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Genetic variation in physiological adaptation of local, exotic and crossbred ducks to heat stress in a tropical environment

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Abstract
Biotic and abiotic environmental factors significantly contribute to the well-being and performance of farm animals. Thermal adaptation is central to livestock survival, performance and profitable enterprise most especially in hot tropical and sub-tropical environments characterized with high environmental temperatures. Heat tolerance of 106 adult Muscovy (Cairina moschata) (20 males and 20 females), Mule (Anas sterilis) (14 males and 12 females) and Mallard (Anas platyrhynchos) (20 males and 20 females) ducks was investigated through physiological indices {respiratory rate (RR), panting rate (PR), skin temperature (ST) and rectal temperature (RT)} collected at two periods {morning (7.00 – 8.30 hours) and afternoon (12.00 – 13.30 hours)}. Variance analysis revealed significant (P<0.05) effect of genotype, period, genotype-period and genotype-sex interactions on heat tolerant indices. The higher physiological indices of Mallard ducks as reflected in genotype, genotype-period interaction and genotype-sex interaction effects compared to Muscovy and Mule ducks indicated physiological stress and poor thermal tolerance. Syntheses of results in this study indicated that Muscovy and Mule ducks were genetically superior in heat tolerance and have higher adaptive capacity to thrive better in sub-optimal hot environment.
Keywords: Genotype; heat tolerance; panting rate; physiological indices; thermal adaptation.

Introduction

In spite of the fortune invested on the management, selection and improvement of livestock, high environmental temperature has been identified as the principal non-genetic exogenous factor adversely affecting vitality, optimum performance, growth, reproduction, production and general well-being of farm animals. Quantum of literature indicated detrimental effects of this bio-climatic factor on ruminants and non-ruminants (Marai et al., 2007; Eduardo, 2009; Fadare et al., 2012; Yakubu et al., 2012; Oguntunji et al., 2015). The adverse effects of this environmental stressor are experienced most especially in developing countries where poultry farmers cannot afford expensive modern artificial control of ambient temperature in poultry houses (Deeb and Cahaner, 2001).

All animals have a range of ambient environmental temperatures termed the thermo-neutral zone. This is the range of temperatures where the animals are able to regulate their body temperature without heat production as temperature changes (Eduardo, 2009). An animal is said to be in its thermo-neutral zone when it is in a temperature range that requires the least thermo-regulatory effort (Howard, 2012) and such temperature regulation is achieved by non-evaporative physical process (Hillman, 2009). Nevertheless, it is worthy to note that the diurnal temperature ranges in most tropical and sub-tropical environments are well above the thermo-neutral zone; thus subjecting animals to thermal stress.

Heat stress and other types of chemical or psycho-social stresses origin have been generally associated with detrimental effects on physiological equilibrium of the animal organism and various systems (nervous, endocrine and immune) (Khansay et al., 1990). These investigators reported further that their mode of action has been implicated with specific responses and reciprocal regulatory influences. Various physiological parameters are influenced by adverse climatic conditions and may be used as indicator of climatic stress (Du Perez, 2000). Under heat stress, a number of physiological and behavioural responses vary in intensity and duration in relation to the animal genetic make-up and environmental factors were observed through the integration of many organs and systems viz. behavioural, endocrine, cardio-respiratory and immune systems (Altan et al., 2003).

Poultry production in Nigeria in Nigeria and Africa at large irrespective of the scale of production or management system adopted is synonymous with chicken while other available native species such as guinea fowl, duck and pigeon are utterly neglected and seldomly exploited for economic or nutritional purposes (Oguntunji, 2013). The utter neglect suffered by duck in Nigeria has been attributed to the hordes of taboos, bias and social stigmas attached to its rearing, consumption, handling and marketing (Oguntunji, 2014). The age-long neglect of duck is corroborated by the scarcity of all-encompassed researches on its husbandry, characterization, production, health management and genetic improvement (Oguntunji, 2014). Muscovy duck commonly referred to as local, native or indigenous duck and others popularly known as common or exotic breeds are reared in Nigeria. The sterile hybrid of Muscovy and Common ducks known as mule duck is also found in the country. Nevertheless, this crossbred is not as popular as the parents; having low population and its production and consumption are restricted to the northern part of Nigeria. Since duck production is at subsistence level, these waterfowls are reared primarily on free range with little or no supplements. There is no gain saying that the prevalence of traditional extensive system predisposes ducks to various environmental challenges with attendant poor performance in respect of growth, vitality, productivity and health of ducks relative to the semi-intensively and intensively reared ones (Oguntunji and Ayorinde, 2015); and the principal among the environmental challenges is high environmental temperature and its attendant heat stress.

Studies on thermal stress adaptation of poultry species in Nigeria and in tropical and sub-tropical environments in general are scarce. Studies by Yakubu et al. (2012) and Isiadomen et al. (2011) revealed differential adaptations of three genotypes of turkey and three strains of chickens, respectively to heat stress using physiological and bio-medical (haematological and biochemical) parameters. However, there is paucity of information on thermal stress adaptation of duck genera and their crossbreds in Tropical and sub-tropical environments. Against this background, this study was designed to investigate genetic variation in thermo-tolerance of Muscovy, Mule and Mallard ducks in Nigeria using physiological parameters

Materials and Methods

Study area

This study was conducted at the Duck Unit of the Teaching and Research farm of Bowen University, Iwo, Nigeria. The study area is located in a Derived Savanna agro-ecological zone. The climate and vegetation were interphase between Rain Forest and Savanna Grassland and are characterized with double maxima rainfall and mixture of deciduous trees and tall grasses. Wet (April – September) and dry (October –March) seasons are the principal seasons in the area; however, each major season could further sub-divided into two sub-seasons: early rainy season (April–June), late rainy season (July–September); early dry season (October–December) and late dry season (January – March) (Oguntunji et al., 2015).

Experimental birds and management

One hundred and six (106) adult Muscovy (20 males and 20 females), Mule (14 males and 12 females) and Mallard (20 males and 20 females) ducks were used for this experiment. Mules are products of inter-specific hybridization of Muscovy and Common ducks. The three genetic groups were sourced from a reputable poultry market in Ibadan, Oyo State. These birds were part of ducks brought to the southern Nigeria for sale from north-west Nigeria. They were reared primarily on traditional extensive management system in their places of origin.

The birds were reared in deep litter for four weeks in order to acclimatize and stabilize them before data collection. Throughout the experimental period, they were fed with commercial layer ration and water was offered ad libitum. Besides, they were quarantined with broad spectrum antibiotics and anti-parasite drugs.

Data collection

Meteorological parameters

Meteorological data on ambient temperature (AT) (dry and wet bulb thermometers); relative humidity (RH) and wind velocity (WV) were harvested from the weather station of the University. The combined impact of temperature and humidity expressed as the temperature-humidity index (THI) was used to characterize the thermal environment according to Marai et al. (2007):

THI = dboC – {(0.31 – 0.31RH) (dboC-14.4)}

Where,

- db = dry bulb temperature (oC)
- RH = relative humidity {(RH%)/100}

Furthermore, the thermal environment was categorized depending on THI values as follows:

- < 22.2 - absence of heat stress
- 22.2 – 23.3 - moderate heat stress
- 23.3 - 25.6 - severe heat stress
- 25.6 and more - extreme heat stress (Marai et al., 2007)

Physiological parameters

Physiological parameters: respiratory rate (RR), panting rate (PR), skin temperature (ST) and rectal temperature (RT) were taken in two periods daily: morning (7.00 – 8.30 hours) and afternoon (12.00 - 13.30 hours). For afternoon measurement, the birds were confined in cross-ventilated local palm-woven cage and exposed to solar radiation. Besides, the birds were denied access to water and feed during the exposure period.

Respiratory rate (RR): This was determined by counting the number of movements of the abdominal region or vent per minute using Stop watch.

Skin temperature (ST): This was taken with an infra-red thermometer in the shaved area under the wing. Body temperature was taken after the sound of alarm of the thermometer.

Rectal temperature (RT): This was taken with the aid of a digital thermometer. The disinfected sensory tip of the thermometer was inserted into the vent and reading was taken after the sound of the alarm of the thermometer.

Panting rate (PR): This was taken with number of times a duck panted in a minute using a Stop watch.

Statistical analysis

Data collected were analysed with the analysis of variance (ANOVA) using a general linear model with the following fixed effect models:

Yíjkl = µ + Gí + Sj + Pk + (GS) íj + (GP) ík + eíjkl

Yíjkl = Individual observation

µ = Fixed overall mean

Gí = Fixed effect of genotype (i= Muscovy, Mule and Mallard ducks)

Sj = Fixed effect of sex (j= Male and Female)

Pk = Fixed effect of period (k = morning and afternoon)

(GS)íj = Interaction effect of genotype and sex

(GP)ík = interaction effect of genotype and period

eíjkl = experimental error assumed to be independently, identically and normally distributed, with zero mean and constant variance i.e. nd (0, σ2).

Differences between means were separated with the New Duncan Multiple Range test at 5% probability level. All statistical analyses were performed with the SPSS (2001) version 16.

Results

Meteorological indices

The results of the climatic variables during the experimental periods were presented in Table 1. All meteorological indices and THI were higher in the afternoon than in the morning except RH and Wet-bulb temperature.

Table 1: Mean meteorological index during the experimental periods

	Climatic variables						
Period	**Minimum temp. (^{0}C)**	**Maximum temp. (^{0}C)**	**Relative humidity (%)**	**Dry bulb temp. (^{0}C)**	**Wet bulb Temp. (^{0}C)**	**Wind Velocity (m/s)**	**THI**
Morning	25.88	26.18	94.25	26.18	25.18	3.03	25.97
Afternoon	32.70	33.38	58.50	33.33	24.05	3.70	30.89

Effects of genotype, period and sex on physiological indices

The results of the main effects (genotype, period and sex) were presented in Table 2. There was a significant (P<0.05) effect of genotype on PR and RT and the values reported for Muscovy and Mule ducks were lower compared to Mallard ducks in all heat tolerant traits. In addition, a unique trend observed in the results of the physiological parameters of the investigated genetic groups was that local Muscovy was the least thermally stressed, followed by cross-bred mule while Exotic Mallard duck was the most stressed. This is demonstrated in Mallard ducks having highest values in all heat-tolerant indices relative to others. Besides, period had significant (P<0.05) effect on physiological parameters and values recorded in afternoon were higher than morning. Sex had no effect (P>0.05) on the parameters. However, males had higher RR and PR than females while females had higher ST and RT.

Table 2. Effects of genotype, period and sex on Physiological parameters

	Physiological variables			
	Respiratory rate (breath/minute)	Panting rate (panting/minute)	Skin temperature (^{0}C)	Rectal temperature (^{0}C)
Genotype				
Muscovy	39.95±17.75^a	4.89±7.36^a	39.29±1.87^a	41.05±1.04^a
Mule	42.23±21.30^a	7.46±9.13^a	39.39±1.82^a	41.38±0.78^{ab}
Mallard	49.05±32.54^a	44.95±54.18^b	39.65±54.18^a	41.80±1.08^b
Period				
Morning	26.32±4.33^a	0.00±0.00^a	37.87±1.18^a	40.76±0.71^a
Afternoon	62.85±26.65^b	48.26±49.26^b	41.08±1.31^b	42.15±0.91^b
Sex				
Male	46.77±27.65^a	27.87±45.36^a	39.42±2.02^a	41.36±1.13^a
Female	42.39±25.10^a	20.38±38.98^a	39.56±2.06^a	41.55±1.00^a

^{ab}*Means along the same column with different superscripts are significantly (P < 0.05) different*

Genotype-period interaction

Genotype-period interactions on all thermo-tolerant traits were significant (P<0.05) (Table 3). The physiological values were significantly (P<0.05) lower in the morning compared to the afternoon in all the parameters for all genotypes except in ST for Muscovy ducks.

The exotic ducks appeared more thermally-stressed; having highest values in the two periods than others in all heat tolerant variables except in ST in the morning and also had highest diurnal increase in all physiological parameters compared to other genotypes.

Table 3: Genotype-period interaction effect on physiological parameters

		Physiological indices			
		Respiratory rate (breath/minute)	Panting rate (panting/minute)	Skin temperature (^{0}C)	Rectal temperature (^{0}C)
Genotype	**Period**				
Muscovy	Morning	25.87 ± 4.32^{a}	0.00 ± 0.00^{a}	37.79 ± 1.00^{a}	40.48 ± 0.68^{a}
Mule	Morning	26.08 ± 7.16^{a}	0.00 ± 0.00^{a}	38.12 ± 1.39^{a}	40.72 ± 0.45^{ab}
Mallard	Morning	26.77 ± 3.03^{a}	0.00 ± 0.00^{a}	37.85 ± 1.26^{a}	41.01 ± 0.71^{b}
Muscovy	Afternoon	54.48 ± 14.27^{b}	9.94 ± 7.77^{ab}	40.84 ± 15.00^{b}	41.65 ± 1.01^{c}
Mule	Afternoon	58.38 ± 18.15^{b}	14.92 ± 7.29^{b}	40.65 ± 1.24^{b}	42.04 ± 0.34^{c}
Mallard	Afternoon	70.78 ± 33.59^{c}	88.78 ± 43.36^{c}	41.41 ± 1.39^{b}	42.57 ± 0.74^{d}

^{abcd}Means along the same column with different superscripts are significantly (P < 0.05) different

Genotype-sex interaction

Significant (P<0.05) genotype-sex interaction effects were observed in PR and RT (Table 4). Separate analyses of the three genetic groups showed that there was no (P>0.05) within genotype-sex interaction effects on all the parameters. It was further observed that Muscovy and Mallard duck males had higher physiological values in non-sensible heat loss mechanisms (RR and PR) compared to their respective females. In addition, Muscovy and crossbred duck males had lower values in temperature-related indices (RT and BT).

Table 4 Genotype-sex interaction effect on physiological parameters

		Physiological indices			
		Respiratory rate (breath/minute)	Panting rate (panting/minute)	Skin temperature (^{0}C)	Rectal temperature (^{0}C)
Genetic group	**Sex**				
Muscovy	Male	40.80 ± 18.3^{a}	5.63 ± 8.03^{a}	39.16 ± 1.99^{a}	40.93 ± 1.06^{a}
Mule	Male	41.75 ± 23.81^{a}	10.75 ± 11.60^{a}	39.16 ± 2.10^{a}	41.23 ± 0.97^{ab}
Mallard	Male	54.26 ± 33.61^{a}	52.38 ± 56.95^{b}	39.68 ± 2.06^{a}	41.76 ± 1.11^{b}
Muscovy	Female	40.03 ± 17.68^{a}	4.48 ± 6.89^{a}	39.48 ± 1.81^{a}	41.22 ± 1.01^{ab}
Mule	Female	42.64 ± 19.83^{a}	4.64 ± 5.29^{a}	39.58 ± 1.60^{a}	41.51 ± 0.57^{ab}
Mallard	Female	43.98 ± 31.04^{a}	37.70 ± 51.00^{b}	39.62 ± 2.40^{a}	41.85 ± 1.04^{b}

^{ab}Means along the same column with different superscripts are significantly (P < 0.05) different

Discussion

Meteorological indices

The ambient temperature in both periods (Morning and Afternoon) were outside the thermo-neutral zone for poultry; thus, indicating that the birds were heat stressed. Results of the thermal conditions (THIs) during the experimental periods revealed that the two periods were thermally stressful for ducks. According to Marai et al. (2007), the THI in the morning (25.97) was severely hot while it was extremely hot (30.89) in the afternoon. This result is not unexpected and is consistent with the other reports that tropical environment is characterised with high environmental temperatures detrimental to livestock welfare and production

(Castanheira et al., 2010; Yakubu et al., 2012).

Effect of genotype on heat tolerant parameters

To the best of our knowledge, this is the first report to provide insights on heat tolerance of Muscovy, Mule and Mallard ducks via physiological parameters. Therefore, literatures are scarce to compare and validate the results. However, the results were compared with the related reports on other poultry species. The higher physiological indices reported for exotic Mallard ducks commonly referred to as exotic duck relative to the local Muscovy and crossbred mule ducks are consistent with the higher physiological indices reported for exotic turkeys compared to their local and cross-bred counterparts in Nigeria (Ilori et al., 2011; Yakubu et al., 2012).

Respiratory and panting rates

Poultry employ various strategies such as behavioural, hormonal, physiological, and biochemical adjustments to maintain homeostasis at high ambient temperatures (Oguntunji and Alabi, 2010). At thermo-neutral temperature ranges, animals dissipate endogenous thermal load through sensible heat loss mechanisms (conduction, convection and radiation) without any attendant stress on the physiological equilibrium of the body. However, as body temperature increases above the thermo-neutral range through increased metabolic activities and absorption of heat from environment via conduction and convection; the heat-dissipating mechanism of the animal is overwhelmed and is unable to dissipate the accumulated heat load through sensible heat loss mechanisms. Therefore, non-sensible heat loss mechanisms such as evaporative heat loss through higher respiratory rate and panting takes over. The report of Salama et al. (2013) buttressed this assertion that at high temperature, water loss by evaporation is the most efficient way to dissipate heat, and it occurs by respiratory system (panting) and by sweating. In addition, evaporative cooling (such as sweating and panting) have been reported to be essential in maintenance of body temperature during heat-related events; open-mouthed breath and panting are some of the most obvious signs of heat stress (Megan, 2015) in birds.

Sweating during heat stress enhances the mitigation of thermal load in the body. However, since birds lack sweat glands, this non-sensible heat loss mechanism does not practically exist in birds. Hence, birds resort to panting and increased respiratory rate. In view of the foregoing and since the principal evaporative heat loss mechanism is panting in hyperthermic animals, the reported highly significant PR in Mallard ducks suggests that they were more thermally stressed than local Muscovy and cross-bred Mule ducks and higher panting rate was necessitated to enhance homeostasis by respiratory evaporation (Fadare et al., 2012). An important thermal regulatory reaction to heat stress is increased RR, which aids in heat dissipation via evaporative cooling (Blackshaw and Blackshaw, 1994). Therefore, the highest RR observed in Mallards is indicative of thermal stress and is an attempt to increase heat loss by evaporative cooling (Gupta et al., 2013).

Rectal and Skin temperatures

Furthermore, between genotype comparisons revealed that RT of Mallard ducks was 0.75 and 0.42 higher than in Muscovy and Mule ducks, respectively. Higher RT is a pointer to poor heat-regulatory mechanism of Mallard ducks and is a further evidence of being thermally stressed than others. Increased RT as observed in Mallard ducks shows that heat-releasing mechanisms were insufficient to maintain homeothermia (Castanheira et al., 2010). The high RT observed in heat-stressed animals has been described as an indicator of disturbance in the homeothermic status of the animals which was not being effectively countered by the enhanced heat loss by physical and physiological processes of thermolysis (Joshi and Tripathy, 1991). A recent report comparing thermo-tolerance of Avian and Cobb strains of broiler revealed that Cobbs were physiologically superior in eliminating thermal load by having lower RT (Nascimento et al., 2012). The report of Silanikova (2000) and Keim et al. (2002) supported this submission that the best physiological parameter to objectively monitor animal welfare in hot environment is the RT, because it drives other heat stress-alleviating mechanisms (Gebremedhin et al., 2008). Higher RT is a pointer to accumulation of thermal load in the body and is also detrimental to the animal welfare and performance. Report of McDowell et al. (1976) corroborated this assertion that even a rise of less than 1oC in RT was enough to reduce performance in most livestock species.

The observed increase in skin temperature for all genotypes could be attributed to the exposure to heat stress, which has been reported to cause vasodilatation of skin capillary bed and consequently increase the blood flow to the skin surface to facilitate heat dissipation (McManus et al., 2009). Skin temperature could also be elevated due to solar radiation, as skin temperature has been shown to be directly related to ambient solar radiation levels (Schutz et al., 2011).

Conversely, the lower RT and ST in local Muscovy and crossbred Mule ducks suggest superior thermoregulatory ability and better adaptation to hot environment compared to Mallard ducks. This submission is consistent with the report of Cheung and McLellan (1998) that animals that are adapted to hot temperatures have a higher sweating rate, normal heart rate and lower core and skin temperatures, indicating less stress suffered by these animals.

It was expected that Muscovy and Mule ducks would have higher ST and RT because of their higher body weights {Table S1 (Supplementary data)}. Studies have shown that heavier animals experience difficulty in heat dissipation than their smaller counterparts (McDowell, 1972; Finch, 1985) and that small body size of tropical breeds is an adaptive measure against thermal susceptibility (Hansen, 2004). However, the result herein reported is contrary, thus pointing to the fact that Muscovy and Mule ducks, though having bigger size but were physiologically superior in dissipating thermal load and that their heat-regulatory mechanism is more efficient than in Mallard ducks.

Effect of period on physiological indices

Lower values reported for ducks in the morning in all the thermo-tolerant indices indicated that ducks were physiologically stable in the morning and not heat-stressed. However, significant differences between the two periods and most especially the higher values recorded in the afternoon are a pointer to the fact that ducks were physiologically stressed in the afternoon when ambient temperature was elevated. Although empirical information on effect of period (morning and afternoon) day on physiological parameters of ducks are scarce; related studies on turkey and duck in tropical environments revealed that these thermo-tolerant traits were higher in dry season noted for high ambient temperature (Ilori et al., 2011; Oguntunji et al., 2015).

Effect of sex on heat-tolerant indicators

Non-significant effect of sex on the thermo-tolerant traits is in agreement with a related study on turkey (Yakubu et al., 2012). One possible reason for higher RR and PR of males irrespective of genotypes compared with females could be their higher body weight {Table S2 (Supplementary data 2)}. There is likelihood that heavier body mass of males encourages production of more metabolic heat and also enhances accumulation of endogenous thermal load than their females. This assertion was corroborated by the report of Finch (1985) that as an animal increases in body weight, the tissue conductance decreases linearly and it becomes more susceptible to heat stress. This was adduced to smaller sized animals having a larger surface area per unit of body weight making them lose heat more rapidly than larger animals (McDowell, 1972).Therefore, non-evaporative physical processes (increased respiration and panting) become the most reliable means of alleviating accumulated endogenous thermal load; hence, higher RR and PR of males. Conversely, the reported lower RT of males, a principal physiological index of thermal stress could be a product of indirect effect of increased RR and PR of heat-stressed animals. Since elevated RR and PR are physiological adjustments of heat-stressed to maintain homeostasis/thermal equilibrium; hence, low RT. This assertion aligns with the report of Starling et al. (2002) that respiratory mechanism is important for thermolysis and maintenance of homeothermy in animals thereby avoiding a rise in RT.

Genotype-period interaction

Within the genotypes, significant differences in the values recorded for the two periods indicated that the elevated ambient temperature in the afternoon had significant effect on heat tolerant traits and also induced disruption in the heat-regulating mechanisms of all genotypes.

The estimated THIs (Table 1) indicated that the environment was thermally stressful both in the morning and afternoon. However, the consistent trend of higher physiological parameters of all indices both in the morning when the environmental condition was considered less stressful and in the afternoon when ambient temperature has been elevated for Mallard ducks suggests that they were less heat tolerant and more physiologically sensitive to change in meteorological promptings than Muscovy and Mule ducks. In addition, the significantly higher values obtained for Mallard ducks in the afternoon in all the heat tolerant traits (RR, PR and RT) further attest to their low heat tolerance compared to Muscovy and Mule ducks.

It is noteworthy that panting rate of Mallard ducks was very high and was about 8.93 folds (88.80%) and 5.95 folds (83.19%) higher than the values reported for Muscovy and Mule ducks, respectively in the afternoon. It is noteworthy that in the course of this experiment, it was observed that Muscovy and Mule ducks were more physiologically stable in the first hour of exposure to solar radiation while Mallard ducks began to pant in less than thirty minutes. Besides, as the exposure time increases, Mallards were observed panting vigorously while none of the local and crossbred ducks panted vigorously but mildly. Evaporative cooling strategies such as panting and increased respiratory rate are central to maintaining homeothermy in hyperthermic animals. Excessive panting and increased RR observed in Mallards in the afternoon are indications of physiological stress and an expression of physiological adjustments to maintain homeostasis.

The superior thermal adaptation of Mule and Muscovy ducks compared to Mallards was further demonstrated by relatively small increase in RT and ST between the two periods. The increase in ST and RT between morning and afternoon were 0.53 and 1.17oC; 1.32 and 1.32; and 1.56 and 1.56oC, respectively for Muscovy, Mule and Mallard ducks. The higher periodic change in ST and RT for mallard ducks indicates higher accumulation of thermal load and inefficiency of heat-regulatory mechanism compared to others. Since the three genotypes under study have not been subjected to mild or intensive selection for any heat-tolerant trait in Nigeria, it is worth emphasizing that consistent lower physiological indices recorded in the two periods and lower within genotype differences for Muscovy and Mule ducks in all the heat tolerant indicators are suggestive of genetic basis for their superior thermal adaptation compared to Mallard ducks.

Genotype-sex interaction

The Lower physiological indices reported in both sexes of Muscovy and Mule ducks in contrast to exotic ducks are suggestive that thermal tolerance ability is not sex dependent/limited but inherent in both sexes. Heat-tolerance is a valuable quantitative economic trait and can be passed from generation to generation. The ability to maintain homeostasis under heat stress is a valuable trait in sub-tropical and tropical regions and this helps to maximize utilization of animal genetic resources (Foster et al., 2009). Between genotype-sex analyses, revealing lower values for both sexes of Muscovy and Mule ducks in contrast to Mallards is a pointer to their superior thermal adaptation and accentuate further that they were genetically superior in thermal tolerance than Mallards.

It is worth emphasising that local Muscovy ducks appear more heat-tolerant than others as revealed in their physiological traits. This could probably be adduced to the age-long natural selection for thermal tolerance in hot tropical environment. This assertion is consistent with the report of Renaudeau et al. (2012) that in tropical areas, the process of natural selection has favoured the emergence of breeds with a high ability to cope with thermal stress. Baker (1989) corroborated further that the ability to regulate temperature is an evolutionary adaptation that allows homeotherms to function in spite of variation in ambient temperature.

Conclusion

The higher values of heat-tolerant traits of Mallard ducks compared to Muscovy and Mule ducks are indicative of physiological stress and low thermal tolerance. Besides, the highest physiological parameters in Mallard ducks also indicate that they were more thermo-sensitive and their heat-regulatory mechanism was less efficient compared with local Muscovy and crossbred Mule counterparts. Though the three genotypes were affected with the elevated ambient temperature in the afternoon; however, the poor heat tolerance of Mallard ducks relative to others suggests further that for this genotype to perform well in hot tropical environment, various temperature-regulatory measures should be employed to mitigate adverse effects of high environmental temperatures. Considering the low values of thermal stress indicators in local Muscovy and crossbred Mule ducks irrespective of sex and period, it can be concluded that they were more heat tolerant and genetically superior to the Mallard ducks in thermal adaptation and would be more suitable in sub-optimal hot tropical environment.

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Authors' contribution:

- Oguntunji, Ayoola and Oluwatomini conceived and designed the experiment.
- All authors performed the experiment and collected data.
- Oguntunji and Oladejo analyzed the data and interpreted the results.
- Oguntunji, Ayoola and Oladejo wrote the manuscript

Conflict of interest: The authors declared that they have no competing interest

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