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Biochemical Assessment of the Impact of Temperature Stress on the Homeostasis System in Quails

Tukazban Rustamova[1], Aytaj Mammadova[2*]

Abstract. *Usually, in birds, as in all warm-blooded animals, homeostasis is understood as a combination of internal processes involving hormones, the endocrine system and metabolism. In order forquails raised in warm temperature conditions (summer months) to not fall into thermostress, biomarkers should be used to make timely diagnoses. In order to clarify the stress caused by temperature stress in breeding (mother) quails during the study period, we aimed to use the hormone cortisol as a biomarker. During the study, in order to examine the homeostasis indicators (physiological and biochemical) of temperature stress in all groups, the internal body temperature of the quails, the amount of cortisol, glucose, and hematological markers were first determined.*
The results showed that good results for quails were obtained during the period of maintaining air exchange at 4.5 m^3/h. Our research showed that the cortisol hormone can be used as a biomarker for timely and accurate determination of stress in quails during hot summer days.

Keywords: *quail, homeostasis, temperature stress, blood, biochemical markers, cortisol, erythrocytes*

Introduction

In the modern globalized world, numerous extreme factors exist that exert adverse effects on most physiological functions of living organisms. Under extreme conditions, alterations in homeostatic processes may occur, leading to the development of serious functional disorders within the organism. In birds, as in all warm-blooded animals, homeostasis is generally understood as the integration of internal processes involving hormones, the endocrine system, and metabolism. A considerable number of studies have been conducted in this field, particularly in regions characterized by high ambient temperatures, where the negative effects of heat stress on birds have been extensively investigated. Heat stress is known to disrupt endocrine balance and metabolic pathways in poultry (Lara & Rostagno, 2013; Scanes, 2016). These studies have focused on the changes occurring in the organism, especially in homeostatic regulation, under conditions of elevated temperature. Prominent researchers working in this area have elucidated the effects of various stress factors on the physiological state and productivity of animals and birds and have developed preventive measures to mitigate such adverse conditions (Mammadova, 2017, pp. 210–212; Taghiyev & Mammadova, 2018, pp. 109–112).

Studies conducted by researchers investigating avian immunity have demonstrated that when the ambient temperature in poultry housing reaches 40 °C for a period of two hours, a fivefold increase in the level of the hormone corticosterone produced by the adrenal glands is observed.

[1] Ganja State University, Doctor of Biological Sciences, Ganja, Azerbaijan
[2] Ganja State University, Ganja, Azerbaijan
[*]Corresponding author. E-mail: aytacmamedova2012@gmail.com
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During this period, alongside elevated corticosterone levels, significant changes in blood glucose concentration occur, resulting in an increase in glucose levels. Exposure to temperatures above the physiological norm not only leads to increased concentrations of corticosterone and glucose but also causes a reduction in hemoglobin content within erythrocytes by up to 28%. These alterations may adversely affect the overall health status and productivity of birds (Gross & Siegel, 1985, pp. 2230–2233; Vertiprakhov, 2021).

As is well known, the hormone cortisol is synthesized in the adrenal glands, which are paired endocrine organs, and plays a continuous role in regulating various stress responses in animals and birds. Adrenocorticotropic hormone (ACTH) is secreted into the bloodstream from the anterior lobe of the pituitary gland and, under its influence, stimulates the production of glucocorticoids in the cells of the adrenal cortex. Among these glucocorticoids, cortisol is considered one of the most essential in humans, animals, and birds. During stress, cortisol production increases in humans, animals, and birds, resulting in elevated cortisol concentrations in the blood. The synthesis of excessive amounts of cortisol requires a substantial expenditure of energy, which may limit the availability of energy necessary for the production of other hormones within the organism (Rustamova, 2019, pp. 63–68; Rzayev & Farzaliyev, 2014; Volodina et al., 2014, pp. 31–36).

To ensure timely diagnosis and prevent the development of heat stress in quails reared under high-temperature conditions during the summer months, the use of appropriate biomarkers is essential (Abushakhmanova, 2001, pp. 28–29; Amirov et al., 2020). During the course of the study, we aimed to identify the stress induced by temperature exposure in breeding (mother) quails by considering the hormone cortisol as a biomarker.

Materials and Methods

The study was conducted on a total of 100 breeding quails of the Texas Albino and Pharaoh breeds, which were divided into four groups using multiple experimental models. During the experiment, to investigate the effects of temperature stress on homeostatic (physiological and biochemical) parameters in all groups, the internal body temperature of the quails was first measured, followed by the determination of blood pH, cortisol levels, alkaline phosphatase activity, total protein content, glucose concentration, and hematological markers. All analyses were performed using modern automated analyzers (URIT-2900Vet Plus and URIT-880Vet).

Results and Discussion

Considering the points mentioned above, to investigate the changes in homeostasis of breeding quails during enhanced air exchange aimed at preventing temperature stress, the level of cortisol was measured. The obtained results are presented in Table 1.

Table 1.
Cortisol Levels in the Blood of Breeding Quails (n = 50, M ± m)
During Different Air Exchange Periods in Housing Facilities

Parameters	Groups				
	Control 3,5 m^3/hour	I experiment 3,0 m^3/hour	II experiment 4,0 m^3/hour	III experiment 4,5 m^3/hour	IV experiment 5,0 m^3/hour
Cortisol mg/dL: Morning	49,87±1,44	50,43±1,73	48,10±1,87	40,20±2,01	40,40±1,69
Cortisol mg/dL: Noon	53,74±2,14	54,70±1,76	49,70±1,64	40,31±2,19	42,14±1,43
Cortisol nmol/l: Evening	47,70±2,19	49,80±1,68	44,50±2,04	39,1 ± 2,11	38,70±1,51

As shown in Table 1, cortisol levels were higher in the morning and at noon, while by the evening (around 19:00), their concentrations decreased across all groups. This decline is attributed not only to the reduction in ambient temperature but also to changes in the microclimate within the housing facility, specifically the decrease in temperature. In the group where air exchange was maintained at a constant rate of 3.0 m³/hour per kilogram of body weight (Experiment 1), cortisol levels in breeding quails were highest in the morning and at noon, reaching 50.43 mg/dL and 54.7 mg/dL, respectively. These elevated cortisol levels indicate a state of significant temperature-induced stress in the breeding quails. In the control group, where breeding quails were kept under standard farm conditions, cortisol levels were considerably lower compared to those in Experiment 1, measuring 0.56 nmol/L and 0.96 nmol/L, respectively. Although the air exchange rates in Experiments II and III differed by only 0.5 m³/hour, cortisol levels in breeding quails maintained in Experiment III did not reach the upper limit observed in quails, remaining within acceptable physiological norms. These results indicate that maintaining an air exchange rate of 4.5 m³/hour produces favorable conditions for quail husbandry. Specifically, in Experiment III, cortisol concentrations were 40.20 ± 2.01 mg/dL in the morning, 40.31 ± 2.19 mg/dL at noon, and 39.1 ± 2.11 nmol/L in the evening. During the period of biomarker assessment, i.e., after confirming that the breeding quails were experiencing stress, their clinical and physiological parameters were determined. The obtained results are presented in Table 2.

Table 2.
Clinical and Physiological Parameters of Breeding Quails During Heat Stress (M ± m, n = 50)

Parameters	Groups				
	Control	I experiment	II experiment	III experiment	IV experiment
Internal (Core) body temperature, ^{0}C	41,70±0,81	41,90±1,04	41,50±0,53	41,25±0,29	41,14±0,73
Heart Rate, 1 min.	193,1±1,14	198,8±1,19	182,5±0,93	180,6±0,72	180,1±0,87
Respiratory Rate, 1 min.	39,9 ± 0,83	43,6 ± 0,75	34,8 ± 0,08	31,1 ± 0,09	29,6 ± 0,03
Erythrocytes, 10^{12}/L	2,81 ± 0,26	2,78 ± 0,14	2,84 ± 0,19	3,02 ± 0,21	3,04 ± 0,11
Leukocytes, 10^9/L	26,56±0,41	26,93±0,28	26,44±0,17	26,39±0,49	26,35±1,04
Hemoglobin, g/L	86,9 ± 2,11	83,9 ± 2,04	93,7 ± 3,06	114 ± 2,78	116 ± 3,19
Erythrocyte Sedimentation Rate (ESR), mm/hour	6,7 ± 0,27	7,2 ± 0,08	4,8 ± 0,08	4,6 ± 0,06	4,5 ± 0,02

As shown in Table 2, after the occurrence of temperature stress in quails, the internal body temperature of breeding quails in the control and Experiment 1 groupswhere air exchange was

maintained at 3.0 m³/hour and 3.5 m³/hour, was observed to increase to 41.90 °C in Experiment 1 and 41.70 °C in the control group. In Experiments III and IV, these values were lower by 0.45 °C and 0.56 °C compared to the control group, and by 0.65 °C and 0.76 °C compared to Experiment I, respectively. Measurement of heart rate revealed that breeding quails in Experiment I, where air exchange was the lowest, exhibited the highest heart rate at 198.8 ± 1.19 beats per minute. In contrast, quails in Experiment III and IV had heart rates of 180.6 ± 0.72 and 180.1 ± 0.87 beats per minute, respectively. Analysis of respiratory rate revealed that during periods of temperature stress, the number of respirations exceeded the physiological norm by 13.9 times. In the control group, breeding quails performed 39.9 ± 0.83 breaths per minute. This parameter was even higher in Experiment 1, where air exchange was maintained at 3.0 m³/hour. Specifically, breeding quails experiencing temperature stress in this group exhibited 43.6 ± 0.75 respirations per minute, representing an increase of 17.6 times above the physiological norm.

Conclusion

1. The results indicate that only minimal differences exist in the effect of air exchange on the clinical and physiological condition of quails in Experiments III and IV.
2. Based on the findings from Experiment III, it was possible to maintain breeding quails at zoohygienic normative levels in housing facilities with an air exchange rate of 4.5 m³/hour per kilogram of body weight, thereby preventing temperature-induced stress while also conserving electrical energy.
3. During the summer months, the impact of temperature stress on homeostasis in breeding quails can be effectively regulated by monitoring blood cortisol levels, allowing for the early detection and mitigation of abnormal physiological conditions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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