

## Effects of Strain and Stocking Density on Body Weight and Heat Tolerance Traits of Broiler Chickens

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### Abstract

*The aim of the study was to evaluate the effects of strain and stocking density on heat tolerance of broiler chickens. A total of 318-day-old broiler chicks of two commercial strains, Cobb 500 and Ross 308, were used in a 2 x 2 factorial experiment arranged in a Completely Randomized Design (CRD) with three replicates per treatment. The two stocking densities investigated were low density (18 birds per replicate) and high density (35 birds per replicate). Data were collected from day 1 to day 56 on body weight, rectal temperature (°C), pulse rate (beats/min), respiratory rate (breathes/min). Data collected were subjected to Two-way Analysis of Variance using the IBM SPSS Version 25.0, and significant means were separated using Duncan's Multiple Range Test at 5% level of significance. Results showed that strain had a significant ( $P<0.05$ ) effect on pulse rate, with Ross 308 recording a significantly ( $P<0.05$ ) higher pulse rate ( $51.46\pm 0.17$  beats/min) compared to Cobb 500 ( $50.51\pm 0.17$  beats/min). The interaction was significant ( $P<0.05$ ) for pulse rate. Cobb 500 birds at low density had significantly ( $P<0.05$ ) lower pulse rate ( $49.94\pm 0.28$  beats/min) compared to Cobb 500 birds at high density ( $51.08\pm 0.21$  beats/min) and Ross 308 birds at both density levels. It can be concluded that Ross 308 exhibited a significantly higher pulse rate than Cobb 500. Cobb 500 strain is recommended for broiler production in hot environments due to its better physiological response to heat stress. Lower stocking density is advisable, as it tends to reduce physiological stress.*

**Keywords:** Strain, Stocking Density, Body Weight, Heat Tolerance Traits, Broiler Chickens

### 1.0 Introduction

Broiler chickens are an important component of the global meat supply, mainly due to their rapid growth rate, efficient feed conversion and low production costs (FAO, 2023; Sam *et al.*, 2025). Broiler strains with different growth potentials, feed efficiencies and

physiological responses have been developed after decades of intensive genetic selection (Sam *et al.*, 2019; Havenstein *et al.*, 2003). The genetic progress has been critical to meet consumer demand, but it also creates new challenges, particularly in relation to the ability of the birds to cope with environmental stressors and to maintain optimum welfare within the intensive production systems (Udo *et al.*, 2025; Castro *et al.*, 2023).

One of the most critical management factors influencing broiler performance and welfare is stocking density. High stocking densities are often employed to maximize output per unit area, but they can lead to reduced growth rates, increased competition for feed and water, compromised litter quality, and elevated stress levels (Dawkins *et al.*, 2004). Conversely, excessively low densities may not be economically viable. The optimal stocking density is a dynamic balance, influenced by factors such as housing design, ventilation, and the specific genetic strain of the birds (Bell and Weaver, 2002). Different broiler strains, with their varying body sizes, activity levels, and heat production, may respond differently to the same stocking density, necessitating a nuanced understanding of these interactions (Sam *et al.*, 2026; Zuidhof *et al.*, 2014).

In addition to management, environmental variables, especially heat stress, provide a significant barrier to sustainable grill production. Broilers, particularly contemporary fast-growing strains, exhibit significant vulnerability to heat stress owing to their elevated metabolic rate, swift growth, and restricted capacity for heat dissipation (Lara and Rostagno, 2013). Heat stress can lead to a cascade of negative effects, including reduced feed intake, decreased growth performance, impaired immune function, altered blood parameters, and increased mortality (Attia *et al.*, 2018). Mallam *et al.* (2025) reported that incorporating a mix of *Digitaria smutsii* with groundnut haulms or cowpea husk can influence heat load management and should be optimized to improve animal comfort and productivity. Diets higher in fibre may reduce excessive heat production and that selection for breeding should consider physiological resilience to heat stress. More frequent monitoring of rectal temperature, pulse, and respiratory rate, especially during the hotter parts of the day, can help in the early detection of heat stress. Providing shade, water *ad libitum*, and dietary adjustments during peak ambient temperatures will enhance goats' thermo-regulation and overall welfare.

Furthermore, heat stress significantly impacts carcass characteristics, often leading to reduced breast meat yield and poorer meat quality (Mujahid *et al.*, 2009). The interaction between genetic strain and heat tolerance is well reported with some strains exhibiting greater resilience to high temperatures than others (Deeb and Cahaner, 2002). Moreover, high stocking density can exacerbate the effects of heat stress by increasing ambient temperature and humidity within the poultry house and limiting individual bird access to cooler areas (Yahav *et al.*, 1997). Understanding how strain and stocking density interact to modulate these indices provides important insight into the systemic effects of management decisions on broiler physiology. The economic feasibility and sustainability of the broiler business are persistently confronted with the necessity to enhance production efficiency while concurrently resolving animal welfare issues and environmental pressures. This work is well-founded since it may yield essential insights and practical advice for broiler producers, geneticists, and legislators. The findings of this study are highly significant for the commercial grill business in Nigeria and comparable tropical regions. Producers consistently pursue methods to enhance revenue while complying with welfare guidelines. This research identifies optimal strain-density combinations that improve growth performance and heat tolerance, thereby assisting farmers in making educated decisions on genetic stock selection and housing management. Identifying strains that thrive at elevated

densities or demonstrate enhanced heat tolerance can mitigate economic losses linked to suboptimal growth, increased mortality, and diminished meat quality during warm conditions (St-Pierre *et al.*, 2003).

The objective of this study therefore is to evaluate the effects of strain and stocking density on body weight and heat tolerance traits of broiler chickens.

## 2.0 Materials and Methods

### 2.1 Study Area

The study was conducted at the Teaching and Research Farm of the Faculty of Agriculture, Nasarawa State University, Keffi, Shabu-Lafia Campus, Nigeria. The study area is located in Lafia, the capital of Nasarawa State, which lies within the Guinea Savanna agro-ecological zone of Nigeria. Lafia is characterized by a tropical climate with a distinct wet and dry season, with mean annual rainfall of approximately 1,300 mm and mean annual temperature ranging between 26°C and 38°C. The hot and humid tropical conditions of the study area make it representative of typical broiler production environments in central Nigeria (NiMet, 2025).

### 2.2 Experimental Birds and Management

A total of three hundred and eighteen (318) day-old broiler chicks consisting of two commercial strains, Cobb 500 and Ross 308, 159 chicks for each strain were obtained from a reputable commercial hatchery. Upon arrival, birds were individually weighed and allocated to their respective treatment pens. All birds were managed under an intensive floor-pen housing system with deep litter bedding. The birds received vaccination against Newcastle disease and infectious bursal disease according to standard veterinary protocols. Feed and water were provided *ad libitum* throughout the experimental period of 56 days. Commercial broiler starter and finisher diets were used in the study: starter diet from day 1 to day 28, and finisher diet from day 29 to day 56. Lighting was continuous (23 hours light and 1 hour darkness) for the first week, and subsequently adjusted to 16 hours light and 8 hours darkness.

### 2.3 Experimental Design and Treatments

The experiment was conducted in a 2 x 2 factorial arrangement fitted into a Completely Randomized Design (CRD) with three replicates per treatment. Factor A was broiler strain (Cobb 500 and Ross 308), and Factor B was stocking density (low and high). The four treatment combinations were:

T1: Cobb 500 at low stocking density (18 birds per replicate pen)

T2: Cobb 500 at high stocking density (35 birds per replicate pen)

T3: Ross 308 at low stocking density (18 birds per replicate pen)

T4: Ross 308 at high stocking density (35 birds per replicate pen)

Each treatment pen was of equal floor space (2 m<sup>2</sup>). All management conditions, including feeding, watering, lighting, and ventilation, were kept uniform across all pens throughout the experimental period.

Number of birds for low density were 18 birds per replicate and 35 birds per replicate for high density for both Cobb 500 and Ross 308.

## 2.4 Body Weight and Heat Tolerance Parameters

**Body Weight:** Individual body weights were recorded weekly using an electronic weighing scale or balance. Birds were weighed early in the morning before feeding to avoid the influence of feed and water in the digestive tract.

**Rectal Temperature:** This was measured weekly per bird/replicate/ treatment using a digital thermometer inserted 2 cm into the cloaca. The measurement was taken in the morning and afternoon to capture daily variation.

**Respiratory Rate:** This was done weekly per bird/replicate/treatment observing the number of abdominal movements per minute when the bird is at rest. A stopwatch was used for accurate timing.

## 2.5 Statistical Analysis

All data collected were subjected to two-way Analysis of Variance (ANOVA) using the IBM SPSS Statistics software Version 25.0, IBM Corp., 2021) to determine the main effects of broiler strain, stocking density, and their interaction on body weight, rectal temperature, pulse rate and respiratory rate.

The statistical model employed was:

$$Y_{ijk} = \mu + S_i + D_j + (SD)_{ij} + \varepsilon_{ijk}$$

Where:

$Y_{ijk}$  = individual observation;  $\mu$  = overall mean;

$S_i$  = effect of the  $i^{\text{th}}$  strain ( $i = 1, 2$ )

$D_j$  = effect of the  $j^{\text{th}}$  stocking density ( $j = 1, 2$ )

$(SD)_{ij}$  = interaction effect of strain and stocking density

$\varepsilon_{ijk}$  = random error.

Where significant differences were observed, Duncan's Multiple Range Test was used for post-hoc comparisons among treatment means.

## 3.0 Results

Table 3.1 shows the effect of strain on body weight and heat tolerance traits. Strain had a significant ( $P < 0.05$ ) effect on pulse rate, with Ross 308 recording a significantly higher pulse rate ( $51.46 \pm 0.17$  beats/min) compared to Cobb 500 ( $50.51 \pm 0.17$  beats/min). No significant differences were observed between the two strains in body weight, rectal temperature, or respiratory rate at the time of heat tolerance assessment.

Table 3.2 presents the effect of stocking density on heat tolerance traits. None of the measured heat tolerance parameters, including body weight, rectal temperature, pulse rate, or respiratory rate, were significantly ( $P > 0.05$ ) affected by stocking density. Numerically, birds at low density had slightly higher body weight compared to birds at high density, and marginally lower pulse rate and respiratory rate.

The interaction effect of strain and stocking density on heat tolerance traits is presented in Table 3.3. The interaction was significant ( $P < 0.05$ ) for pulse rate only. Cobb 500 birds at

low density had significantly lower pulse rate ( $49.94 \pm 0.28$  beats/min) compared to Cobb 500 birds at high density ( $51.08 \pm 0.21$  beats/min) and Ross 308 birds at both density levels.

**Table 3.1: Effect of Strain on Body Weight and Heat Tolerance Traits of Broiler Chickens**

Parameters	Strain		P-value
	Cobb 500	Ross 308	
Body Weight (kg)	$0.84 \pm 0.02$	$0.85 \pm 0.02$	$0.8530^{NS}$
Rectal Temperature ( $^{\circ}C$ )	$41.14 \pm 0.03$	$41.09 \pm 0.03$	$0.2310^{NS}$
Pulse Rate (beats/min)	$50.51 \pm 0.17^b$	$51.46 \pm 0.17^a$	$0.0000^*$
Respiratory Rate (breathes/min)	$134.66 \pm 0.40$	$134.80 \pm 0.41$	$0.8120^{NS}$

a,b Means within the same row bearing different superscripts differ significantly ( $P < 0.05$ ), \* = Significant at  $P < 0.05$ , NS= Not significant

**Table 3.2: Effect of Stocking Density on Body Weight and Heat Tolerance Traits of Broiler Chickens**

Parameters	Stocking Density		P-value
	Low density (18 birds/ $m^2$ )	High density (35 birds/ $m^2$ )	
Body Weight (kg)	$0.87 \pm 0.03$	$0.82 \pm 0.02$	$0.1350^{NS}$
Rectal Temperature ( $^{\circ}C$ )	$41.12 \pm 0.03$	$41.12 \pm 0.02$	$0.9800^{NS}$
Pulse Rate (beats/min)	$50.80 \pm 0.20$	$51.18 \pm 0.15$	$0.1140^{NS}$
Respiratory rate (breathe/min)	$134.91 \pm 0.48$	$134.55 \pm 0.35$	$0.5480^{NS}$

**Table 3.3: Interaction Effect of Strain and Stocking Density on Heat Tolerance Traits of Broiler Chickens**

Parameters	Cobb 500		Ross 308		P-values
	Low density	High density	Low density	High density	
Body Weight (kg)	0.86±0.04	0.82±0.04	0.87±0.04	0.82±0.03	0.9490 <sup>NS</sup>
Rectal Temperature (°C)	41.13±0.05	41.15±0.03	41.10±0.05	41.08±0.03	0.6080 <sup>NS</sup>
Pulse Rate (beats/min)	49.94±0.28 <sup>b</sup>	51.08±0.21 <sup>a</sup>	51.64±0.28 <sup>a</sup>	51.28±0.21 <sup>a</sup>	0.0020 <sup>*</sup>
Respiratory Rate (breathes/min)	131.52±0.67	134.80±0.49	135.29±0.67	134.30±0.49	0.2770 <sup>NS</sup>

<sup>a,b</sup> Means within the same row bearing different superscripts differ significantly (P<0.05), \* = Significant at P<0.05, NS= Not significant

#### 4.0 Discussion

The significant effect of strain on pulse rate, with Ross 308 recording higher values (51.46 beats/min) compared to Cobb 500 (50.51 beats/min), suggests differential cardiovascular thermoregulatory responses between the two strains under tropical conditions. A higher pulse rate indicates greater cardiovascular effort to facilitate circulatory cooling and maintain thermal homeostasis as reported by Yahav (2000). This finding aligns with the report of Shim *et al.* (2022), who noted that strain-specific differences in thermoregulatory capacity are often reflected in cardiovascular parameters even when surface temperature and respiratory rate remain similar. The absence of significant differences in rectal temperature between strains is noteworthy. Rectal temperature is widely recognized as a primary indicator of core body temperature homeostasis in poultry (Poku *et al.*, 2024). The maintenance of similar rectal temperatures despite differential pulse rates suggests that both strains were able to achieve thermal balance through different physiological strategies. While Ross 308 employed greater cardiovascular effort (higher pulse rate), Cobb 500 may have utilized more efficient heat dissipation mechanisms or generated less metabolic heat per unit body weight. The comparable respiratory rates between strains (134.66 vs. 134.80 breathes/min) suggest similar reliance on evaporative cooling through panting. This finding contrasts with Xu *et al.* (2018), who reported significant strain differences in respiratory rate under heat stress conditions when comparing fast-growing commercial strains with slower-growing local breeds. The absence of difference between Cobb 500 and Ross 308 may reflect the similar genetic selection history of both strains for rapid growth, which has resulted in comparable metabolic rates and heat production.

The numerical trends observed, with low-density birds having slightly lower pulse rate (50.80 vs. 51.18 beats/min) and respiratory rate (134.91 vs. 134.55 breathes/min), suggest a trend toward reduced thermoregulatory effort at lower densities. According to Dawkins *et al.* (2004), the effects of stocking density on broiler welfare are strongly influenced by housing conditions, particularly ventilation and ambient temperature. Under well-ventilated conditions, the thermal load from high stocking density may be partially dissipated, allowing birds to maintain normal body temperature despite increased metabolic heat production per unit area. The no significant density effects on rectal temperature, despite its significant impact on mortality, suggests that mortality at high density may be attributable to factors other than acute heat stress, such as increased disease transmission, reduced immune function, or cardiovascular strain from chronic social stress. Zhou *et al.* (2024) reported that high stocking density increased the incidence of footpad dermatitis and respiratory diseases, which may contribute to mortality independent of core body temperature elevation.

No significant interaction effects were found for rectal temperature, body weight, or respiratory rate. The significant strain by stocking density interaction for pulse rate is a critical finding that reveals differential cardiovascular responses to increasing density between the two strains. Cobb 500 birds at low density had the lowest pulse rate (49.94 beats/min), indicating minimal cardiovascular thermoregulatory demand under optimal spatial conditions. However, Cobb 500 at high density showed a significant increase in pulse rate (51.08 beats/min), approaching the levels observed in Ross 308 at both density levels. This suggests that Cobb 500's cardiovascular system is more sensitive to spatial restriction, exhibiting a pronounced stress response when density increases. In contrast, Ross 308 maintained relatively stable pulse rates across density levels (51.64 vs. 51.28 beats/min), suggesting a more buffered cardiovascular response to environmental variation. This finding has important implications for strain selection in high-

density production systems. While Cobb 500 may offer advantages in feed efficiency and growth performance under optimal conditions, Ross 308 may be better suited to high-density environments due to its more stable cardiovascular response to spatial stress. The mechanism underlying this differential response may relate to inherent differences in cardiovascular capacity and autonomic regulation between strains. Kim *et al.* (2025) highlighted that fast-growing strains typically exhibit reduced heart size relative to body weight, creating a physiological mismatch between metabolic demand and cardiopulmonary capacity. The present findings suggest that Cobb 500 may have less cardiovascular reserve capacity to cope with the additional stress of high stocking density, resulting in a more pronounced pulse rate elevation.

## 5.0 Conclusion and Recommendations

This study demonstrated that strain significantly affected pulse rate, with Ross 308 recording higher values than Cobb 500, while both strains maintained similar rectal temperatures and respiratory rates, indicating comparable overall heat tolerance achieved through differing cardiovascular strategies. Stocking density did not significantly alter any heat tolerance parameter, suggesting that the density range applied was insufficient to critically disrupt core thermoregulation, and that density-related mortality may be driven more by non-thermal factors such as disease pressure and immune suppression than by acute heat stress. The significant strain by stocking density interaction for pulse rate revealed that Cobb 500 exhibits greater cardiovascular sensitivity to spatial restriction, while Ross 308 maintained more stable pulse rates across density levels, reflecting superior cardiovascular buffering capacity.

Based on the findings, Ross 308 is recommended for high-density production systems due to its more stable cardiovascular response to spatial stress, while Cobb 500 should be managed at lower stocking densities with enhanced ventilation and cooling to offset its greater sensitivity to density-induced cardiovascular strain. Pulse rate should be adopted as a routine welfare indicator during heat challenge assessments.

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