OPEN ACCESS Journal of Animal Health and Production

Research Article

Relationship Between Growth Rates with Body Dimensions and Some Physiological Parameters of Female Japanese Quails Reared Under Heat Stress

Khalid Chillab Kridie Al-Salhie*, **Sabah Kadhum Marzooq Al-Hummod**

Department of Animal Production, College of Agriculture, University of Basrah, Basrah, Iraq.

Abstract | This study aimed to examine the relationship between growth rates, body dimensions, and physiological parameters in female Japanese quails under heat stress. A total of 240 quails were divided into two groups of 120, with each group further subdivided into four replicates of 30 females. The first group was exposed to 35°C for 8 hours daily (long-term heat stress), while the second group was exposed for 4 hours daily (short-term heat stress). Quails exposed to 4 hours of daily heat stress showed better weight gain, live body weight, and feed conversion compared to those exposed to 8 hours, with no significant difference ($p>0.05$) in feed intake. Long-term heat stress resulted in a significant ($p<0.05$) decrease in body height, leg, and wing length, but no effect on head and beak, or neck length. Short-term heat stress decreased ($p<0.05$) packed cell volume (PCV), while long-term exposure increased ($p<0.05$) the H/L ratio and corticosterone levels. Additionally, serum pH decreased ($p<0.05$), and superoxide dismutase activity increased ($p<0.05$) in quails exposed to 4 hours of heat stress. Correlation analysis revealed negative associations between body dimensions and growth parameters. Larger body dimensions, especially wing and leg lengths, correlated with lower feed conversion efficiency (FCR). Head and beak lengths had minimal effects on FCR. Furthermore, negative correlations were observed between body weight, weight gain, feed intake and stress parameters (PCV, H/L ratio, corticosterone and serum pH). In conclusion, 4 hours of heat stress enhanced growth and feed conversion, while 8 hours reduced body dimensions and increased stress parameters.

Keywords | Body dimensions, Growth rate, Heat stress, Physiological parameters, Serum pH, Quail

Received | April 16, 2025; **Accepted** | June 24, 2025; **Published** | August 06, 2025
***Correspondence** | Khalid Chillab Kridie Al-Salhie, Department of Animal Production, College of Agriculture, University of Basrah, Basrah, Iraq; **Email:** Khalid.chillab@uobasrah.edu.iq
Citation | Al-Salhie KCK, Al-Hummod SKM (2025). Relationship between growth rates with body dimensions and some physiological parameters of female Japanese quails reared under heat stress. J. Anim. Health Prod. 13(3): 768-774.
DOI | https://dx.doi.org/10.17582/journal.jahp/2025/13.3.768.774
ISSN (Online) | 2308-2801

INTRODUCTION

Poultry are exposed to various types of stress, including nutritional stress caused by the salinity of drinking water (Hussain and Al-Salhie, 2022a, b), the presence of heavy metals in the diet (Hana and Al-Salhie, 2024), heat stress (Hadi *et al*., 2024), and others. Although researchers have employed various methods to mitigate the effects of these stressors and improve the productive and physiological performance of quail (Al-Salhie and Al-Waeli, 2019; Al-Ashoor and Al-Salhie, 2020; Al-Mosawy and Al-Salhie, 2021), stress still has detrimental effects, particularly in tropical climates. Heat stress is a critical factor that can impair performance and welfare of poultry, including species like the Japanese quail. This issue particularly pronounced in regions where high ambient temperatures are common, and it becomes even more significant with growing demand for poultry products in these areas (Wasti *et al*., 2020; Batool *et al*., 2023). In poultry farming, heat stress can reduce feed intake, lower growth rate, and lead to a higher incidence of disease, ultimately affecting both the health and bird's productivity (Mangan and Siwek, 2024).

Given the increasing frequency of extreme weather events and climate change, understanding how heat stress impacts various physiological and morphological aspects of quails is essential for improving animal management and ensuring sustainable production (Mehaisen *et al*., 2019).

Japanese quails are increasingly in both research and agricultural settings due to their fast growth rate, high reproductive output and adaptability to different environments (Arunrao *et al*., 2023). However, like many avian species, they are highly sensitive to environmental stressors, including elevated temperatures. Heat stress can disrupt normal metabolic processes, causing alterations in body composition and growth patterns (Wasti *et al*., 2020). This stress response can manifest in a variety of ways, such as reduced body weight, changes in body dimensions and shifts in fat and muscle distribution. As such examining the relationship between growth rates and body dimensions in female Japanese quails under heat stress conditions is crucial for identifying key areas where intervention may help mitigate the negative effects of high temperatures on their development (Santana *et al*., 2021). In term of body dimensions, heat stress can affect both skeletal and soft tissue growth. The skeletal system, in particular, may undergo changes in density and structure, which can influence overall body size and weight (Choi *et al*., 2016). Furthermore, excessive heat stress can disrupt protein synthesis and energy metabolism, which are fundamental to proper growth (Wasti *et al*., 2020). The effect of heat stress is not uniform with younger birds, females and birds in different genetic line or strain showing varying degree of susceptibility (Wang *et al*., 2024). Thus, understanding these differences in vital to developing heat stress management strategies tailored to specific quail populations. Previous studies have documented the impact of heat stress on various aspects of quail growth, but there is still a gap in the understanding of how specific body dimensions, such as weight, length and girth, respond to prolonged exposure to high temperature (Santana *et al*., 2021). Additionally, while some research has focused on the physiological changes in quail under heat stress, few studies have comprehensively linked these changes to measurable growth patterns (Truong and King, 2023). This research aims to fill that gap by analyzing the relationship between growth rates with body dimensions and some physiological parameters in female Japanese quails exposed to heat stress conditions.

MATERIALS AND METHODS

The present study was conducted at the quail field of the College of Agriculture, University of Basrah after getting institutional approval. All the study procedures were carried out in line with the International Animal Ethical Standards. A total of 400 day-old Japanese quail chicks were raised until the third weeks of age. During the first three weeks, the ambient temperatures were 35, 32 and 30 C° respectively. Subsequently, the chicks were sexed in order to select only the females.

Management of the Birds

A total of 240 female Japanese quails were used, divided into two groups, with 120 females in each group. The birds in each group were distributed into four replicates, with 30 females per replicate. The birds in each replicate were housed in cages each with dimensions of 100 × 50 × 50 cm. The birds were raised until the seventh week of age. Females in the first group were exposed to a temperature of 35 C for 8 hours daily (long-term heat stress period), while females in the second group were exposed to a temperature of 35 C for 4 hours daily (short-term heat stress period). The birds were fed a standard diet containing 23% crude protein and 2900 kcal/kg of Metabolizable energy. Feeders and drinkers were provided for each cage, with one feeder and drinker per cage. An 18-hour light and 6-hour dark photoperiod was used until the end of the experiment.

Data Collection

Total weight gain was calculated as the difference between final body weight and initial body weight. Accumulative feed intake was determined by averaging female daily feed intake over 35 days. Feed conversion ratio was calculated by divided the accumulative feed intake to total weight gain. At the end of the 7th week, the body height, leg, head, neck, and wing length were measured using a precise measuring tape. At the end of 7th week, blood samples were collected on a random basis from 12 females/ group. Blood samples were collected directly from the jugular vein in tubes containing EDTA for Packed cell volume (PCV) and heterophils/ lymphocytes ratio (H/L) examination, and without EDTA tubes to the detection of serum biochemical parameters. PCV and H/L were determined according to Archer (1965). Serum glutathione peroxidase (GPx), superoxide dismutase (SOD) and corticosterone hormone were examined by commercial kits. Serum pH was determined by pH meter device.

Date Analysis

All the data were analyzed by using the statistical software program (SPSS, 2018), and the Duncan (1955) test was used to compare mean differences between groups at P≤ 0.05.

RESULTS AND DISCUSSION

Effect of Short- and Long-Term Heat Stress on Productive Performance

The results of Table 1 indicate that female quail exposed to a short-term heat stress period exhibited improvements in live body weight, weight gain and feed conversion ratio compared to those subjected to longer heat stress exposure. Interestingly, there was no significant effect on accumulative feed intake between the two groups. The results of this study suggest that the duration of heat stress plays a crucial role in the performance of quail, particularly in terms of live body weight, weight gain and feed conversion efficiency. Bird subjected to shorter period of heat stress showed improved growth and feed conversion efficiency compared to those exposed to longer period of heat stress. This observation is consistent with other studies that have reported that heat stress negatively impacts poultry growth performance, but the extent of the effect is often dependent on the duration and intensity of the stress (Nawaz *et al*., 2021; Ahmad *et al*., 2022). One possible explanation for the improved performance in birds exposed to shorter duration of heat stress could be that these birds were better able to maintain physiological homeostasis during milder heat stress. When exposed to moderate heat stress, birds can employ thermoregulatory mechanisms, such as increased panting and change blood flow to limit heat accumulation (Wasti *et al*., 2020). These responses may allow the birds to conserve energy for growth, which could explain the improved weight gain and feed conversion efficiency observed in the 4-hour heat stress group. In contrast, longer durations of heat stress could result in more severe thermal stress, leading to a higher metabolic rate, greater energy expenditure for thermoregulation and consequently reduced growth (Zmrhal *et al*., 2023).

Table 1: Effect of short- and long-term heat stress on the productive performance of female Japanese quail (Mean ± SE).

Parameters	Long-term heat stress	Short-term heat stress	P value
Initial body weight (g)	87.54 ± 0.54	87.42 ± 1.49	0.945
Final body weight (g)	204.56 ± 1.61[b]	220.25 ± 0.47[a]	<0.001
Total weight gain (g)	117.02 ± 1.98[b]	132.82 ± 1.50[a]	0.001
Accumulative feed intake (g)	503.75 ± 2.86	512.87 ± 4.28	0.127
Total feed conversion ratio (g/g)	4.30 ± 0.06[a]	3.85 ± 0.07[b]	0.004

Different letters indicate significant differences for the same row at (P≤0.05).

Moreover, the lack of a significant effect on total feed consumption in both groups in noteworthy. Studies have shown that under heat stress conditions, poultry may adjust their feeding behavior to compensate for changes in energy demands (Nawab *et al*., 2018). This aligns with findings by Nawab *et al*. (2018) who reported that poultry exposed to heat stress could adjust their feed intake but still exhibit reductions in weight gain and feed conversion efficiency due to the metabolic cost of coping with the heat. Furthermore, the results of this study are in agreement with the concept that the critical period for the development of thermoregulation in poultry is around the age range of 3 to 7 weeks. During this period, birds are still developing their capacity to cope with environmental stressors, which may make them more susceptible to the adverse effects of prolonged heat stress (Oluwagbenga and Fraley, 2023).

Table 2: Effect of short- and long-term heat stress on body dimensions of female Japanese quail (Mean ± SE).

Parameters	Long-term heat stress	Short-term heat stress	P value
Body high (cm)	11.21 ± 0.12[b]	12.39 ± 0.14[a]	<0.001
Leg length (cm)	9.38 ± 0.11[b]	10.11 ± 0.12[a]	<0.001
Wing length (cm)	16.44 ± 0.05[b]	16.75 ± 0.06[a]	<0.001
Head and beak length	3.60 ± 0.06	3.72 ± 0.05	0.151
Neck length (cm)	3.82 ± 0.018	3.80 ± 0.019	0.490

Different letters indicate significant differences for the same row at (P≤0.05).

Effect of Short- and Long-Term Heat Stress on Body Dimensions

The results of Table 2 indicate a significant (p≤0.05) decrease in the body height, leg and wing length in the birds exposed to 8 hours of heat stress daily. However, no significant effect was observed in the head and beak length and neck length between both groups. Heat stress has been extensively studied for its impact on physiological and morphological traits in avian species. The significant decrease in the body height, leg and wing length in the birds exposed to 8 hours of heat stress is consistent with findings from previous studies in birds, where prolonged exposure to heat has been shown to impair growth and development (Awad *et al*., 2020; Apalowo *et al*., 2024).Heat stress leads to physiological stress responses, such as increased body temperature, dehydration and metabolic alteration which can directly affect growth parameters (Khan *et al*., 2023). The reduction in body height and limb lengths (leg and wing) in the 8-hour of heat stress suggests a detrimental effect on overall growth. These traits are influenced by energy allocation and under heat stress, the body of birds may prioritize survival over growth, diverting energy from growth processes toward heat dissipation (Wasti *et al*., 2020). Interestingly, no significant changes were observed in the head and beak length and neck length, suggesting that these specific morphological traits might be less sensitive to heat stress compared to body and limb growth. This could be due to the fact these traits may be regulated by different growth mechanisms or gene that are less affected by heat stress (Sztandarski *et al*., 2021; Tadele *et al*., 2023).

Effect of Short- and Long-Term Heat Stress on PCV, H/L Ratio and Corticosterone Level

The results of Table 3 showed a significant (p≤0.05) decrease in PCV in quails exposed to 4 hours of heat stress compared to those subjected to 8 hours of heat stress. While H/L ratio and Corticosterone levels were a significant (p≤0.05) increase in quails exposed to 8hours of heat stress compared to those subjected to 4 hours of heat stress. These results suggest that shorter durations of heat stress may have a more pronounced effect on these physiological parameters than longer durations. Heat stress is known to affect the hematological profile of animals and it often leads to changes in blood parameters due to dehydration and the redistribution of body fluids. In the case of shorter heat stress exposure, the decrease in PCV may be linked to acute response to heat stress, causing vasodilation, fluid shifts and an initial reduction in red blood cells (Blake *et al*., 2000; Brugaletta *et al*., 2022). The H/L ratio is a widely used indicator of stress in poultry (Lentfer *et al*., 2015; Hussain and Al-Salhie, 2022a). Shorter heat stress might lead to an initial increase in the H/L ratio, but the body may have a chance to adapt and stabilize the immune system over time, leading to a less pronounced immune response. Longer heat stress exposure results in chronic stress, leading to prolonged increase H/L ratio. This increase is generally reflective of an imbalance between immune response (increase in Heterophils) and immune regulation (decrease in lymphocytes), often indicating acute stress or inflammation (Zmrhal *et al*., 2023). Prolonged exposure of heat stress likely triggers more intense inflammation response, which could lead to observed increase in the H/L ratio (Xu *et al*., 2018). Corticosterone is released as part of the hypothalamic-pituitary-adrenal axis activation and higher levels of this hormone signal greater activation of the body's stress response (He *et al*., 2019). This increase in corticosterone could result in metabolic disturbances, immune modulation and behavioral changes, all of which are commonly associated with prolonged heat exposure (Nazar *et al*., 2018).

Table 3: Effect of short- and long-term heat stress on PCV, H/L ratio and corticosterone level of female Japanese quail (Mean ± SE).

Parameters	Long-term heat stress	Short-term heat stress	P value
PCV (%)	39.50 ± 0.64[a]	35.37 ± 0.74[b]	0.006
H/L	0.68 ± 0.02[a]	0.52 ± 0.01[b]	0.003
Corticosterone (ng/ml)	2.03 ± 0.031[a]	1.87 ± 0.033[b]	0.016

Different letters indicate significant differences for the same row at (P≤0.05).

Effect of Short- and Long-Term Heat Stress on Serum pH, SOD and GPx Activity

The results of Table 4 showed a significant (p≤0.05) decrease in serum pH in quails exposed to 4 hours of heat stress compared to those subjected to 8 hours of heat stress. While, a significant increase in SOD (p = 0.016) and GPx (p = 0.051) activity were recorded in quails exposed to 4 hours of heat stress compared to those subjected to 8 hours of heat stress. Short-term heat stress can cause an increase in metabolic activity, leading to metabolic acids production, which may lower the blood pH (Teeter *et al*., 1985). In contrast, longer heat stress exposure allows for compensatory mechanisms to activate, including improved acid-base regulation, which explain why the pH did not decrease as drastically in this group (Teeter and Smith, 1986). Increased in SOD and GPx activity were recorded in quails exposed to 4 hours of heat stress likely reflects a more acute oxidative stress response. The 4-hours of heat stress might trigger a rapid production of ROS, which in turn induces the activation of these antioxidant enzymes to neutralize free radicals and protect cellular integrity. In contrast, longer heat stress exposure likely result in adaptive responses where the bird's antioxidant system might become more efficient or less reactive over time. The relatively stable or lower of SOD and GPx activity in the 8-hours heat stress group may indicate that these birds have undergone an adaptation to oxidative stress, potentially improving the efficiency of antioxidant system (Akbarian *et al*., 2016).

Table 4: Effect of short- and long-term heat stress on serum pH, SOD and GPx activity of female Japanese quail (Mean ± SE).

Parameters	Long-term heat stress	Short -term heat stress	P value
pH	7.43 ± 0.01[a]	7.31 ± 0.02[b]	0.008
SOD (ng/ml)	214.69 ± 2.19[b]	222.37 ± 0.74[a]	0.016
GPx (ng/ml)	7.39 ± 0.25	8.02 ± 0.05	0.051

Different letters indicate significant differences for the same row at (P≤ 0.05).

Table 5: Correlation between productive traits and body dimensions of female Japanese quail.

Parameters	Body height	Leg length	Wing length	Head and beak length	Neck length
Final body weight	0.249	0.225	0.370	0.153	-0.134
Total weight gain	0.330	0.305	0.431	0.088	-0.065
Accumulative feed intake	0.238	0.093	-0.249	0.071	-0.180
Total feed conversion ratio	-0.292	-0.330	-0.552	-0.042	0.067

Correlation Between Productive Traits and Body Dimensions

The results of Table 5 showed the correlation analysis between growth parameters and body dimensions. Neck length indicated a weak negative correlation with final body weight (-0.134), weight gain (-0.065) and feed intake (-0.180). Additionally, wing length exhibited a negative correlation with feed intake (-0.249). Furthermore, feed conversion ratio was negatively correlated with body high (-0.292), leg length (-0.330), wing length (-0.552) and head length (-0.042). In contrast, head and beak length showed minimal impact on feed conversion ratio (-0.042). Overall, these results highlight the complex relationship between body dimensions and growth performance, suggesting that certain morphological traits may influence feed ratio and growth in Japanese quail. Adil *et al.* (2024) found correlations between the body weight of quail and body dimensions, including a negative correlation between body weight and drumstick length.

Correlation Between Productive and Physiological Traits

Final body weight has a negative correlation with PCV, H/L ratio, corticosterone hormone and pH, according to the results shown in Table 6. Correlation coefficients reached of -0.764, -0.876, -0.721, and -0.769, respectively. Additionally, the results showed that the corticosterone hormone, pH, PCV and H/L ratio all had negative correlations with total weight gain. Correlation coefficients reached of -0.780, -0.879, -0.664, and -0.767, respectively. On the other hand, the results showed that these parameters were negatively correlated with feed intake, with correlation coefficients of -0.264, -0.394, -0.259, and -0.329, respectively. Feed conversion ratio was also negatively correlated with PCV, H/L ratio, and the activities of SOD and GPx enzymes, with correlation coefficients of -0.771, -0.878, -0.501, and -0.445, respectively.

Table 6: Correlation between productive and physiological traits of female Japanese quail.

Parameters	PCV	H/L	Corticosterone	pH	SOD	GPx
Final body weight	-0.764	-0.876	-0.721	-0.769	0.662	0.518
Total weight gain	-0.780	-0.879	-0.664	-0.767	0.573	0.475
Accumulative feed intake	-0.264	-0.394	-0.259	-0.329	0.461	0.199
Total feed conversion rati	-0.771	-0.878	0.654	0.758	-0.501	-0.445

CONCULUSIONS AND RECOMMENDATIONS

In conclusion, the study demonstrates that short-term heat stress (4 hours daily) improves growth performance and feed conversion ratio in quail compared to longer heat stress (8 hours daily). Prolonged heat stress negatively affected body dimensions. Additionally, short-term heat stress leads to a decrease in PCV, while prolonged heat stress increased H/L ratio and corticosterone levels. Furthermore, 4-hours of heat stress was associated with a decrease in serum pH and an increase in antioxidant enzymes. Overall, these results highlight the complex interplay between heat stress duration, physiological response and growth performance in female Japanese quail.

ACKNOWLEDGMENTS

We sincerely thank the staff of the physiology laboratory in animal production department for their support in helping us complete the research requirements.

NOVELTY STATEMENTS

The present study showed that the short-term heat stress can improve performance, growth rate and feed conversion of female Japanese quails but continuous exposure to high temperature be harmful by decrease in bird size and increasing physiological markers. It also shows the presence of a negative relationship between higher body size and feed efficiency, an inverse association among body weight, weight gain and feed intake with stress indicators. These results may provide valuable information for a better management of heat stress in poultry production.

AUTHOR'S CONTRIBUTIONS

All authors contributed equally.

Conflict of Interest

None.

REFERENCES

Adil M, Tayyab M, Hussain J, Firyal S, Ali S, Azam M, Wasim M, Awan AR (2024). Relationship between body weight and linear body measurements in Pakistani quail (*Coturnix japonica* PK). Pak. J. Zool., 56(3): 1423-1431. https://dx.doi.org/10.17582/journal.pjz/20221118031144

Ahmad R, Yu YH, Hsiao FS, Su CH, Liu HC, Tobin I, Zhang G, Cheng YH (2022). Influence of Heat Stress on Poultry Growth Performance, Intestinal Inflammation, and Immune Function and Potential Mitigation by Probiotics. Animals: Open Access J. MDPI, 12(17): 2297. https://doi.org/10.3390/ani12172297

Akbarian A, Michiels J, Degroote J, Majdeddin M, Golian A, De Smet S (2016). Association between heat stress and oxidative stress in poultry; mitochondrial dysfunction and dietary interventions with phytochemicals. J. Anim. Sci. Biotechnol., 7: 37. https://doi.org/10.1186/s40104-016-0097-5

Al-Ashoor DSA, Al-Salhie KCK (2020). Effect of Adding Broccoli Leaves (*Brassica oleracea* L. var. italica) Extract to Drinking Water on Eggs Production and Intestinal Microflora of Japanese Quail *Coturnix japonica* Temmink and Schlegel, 1849, Basrah J. Agric. Sci., 33: 42-51. https://doi.org/10.37077/25200860.2020.33.2.04

Al-Mosawy AMS, Al-Salhie KCK (2021). The Effect of Alcoholic

Extract of Rhizomes of Greater Galangal (*Alpinia galanga* L.) on the Serum Antioxidant Enzymes for Japanese Quail During Oxidative Stress Induced by Hydrogen Peroxide. Basrah J. Agric. Sci., 34(1): 171–179. https://doi.org/10.37077/25200860.2021.34.1.15

Al-Salhie KCK, Al-Waeli AM (2019). The Effect of Using Different Levels of Red Ginseng Roots Powder on some Physiological Characteristics of Japanese Quail Males (*Coturnix japonica*). Basrah J. Agric. Sci., 32(1): 34–38. https://doi.org/10.37077/25200860.2019.124

Apalowo OO, Ekunseitan DA, Fasina YO (2024). Impact of Heat Stress on Broiler Chicken Production. Poultry, 3(2): 107-128. https://doi.org/10.3390/poultry3020010

Archer RK (1965). Hematological Techniques for Use on Animals. Blackwell Scientific Publications, Oxford.

Arunrao KV, Kannan D, Amutha R, Thiruvenkadan AK, Yakubu A (2023). Production performance of four lines of Japanese quail reared under tropical climatic conditions of Tamil Nadu, India. Front. Genet.,14: 1128944. https://doi.org/10.3389/fgene.2023.1128944

Awad EA, Najaa M, Zulaikha ZA, Zulkifli I, Soleimani AF (2020). Effects of heat stress on growth performance, selected physiological and immunological parameters, caecal microflora, and meat quality in two broiler strains. Asian-Australas. J. Anim. Sci., 33(5): 778–787. https://doi.org/10.5713/ajas.19.0208

Batool F, Bilal RM, Hassan FU, Nasir TA, Rafeeque M, Elnesr SS, Farag MR, Mahgoub HAM, Naiel MAE, Alagawany M (2023). An updated review on behavior of domestic quail with reference to the negative effect of heat stress. Anim. Biotechnol., 34(2): 424–437. https://doi.org/10.1080/10495398.2021.1951281

Blake AS, Petley GW, Deakin CD (2000). Effects of changes in packed cell volume on the specific heat capacity of blood: implications for studies measuring heat exchange in extracorporeal circuits. Br. J. Anaesth., 84(1): 28–32. https://doi.org/10.1093/oxfordjournals.bja.a013376

Brugaletta G, Teyssier JR, Rochell SJ, Dridi S, Sirri F (2022). A review of heat stress in chickens. Part I: Insights into physiology and gut health. Front. Physiol., 13: 934381. https://doi.org/10.3389/fphys.2022.934381

Choi YM, Chen PR, Shin S, Zhang J, Hwang S, Lee K (2016). Mild heat stress enhances differentiation and proliferation of Japanese quail myoblasts and enhances slow muscle fiber characteristics. Poult. Sci., 95(8): 1912–1917. https://doi.org/10.3382/ps/pew116

Duncan DD (1955). Multiple range and Multiple F-Test. Biometrics, 11:1 – 42.

Hadi SA, Gandahi JA, Shah MG, Masood S, Gandahi NS (2024). Protective response of zinc oxide nanoparticle with chitosan oligosaccharide on intestinal integrity, goblet cell count, and meat quality of broiler chicken under heat stress. J. Anim. Health Prod., 12(4): 621-629

Hana S, Al-Salhie KCK (2024). Evaluate the Impact of the Alcoholic Extract of Eruca sativa Seeds on the Physiological and Productive Responses of Broiler Chickens Exposed to Lead Acetate-Induced Oxidative Stress. Tikrit J. Agric. Sci., 24(3): 284-295. https://doi.org/10.25130/tjas.24.3.22

He X, Lu Z, Ma B, Zhang L, Li J, Jiang Y, Zhou G, Gao F (2019). Chronic heat stress alters hypothalamus integrity, the serum indexes and attenuates expressions of hypothalamic appetite genes in broilers, J. Therm. Biol., 81: 110-117. https://doi.org/10.1016/j.jtherbio.2019.02.025

Hussain SJ, Al-Salhie KCK (2022a). Effect of Water Quality and Vitamin C on the Growth Performance and Haematological Parameters of Broiler Chickens. Basrah J. Agric. Sci., 35(2): 248–258. https://doi.org/10.37077/25200860.2022.35.2.18

Hussain SJ, Al-Salhie KCK (2022b). Effect of Different Water Quality with and Without Vitamin C on Some Physiological Parameters of Broiler Chickens. IOP Conf. Ser. Earth Environ. Sci., 1060: 012075. https://iopscience.iop.org/article/10.1088/1755-1315/1060/1/012075

Khan RU, Naz S, Ullah H, Ullah Q, Laudadio V, Qudratullah Bozzo G, Tufarelli V (2023). Physiological dynamics in broiler chickens under heat stress and possible mitigation strategies. Anim. Biotechnol., 34(2): 438–447. https://doi.org/10.1080/10495398.2021.1972005

Lentfer TL, Pendl H, Gebhardt-Henrich SG, Fröhlich EK, Von Borell E (2015). H/L ratio as a measurement of stress in laying hens - methodology and reliability. Br. Poult. Sci., 56(2): 157–163. https://doi.org/10.1080/00071668.2015.1008993

Mangan M, Siwek M (2024). Strategies to combat heat stress in poultry production—A review. J. Anim. Physiol. Anim. Nutr.,108(3): 576-595. https://doi.org/10.1111/jpn.13916

Mehaisen GMK, Desoky AA, Sakr OG, Sallam W, Abass AO (2019). Propolis alleviates the negative effects of heat stress on egg production, egg quality, physiological and immunological aspects of laying Japanese quail. PloS One, 14(4): e0214839. https://doi.org/10.1371/journal.pone.0214839

Nawab A, Ibtisham F, Li G, Kieser B, Wu J, Liu W, Zhao Y, Nawab Y, Li K, Xiao M, An L (2018). Heat stress in poultry production: Mitigation strategies to overcome the future challenges facing the global poultry industry. J. Therm. Biol., 78: 131–139. https://doi.org/10.1016/j.jtherbio.2018.08.010

Nawaz AH, Amoah K, Leng QY, Zheng JH, Zhang WL, Zhang L (2021). Poultry Response to Heat Stress: Its Physiological, Metabolic, and Genetic Implications on Meat Production and Quality Including Strategies to Improve Broiler Production in a Warming World. Front. Vet. Sci., 8: 699081. https://doi.org/10.3389/fvets.2021.699081

Nazar FN, Videla EA, Fernandez ME, Labaque MC, Marin RH (2018). Insights into thermal stress in Japanese quail (Coturnix coturnix): dynamics of immunoendocrine and biochemical responses during and after chronic exposure. Stress (Amsterdam, Netherlands): 21(3): 257–266. https://doi.org/10.1080/10253890.2018.1442430

Oluwagbenga EM, Fraley GS (2023). Heat stress and poultry production: a comprehensive review. Poult. Sci., 102(12): 103141. https://doi.org/10.1016/j.psj.2023.103141

Santana TP, Gasparino E, de Souza Khatlab A, Brito CO, Barbosa LT, Lamont SJ, Del Vesco AP (2021). Effect of prenatal ambient temperature on the performance physiological parameters, and oxidative metabolism of Japanese quail (*Coturnix coturnix japonica*) layers exposed to heat stress during growth. Sci. Rep., 11(1): 9809. https://doi.org/10.1038/s41598-021-89306-0

SPSS (2018). Statistical Packages of Social Sciences. IBM Corp. Released 2018. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp. https:// www. ibm. com/analytics/spss-statistics-software

Sztandarski P, Marchewka J, Wojciechowski F, Riber AB, Gunnarsson S, Horbańczuk JO (2021). Associations between neck plumage and beak darkness, as well as comb size measurements and scores with ranging frequency of Sasso and Green-legged Partridge chickens. Poult. Sci., 100(9): 101340. https://doi.org/10.1016/j.psj.2021.101340

Tadele A, Berhane G, Esatu W, Wassie T (2023). Effect of genotype on hatchability, growth, morphometric and carcass traits of Chicken, J. Agric. Food Res.,11: 100531. https://doi.org/10.1016/j.jafr.2023.100531

Teeter RG, Smith MO, Owens FN, Arp SC, Sangiah S, Breazile JE (1985). Chronic heat stress and respiratory alkalosis: occurrence and treatment in broiler chicks. Poult. Sci., 64(6): 1060–1064. https://doi.org/10.3382/ps.0641060

Teeter RG, Smith MO (1986). High chronic ambient temperature stress effects on broiler acid-base balance and their response to supplemental ammonium chloride, potassium chloride, and potassium carbonate. Poult. Sci., 65(9): 1777–1781. https://doi.org/10.3382/ps.0651777

Truong L, King AJ (2023). Lipid oxidation and antioxidant capacity in multigenerational heat stressed Japanese quail (*Coturnix coturnix japonica*). Poult. Sci., 102(11):103005. https://doi.org/10.1016/j.psj.2023.103005

Wang Y, Saelao P, Chanthavixay G, Gallardo RA, Wolc A, Fulton JE, Dekkers JM, Lamont SJ, Kelly TR, Zhou H (2024). Genomic Regions and Candidate Genes Affecting Response to Heat Stress with Newcastle Virus Infection in Commercial Layer Chicks Using Chicken 600K Single Nucleotide Polymorphism Array. Int. J. Mol. Sci., 25(5): 2640. https://doi.org/10.3390/ijms25052640

Wasti S, Sah N, Mishra B (2020). Impact of Heat Stress on Poultry Health and Performances, and Potential Mitigation Strategies. Animals: Open Access J. MDPI, 10(8): 1266. https://doi.org/10.3390/ani10081266

Xu Y, Lai X, Li Z, Zhang X, Luo Q (2018). Effect of chronic heat stress on some physiological and immunological parameters in different breed of broilers. Poult. Sci., 97(11): 4073–4082. https://doi.org/10.3382/ps/pey256

Zmrhal V, Svoradova A, Venusova E, Slama P (2023). The Influence of Heat Stress on Chicken Immune System and Mitigation of Negative Impacts by Baicalin and Baicalein. Animals: an Open Access J. MDPI, 13(16): 2564. https://doi.org/10.3390/ani13162564