by the LSMEANS and compared using the PDIF options of SAS (2010). Significance was considered at the 5% level of probability. The following was used to model the data: $Y_{ijklmn} = \mu + B_i + S_j + WK_k + H_l + THI_m + (B \times S)_{ij} + \varepsilon_{ijklmn}$, where; Y_{ijklmn} = response variable (BW, RT, HR and RR), μ = overall mean, B_i = effect of the i^{th} strain ($i = NN, OV, PK$), S_j = effect of

the j^{th} sex ($j = \text{Male, female}$), WK_k = effect of the k^{th} week ($k = 1, 2, 3, 4$), H_l = effect of l^{th} rearing system ($l = \text{Intensive, extensive}$) and THI_m = combined effects due to environmental temperature and humidity, $(B \times S)_{ij}$ = effect of the interaction between strain and sex of bird, and ε_{ijklmn} = the random residual error. A linear regression model was used to test the relationship between THI and the physiological response parameters. Interactions that had no effect at the 5% level of probability were dropped from the model.

RESULTS

Body weight

All factors studied influenced ($p < 0.05$) BW. There was an interaction ($p < 0.05$) between strain and sex of bird on this parameter (Figure 1). Body weight sexual dimorphism was observed, with the highest BW in the extensive system being recorded in males. Males of the NN and OV strains were significantly heavier ($p < 0.05$) than females (Figure 1). Among the three strains, the OV chickens were the heaviest ($p < 0.05$), followed by PK and lastly, NN strain (Table 2).

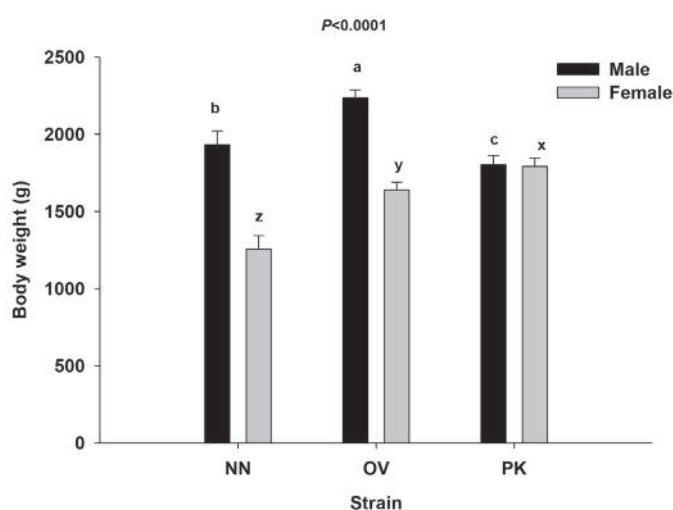


Figure 1 – Body weight (BW) of male and female Potchefstroom Koekoek, Ovambo and Naked Neck chickens.

Table 2 – Changes in live body weights (BW) of Naked Neck (NN), Ovambo (OV) and Potchefstroom Koekoek (PK) chickens

Age of bird (weeks)	Strain, BW* (g)			SEM†	P-value
	Naked Neck	Ovambo	Potchefstroom Koekoek		
21	1646.5 ^c	1981.2 ^a	1877.6 ^b	46.59	< 0.0001
22	1649.8 ^c	1919.4 ^a	1757.1 ^b	49.40	< 0.0001
23	1539.8 ^c	1862.1 ^a	1734.8 ^b	49.06	< 0.0001
24	1537.3 ^c	1986.2 ^a	1818.1 ^b	52.17	< 0.0001

a, b, c Values in the same row with different superscripts differ significantly ($p < 0.05$)

*BW Body weight

†SEM Standard error of the mean



During the study period, the T_a ranged between 17 and 39.7°C. The lowest mean T_a (17.6°C) was recorded in week 3 in the extensive system while the highest (38.8°C) was observed in the first week of study. The overall average temperatures recorded were $24.7 \pm 0.98^\circ\text{C}$ and $22.7 \pm 2.88^\circ\text{C}$ in the extensive and intensive systems, respectively. Higher RH was recorded inside at $63.6 \pm 11.9\%$ compared to $55.9 \pm 0.06\%$ observed outside. Temperature humidity index means ranged from 68 to 86.1 and 68.0 to 73.2 for the two rearing systems. The overall mean THI values

were 70.0 ± 3.55 and 74.0 ± 4.95 inside and outside, respectively. The highest maximum THI of 86.1 was recorded inside vs 73.2 observed outside. Overall mean THI was consistently higher in the intensive system as shown in Figure 2d.

Physiological responses

Rectal temperature

None of the factors studied influenced RT ($p>0.05$; Figure 2a). An overall mean RT of 41.6°C was recorded over the duration of the study period.

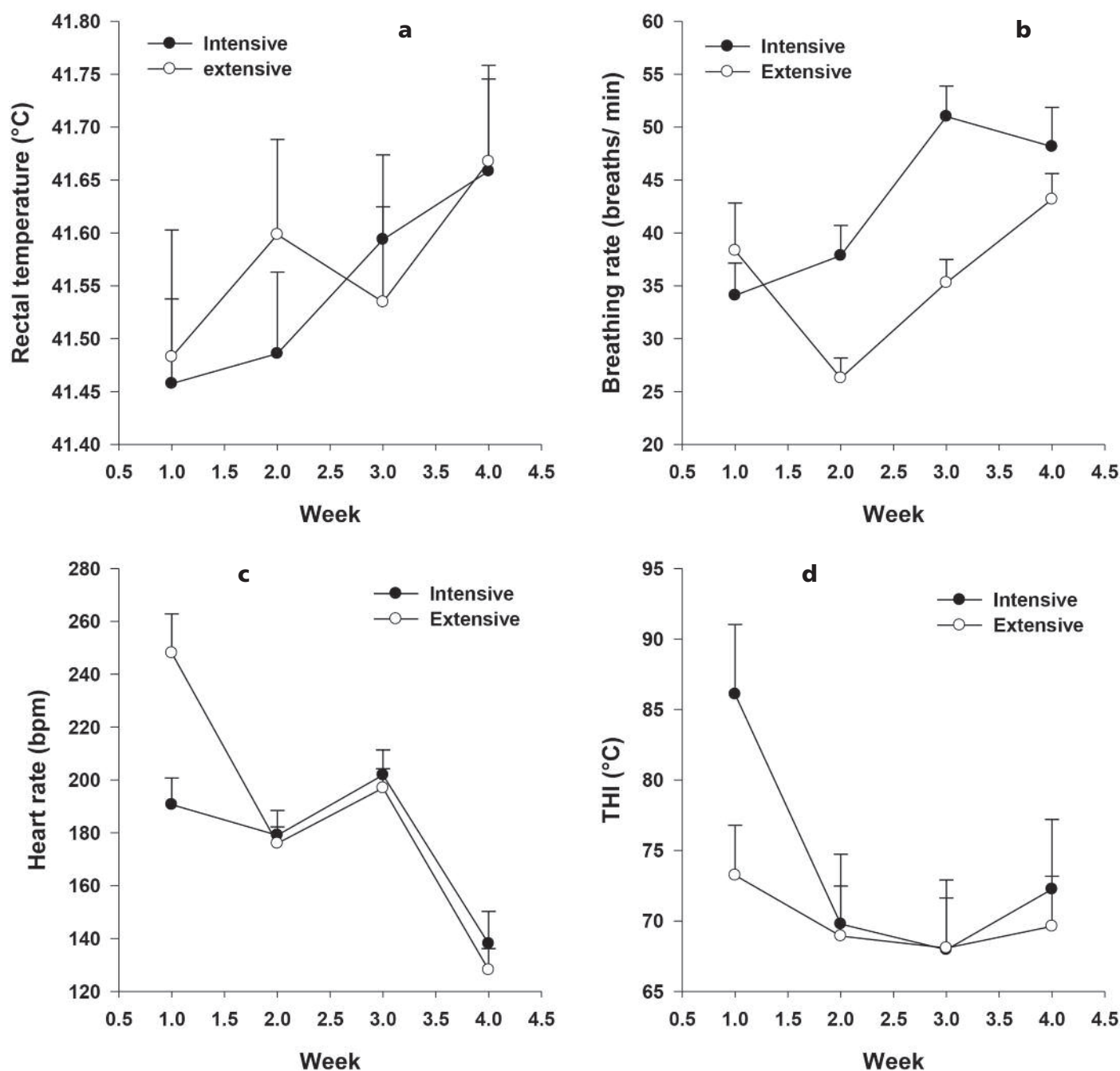


Figure 2 – Rectal temperature (RT), respiratory rate (RR), heart rate (HR) and temperature humidity index (THI) in Naked Neck (NN), Ovambo (OV) and Potchefstroom Koekoek (PK) chickens.



Respiratory rate

Strain and sex had no effect ($p > 0.05$) on RR. Rearing system and experimental week influenced ($p < 0.001$) RR (Figure 2b). No interactions were observed on RR. Respiratory rate was higher ($p < 0.001$) in birds under the intensive than extensive system. The lowest and highest RR were 26.3 ± 3.06 breaths/min and 43.2 ± 2.44 breaths/min, respectively, for birds in the extensive system. There was significant positive correlation (Table 3) between RR and THI under extensive rearing system: RR increased by 0.56 breaths/min ($p = 0.01$) per unit increase in THI.

Heart rate

Sex, rearing system and week influenced ($p < 0.05$) HR. No interactions ($p > 0.05$) were observed on HR. Figure 2c shows that HR was highest in the first week of study, particularly in the extensive system, and generally decreased up to week 4. Effects of strain and sex of bird on HR are shown in Figure 3. The mean HR was higher ($p < 0.05$) in males than females (Figure 3). There was significant positive correlation (Table 3) between HR and THI under the extensive rearing system: HR increased by 1.90 bpm ($p = 0.01$) per unit increase in THI.

Table 3 – Effect of rearing system on RT, RR and HR in Naked Neck (NN), Ovambo (OV) and Potchefstroom Koekoek (PK) chickens

Response	Rearing system							
	Extensive				Intensive			
	Estimate	t-value	p-value	Error DF	Estimate	t-value	p-value	Error DF
RT	0.00	0.49	0.64	36.0	0.00	0.31	NS	50
RR	0.56	3.26	0.01	36.0	0.73	1.45	NS	50
HR	1.90	2.83	0.01	36.0	1.20	0.51	NS	50

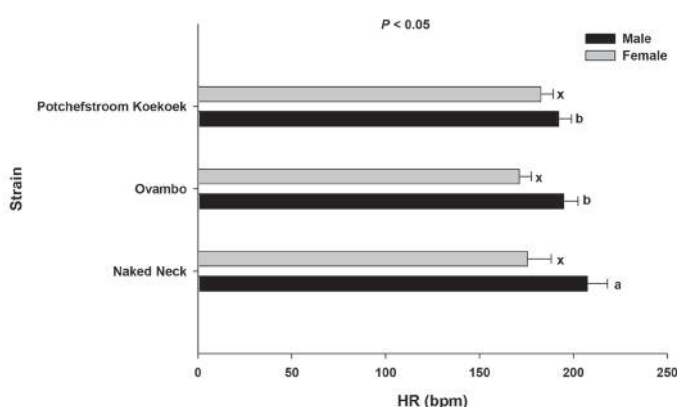


Figure 3 – Influence of strain and sex of chicken on heart rate (bpm).

DISCUSSION

It appears that the thermoregulation of birds maintained in the extensive system was more efficient compared with those under the intensive rearing conditions. Internal body temperature, as reflected by RT, was not significantly different between rearing systems or among the evaluated strains. Our findings suggest that free-range systems enable, to a certain degree, more efficient thermoregulation in birds.

It was not surprising that birds under intensive rearing were significantly heavier than birds in the extensive system. Similar observations have been reported before (Miao *et al.*, 2005; Dou *et al.*, 2009). In addition to restricted space allowances in the house, minimizing energy lost due to walking longer distances, housed

birds had *ad libitum* access to feed. In contrast, birds reared in the extensive system had to forage to meet their nutrient requirements, which might have meant a lower plane of nutrition. In addition to absence of unlimited feed access, the mean T_a on the extensive system fluctuated between 17.6 and 38.8°C, implying possible cyclic exposure of birds to varying degrees of heat stress. Exposure to moderate chronic heat induces a decline in performance and birds tend to decrease their heat production by limiting feed consumption (Collin *et al.*, 2012), leading to reduced BW. Decreases in BW gain were recorded in broilers exposed to temperatures of 31 to 36°C and 28 to 36°C (Quinteiro-Filho *et al.*, 2010). Furthermore, Emery *et al.* (1984) showed that laying hens under cycling temperatures, ranging between 21.1 to 37.7°C, lost more BW than birds at a constant temperature of 23.9°C, which was largely attributed to reduced feed consumption.

The strain differences observed in BW at the end of the trial are consistent with literature (Chikumba & Chimonyo, 2014). In their study, OV chickens were significantly heavier than PK, which, like in the current study, were heavier than NN at 26 weeks of age. Sexual dimorphism in BW is common in various chicken genotypes (Bogosavljevic-Boskovic *et al.*, 2006), including in slow-growing strains, and therefore, this was expected in the current study.

The lowest mean T_a recorded in the current study is comparable to the 17.9°C observed by Chikumba & Chimonyo (2014) in the same study area. The same is



not true, however, for the highest mean T_a . Chikumba & Chimonyo (2014) recorded 25.4°C while 38.8°C was recorded in the current study and this might be as a result of the differences in the years studied. Remarkable variability was observed in weather during the observation period. The THI range shows that, at one point or another, birds were exposed to varying degrees of heat stress in both rearing systems. According to Purswell *et al.* (2012), the critical THI lies between 20.6 and 26°C for broilers, while RH values of around 70% promote a comfort condition in chickens. The response of chickens to high ambient temperatures differs with different RH (Ajakaiye *et al.*, 2011). The regression results indicate that the birds under extensive rearing conditions were more affected by changes in THI, hence, environmental conditions than those under intensive rearing. Conversely, THI was lower under extensive rearing conditions, suggesting that perhaps it is its variability that triggers fluctuations in RR and HR as birds try to maintain equilibrium.

The fact that none of the variables studied influenced RT is contrary to observations of Tan *et al.* (2010), Purswell *et al.* (2012) and Zahoor *et al.* (2016). Tan and co-workers (2010) noted that exposure to high ambient temperatures (32, 35, and 38°C; RH 70 ± 5%) resulted in significant increases in RT compared with lower ambient temperature values (25°C, RH 70 ± 5%). Zahoor *et al.* (2016) reported lower RT in birds exposed to cooler temperatures. This discrepancy might be a result of strain differences as well of the duration and nature of exposure. Broilers, as fast-growing birds, tend to suffer higher thermal loads compared with slow-growing birds. The strains used in our study are probably fairly well-adapted to the conditions prevailing in the study area and were, as such, only narrowly affected by the prevailing environmental conditions. The birds were also reared in a similar environment prior to introduction to the outside pens, and therefore, possible acclimation cannot be ruled out. This, together with the 7d adaptation window, might have enabled the birds to acclimatize to ensuing study conditions. This might explain why even the combined effects of T_a and humidity did not have a significant suppressive effect on heat dissipation mechanisms in the birds as reflected in the narrow core (RT) temperature range. In broilers under comfort conditions, ideal RT values vary between 41 and 42°C (Elson, 1995). We hypothesize that this range may be considerably wider for local strains. It appears the strains used in the current study were able to efficiently thermoregulate and maintain their core temperature within a narrow range even at T_a above the TNZ. The TNZ is the interval of thermal

environment usually characterized by T_a over which heat production is relatively constant for a given energy intake (Renaudeau *et al.*, 2011). It is defined as a T_a range in which the metabolic rate is minimal and the best performance is achieved (de Souza *et al.*, 2015). Any variation in RT indicates that heat exchange mechanisms on the body surface are not sufficient for the maintenance of thermal equilibrium (Nascimento *et al.*, 2012).

Exposing birds to high ambient temperature generates behavioral (Li *et al.*, 2015), physiological and immunological responses, which have detrimental consequences to their productivity. Changes in heart rate, as well as in other cardiovascular variables and other metabolic systems also participate in the thermoregulatory processes by modulating heat dissipation (Olanrewaju *et al.*, 2010; Lara & Rostagno, 2013). The average HR from our study was lower those reported in literature (Darre & Harrison, 1986), which may be attributed to strain differences. Evaporative heat loss increases along with T_a and decreases with increasing RH (Lin *et al.*, 2010). This explains the positive linear relationship between THI and HR as observed in this study. Our observation on the reduction in HR with increasing T_a , thus, agrees with earlier observations.

Heart rate was highest in the first week of study and decreased progressively. The high HR in the first week may have resulted from the high relative humidity. Literature reports show that direct meteorological factors affecting chickens include elevated T_a and high RH, resulting in heat stress which leads to elevated HR (Ayo *et al.*, 2011). The subsequent HR decreases observed in this study could also be a consequence of habituation due to repeated exposure to similar environmental conditions as well as to handling. Following handling, common eiders (*Somateria mollissima*) display an elevated HR for 2-3 min (Cabanac & Guillemette, 2001) after which it decreases. Habituation is the reduction of physiological responses elicited by exposure to a repeated stressor. Overall, sexual dimorphism was observed in the present study, with higher HR in females. This result contradicts the findings of Espinha *et al.* (2014), who reported HR of 211.5 ± 6.56 and 168.0 ± 7.28 bpm in female and male broiler chickens, respectively.

Several factors interact to influence HR in any given environment. Heart rate varies with the method of determination, time of day, sex and age, among other factors. Faster HR are obtained when birds are restrained than when they are free to move about. Measurements are probably most meaningful



when made while the birds are free to move about in their normal surroundings. In a hot environment, homeothermic animals increase heat dissipation, reduce heat production and absorption from their environment. A reduction in heat generation often follows a reduction in feed intake. It has also been postulated that thermoregulatory responses start with a decreased HR and peripheral vasodilation and leads to decreased blood pressure (Darre & Harrison, 1986). These cardiovascular changes occur before thermal panting, which is primarily dependent upon core temperature and begins at about 42°C in chickens. Panting was not observed even at the highest mean T_a of 38.8°C recorded in the current study. This probably indicates a higher degree of thermal tolerance in the strains used. Panting allows poultry to increase evaporative heat loss during heat stress; however, it reduces production efficiency as metabolic energy is diverted from growth and development to maintaining homeothermy (Purswell *et al.*, 2012).

Although a higher mean T_a was observed in the extensive system, humidity and THI were higher under the intensive system. This probably explains the higher RR observed under intensive management. Humidity suppresses evaporative heat loss such that when body temperature increases, as reflected by an increase in RT, the RR also increases. The observation that there were no strain differences in RR is not consistent with our expectations. It was anticipated that the NN strain would better withstand the effects of high T_a and RH. It is thought that reduced feather cover may be advantageous for thermoregulation at high T_a (Fathi *et al.*, 2013) by increasing sensible heat loss. It has been reported that body temperature changes are accompanied with marked alterations in breathing pattern (Zila & Calkovska, 2011). Increases in RR of up to 165 breaths/min were observed in broilers at 42 d of age under high temperatures (Silva *et al.*, 2007). The effect of thermal stress is more pronounced in specialized strains with high growth potential compared to the slower-growing chickens. The mean RR range observed in this study, is wider but generally lower than the 40 to 60 breaths/min observed in commercial broiler strains (Nascimento *et al.*, 2012). When the thermal requirement of chickens is not satisfied, heat stress may occur, depending on the strain, feathering and nutrition (Lin *et al.*, 2010).

CONCLUSIONS

The Naked Neck, Ovambo and Potchefstroom Koekoek chicken strains appear to exhibit comparable

thermal tolerance as they were able to maintain a fairly constant core temperature as reflected by RT. Chickens reared both in the extensive and intensive systems suffered some degree of thermal stress, as shown by the increases in HR and RR. However, intensive management appears to subject birds to greater thermal stress, compromising their general welfare, as indicated by higher HR and RR values.

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DISCLOSURE STATEMENT

Authors wish to indicate there are no current or potential conflicts of interest to declare.

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