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Effect of early age thermal challenge on growth performance, haematological parameters and carcass yield of Indigenous Guinea fowl (*Numida meleagris*)

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Abstract

This study aimed to evaluate the effect of thermal stress on haematological profile and carcass yield of guinea fowl (GF). A total of 180 one-day old GF keets were assigned to 3 treatments, having 4 replicates of 15 birds each. The treatments were: control (T1); mild heat stress for 6h/day (T2), and high heat stress for 8h/day (T3). Data were collected on weekly body weights, feed intake and feed conversion ratio of the birds. At 6-weeks old, blood samples were collected from 8 GF for determination of haematological profile. At 14-weeks old, 8 birds were also slaughtered per treatment to evaluate relative organ weights, carcass characteristics and immune response. Results showed that the body weight gain and feed intake of the birds of T1 and T2 were similar and significantly higher than that of T3 at week 1 of age. The FCR of the birds in T1 and T2 were also better at this stage. Lymphocyte counts were higher ($p<0.01$) in the birds of T2 ($95\ 10^3$/mL) than those of the control ($93.33\ 10^3$/mL) and T3 ($93.33\ 10^3$/mL). The weights of lymphoid organs of T2 and T3 birds were higher ($p<0.05$) than those of the control group. It was concluded that exposure of keets to heat stress for 8h/day had adverse effects on growth performance at the early age but this effect faded with age. The thermal manipulation in this study didn't influence the carcass yield but improved the weights of lymphoid organs of indigenous GF, indicating a better thermo-tolerance.

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Introduction

Poultry farming is a reliable source of income and animal protein for households (Tossou *et al.,* 2014; Kouassi *et al.,* 2019) in the tropics. Indeed, it represents a means of rapidly increasing meat production to meet human protein needs, due to its short production cycle (Dahouda, 2003). There is however a paucity of scientific data on their management in the tropical environments. The importance attached to its meat and eggs in the world necessitates further attention for the improvement of the birds.

In the management of GF in the tropical environment, thermal challenge is one of constraints as it negatively impacts the health, welfare and productivity, thereby resulting in high morbidity and mortality of the birds, especially at the early stage of growth.

Several factors including global climate change, affect poultry production. High ambient temperature is one of the major factors that affect sustainability of livestock production systems in tropical climate (Sinha *et al.,* 2017; Jaiswal *et al.,* 2017; Oke *et al.,* 2017; Oke, 2018). Climate change, a complex global problem, has not only impacts on economy of domestic livestock production worldwide but also affects these production systems through the cumulative effects on food availability, health and heat stress (Renaudeau *et al.,* 2015).

There is growing interests on the improvement of local GF and efforts have been made to assess its hardiness against unfavourable climatic conditions. A multidisciplinary approach is needed to understand its impacts in order to provide appropriate solutions (Renaudeau *et al.,* 2015). High temperature associated with satisfactory performance of poultry is about 30°C (Ipek, 2007). Ambient temperatures above 32°C are considered to have a negative effect on poultry performance (Kirunda *et al.,* 2001). However, little research has been conducted on GF despite the significant income often generated from the sales of the birds in rural communities. The determination of haematological parameters is essential in the diagnosis of various pathological and metabolic disorders (Ibrahim *et al.,* 2011).

It provides major information on the physiological state of the animals (Harr, 2002, Adedibu *et al.,* 2014). In addition, haematological parameters provide information not only about diagnosis and management objectives, but can also be incorporated into production programs (Ibrahim *et al.,* 2011). In order to assess the effects of thermal challenge on poultry birds, several studies have been carried out on chickens (Borges *et al.,* 2003; Mohammed *et al.,* 2018; Oke *et al.,* 2020). In fact, growth performance, feed intake and feed efficiency of broilers were reduced by heat stress at 7-days old (Kutlu *et al.,* 1993; Bengharbi *et al.,* 2014). However, a study of the effect of thermal variation on local GF is important in order to develop the appropriate strategies to improve their production under harsh environmental conditions. Therefore, this study was undertaken to evaluate the effects of early age thermal challenge on growth performance and haematological profile of indigenous GF.

Materials and methods

Experimental site

The experiment was carried out at the experiment unit (N 6°24’58”; E 2°20’20”) of the Faculty of Agricultural Sciences, University of Abomey-Calavi, Republic of Benin (LaRAZE/FSA/UAC/RB).

Experimental birds and management

A total of one hundred and eighty, unsexed, one day-old local GF were purchased from a reputable hatchery and allotted to 3 treatments, having 4 replicates of 15 birds each. The treatments were: GF subjected to ambient temperature (control) (T1), birds subjected to mild heat stress (37°C - 42°C) for 6 h (10 am - 4 pm) per day (T2) and birds subjected to high heat stress (37°C - 42°C) for 8h (9 am - 5 pm) per day during their first week of life (T3). Diet containing 2879 Kcal /kg of metabolizable energy and 20.22% of crude protein was fed *ad libitum* to the birds. The birds were fed with the same diets. All the birds were maintained at the same ambient temperature (27°C - 32°C) from week 7 to 14-weeks of age for the assessment of carcass quality and lymphoid organs.

Data collection

Growth performance

A digital scale was used in recording the body weights of the guinea fowl weekly. Also, feed intake was measured as the difference between the weights of the feed supplied in and the unconsumed feed at the end of each period. Feed conversion ratio of the birds was calculated by dividing the feed intake by the weight gain.

Haematological parameters

At the end of the 6-weeks of age, eight GF per treatment were randomly selected and blood samples were collected for the determination of haematological profile. The blood samples were collected into vials from each GF from the wing vein using a sterilized disposable syringe and needle. Sterile universal bottles containing Ethylene Diamine Tetra-Acetic acid (EDTA) as an anticoagulant were used to collect blood and haematological parameters were performed in a haematology analyzer QS Kontrolab EasyVet (Ortiz *et al.,* 2020).

Carcass characteristics and immune organs

At 14 weeks of age, eight GF were randomly selected per treatment. The birds were slaughtered by severing the jugular vein and the feathers were removed. They were eviscerated, the internal organs collected, weighed separately and expressed as a percentage of live weight. The immune organs were also weighed and the carcass yield was determined according to the live body weight of the birds, the relative cut parts and organs were calculated with respect to carcass weight.

Statistical analysis

Data were subjected to one-way analysis of variance (ANOVA) using R version 3.6.2 (R Core Team, 2019). The analysis of variance was performed to assess the effect of environmental conditions on the performance and haematological parameters and carcass quality. All the values were expressed as mean ± standard deviation. Significant differences ($p < 0.05$) among treatment means were determined using Student Newman Keuls (SNK) multiple range test. The ambient condition was considered significant from one treatment to another if $p < 0.05$. Growth curve was made using Graph Pad Prism 5.00 (Software, Inc., a privately held California, USA).

Results

Effect of heat on growth performance of GF

Feed intake of GF under heat stress

Table 1 shows the effect of thermal challenge on growth performance of GF. The average feed intake of the birds was significantly different ($p < 0.05$) during the first week of the trials. GF of T3 had lower feed intake (4.08 g/bird/day) than those of control group (7.67 g/bird/day) and T2 (6.31g/bird/day). However, beyond week 1, there was no significant difference ($p > 0.05$) in the feed intake of the birds across the treatment groups.

Water intake of GF under heat stress

During the first week, a significant difference ($p < 0.001$) was observed in the water intake of the GF. The water intake of GF in T3 (36.12mL/bird/day) was significantly higher ($p < 0.001$) than that of the control group (16.49mL/bird/day); while there was not difference between T2 and the control group (T1) (Table 1).

Live body weight of GF subjected to heat stress

Overall, no significant differences ($p > 0.05$) were found in the live body weight of the birds across the treatments groups (Table 1). The growth curve of the birds is presented in

Body weight gain for GF under heat stress

Table 1 shows a significant difference ($p < 0.01$) between the daily weight gain (BWG) of GF in the three treatments during the first week., DWG of GF in T3 was significantly lower (0.38 ± 0.05g) than those of the T2 (0.95 ± 0.09g) and T1 (1.17 ± 0.3g) in the first week of age. At starter stage, no significant difference was noted.

Effect of heat challenge on the feed conversion ratio

The feed conversion ratio of GF of T3 (10.51 ± 2.77g feed/g BWG) at 7-days of age was statistically higher ($p < 0.05$) than those of T2 (6.70 ± 1.15g feed/g BWG) and the control group (6.71 ± 0.74g feed/g BWG). At 3weeks, there was a significant difference ($p < 0.05$) between the treatments.

The feed conversion ratio of T3 birds (6.8 ± 0.51g feed/g BWG) was significantly higher than that of T2 (3.59 ± 0.27g feed/g BWG) but similar to that of the control (5.39 ± 1.91g feed/g BWG) (Table 1). However, there was no significant difference ($p > 0.05$) at 6 weeks of age across the treatments.

Table 1. Growth performance of guinea fowl under heat stress

Periods	Parameters	T1	T2	T3	p-value
Week 1	BW d 1	30.49 ± 0.37	30.18 ± 1.59	29.00 ± 2.14	0.505
	BW d 7	40.23 ± 3.54	37.57 ± 1.94	37.53 ± 1.85	0.394
	BWG	1.17 ± 0.3^a	0.95 ± 0.09^a	0.38 ± 0.05^b	0.005**
	FI	7.67 ± 1.13^a	6.31 ± 0.49^a	4.08 ± 1.37^b	0.017*
	WI	16.49 ± 4.80^b	20.34 ± 0.51^b	36.12 ± 0.89^a	0.0003***
	FCR	6.71 ± 0.74^b	6.70 ± 1.15^b	10.51 ± 2.77^a	0.043*
Week 2	BW d 14	51.54 ± 6.09	49.59 ± 4.63	47.01 ± 2.90	0.536
	BWG	1.10 ± 0.19	1.41 ± 0.55	0.71 ± 0.59	0.272
	FI	7.08 ± 1.63	6.37 ± 0.31	4.50 ± 1.66	0.130
	WI	21.55 ± 4.32	23.10 ± 2.59	26.57 ± 6.76	0.478
	FCR	6.72 ± 2.51	5.01 ± 2.01	8.65 ± 5.81	0.545
Week 3	BW d 21	68.94 ± 17.17	68.36 ± 8.70	59.16 ± 3.90	0.532
	BWG	2.33 ± 1.8	2.68 ± 0.61	1.32 ± 0.25	0.359
	FI	10.37 ± 3.77	9.52 ± 1.54	8.94 ± 1.52	0.792
	WI	25.91 ± 5.46	28.69 ± 0.52	28.64 ± 5.92	0.718
	FCR	5.39 ± 1.91^{ab}	3.59 ± 0.27^b	6.80 ± 0.51^a	0.032*
Week 4	BW d 28	90.88 ± 27.77	82.55 ± 17.90	77.80 ± 13.42	0.744
	BWG	2.91 ± 1.8	2.03 ± 1.42	2.66 ± 1.46	0.786
	FI	15.08 ± 7.67	11.86 ± 5.69	15.66 ± 8.48	0.800
	WI	33.32 ± 9.03	34.25 ± 9.77	35.13 ± 4.47	0.963
	FCR	5.72 ± 2.21	6.48 ± 1.42	4.51 ± 1.48	0.432
Week 5	BW d 35	126.86 ± 36.94	119.36 ± 30.82	99.48 ± 18.11	0.541
	BWG	4.56 ± 2.22	5.04 ± 2.15	3.09 ± 1.03	0.468
	FI	20.77 ± 4.15	16.71 ± 4.82	21.99 ± 12.77	0.725
	WI	41.65 ± 14.23	48.84 ± 14.54	34.06 ± 4.56	0.383
	FCR	5.22 ± 2.15	3.47 ± 0.63	6.77 ± 1.95	0.146
Week 6	BW d 42	155.78 ± 45.16	144.08 ± 35.99	122.03 ± 23.22	0.541
	BWG	4.13 ± 1.18	3.19 ± 1.17	3.22 ± 0.74	0.503
	FI	29.08 ± 2.84	23.13 ± 3.79	26.37 ± 11.00	0.600
	WI	51.43 ± 13.88	72.37 ± 22.75	37.57 ± 4.16	0.086
	FCR	7.27 ± 1.21	7.66 ± 1.86	7.96 ± 1.51	0.861
Total	BWG	2.79 ± 1.00	2.62 ± 0.89	1.89 ± 0.48	0.423
	FI	15.56 ± 2.96	12.67 ± 2.01	13.78 ± 5.93	0.687
	WI	33.12 ± 7.73	39.09 ± 6.02	34.50 ± 4.69	0.514
	FCR	5.77 ± 0.86	5.03 ± 0.84	7.02 ± 1.38	0.146

T1 = Control; T2 = Mild heat stress group; T3 = Chronic heat stress group

BW=body weight (g); BWG=body weight gain (g); FI=feed intake (g); WC=water intake; FCR=feed conversion ratio (g feed/g BW); *Significant and $p < 0.05$; ** Highly significant and $p < 0.01$; *** Very highly significant and $p < 0.001$;

$^{a, b}$ Means with unlike superscripts in the same row differ significantly ($P < 0.05$).

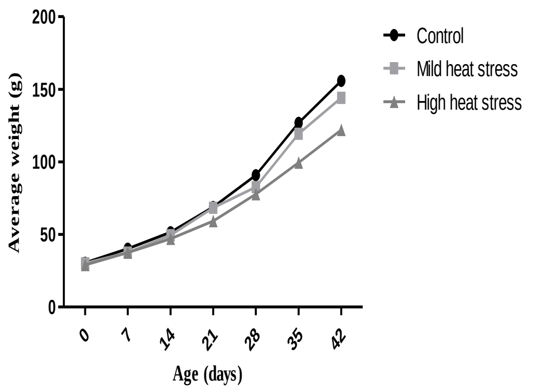

Fig. 1. Growth curve of the three groups of guinea fowl.

Haematological parameters and carcass characteristics

Effect of heat on haematological parameters of GF

Table 2 shows the effect of thermal challenge on haematological profile of GF. There was no significant difference ($p > 0.05$) in all the haematological parameters (red blood cell, haemoglobin, haematocrit, mean corpuscular volume, mean corpuscular haemoglobin, white blood cell, monocyte and platelets) except the mean corpuscular haemoglobin concentration (MCHC) and lymphocytes.

Themc HC of the birds in T3 (39.37 ± 0.66g/dl) was significantly higher ($p < 0.05$) than those of T1 (35.43 ± 0.41g/dl) but similar to those of T2 (37.13 ± 2.00g/dl). In addition, lymphocyte counts were statistically higher ($p < 0.01$) in the T2 birds (95 ± 0.00 10^3/mL) than those of the control (93.33 ± 0.58 10^3/mL) and T3 (93.33 ± 0.29 10^3/mL).

Organs involved in the immune response

The weights of thymus of GF of T2 (0.82 ± 0.08mg) and T3 (0.72 ± 0.08mg) were significantly ($p < 0.01$) higher than that of the control group (0.25 ± 0.18mg) (Table 3). The weights of the spleen of the T2 (0.65 ± 0.10 mg) and T3 (0.53 ± 0.15mg) were also significantly ($p < 0.05$) higher than those of the control group (0.23 ± 0.15mg).

Table 2. Effect of thermal challenge on haematological profile of guinea fowl.

Haematological parameters	Treatments			p-value
	T1	T2	T3	
Red blood cell (10^6/mm^3)	2.22 ± 0.60	2.31 ± 0.79	2.55 ± 0.19	0.783
Haemoglobin (g/dl)	12.35 ± 3.26	12.15 ± 3.25	14.02 ± 0.90	0.672
Haematocrit (%)	34.90 ± 9.06	33.17 ± 9.99	35.50 ± 1.87	0.932
Mean corpuscular volume (fL)	159.27 ± 5.69	145.75 ± 14.38	139.77 ± 5.67	0.107
Mean corpuscular haemoglobin (pg)	56.38 ± 2.25	54.03 ± 6.15	55.03 ± 2.71	0.787
Mean corpuscular haemoglobin concentration (g/dl)	35.43 ± 0.41^b	37.13 ± 2.00^{ab}	39.37 ± 0.66^a	0.023*
White blood cell (g/l)	126.42 ± 25.61	121.52 ± 35.37	141.42 ± 9.59	0.639
Neutrophil granulocytes (10^3/mL)	4.67 ± 1.26	3.67 ± 0.58	4.67 ± 0.58	0.332
Monocytes (10^3/mL)	2.00 ± 0.87	1.33 ± 0.58	2.00 ± 0.50	0.422
Lymphocytes (10^3/mL)	93.33 ± 0.58^b	95.00 ± 0.00^a	93.33 ± 0.29^b	0.002**
Platelets (10^3/mL)	14.00 ± 5.07	11.17 ± 3.05	11.83 ± 2.31	0.636

*Significant and $p < 0.05$; **: Highly significant and $p < 0.01$;

$^{a,\,b}$ Means with unlike superscripts in the same row differ significantly ($p < 0.05$);

Table 3. Organs involved in the immune response (mg).

Immune organs	Treatments			p-value
	T1	T2	T3	
Bursa of Fabricius	0.55 ± 0.35	0.90 ± 0.30	0.55 ± 0.26	0.344
Thymus	0.25 ± 0.18^b	0.82 ± 0.08^a	0.72 ± 0.08^a	0.003**
Spleen	0.23 ± 0.15^b	0.65 ± 0.10^a	0.53 ± 0.15^a	0.024*

*Significant and $p < 0.05$; ** Highly significant and $p < 0.01$;

$^{a,\,b}$ Means with unlike superscripts in the same row differ significantly ($p < 0.05$).

Table 4. Carcass yield and organs proportion (%).

Variables	Treatments			p-value
	T1	T2	T3	
Carcass yield	75.18 ± 0.49	75.48 ± 1.40	80.54 ± 4.28	0.084
Heart	0.52 ± 0.01	0.53 ± 0.03	0.48 ± 0.11	0.595
Liver	2.03 ± 0.17	2.24 ± 0.35	2.08 ± 0.53	0.783
Sternum	27.23 ± 2.72	28.09 ± 4.94	24.99 ± 3.46	0.617
Thigh	8.78 ± 1.65	9.24 ± 2.10	8.98 ± 2.05	0.962
Drumstick	5.90 ± 0.62	7.06 ± 1.31	6.35 ± 1.35	0.502
Gizzard	3.69 ± 0.10	3.98 ± 0.93	3.28 ± 0.66	0.481

Carcass yield and organs' relative weights

The GF carcass yield at the 14th week of age and the relative weights of organs of the guinea fowls are presented in Table 4. There was no significant difference ($p > 0.05$) across the treatments groups.

Discussion

Temperature is a major factor in the production efficiency for GF. The results of this study indicate that, at the first week of age, thermal challenge decreased the FI of GF subjected to high thermal challenge. This may be attributed to a reduction in thyroid hormone (Daneshyar *et al.,* 2012; Fernandes *et al.,* 2013) causing a delay in the development of intestinal villi, thus reducing the absorption of nutrients. This study showed that the use of high heat stress resulted in a lower FI at the first week of exposure. Beyond week 1, early age thermal challenge did not have significant effect on the feed intake of GF. This result is at variance with those obtained on broilers (Kutlu *et al.,* 1993; Al-Batshan, 1999; Mashaly *et al.,* 2004), which showed that heat stress had a negative effect on broiler FI. This discrepancy may be explained by species difference and environmental conditions.

The higher water intake of the birds under the higher thermal challenge at the early age in the present study is in agreement with the findings of some authors (Uni *et al.,* 2001; Ranjan *et al.,* 2019). This suggests that the effect of high heat exposure was pronounced on GF. In this respect, exposure of the GF to thermal challenge up to 42°C for 8 hours a day for one week increased the consumption of water. This result could be explained by the increasing of water consumption of the birds to cope with heat stress in order to balance the disrupted thermal equilibrium as heat production and dissipation would have been affected (Wiernusz and Teeter, 1993, 1996; Zhou and Yamamoto, 1997). This is consistent with the results of Kutlu *et al.* (1993) who varied the temperature of broilers. Also, it has been reported that water intake of birds increased about 7% for every 1°C increase above 21°C (NRC, 1994).

At 7-days old, the similarity in the body weights of the birds suggest that the thermal manipulation in this study did not have a lasting impact on the growth of guinea fowls, as the birds in T3 had a compensatory growth to catch up with the birds in the other treatment groups. Due to the fact that GF are Africa-native, it could acclimate to a higher heat stress than broiler chickens that are adapted to temperate region with a shorter range of thermo tolerance. Heat stress at mild or high level did not have a dramatic negative effect on GF growth in the present study. This result is in agreement with findings of Bengharbi *et al.* (2014) who reported that thermal challenge did not have adverse effect on growth of broilers chickens.

No significant difference was found in feed intake of the GF from the second to the sixth week age in this study. This could explain the similarity in their body weights. These results are in contradiction with those of Kutlu *et al.* (1993) and Al-Batshan (1999). The discrepancy may be due to the difference in species. Also, at 7-days old, feed conversion ratio of GF exposed to high heat stress was significantly higher than those of the other treatments. This suggests that the exposure of GF to heat for 8h/day during the first week increased the feed conversion ratio of the birds. High environmental temperatures activate the hypothalamic-pituitary-adrenal (HPA) axis. The stress-activated HPA axis was found to be responsible for the negative effects of heat stress on broiler performance (Quinteiro-Filho *et al.,* 2012).

Across the treatment, haematological parameters were similar, except formc HC and lymphocyte levels. The significant difference obtained between themc HC of GF exposed to early high heat stress and that of the control group in the present study is indicative of a strong pigmentation of the skin of GF raised under high heat stress. The control group then tend towards a case of hypochromia. Heat stress in the first week of breeding and in addition the duration of exposure to heat increase the number of red blood cells in the blood and thus themc HC. The number of red blood cells has increased under the effect of heat because of the increasing need for respiratory exchange.

Moreover, the difference in the lymphocyte of GF exposed to heat stress showed an increase of the resistance of the birds with the persistence of heat stress by increasing the size of lymphatic organs such as spleen and thymus. These results are at variance with the finding of Khan *et al.* (2002); Kadam *et al.* (2009) and Yousaf *et al.* (2018), who reported that thermal challenge reduces lymphocyte levels in broilers chickens. This discrepancy can be explained by difference in species. Our observation suggests that this high level of lymphocytes induced by heat stress thus enhances the immunity of these GF effectively in response to heat stress.

Despite the absence of a significant difference in the level of monocyte of the birds in this study, it is found that it decreases under the prolonged effect of heat on GF. These results are similar to the findings of Marchini *et al.* (2011). However, they are in contradiction with that of Altan *et al.* (2000) who reported that heat stress increased the level of monocytes in the blood. This may not only be due to the difference of the species of birds but also by environmental conditions and severity of heat stress. Although, statistical analysis showed no significant difference in the number of white blood cells, the number of white blood cells of the birds under heat stress decreased. The decline in the white blood cells in the present study are consistent with the findings of Rosales (1994) and Yalcin *et al.* (2004) who reported that heat stress induced a change in the number of white blood cells.. Also, Hsturkie (1998) found that heat stress induced an increase in adrenal steroid release into the bloodstream, leading to an alteration in the number of leukocytes. This implies that heat stress weakens the body's immune system against potentially harmful foreign substances. The slight increase in the number of red blood cells under heat stress in this study may be due to the increasing need for respiratory exchange.

The bursa of Fabricius, thymus, spleen and the adrenal glands are the organs involved in the GF's immune response. The weights of thymus and spleen of GF subjected to heat stress in this study were higher than that of the control group. This suggests that early age thermal manipulation must improve the immunity of the birds, suggesting a better thermo tolerance. These results are in contrast with the results of Prayuwidayati *et al.* (2012) who reported that heat stress had a negative effect on the weight of the thymus, the bursa of Fabricius and the spleen of broiler chickens.

In contrast, Oke *et al.* (2020) reported that there was no effect of early age thermal manipulation on the lymphoid organs of broiler chickens. The differences in these results can be explained by the difference of strains and the ability of different poultry species to adapt their metabolism to various environments.

The similarity in the carcass traits of the birds in the present study is in agreement with the findings of Al-Batshan (1999) who obtained the values of 68.5% and 68.9%, respectively for chickens subjected to heat stress and those of the control group. However, the findings of Liu *et al.* (2019) showed that after 10 weeks of heat stress, broilers in the heat stress group had lower eviscerated carcass rate and breast muscle yield than those in control group.

The similarity in the carcass traits in the present study indicates that GF are able to have a catch-up growth after exposure to unfavorable conditions at the earlier age. This is in consonance with the findings of Sakomura *et al.* (2013) who reported that there was no significant impact of heat stress on carcass, leg, and breast yield of broilers. In contrast, Lu *et al.* (2018) found that carcass parameters were negatively affected by high heat stress in broilers. The possible reasons of these results might be due to the experimental conditions and genetic makeup of GF.

Conclusion

It appears from this experiment that high heat stress had negative effect on the weight gain and feed conversion ratio of GF at the early age. There was however a compensatory growth at the older age. Also, heat stress in the first week of rearing increased the number of red blood cells in the blood and thus the mean corpuscular hemoglobin concentration. The improved lymphoid organs in this study indicates that high early age thermal exposure enhanced the immunity of GF.

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