Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 11:2026
DOI: 10.5281/zenodo.24106431

PHYSIOLOGICAL RESPONSES TO STRESS IN BROILER CHICKENS : A COMPREHENSIVE ANALYSIS

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Abstract

Transportation and heat stress are some of the many stress factors that broilers encounter, which have great impacts on the welfare, productivity, and physiology of the birds. The objective of the present study was to assess the impacts of these stress factors on several physiological parameters such as oxidative stress markers, endocrine, hematology, thermoregulatory, and cardiovascular parameters. This research employed a quantitative methodology. Thirty broilers (Gallus gallus domesticus) were used as subjects. The analysis was done by using computer software known as SPSS. The findings revealed that the elevation in corticosterone, increase in H/L ratio, and variation in heart rate, respiration rate, and body temperature were as a result of heat and transit stress. This shows that there could be immunosuppression

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and HPA axis stimulation. The broiler feed should be enriched with antioxidants and electrolytes, optimize transport, and control the environment.

Keywords: Physiological, Responses, Stress, Broiler, Chickens.

I. INTRODUCTION

Broiler chickens are the most cost-effective livestock and have the benefit of producing meat quickly, since they can eat them with only a 4- to 5-week maintenance period. Chicken producers use trucks and similar vehicles for transportation in order to carry out distribution activities. Because their surroundings change while they are being transported, the hens' physiological states also alter. Changes in the environment, such travel lengths, are believed to stress hens, interfering with their homeostatic functions and metabolism (Kim et al., 2023). Stress impacts on the physiology of the livestock, especially the metabolic components of the same, leading to weight loss and sometimes to death. Furthermore, after transportation, the physiological components including blood and hormones change and affect the physiological state of the livestock, and this in turn impacts the composition of the meat obtained. Because of the disparity between the body temperature and environmental temperature, elements such as travel distance, density of the livestock in the transportation basket, speed, and vibrations could stress the hens. Because of changes in their surroundings, broilers may experience stress throughout the transit process. Livestock are stressed throughout the lengthy transportation procedure and may experience shocks as a result of bad road conditions. It may have an impact on modifications to livestock's physiological circumstances (Balakrishnan et al., 2023). One of the many things that stressed chickens will lack during transit is the ability to lose body weight. The loss of fluids and nutrients is the reason for weight loss. Because excessive body weight loss reduces farmer revenue, efforts should be taken to limit this loss during transportation. Furthermore, it is believed that the hematological of animals would see an increase in heart rate, respiration, and body temperature throughout the transit procedure. Furthermore, unlike acute heat stress, chronic heat stress destroys the muscular section of the bird and increases its fat content, which has a lifelong negative impact on broiler chickens. In addition to heat stress duration, heat stress intensity also affects the amount of production damage (Nawaz et al., 2021). As temperatures continue to rise owing to global warming, it will become more difficult to prevent the harmful effects of heat exhaustion in animal husbandry, where the temperature surpasses the thermo-neutral zone and the animal loses its ability to control its body temperature (Ahmad et al., 2021). Climate change caused by global warming is becoming increasingly important these days, especially for the chicken meat industry. Broilers are particularly susceptible to heat stress due to their rapid development and metabolism, which increases production costs and drastically reduces meat quality. When chickens, especially broilers, are raised in a heat-stressed environment, metabolic changes take place that result in a significant reduction in the size of their breast muscles. The decrease in muscle protein content is also caused by heat stress (Wasti et al., 2020). The purpose of this study is to investigate how broiler chickens' bodies react to stress.

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II. LITERATURE REVIEW

Physiological Responses To Stress

Physiological response to stress refers to biological or biochemical changes taking place within an organism due to the presence of a stressor. By stimulating the hypothalamus-pituitary-adrenal axis and the sympathetic-adrenal-medullary axis, such responses affect the hormones, metabolism, circulatory system, and immune system in broilers (Huang et al., 2024). Elevated corticosterone levels, elevated cardiac and respiratory activity, oxidative stress, immune system suppression, and variations in temperature are some of the physiological markers of such stressors. Even though these responses may be aimed at enabling chickens to deal with stress conditions, they have the potential of affecting welfare and productivity of the chickens negatively (Zmrhal et al., 2022). Stress integration in animals is a complex and coordinated process involving neurological and physiological responses to stressors. A sequence of interrelated processes inside an animal's body results from this stress response, which includes the organism's reaction to both internal and external stressors (Tsigos et al., 2020). The first step in an animal's response to stresses is the biological processes' recognition and communication of a perceived threat. This then sets off the neurophysiological mechanisms that are meant to start a biological reaction to fend against and lessen any damage (Grogans et al., 2023).

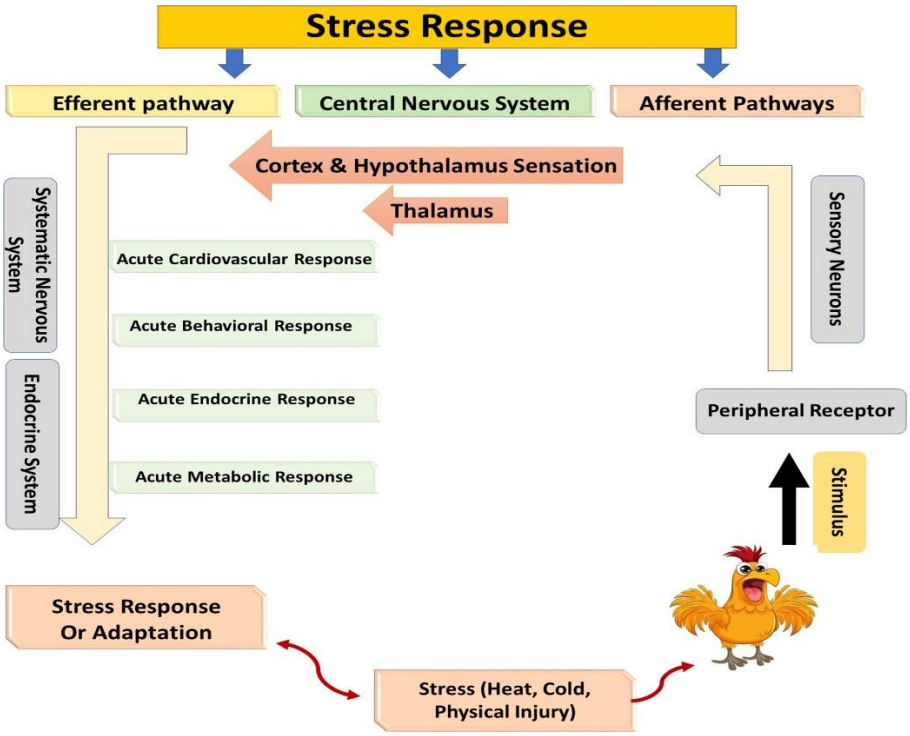

Figure 1: Mechanism of the Stress Response in Poultry Animals (Ncho Et Al., 2024)

Interestingly, in addition to receiving information about the stressor, the different sensory detectors also translate this information into brain impulses. To help the body respond to

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challenges in a coordinated manner, these signals are then sent to cognitive and noncognitive areas of the neurological system. This concerted reaction consists of the interaction between the central nervous system (CNS), endocrine system, and immune system, which operate in conjunction with each other to react to stress and affect the behavior of the organism, as illustrated in Figure 1. It is emphasized by the presence of the relationship and coordination between the three systems by the presence of shared hormones, neurotransmitters, and receptors (Ncho et al., 2024).

Temperature-Related Stressors

Temperature has a significant impact on poultry growth at every stage, from embryonic to mature (Liu et al., 2022). Common chicken species are not very good in controlling their body temperature, particularly when the outside temperature is outside of the 16–26°C range. Because of this trait, chickens are susceptible to both high and low ambient temperatures, particularly the more recent strains that are the result of years of selective breeding (Shakeri & Le, 2022). For example, several species utilized in animal production need temperatures higher than 36°C during their embryonic development. Furthermore, departures from the ideal temperature, including being exposed to cold temperatures during the first week following hatching, can result in serious health problems and, eventually, death (Sampaio et al., 2023). For instance, at 27 days of age, broilers develop best at temperatures between 20°C and 24°C. Therefore, it is essential to comprehend how chickens' bodies react to drastic temperature changes. Figure 2 illustrates the detrimental consequences of both heat and cold stress, highlighting the need of comprehending the intricate connection between temperature variations and avian physiology (Ncho et al., 2024).

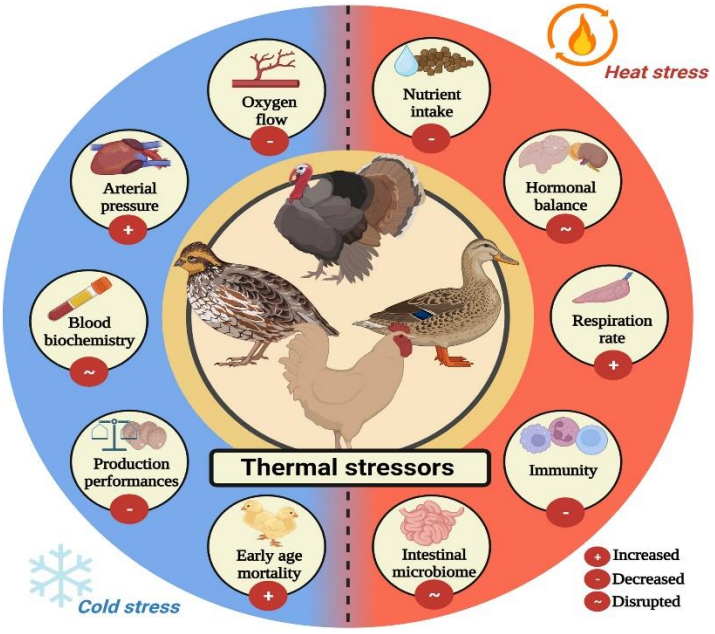

Figure 2: Selected Established or Suggested Effects of Thermal Stressors on the Poultry (Ncho Et Al., 2024)

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The physiological, metabolic, and genetic alterations brought on by heat stress are depicted in Figure 3, along with how they affect the quantity and quality of chicken meat. Stress is defined as any external stimulus that interferes with the normal biological and physiological processes in living cells and jeopardizes the existence of the living organism (Nawaz et al., 2021). Temperature is one of the factors that contribute to environmental stress in the development of broilers, it lowers food safety and production efficiency while upsetting the physiology of chickens. According to Olejnik et al. (2022), Three levels of stress are common in animals. The first, the term alert state, refers to the way the body responds to external stress. Second, stress triggers the immune system in living cells; as a result, the body attempts to adjust to the new surroundings if stress continues (Alotiby, 2023). The fatigue stage results if the body is unable to handle the stress in spite of all the resistance. Depending on the severity and length of the stress, every living thing reacts to heat stress differently (Nawaz et al., 2021). Since heat-stressed chickens spend the majority of their time acclimatizing to the heat stress by resting, drinking more water, and panting, numerous studies have documented a significant decrease in feeding and walking duration (discrete values) of chickens kept under heat stress conditions (Dedousi et al., 2022). By triggering the autonomic nerve system (ANS), which frequently controls fight-or-flight responses in living things, the neuroendocrine system plays a crucial part in the heat stress response. The ANS assumes control in reaction to heat stress, causing tachycardia (an elevated pulse), raising breathing rate, and improving blood flow to the skin and body's peripheries for optimal heat loss and temperature maintenance (Shakeri et al., 2020).

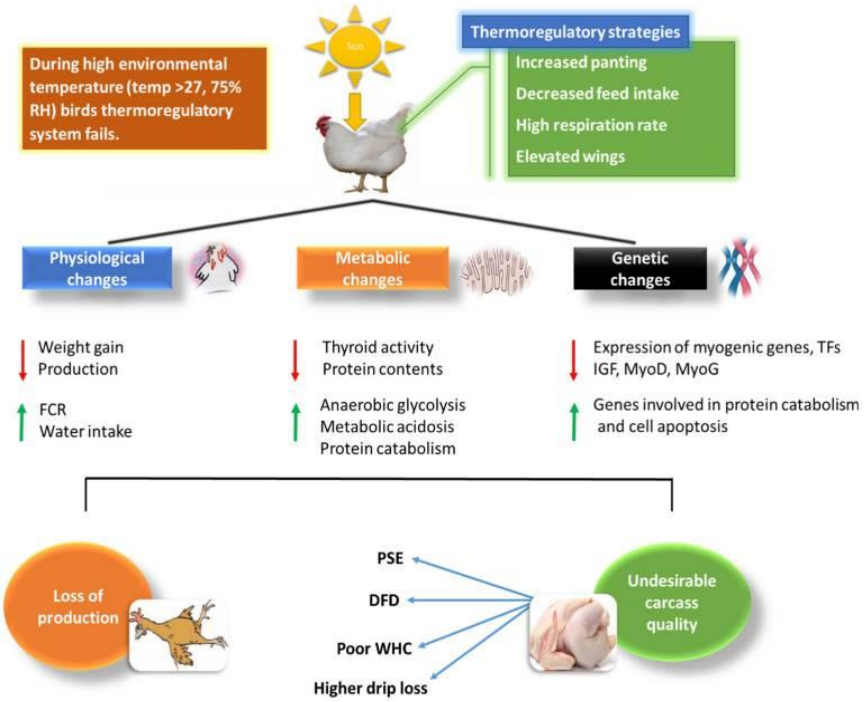

Figure 3: Relationship of HS With Physiological and Biochemical Changes in Chicken and How it Affects Broiler Chickens' Meat Quality (Nawaz Et Al., 2021)

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Additionally, it decreases muscles' ability to store energy by encouraging the breakdown of glycogen into glucose. Catecholamine release is favorably regulated by neuroendocrine system activation (Kwakye et al., 2023). In that regard, since it inhibits the functioning of the enzyme glycogen phosphorylase and activates muscle glycogenolysis via acting through beta androgenic receptors of the muscles, catecholamines inhibit the normal functioning of enzymes in the skeletal muscles. Besides triggering the activation of SAM pathway, heat stress is also responsible for the activation of HPA pathway, which is associated with glucocorticoids and causes muscle vasodilation, lipolysis, and proteolysis (Alaqil et al., 2021).

Broiler Chickens

Domesticated birds that have been selectively bred and reared specifically for the purpose of producing meat, broiler chickens are characterized by good meat yield, rapid rate of growth, and efficient feed conversion. Broilers are purposely bred to attain market weight within a short duration of about 5 to 7 weeks, and they belong to the species of Gallus gallus domesticus (Tellis et al., 2023). The broilers have unique physiological features, and unlike the laying hens, which are reared for egg production, broilers have unique features such as high metabolic rate, good appetite, and superior muscle growth, particularly the breast and thigh muscles. According to Ferreira et al. (2024), broilers are usually kept under regulated conditions whereby efficiency of feed utilization and growth performance is optimized by regulating certain variables like temperature, humidity, lighting, and nutrition.



Figure 3: Broiler Chicken (Baxter & O'connell, 2023)

Advances in broiler genetics have been achieved using selective breeding, producing fast-growing breeds like Arbor Acres, Cobb 500, and Ross 308, all of which dominate the poultry industry at present. These cickens are able to store meat and maintain energy due to their calm nature and low level of physical activity. These chickens tend to be pale yellow in color and have white feathers (Tudorache et al., 2022). In order to boost their

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growth and development as well as protect their health, high-energy food containing high levels of proteins, vitamins, and minerals is provided. Nevertheless, such fast growth also results in various problems such as metabolic disorders, such as ascites and sudden death syndrome, skeletal problems, as well as cardiovascular issues (Lee and Mienaltowski, 2023). Due to being cheap and highly nutritious, the production of broiler chickens is an important part of the poultry farming industry (Haque et al., 2020). Some of the biggest broiler meat producing countries are, for example, the USA, Brazil, China and India. In order to cater to the rising demand for high-quality chicken products, the use of sustainable broiler meat production is gaining prominence to increase welfare conditions for chickens and minimize the adverse effects on the environment. These sustainable practices include stress mitigation procedures, appropriate diet and housing. The progress achieved in the genetic breeding, nutrition and management of broilers has resulted in broiler production becoming a major agricultural industry (Leite et al., 2024).

III. MATERIALS AND METHODS

The physiological reactions of broiler chickens in Libya to various stressors were assessed using a quantitative approach in this study. In this experiment, thirty broilers (Gallus gallus domesticus) were used as subjects. The broilers were randomly allocated to three groups: those exposed to temperature stress, transportation stress, and the control group without any stress. This experiment was carried out in an experimental station for poultry, where the environment had been controlled in terms of temperature, humidity, and light conditions. The following are stress reduction techniques:

1. The Control (No Stress) Group was maintained in a perfect habitat with 22–24°C temperatures, sufficient ventilation, unrestricted access to food and water, and no human involvement.
2. The Thermal Stress Group was subjected to high temperatures of 35°C for six hours every day for a predefined amount of time in order to replicate heat stress conditions that are typical in chicken farms.
3. The Transport Stress Group underwent a two-hour simulated transport process that included confinement at a certain stock density inside a transport container to mimic real-world transport situations that result in mechanical and environmental stress.

Numerous biological indicators were evaluated in order to evaluate physiological stress reactions.Blood samples were taken from the brachial vein of each bird at the end of the experiment to analyze corticosterone, an important marker of stress. The immune response was assessed by measuring hematological indicators, such as the heterophil to lymphocyte ratio (H/L), using standard laboratory techniques. In addition, body temperature was recorded using a digital thermometer, a portable heart rate monitor is used to assess heart rate, and direct observation is used to determine respiratory rate. To assess the amount of cellular stress, spectrophotometry was used to measure oxidative stress markers such as malondialdehyde (MDA) levels and superoxide dismutase (SOD) activity (Leishman et al., 2021).

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All measurements were made in the morning to minimize time variations. Analysis of the experiment was done using statistical tools in the SPSS software program. Physiological responses of the three groups were assessed through a one-way analysis of variance (ANOVA) method then multiple comparisons using the Tukey's post-hoc test. All experiments in the research follow international standards of caring for animals because of strict adherence to ethical considerations. The study allowed for an in-depth examination of the influence of various types of stress on the physiological response of broilers (Zou et al., 2024).

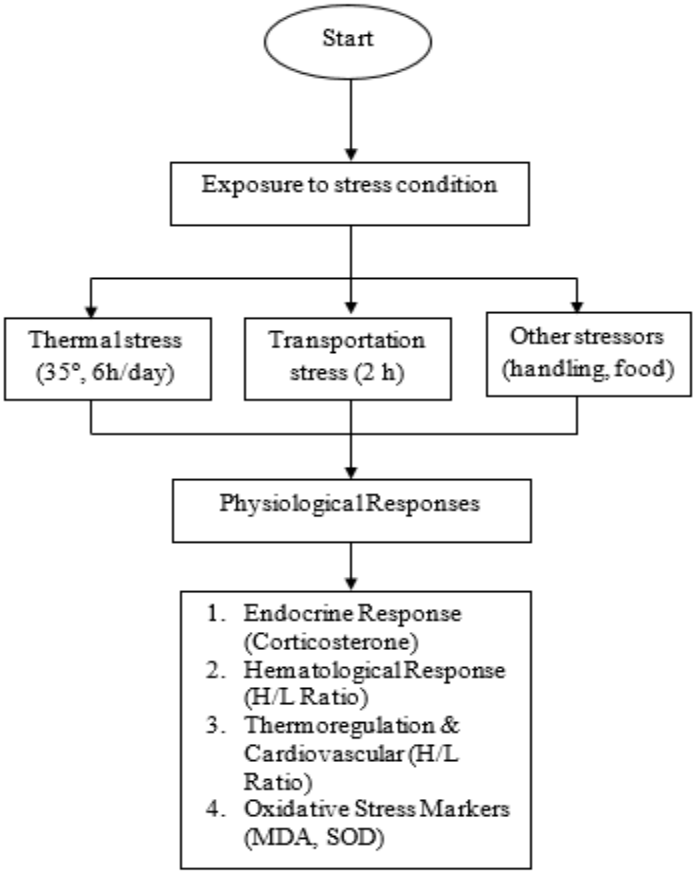

Figure 4: Research Flowchart

IV. RESULT AND DISCUSSION

Result

Table 1: Endocrine Response (Corticosterone Levels)

Group	Corticosterone (ng/mL)
Control (No Stress)	3.5 ± 0.5
Thermal Stress (35°C, 6h/day)	7.8 ± 1.2
Transportation Stress (2h)	6.2 ± 0.9
p-value	**<0.01**

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The amount of corticosterone in broilers differed considerably between the groups under study, showing that there are physiological consequences of stress for the functioning of the endocrine system. In optimal conditions, the control group has the smallest amount of corticosterone (3.5 ± 0.5 ng/mL) and is not stressed, which means that it has a basal level of hormones. On the other hand, the largest amount of corticosterone (7.8 ± 1.2 ng/mL) in the heat stress group shows an intense reaction of the endocrine system because of heat. The increased level of corticosterone is likely a result of heat stress causing the activation of the hypothalamic-pituitary-adrenal axis, making the organism produce more corticosterone to deal with the stress from the environment. The relatively large p-value (<0.01), confirming that the group differences were statistically significant, supports the idea that heat and transport stressors result in an acute endocrine stress response in broilers.

Table 2: Hematological Response (Heterophil/Lymphocyte Ratio)

Group	H/L Ratio
Control (No Stress)	0.45 ± 0.08
Thermal Stress (35°C, 6h/day)	0.92 ± 0.12
Transportation Stress (2h)	0.75 ± 0.10
p-value	**<0.01**

High heterophil/lymphocyte (H/L) ratio is an indicator of stress in chickens. The H/L ratio, which shows a healthy immune system in the absence of stress, was at its minimum in the control group (0.45 ± 0.08). The transport stress (0.75 ± 0.10) and heat stress (0.92 ± 0.12) groups showed significant increases in the H/L ratio, signifying that there were physiological effects of stress in the immune system. In the thermal stress group, the highest H/L ratio can be attributed to the highest amount of stress caused by the presence of elevated temperature due to increased corticosterone production. In the transport stress group, a high H/L ratio indicated a minor immunological response to mechanical and environmental stress, but smaller than the H/L ratio in the thermal stress group. The statistically significant p-value (<0.01) indicates that hematological indicators are greatly influenced by stress exposure, and the immunological balance of broilers can be disturbed by heat stress and transport stress.

Table 3: Thermoregulation and Cardiovascular Response

Parameter	Body Temperature (°C)	Heart Rate (beats/min)	Respiratory Rate (breaths/ min)
Control (No Stress)	41.2 ± 0.3	280 ± 15	65 ± 5
Thermal Stress (35°C, 6h/day)	43.1 ± 0.5	340 ± 20	110 ± 8
Transportation Stress (2h)	42.5 ± 0.4	320 ± 18	95 ± 7
p-value	<0.01	<0.01	<0.01

The considerable physiological differences in terms of thermoregulation and cardiovascular systems between the groups prove how distinct stimuli impact broiler chickens. Heart rate (280 ± 15 beats/min), body temperature (41.2 ± 0.3°C) and respiration rate (65 ± 5 breaths/min) of the control group are normal too. However, thermal stress resulted in the greatest changes in all indicators; the heart rate increased to 340 ±

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20 beats per minute, the respiratory rate increased to 110 ± 8 breaths per minute, and body temperature increased to 43.1 ± 0.5°C. The body's mechanism of dissipating excess heat by increasing breathing activity (panting) and cardiovascular system changes in order to restore the balance.

Similarly, the body temperature of the transportation stress group was 42.5 ± 0.4°C, their heart rate was 320 ± 18 beats per minute, and respiration rate was 95 ± 7 breaths per minute. All these parameters are higher in comparison with the control group. Despite the fact that these indicators are smaller than in thermal stress group, they reflect the serious stress reaction due to mechanical and environmental perturbations during transportation. Substantial p-values (<0.01) for all parameters indicate severe impacts of temperature and transport stress on cardiovascular and thermoregulatory function. Heat and transportation stress are two of the most obvious physiological stressors, emphasizes the need for stress reduction techniques to maintain broiler production and health.

Table 4: Oxidative Stress Markers

Parameter	MDA (nmol/mg protein)	SOD Activity (U/mg protein)
Control (No Stress)	2.1 ± 0.3	12.5 ± 1.1
Thermal Stress (35°C, 6h/day)	4.5 ± 0.6	7.2 ± 1.0
Transportation Stress (2h)	3.9 ± 0.5	8.5 ± 0.9
p-value	<0.01	<0.01

Superoxide dismutase (SOD) and malondialdehyde (MDA) are two examples of oxidative stress markers which give insights into the physiological effect of stress on the antioxidant defense system of broiler chicken cells. The least concentration of MDA (2.1 ± 0.3 nmol/mg protein) was recorded in the control, and it indicates low levels of lipid peroxidation while the greatest value of SOD activity (12.5 ± 1.1 U/mg protein) was also noted, indicating strong antioxidant defense system. Under heat stress, there was a great increase in MDA concentration (4.5 ± 0.6 nmol/mg protein), indicating accelerated lipid peroxidation due to oxidative damage caused by the heat treatment. However, there was a reduction in SOD activity (7.2 ± 1.0 U/mg protein).

Similar results were observed in the case of transportation stress; the SOD activity was low (8.5 ± 0.9 U/mg protein) and MDA concentration was high (3.9 ± 0.5 nmol/mg protein), but to a slightly lesser extent than in the case of heat stress. On the basis of p-values <0.01, both types of stress caused oxidative stress, although heat stress caused more harm. These observations show the physiological impact of oxidative stress in the lives of broilers.

Table 5: Respiratory Response

Group	Respiratory Rate (breaths/min)
Control (No Stress)	55 ± 5
Thermal Stress (35°C, 6h/day)	78 ± 7
Transportation Stress (2h)	72 ± 6
p-value	**<0.01**

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Compared with the control group, the respiratory rate of broiler chickens increased drastically during stress. Chickens exposed to temperature stress (35°C, 6 hours per day) experienced an increase in respiratory rate to 78 ± 7 breaths per minute, in contrast, individuals who experienced two hours of travel stress achieved 72 ± 6 breaths per minute. The respiratory rate of the control group remained at 55 ± 5 breaths per minute. The statistical significance of this difference is indicated by the p value (<0.01). This suggests that hyperventilation is a natural strategy to control body temperature during stress, particularly heat stress. Although not as severe as temperature stress, transport stress also increases respiratory rate, most likely as a result of increased metabolic demand and anxiety.

Table 6: Plasma Glucose Levels

Group	Plasma Glucose (mg/dL)
Control (No Stress)	185 ± 10
Thermal Stress (35°C, 6h/day)	245 ± 15
Transportation Stress (2h)	220 ± 12
p-value	**<0.01**

It has been observed that the stressed birds had high plasma glucose levels as compared to the control group of birds, which is an indication of endocrine response due to stress. The glucose level in control birds was found to be 185 ± 10 mg/dL, while in temperature stress it was found to be 245 ± 15 mg/dL, and for transport stress, it was found to be 220 ± 12 mg/dL. The increase in glucose concentration in both the conditions can be attributed to the effect of stress that results in the mobilization of energy sources such as glycogenolysis and gluconeogenesis. The greater increase under thermal stress suggests that chronic heat exposure has a greater metabolic impact than transport stress, which is more acute in nature.

Table 7: Muscle Glycogen Content

Group	Muscle Glycogen (mg/g tissue)
Control (No Stress)	15.2 ± 1.3
Thermal Stress (35°C, 6h/day)	9.4 ± 1.0
Transportation Stress (2h)	11.1 ± 1.2
p-value	**<0.01**

Stressed broilers had a considerably lower muscle glycogen content than the control group. The control group's chickens had a muscle glycogen content of 15.2 ± 1.3 mg/g tissue, but the thermally stressed chickens showed a significant reduction to 9.4 ± 1.0 mg/g tissue, and the transportation-stressed chickens had a nitrogen content of 11.1 ± 1.2 mg/g tissue. The p-value (<0.01) confirms that this change is significant. Stress increases energy requirements, which in turn increases the use of glycogen to make ATP, as seen by the reduction in muscle glycogen. The most significant effects were caused by thermal stress, as more energy was required to maintain thermoregulation, whereas transport stress produced modest but still significant depletion, probably due to physical strain and anxiety-related energy mobilization.

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DISCUSSION

Stress is a major problem in broiler production because it can have significant impacts on health, productivity, and physiological processes. Recent research has examined the physiological responses of broiler chickens to various stressors, including heat and transport stress. These findings highlight the negative impacts of mechanical and environmental stressors on broiler physiology by showing that both types of stress resulted in significant changes in oxidative stress, hematological, thermoregulatory, cardiovascular, and endocrine stress markers. Increased corticosterone levels caused by the hypothalamic-pituitary-adrenal (HPA) axis are one of the main markers of stress (Abraham et al., 2025). According to studies, corticosterone levels were significantly higher in the stressed group, with the highest values observed in the thermal stress group. This response indicates that exposure to heat results in more physiological stress to broilers than transport stress (Malila et al., 2022). High levels of corticosteroids can affect growth performance, appetite, and immunity; hence, there is a need for proper heat stress management strategies. The immunosuppressive effects of stress are further supported by the hematological response, namely the heterophil/lymphocyte (H/L) ratio (Onagbesan et al., 2023). The substantial rise in the H/L ratio during stressful situations implies that immunological dysfunction is caused by both temperature and transportation stress. Heat exposure caused more severe immune suppression, as evidenced by the highest H/L ratio in the thermal stress group (Wasti et al., 2020). The weakened immune system of broiler chickens makes them more susceptible to disease and infection, which will ultimately reduce their welfare and productivity. Significant increases in heart rate, respiratory rate, and another indicator of cardiovascular and thermoregulatory reactions to stress includes body temperature (Zmrhal et al., 2023).

The most visible changes are caused by thermal stress, this causes the bird to change its circulatory system and breathe more in an effort to reduce heat. The increase in physiological markers in the transport stress group, although to a lesser extent, indicates that the body experiences significant levels of physiological stress as a result of mechanical and environmental disturbances during transit (Sesay, 2022). These results emphasize the importance of maintaining ideal environmental conditions and reducing transport stress to maintain bird welfare and performance. Further indicators of cell stress include indicators of oxidative stress such as superoxide dismutase (SOD) activity and malondialdehyde (MDA) concentration (Oke et al., 2024).In both types of stress, high MDA concentrations indicated more severe oxidative stress and peroxidation of lipids. Additionally, stressed chickens had much less SOD activity, showing malfunction of their antioxidant protection system (Tang et al., 2022). Given that the thermal stress group demonstrated the highest level of oxidative stress reaction, it is logical to suppose that heat treatment creates more physiological stress for birds than transport stress. It is critical to regulate oxidative stress since it may result in tissue damage, metabolism disorders, and reduced performance (Mancinelli et al., 2023).

Transportation and heat stress have notable physiological effects on broilers because of the effect on oxidative stress, cardiovascular, thermoregulatory, hematological, and

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DOI: 10.5281/zenodo.24106431

endocrine parameters. The increased concentration of corticosterone hormones in the stressed groups, particularly in the thermal stressed group, suggest that there is significant activation of the HPA axis, which is a major physiological response to stress (Khan et al., 2021). While such a physiological reaction is an adaptive one to environmental stressors, it can have detrimental effects on health and development in case it continues. Another evidence of the effect of stress on physiology is the heterophil/lymphocyte ratio test (Thiam et al., 2022). Immune suppression is suggested by the significant rise in the H/L ratio in both stress groups, with thermal stress eliciting the most severe reaction. Chickens' resistance to disease may be reduced due to these immunological changes, increasing their susceptibility to disease and infection (Al-Ela et al., 2021). Thermal stress has the most pronounced effects on thermoregulation and cardiovascular function, as seen by a marked increase in body temperature, heart rate, and respiratory rate. Broilers' physiological attempts to disperse heat through panting and circulatory modifications are reflected in these alterations (Brugaletta et al., 2022).

Although to a lesser degree, transportation stress also increased these indicators, suggesting that mechanical and environmental stressors during transportation continue to place a significant physiological burden on hens. The damaging effects of stress on cell integrity are further highlighted by indicators of oxidative stress. An increase in MDA and a reduction in SOD in stressed chickens suggests that the birds have weak antioxidant defense systems and too many free radicals (Oke et al., 2024). This oxidative imbalance is quite worrying because it can cause tissue damage, poor metabolic function, and poor overall performance of broilers. By reducing heat exposure, improving transport conditions, and providing antioxidant support, broiler welfare and productivity can be improved and the negative impacts of stress can be reduced (Goel et al., 2021).

The findings also showed that both stressors resulted in significant changes in endocrine, hematological, cardiovascular, respiratory, and metabolic parameters, which are indicative of the chickens' adaptation mechanisms to stress. Corticosterone levels showed a significant increase in endocrine response under stress conditions, with the largest increase occurring under temperature stress conditions (Galosi et al., 2024). This implies that extended exposure to high temperatures causes the hypothalamic-pituitary-adrenal (HPA) axis to become more strongly activated, which in turn causes an increase in corticosterone release. Likewise, albeit to a lesser degree, transportation stress also led to increased corticosterone levels. According to Hillebrecht et al. (2024), this means that although acute stressors such as movement and contact still cause the release of stress-related chemicals, compared with chronic heat stress, the consequences may not be long-lasting.

The heterophil to lymphocyte ratio (H/L) increases significantly during stress, among other hematological changes. An increased H/L ratio is a well-known biomarker of physiological stress in chickens indicating altered immune function (Thiam et al., 2021).Thermal stress caused the most marked increase, suggesting that prolonged heat exposure may have a more negative impact on immunological function than transport-related stress. This emphasizes the need for methods to reduce heat stress in industrial broiler production,

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such as water spraying, increased ventilation, and nutritional modification (Goel et al., 2025). The physiological effects of stress on broilers are further highlighted by thermoregulatory and cardiovascular reactions. According to Saleh et al. (2020), both stress groups experienced marked increases in body temperature and heart rate, with the largest increase caused by thermal stress.. According to the known consequences of heat stress, to generate more heat, chickens increase their metabolic and cardiovascular output. It's also possible that the elevated heart rate under stressful situations is a compensating strategy to keep oxygen flowing to areas with higher metabolic demands (Ariyo et al., 2022). Chickens under heat stress showed the highest rates of respiratory responses, which were determined by respiratory rate and followed a similar pattern. Chickens often react to heat stress by hyperventilating in an attempt to dissipate heat through evaporative cooling (Kim et al., 2024). In contrast, metabolic abnormalities may worsen due to respiratory alkalosis caused by prolonged panting. Transport stress increases respiratory rate significantly, but less than heat exposure. This is likely because of increased handling, exercise, and stress. The broilers under stress undergo various metabolic changes, characterized by high plasma glucose concentrations and reduced muscle glycogen. Thermoregulation necessitates metabolic activity; hence, thermal stress results in a higher glycogen consumption compared to transport stress (Xing et al., 2022).

V. CONCLUSION

Heat and transport stress have a significant effect on broiler physiological responses, as evidenced by changes in endocrine, hematological, thermoregulatory, cardiovascular, and oxidative stress indicators. Higher corticosterone levels in the stressed group indicate that the hypothalamic-pituitary-adrenal (HPA) axis, it is clearly active in this group and is important for the body's physiological reactions to stress. In addition, an increase in the heterophil/lymphocyte (H/L) ratio during stress indicates immune suppression, which makes broilers more susceptible to infection. Thermal stress had the most negative effects, as seen by the highest corticosterone levels, H/L ratio, body temperature, heart rate, and respiratory rate.Increased HPA axis activity is indicated by higher corticosterone levels in stressed chickens, with temperature stress causing the most pronounced increase. Additional evidence regarding the negative physiological effects of stress, the increase in the heterophil to lymphocyte ratio (H/L) indicates the effects of very long-term heat exposure. In addition, the oxidative stress response was more pronounced in the thermal stress group, with increased malondialdehyde (MDA) levels and lower superoxide dismutase (SOD) activity, suggesting substantial cellular damage and antioxidant depletion. Transport stress also causes physiological changes, although the effects are not as strong as those caused by temperature stress. Taking everything into account,these findings demonstrate how mechanical and environmental stress have detrimental effects on the health and performance of broiler chickens. To reduce these physiological disturbances and increase chicken production, effective stress reduction strategies are essential. Some recommendations have been made to counteract the above adverse impacts. First, there are environmental controls that should be put in place

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such as the installation of evaporative cooling pads, misting system, and ventilation to maintain the appropriate humidity and temperature in the broiler house. Another way to prevent overheating in the broilers is shading and maintenance of adequate density in cages. As another way to save time, the vehicle should be well ventilated, and the chickens handled gently in loading and unloading to minimize physiological stress during transportation. It is advisable to transport broilers when it is cool to prevent overheating. Apart from giving nutritional support using dietary supplements containing antioxidants like vitamin E, selenium, and polyphenols, electrolyte supplementation in drinking water helps in hydration and balance of the body.

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