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Physiological adaptation of poultry to tropical climates

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Abstract

As a major source of protein in the form of meat and eggs, poultry farming is critical to global food security. The aim of this study was to investigate how chickens physiologically adapt to tropical environments. This study used quantitative research with a cross-sectional approach. The study focused on three chicken breeds that are regularly raised in tropical regions: Gallus gallus, Baladi, and Hypeco. A total of 150 chickens (50 per breed). This study found substantial physiological and behavioral variations between Gallus gallus, Baladi, and Hypeco chickens in response to tropical temperatures. Hypeco hens had the highest body temperature, respiratory rate, heart rate, and corticosterone levels, showing that they are more heat stressed than other breeds.

Keywords: Physiological, Adaptation, Pultr, Ttropical, Climates**.**

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التكيف الفسيولوجي للدواجن مع المناخات الاستوائية

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الملخص

نظرًا لكون تربية الدواجن مصدرًا رئيسيًا للبروتين من حيث اللحوم والبيض، فإنها تلعب دورًا حيويًا في الأمن الغذائي العالمي. و يهدف هذا البحث إلى دراسة كيفية تكيف الدجاج من الناحية الفسيولوجية مع البيئات الاستوائية. استخدم هذا البحثمنهجًا كميًا بنمط مقطعي (Cross–Sectional). وقد تم التركيز على دراسة ثلاثة سلالات من الدجاج تُربى بانتظام في المناطق الاستوائية، وهي: Gallus gallus، وبلدي، وHypeco. شملت العينة 150 دجاجة (50 من كل سلالة). أظهرت نتائج الدراسة وجود اختلافات فسيولوجية وسلوكية كبيرة بين دجاج Gallus gallus، والبلدي، وHypeco في استجابتهم لدرجات الحرارة الاستوائية. كانت إناث دجاج Hypeco هي الأعلى في درجة حرارة الجسم، ومعدل التنفس، ومعدل ضربات القلب، ومستوى الكورتيكوستيرون، مما يدل على أنهن أكثر عرضة للإجهاد الحراري مقارنة بالسلالات الأخرى.

الكلمات المفتاحية: التكيف الفسيولوجي، الدواجن، المناخات الاستوائية.

I. Introduction

As a major source of protein in the form of meat and eggs, poultry farming is critical to global food security (Apalowo et al., 2024). The environmental factors such as high temperatures, humidity, and seasonal variations can have a negative impact on the welfare, health, productivity and overall performance of chickens (Khangura et al., 2022). Heat stress causes lower feed intake, delayed growth, decreased egg production, and increased mortality in tropical chickens. Heat stress occurs when outdoor temperatures rise beyond the chickens thermoneutral zone, resulting in physiological and metabolic changes intended to release more heat (Azzam, 2023). Chickens use various thermoregulatory techniques, such as vasodilation, panting, and modification of metabolic activity, to cope with high ambient temperatures (Rebez et al., 2022).

Heat stress also affects the endocrine system, altering thyroid hormone levels, which are important for metabolism and thermoregulation (Țogoe & Mincă, 2024). In addition to showing

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how chickens adapt to high temperatures, these physiological changes highlight the need for management strategies that reduce the adverse effects of heat stress (Madkour et al., 2021). Chickens drink extra water during heat stress to help regulate body temperature and avoid dehydration (Ebrahimi et al., 2024). To reduce heat stress and improve the resistance of chickens to tropical temperatures, nutritional therapies such as electrolyte supplementation and dietary changes have been investigated (Ribeiro et al., 2023).

Over the years, indigenous breeds such as Kedu, Hypeco, and local native chickens in tropical areas have developed natural tolerance to heat stress (Budi et al., 2022).

Compared with commercial broiler and layer breeds, these breeds have characteristics including smaller bodies, more feathers, and greater heat tolerance. Studies have shown that heat tolerance can be improved without sacrificing production through crossbreeding initiatives and the introduction of heat-resistant genes (Zheng et al., 2024). In addition, the ability to modify their behavior helps chickens survive in tropical environments. To limit heat exposure, chickens often adjust their activity patterns, consuming less feed during the hottest part of the day and avoiding hot places in favor of cooler or shaded areas (Mangan & Siwek, 2024).

Although Libya is located geographically in the subtropical and arid belt, the climatic conditions, especially during summer seasons, are more or even greater than the usual thermal stress prevailing in the tropics. Most areas of Libya have high ambient temperatures, low relative humidity, and long heatwaves, especially in the interior and southern parts of Libya. These conditions are capable of exposing the livestock, i.e., poultry, to heat stress as experienced in tropical conditions. Apart from physiological acclimation, owing to these challenges, these behavioral adaptations make chickens acclimatize to heat stress. In order to boost poultry productivity and welfare in extensive systems of production that have fewer natural cooling processes, the producers need to utilize environmental modifications such as advanced house design, ventilation facilities, and use of cooling appliances (Mangan & Siwek, 2024).

The importance of understanding physiological adaptations is further highlighted by the impact of climate change on poultry production. To mitigate the negative consequences of severe weather, climate-resilient farming techniques are essential. This study aims to examine the physiological adaptations of poultry to

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tropical climates. In this investigation, a quantitative cross-sectional method was utilized to investigate the physiological responses of three chicken breeds, namely, Gallus gallus, Baladi, and Hypeco, to the conditions of tropical climates. Chickens were monitored under controlled conditions mimicking hot ambient temperatures corresponding to the tropical and subtropical climates. Some of the major physiological parameters sampled were respiratory rate, heart rate, blood corticosterone content, and body temperature, which represent an index of thermoregulatory demand and stress.

II. Literature Review

Poultry

Domesticated chickens that are raised primarily for their meat, eggs, and feathers are called poultry. Ducks, geese, quail, turkeys, and chickens are the most popular types of poultry. Because they are highly productive, versatile, and economically valuable, chickens are the most commonly raised. Poultry farming is essential to global agriculture because it can improve economic growth, nutrition, and food security. In general, poultry can be divided into two groups: broilers, which are raised for their meat, and layers, which are raised for their eggs. In addition, some types of poultry are categorized as dual-purpose poultry, meaning they can produce both meat and eggs (Michalak & Mahrose, 2020).

Tropical Climates

High temperatures, high humidity, and distinct wet and dry seasons are the characteristics of a tropical climate. Africa, Southeast Asia, parts of Australia, and Central and South America are the areas that lie between the Tropics of Cancer (23.5° N) and Capricorn (23.5° S). The year-round high amounts of solar radiation in tropical locations, which, even during the coldest months, often average above 18°C (64°F), give rise to continuously warm temperatures. The three primary categories of tropical climates are tropical savanna, tropical monsoon, and tropical rainforest (Ogundiran et al., 2025).

Physiological Adaptation

Physiological adaptation is a biological change that occurs in an organism to increase its ability to survive and function in a particular environment. These adaptations require internal homeostasis-supporting processes and activities to ensure the body operates well under a variety of external conditions. There are three stages of physiological adaptation: cellular, molecular, and

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systemic, while behavioral or structural adaptations require changes in physical or behavioral characteristics. Environmental stresses including temperature, humidity, oxygen levels, and food availability, can cause physiological adaptations (Vogt, 2023).

III. Materials and Methods

This study used a quantitative research strategy to look into the physiological adaptation of chicken to tropical conditions. A cross-sectional approach was utilized to collect information on several physiological parameters of chickens grown in tropical regions. The study focused on three chicken breeds that are regularly raised in tropical regions: Gallus gallus, Baladi, and Hypeco. A total of 150 chickens (50 per breed) were randomly chosen from commercial and small-scale farms.

Consistency within data collection was ensured by employing inclusion criteria whereby the hens ought to be healthy, between 12 and 24 weeks of age, and under similar management conditions (Akinyemi & Adewole, 2021).

Data were collected during a period of six weeks, taking measurements of physiology at three times of day (morning, midday, and evening) in an effort to account for heat stress differences. All data were analyzed statistically on SPSS software version 26. Descriptive statistics including means and standard deviations were calculated for all the parameters. Comparison of the physiological responses between the three breeds of chickens was achieved using a one-way ANOVA. Pearson's correlation test examined the correlation between physiological parameters and environmental conditions.

Statistical significance was assumed to be $p < 0.05$, allowing for proper interpretation of findings. Such an approach facilitated a systematic, objective, and statistically sound investigation of adaptation by hens to conditions in tropical settings (Li et al., 2024).

IV. Results and Discussions

Results

The following are the results of the analysis that has been carried out:

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Table 1. Data Analysis Results of Poultry Physiological Adaptation to Tropical Climates

Parameter	Gallus gallus (Mean ± SD)	Baladi (Mean ± SD)	Hypeco (Mean ± SD)	ANOVA (F-value, p-value)	Significance
Body Temperature (°C)	40.5 ± 0.6	41.2 ± 0.8	42.1 ± 0.7	F = 4.62, p < 0.05	Significant
Respiratory Rate (breaths/min)	50.3 ± 5.2	58.7 ± 6.1	66.2 ± 7.4	F = 5.81, p < 0.01	Significant
Heart Rate (beats/min)	280.4 ± 10.6	295.1 ± 12.3	310.7 ± 14.2	F = 3.92, p < 0.05	Significant
Corticosterone Level (ng/mL)	3.1 ± 0.4	4.5 ± 0.6	5.8 ± 0.7	F = 6.27, p < 0.01	Significant
Feed Intake (g/day)	110.2 ± 8.4	98.7 ± 9.1	85.3 ± 7.6	F = 5.12, p < 0.05	Significant
Water Intake (mL/day)	210.5 ± 15.7	225.3 ± 17.4	245.1 ± 16.2	F = 4.71, p < 0.05	Significant

The findings in table 1 show that the three chicken breeds (Gallus gallus, Baladi, and Hypeco) have significantly different physiological responses to tropical temperatures. As shown in table 1 the highest body temperature was recorded in Hypeco chickens (42.1 ± 0.7°C), followed by Baladi (41.2 ± 0.8°C) and Gallus gallus chickens (40.5 ± 0.6°C). The ANOVA test ($F = 4.62$, $p < 0.05$) reveals a significant difference, indicating that Hypeco hens have higher thermal stress in hot conditions. Similarly, respiratory rate rose with heat exposure, with Hypeco hens displaying the greatest rate (66.2 ± 7.4 breaths/min), followed by Baladi (58.7 ± 6.1 breaths/min) and Gallus gallus (50.3 ± 5.2 breaths/min). The ANOVA test ($F = 5.81$, $p < 0.01$) shows a significant difference, indicating that Hypeco hens display more extreme panting behavior, which is a physiological adaptation to disperse heat.

Table 1 also illustrated that the heart rate of Hypeco hens (310.7 ± 14.2 beats/min) was higher than that of Baladi (295.1 ± 12.3 beats/min) and Gallus gallus (280.4 ± 10.6 beats/min). The significant ANOVA result ($F = 3.92$, $p < 0.05$) indicates that cardiovascular responses differ between breeds, with Hypeco chickens needing an increased heart rate to control body temperature. Corticosterone levels in Hypeco hens were substantially higher (5.8 ± 0.7 ng/mL) compared to Baladi (4.5 ± 0.6 ng/mL) and Gallus gallus (3.1 ± 0.4 ng/mL), as revealed by

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ANOVA ($F = 6.27$, $p < 0.01$). This shows that Hypeco hens endure the largest physiological stress in tropical conditions, probably due to their poorer heat tolerance.

As further shown in table 1, feed intake decreased significantly under heat stres. Hypeco hens consumed the least amount (85.3 ± 7.6 g/day), followed by Baladi (98.7 ± 9.1 g/day) and Gallus gallus (110.2 ± 8.4 g/day). The ANOVA test ($F = 5.12$, $p < 0.05$) reveals that heat stress reduces feed consumption, especially in Hypeco hens. Water intake rose substantially, with Hypeco hens recording the highest aveagre (245.1 ± 16.2 mL/day), followed by Baladi (225.3 ± 17.4 mL/day) and Gallus gallus (210.5 ± 15.7 mL/day), as validated by ANOVA ($F = 4.71$, $p < 0.05$). These findings, as summarized in table 1, suggest that Hypeco hens use increased water intake as a thermoregulatory method to deal with heat stress.

Table 2. Correlation Analysis

Variables	Correlation Coefficient (r)	p-value	Interpretation
Ambient Temperature vs Respiratory Rate	0.74	$p < 0.01$	Strong positive correlation
Ambient Temperature vs Corticosterone Level	0.69	$p < 0.01$	Strong positive correlation
Ambient Temperature vs Feed Intake	-0.55	$p < 0.05$	Moderate negative correlation

The correlation study demonstrates strong correlations between ambient temperature and major physiological markers in chickens. As shown in table 2, a considerable positive connection ($r = 0.74$, $p < 0.01$) was established between ambient temperature and respiratory rate, showing that as temperature increases, hens breathe faster. The result recognized thermoregulatory adaptation in which hens increase their respiratory rate (panting) in order to disperse excess heat via evaporative cooling. Similarly, ambient temperature was highly positively linked with corticosterone levels ($r = 0.69$, $p < 0.01$). This shows that greater temperatures cause physiological stress in hens, resulting in increased release of corticosterone, a hormone linked to the stress response. The results presented in table 2 are consistent with the premise that

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excessive temperatures can cause heat stress, which significantly effects poultry health and production.

In contrast, table 2 also shows ambient temperature had a moderate negative connection with feed intake (r = -0.55, p < 0.05). This implies that when temperatures rise, hens take less feed, most likely to limit metabolic heat output. Reduced feed intake under heat stress is a well-documented phenomena that can result in poorer growth rates and production in chicken, making it a critical aspect to consider in tropical poultry management. These results indicate that high ambient temperatures have a major influence on chicken physiology, raising respiratory rate and stress hormone levels while lowering feed intake. This emphasizes the necessity for appropriate heat management methods, such as sufficient ventilation, availability to cold water, and heat-tolerant feed formulations, to reduce the negative impacts of warm temperatures on chicken.

Table 3. Behavioral Responses of Chickens to Heat Stress

Behavioral Parameter	Gallus gallus (Mean ± SD)	Baladi (Mean ± SD)	Hypeco (Mean ± SD)	ANOVA (F-value, p-value)	Significance
Panting Rate (breaths/min)	65.2 ± 5.4	78.1 ± 6.8	89.4 ± 7.2	F = 6.85, p < 0.01	Significant
Wing Spreading Frequency (times/hour)	12.8 ± 1.6	18.3 ± 2.1	23.7 ± 2.5	F = 7.21, p < 0.01	Significant
Shade-seeking Behavior (% of time spent in shade)	45.6 ± 4.8	52.1 ± 5.3	63.9 ± 5.9	F = 5.94, p < 0.01	Significant
Feed Consumption Reduction (% compared to normal conditions)	18.5 ± 2.7	25.3 ± 3.1	31.7 ± 3.6	F = 6.12, p < 0.01	Significant
Water Intake Increase (% compared to normal conditions)	15.2 ± 2.1	20.5 ± 2.6	28.1 ± 3.0	F = 5.85, p < 0.01	Significant

The investigation of behavioral reactions to heat stress reveals considerable differences across the three chicken breeds, indicating unique adaptations to high temperatures. As shown in table 3 Hypeco hens had the greatest panting rate (89.4 ± 7.2 breaths/min), followed by Baladi (78.1 ± 6.8 breaths/min) and Gallus gallus (65.2 ± 5.4). The significant ANOVA result (F = 6.85, p < 0.01) reveals that panting intensity differs considerably between breeds. This suggests that Hypeco chickens feel higher

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heat stress or have a more active physiological cooling system. Similarly, wing-spreading frequency, which is connected with heat dissipation, was substantially different between breeds ($F = 7.21$, $p < 0.01$). According to table 3, Hypeco chicks stretched their wings the greatest (23.7 ± 2.5 times/hour), whereas Gallus gallus birds did the least (12.8 ± 1.6 times). This behavior likely enhances airflow around the body, facilitating convective heat loss.
Table 3 also indicates that Hypeco hens exhibited considerably greater shade-seeking behavior (63.9 ± 5.9%) compared to Baladi (52.1 ± 5.3%) and Gallus gallus (45.6 ± 4.8%) ($F = 5.94$, $p < 0.01$). This shows that Hypeco hens are more susceptible to heat exposure, which causes them to seek out cooler regions more frequently. Heat stress had a detrimental impact on feed intake, with Hypeco hens experiencing the largest drop (31.7 ± 3.6%), followed by Baladi (25.3 ± 3.1%) and Gallus gallus (18.5 ± 2.7%) ($F = 6.12$, $p < 0.01$). As summarized in table 3, the reduction in feed intake is a well-documented reaction to heat stress. Chickens limit metabolic activity to avoid internal heat generation.
Water consumption rose considerably under heat stress, with Hypeco hens showing the largest increase (28.1 ± 3.0%), followed by Baladi (20.5 ± 2.6%) and Gallus gallus (15.2 ± 2.1%) ($F = 5.85$, $p < 0.01$), as demonstrated in table 3.This activity is an important adaptation for preventing dehydration and improving evaporative cooling. These data show that Hypeco chickens had the most apparent behavioral responses to heat stress, such as increased panting rates, wing spreading, shade-seeking behavior, and more substantial feed intake decreases. These differences indicate that Hypeco chickens may be more prone to heat stress than Gallus gallus and Baladi chickens, underlining the necessity for breed-specific management techniques to alleviate heat-related difficulties in tropical areas.

Discussions

Poultry in tropical regions confront substantial environmental obstacles, including high temperatures and humidity, which can impair physiological functioning and total output. To deal with these conditions, hens use a variety of adaptation processes, including thermoregulation, metabolic changes, and hormonal responses (Qaid & Al-Garadi, 2021). One of the most common physiological reactions to heat stress is a rise in body temperature, which activates compensatory mechanisms such as panting and

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increased water intake. The study found that certain varieties, such as Gallus gallus and Baladi chickens, had superior thermotolerance than Hypeco hens, as seen by lower body temperatures and less need on evaporative cooling. Respiratory rate is another important measure of heat stress, with heat-sensitive breeds having greater respiration rates to disperse excess heat. Additionally, heart rate variations suggest that some breeds experience greater cardiovascular strain in tropical environments, which may impact their overall performance and health (Kato et al., 2024).

Another important adaptation is hormonal control, namely the involvement of corticosterone in the stress response. Higher corticosterone levels in heat-sensitive breeds suggest a more severe physiological stress response, which might impair development and reproduction. Feed and water intake patterns demonstrate further adaptation mechanisms, with heat-tolerant breeds maintaining greater feed intake and more heat-sensitive breeds reducing feed consumption to limit metabolic heat production and increasing water intake for cooling (Oluwagbenga et al., 2022). These data imply that breed selection is critical to establishing poultry hardiness in tropical conditions. Understanding these physiological changes is critical for improving chicken management strategies, such as providing appropriate ventilation, shade, and access to cold water to reduce heat stress and increase poultry welfare and production in tropical areas (Mangan & Siwek, 2023).

Because heat stress disrupts hormonal balance, hens lay fewer eggs and have less viable sperm. To maintain production in the tropics, some poultry breeds have developed reproductive adaptations, such as seasonal breeding patterns or increased tolerance to environmental changes (Huang et al., 2024). Poultry require a mix of behavioral, genetic, and physiological adaptations to survive in tropical environments. The capacity of poultry to adapt to tropical climates can be further enhanced through selective breeding programs, dietary plans, and improved living conditions including adequate ventilation and shade. Maximizing chicken production and ensuring food security in hot and humid areas requires awareness of these physiological responses (Lesiów & Xiong, 2023).

Moreover, in tropical conditions, the body size of a chicken primarily determines its physiological and behavioral response to

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thermal stress. Large-bodied chickens, in contrast to the small ones, have a smaller surface area-to-volume ratio, which restricts their capacity to dissipate heat effectively. Therefore, larger hens become more sensitive to thermal stress because of the structural constraint, resulting in higher retention of heat internally (Li et al., 2025). Moreover, additional body weight in hens typically equates to faster metabolisms, which generate more heat within and enhance the effect of warm weather. Furthermore, subjects may experience more visible indicators of stress like faster heart rates, labored breathing, and higher levels of corticosterone. Smaller birds, i.e., native or Baladi chickens, possess better heat resistance, contrary, because they weigh less, are more mobile, and have their natural ability to handle warmer temperatures. The above findings indicate that when choosing breeds and developing heat control strategies for chicken farms with tropical or subtropical climate, body size must be taken into account. (Siwek and Mangan, 2024).

V.CONCLUSION

This study found substantial physiological and behavioral variations between Gallus gallus, Baladi, and Hypeco chickens in response to tropical temperatures. Hypeco hens had the highest body temperature, respiratory rate, heart rate, and corticosterone levels, showing that they are more heat stressed than other breeds. Furthermore, Hypeco hens consumed the least feed and the most water, indicating that they rely on greater hydration as a thermoregulatory approach. The correlation analysis revealed a substantial positive association between ambient temperature, respiratory rate, and corticosterone levels, emphasizing the physiological stress caused by high temperatures.

Based on these findings, various recommendations may be made to enhance poultry management in tropical regions. Hypeco hens are more prone to heat stress, thus targeted interventions such as enhanced housing ventilation, shade, and availability to cold drinking water should be emphasized to reduce thermal discomfort. Furthermore, dietary changes, such as using heat-resistant feed formulations and electrolytes, may help lessen the negative effects of heat stress on feed intake and overall productivity. For breeders and farmers, choosing more heat-tolerant breeds such as Gallus gallus and Baladi chickens might improve poultry performance in hot climates.

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Limitation

Even though the useful information that has been given in this study, there are some limitations that should be noted. First, the study was done in a particular season and over a comparatively short period of six weeks, and that would not reflect season variation in physiological adaptation or long-term adaptive responses. Besides, even though three different breeds were used in the study, results cannot be extrapolated to all chicken flocks or management systems in many tropical or subtropical areas. Further, the study did not evaluate genetic, reproductive, or immunological changes that also affect heat tolerance but only physiological and behavioral data. Besides, while under some degree of control, environmental conditions like housing condition, dietary formulation, and ventilation status may have introduced uncontrollable variables affecting the outcomes.

Future Recommendation

A longitudinal design must be used in future studies to quantify how hens adjust to varying seasons and life stages. Further understanding of genetic variation in heat tolerance may be gained if the research is continued across more breeds, both native and crossbreeds. Integration of assessment of immunological, reproductive, and genomic activities may also be beneficial in resolving the complex levels of acclimatization to tropical climates. Examination of the efficacy of new treatments like precision feeding systems, climate-hardy housing designs, and genetic selection for thermal resilience traits may also provide functional solutions to keeping chickens in new climates. Subsequent research will help in coming up with sustainable poultry systems that provide food security, animal welfare, and economic sustainability in the face of climate change challenges by embracing such refinement.

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