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Physiological and Behavioral Indicators of Welfare in Broiler and Noiler Chicken Strains Raised in a Semi-Arid Environment

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Abstract: This study evaluated two broiler strains (Marshall and Cobb 500) and an indigenous improved dual-purpose (Noiler) strain for thermotolerance, hematological indices, serum metabolites, and behavioral traits. The collected data were analyzed using appropriate models, including a linear mixed model, one-way ANOVA and an ordinal regression model. Results of the study indicated a significant (p < 0.05) effect of age on physiological variables but not strain. Similarly, WBC was higher in Cobb 500 birds than Noiler chickens (p < 0.05). Conversely, ALP and urea were higher in Noiler than in the exotic strains, whereas enzyme activity had a nuanced pattern among the study strains. In the same vein, Marshall and Noiler chickens spent more time moving around the pen and sawdust bathing compared to Cobb 500 (p < 0.05). There was a higher number of Noiler birds touchable (χ^2 = 17.51, p = 0.002), but Cobb 500 birds were less frightened by the grab test (χ^2 = 8.76, p = 0.0126). These results indicated a trade-off between productivity and welfare across the three genetic groups, highlighting the importance of balancing genetic selection for production with the preservation of natural behaviors and physiological resilience to foster sustainable poultry welfare in a changing climate and escalating environmental stressors.

Keywords: Adaptation, Behavior, Welfare, Noiler, Broiler, Semi-Arid

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1. Introduction

Poultry production is the leading source of animal-derived protein globally, playing a crucial role in food security and human health. Broiler production has seen significant growth in the drier parts of the world, despite the region's challenging environment, which has been further aggravated by climate change. The production environment impacts not only the birds' productivity but also their welfare and the quality of their products. This necessitates producers selecting appropriate strains that can thrive in such conditions while providing high-quality meat under humane conditions. Fast-growing broiler strains like Cobb, Ross, and Arbor Acre are developed by optimizing their metabolic turnover and ability to convert low-quality plant-based proteins into meat [1,2]. However, this efficiency is accompanied by metabolic stress and increased vulnerability to environmental stressors, leading to deteriorating welfare due to the reduced expression of natural behaviors [3].

Natural behaviors, such as feeding, drinking, self-cleaning, and play, serve as observable indicators of chicken welfare that producers should monitor to ensure their birds are not distressed. Differences in behaviors and physiology, such as metabolic rate and immune response are regulated by the hypothalamic-pituitary-adrenal axis [4]. Hematological components can also indicate stress and welfare in chickens. White blood cells (WBC, leucocytes) provide a robust measure of chickens' immune response, with heterophils and lymphocytes being the most important leucocytes in the chicken immune system [5,6]. Additionally, the heterophil-to-lymphocyte ratio (H/L) correlates with immune system strength and serves as a stress marker in chickens [6-9].

Furthermore, serum metabolites and enzyme activities, including blood lipids, urea, aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP), are valuable indices for monitoring the health and the impact of environmental stress on broiler birds [10,11]. Chicken genotypes vary in their response to stress, metabolic efficiency, and immune response, making genotype selection a critical decision for informed and profitable poultry production. Studies have demonstrated a significant genotype-by-environmental interaction among chicken strains (fast-growing, medium-growing, and slow-growing indigenous birds) and rearing conditions.

This study aimed to evaluate two commonly reared fast-growing broiler strains and an indigenous improved dual-purpose Noiler strain for thermotolerance, behavior, hematological indices, serum metabolites, and enzyme activities.

2. Materials and Methods

2.1 Experimental Birds and their Management

In this study, three strains of meat-type chickens were utilized: two improved exotic strains, Marshall and Cobb 500, and one Nigerian improved dual-purpose strain, Noiler. A total of 150 day-old chicks, with each strain comprising 50 birds, were managed on a deep litter system for eight weeks. The chicks in each strain were divided into three replicates. Routine management of birds, including vaccinations against Newcastle disease and infectious bursal disease, feeding and watering, was carried out according to guidelines outlined in Oluyemi and Roberts [12]. The birds were managed at the teaching and research farm of the Department of Animal Science, Usmanu Danfodiyo University, Sokoto, Nigeria.

The experimental site is located within the Sudan savannah agroecology, in the extreme northwestern part of Nigeria. The average temperature and relative humidity of the site during the experimental period were 35℃ and 45%, respectively. The farm is located at an altitude of 350 m above sea level.

2.2 Diet of Experimental Birds

The diet used for feeding the birds consisted of a broiler starter given at the starter phase (0-4 weeks) and a broiler finisher diet given at the last phase of the experiment (5-8 weeks). The starter diet contained 2950 kcal/kg of metabolizable energy (ME), 22% crude protein (CP), and 5% crude fiber (CF). Similarly, the finisher diet contained 3100 kcal/kg ME, 19.5% CP and 12.5% CF. Feed was offered to the birds *ad libitum*.

2.3 Data Collection

Thermotolerance data, including rectal temperature and respiratory rate, were measured in a random sample of five birds from each replicate once a week from the third week until the eighth week of the experiment. These parameters were recorded as described by Ruzic et al. [13]. Similarly, behavioral traits were recorded weekly. Traits monitored include the proportion of the time spent by the birds resting, eating, drinking, sawdust bathing, preening, and moving (locomotion). These behaviors were recorded as described by Lourenço da Silva et al. [14]. Briefly, a video was recorded for each replicate for 15 minutes and analyzed to estimate the time each bird spent resting (when the bird lies on the floor) and eating (when the head of the bird is on top or around the feeding trough). In the same vein, time spent drinking (when the birds actively take in water) saw dust bathing (the act of pecking and of the litter material followed by sitting on the substrate and flapping of wings within the substrate), preening (a repetitive behavior involving pecking a litter and scratching of the beak afterwards), locomotion (the movement or standing of birds at will, within the pen) were recorded.

Additionally, touch (TT) and grab tests (GT) were carried out on days 35 and 49 of the birds' age, respectively. These tests were conducted according to the method described by Lourenco da Silva et al. [14]. For TT, an experimenter entered the pen and remained idle for 3 minutes, allowing the birds to adapt to his presence. He then extended his arms and counted how many birds he could touch. For the GT, the birds were taken to an empty pen, and after 3 minutes, the assessor attempted to catch them by grabbing, then rated their response from 1 to 5. For score 1, the bird does not move. A bird that walks away but neither vocalizes nor runs was rated 2. A score of 3 is when the bird walks away and vocalizes. A bird that runs away and vocalizes was scored 4, while the one that leaps to avoid being grabbed was scored 5.

On the 56th day, blood samples were collected from three birds in each strain, one from each replicate, in two types of collection tubes. A total of 6 ml of blood was collected from each bird. One portion was poured into an EDTA bottle for hematological analysis, while the other portion was poured into a plain bottle for serum biochemical index analysis.

2.4 Data Analysis

The data collected from the experiment were analyzed using different models. Data on rectal temperature and respiratory rate were analyzed using a generalized linear mixed model (GLMM). Strain and age were considered as fixed effects, while individuals were considered random effects. Additionally, one-way ANOVA was used to analyze data on hematological indices and serum biochemistry as well as the time spent exhibiting natural behaviors. Before the analysis, assumptions of normality and equality of variance were tested using the Shapiro-Wilk and Levene tests, respectively. These exploratory analyses indicated that the data are normally distributed with equal variance ($p > 0.05$). For the welfare traits, a generalized linear model (GLM) was used to analyze the touch test data (count data) with a Poisson distribution. The data for the grab test were analyzed using ordinal regression model.

Means that showed significant differences at 5% were separated using the Tukey method in ANOVA and contrast in the case of GLMM and GLM. All statistical analyses were carried out in JMP statistical software.

3. Results

3.1. Physiological Traits of Chicken Strains Reared in Semi-arid Environment

The results for rectal temperature and respiratory rate, which are the thermo-adaptive traits measured in the birds, indicated that strain has no significant influence on these traits (Table 1). While the rectal temperature of the birds in the three strains was close to the lower reference value of 40 °C, the respiratory rates were lower than the lower reference value established for chickens. However, age has a significant effect on these traits. Both rectal temperature and respiratory rate decrease with age. Whereas the decrease in rectal temperature began in the fifth week, the decrease in respiratory rate began in the seventh week.

Table 1. Rectal temperature and respiratory rates of Noiler and broiler chicken strains

Effect	Rectal temperature (°C)	Respiratory rate (breaths/min)
Strain		
Marshall	40.43	33.22
Cobb 500	40.56	37.33
Noiler	40.60	39.44
SEM	0.24	2.33
Age (weeks)		
3	41.53 ^{a}	36.67 ^{a}
4	41.17 ^{a}	37.41 ^{a}
5	40.16 ^{b}	37.74 ^{a}
6	40.12 ^{b}	35.67 ^{b}
7	40.31 ^{b}	32.78 ^{b}
8	40.30 ^{b}	30.00 ^{b}
SEM	0.14	1.29
Reference*	40-42	40-60

[a b] Means within the same column with different superscripts are significantly different at $p < 0.05$. [*]Whittow [15].

The results indicated that all hematological indices measured were similar among the strains except leucocyte counts, which were significantly different (P = 0.007) between Noiler and Cobb 500 chickens (Table 2). Overall, differential leucocyte counts for Marshall were similar to those of the other strains. It is worth noting that WBC counts for Cobb 500 birds (10.37 [$\times 10^9$/L]) were above the reference values for chickens (1.9-9.5). For the differential counts, heterophils and monocytes had marginal p-values. No basophils were detected in the three strains.

Furthermore, values for hemoglobin, PCV, MCV, MCH, and MCHC observed in the three strains were outside the reference limits for chickens. Specifically, values observed were lower than the lower reference values.

Table 2. Hematological indices of Noiler and broiler chicken strains.

Parameter	Marshall	Cobb 500	Noiler	SEM	P-value	Reference*
Haemoglobin (g/dl)	8.8	8.83	8.63	0.16	0.65	10.2 -12.5
PCV (%)	27.00	27.40	27.23	0.31	0.67	30-49
RBC ($\times 10^{12}$/L)	2.73	2.70	2.83	0.13	0.75	2.5-3.9
MCV	72.83	75.63	71.57	1.18	0.12	104-135
MCH	23.33	25.67	23.83	0.55	0.05	32.0-43.9
MCHC	29.67	29.00	29.67	0.54	0.63	32.2-36.2
WBC ($\times 10^9$/L)	9.43 ^{ab}	10.37 ^{a}	8.23 ^{b}	0.29	0.007	1.9-9.5
Heterophils ($\times 10^9$/L)	1.68	1.52	1.52	0.11	0.53	0.5-7.6
Lymphocytes ($\times 10^9$/L)	3.16	3.15	2.71	0.12	0.056	1.2-4.2
Monocytes ($\times 10^9$/L)	0.014	0.07	0.00	0.02	0.066	0.0-1.0
Eosinophils ($\times 10^9$/L)	0.16	0.06	0.08	0.06	0.52	0.0-1.8
H:L ratio	0.53	0.48	0.56	0.04	0.48	-

[a b] Means within the same row with different superscripts are significantly different at $p < 0.05$. * Samour [16].

3.2. Enzyme Activity and Serum Biochemical Indices of Noiler and Broiler Chickens

Biochemical indices and enzyme activity of chicken birds reared in the semi-arid environment of Sokoto are presented in Table 3. Among the enzyme activities, AST and ALP showed significant differences among the strains (P<0.05). For AST, Noiler chickens had lower enzyme activities than the two improved strains. Conversely, Cobb 500 and Marshall strains had significantly lower ALP activity than the Noiler strain.

Additionally, the Marshall strain had significantly higher low-density lipoproteins (LDL) than the Cobb 500 strain, but Noiler birds had similar values with both the Marshall and Cobb 500 strains. Conversely, Noiler birds had significantly higher urea in the serum than Marshall birds (P = 0.03), while the Cobb 500 strain had the same values as both Noiler and Marshall strains. Other metabolites, including ALT, high-density lipoproteins (HDL), creatinine, and triglycerides, were similar among the three chicken strains.

Table 3. Serum biochemical indices of Noiler and broiler chicken strains.

Parameter	Marshall	Cobb 500	Noiler	SEM	*p* Value
ALT (U/L)	30.93	33.93	34.33	1.21	0.08
AST (U/L)	119.00 ^{a}	118.67 ^{a}	98.67 ^{b}	3.27	0.007
ALP (U/L)	16.33 ^{b}	16.50 ^{b}	19.33 ^{a}	0.32	<0.001
HDL (mg/dl)	54.33	59.67	61.67	3.60	0.39
LDL (mg/dl)	33.33 ^{a}	28.00 ^{b}	33.00 ^{ab}	1.17	0.031
Urea (mg/dl)	3.80 ^{b}	4.93 ^{ab}	5.53 ^{a}	0.36	0.037
Creatinine (mg/dl)	0.73	0.87	0.97	0.11	0.35
Triglycerides (mg/dl)	127	103	113	7.00	0.16

a b Means within the same row with different superscripts are significantly different at $p < 0.05$.

3.3. Behavioral Traits of Noiler and Broiler Chicken Strains

Table 4 presents the behavioral traits of chicken strains reared in the semi-arid environment of Sokoto. The results showed that the time spent on sawdust bathing (SDB) and locomotion was significantly different between strains. Marshall and Noiler spent comparable time on SDB, whereas the Cobb 500 strain did not express this behavior within the period of observation. As for movement with the pen, broiler strains spent comparable time (10.38-11.58 min/hr) moving within the pen (locomotion), which is statistically shorter than the time spent by birds of the Noiler strain (14.38 min/hr). Other behaviors, including resting, eating, drinking, and preening, did not differ among the strains ($p > 0.05$). Generally, birds spend more time eating than any other activity, followed by resting.

Table 4. Behavioral traits of Noiler and broiler chicken strains.

Behavior (min/hour)	Marshall	Cobb 500	Noiler	SEM	*p* Value
Resting	15.71	14.04	11.53	1.50	0.22
Eating	13.81	14.04	15.63	0.53	0.10
Drinking	10.83	14.50	10.14	1.66	0.21
Sawdust bathing	4.59 ^{a}	0.00 ^{b}	3.61 ^{a}	0.67	0.007
Preening	4.58	6.38	4.72	0.69	0.21
Locomotion	11.58 ^{a}	10.38 ^{b}	14.38 ^{a}	1.73	0.03

a b Means within the same row with different superscripts are significantly different at $p < 0.05$.

3.4. Fear Response of Noiler and Broiler Chicken Strains

The fear response of birds was measured using two tests of touch and grab, and the results are presented in Table 5, which showed that the number of birds touchable was affected by strain (χ^2=17.51, p= 0.002). There were more birds touchable in the Noiler (7.83) during the test, which is significantly higher than those in Cobb-500 (4.50), followed by Marshall (2.67). Similarly, strain had a significant effect on the grab test (χ^2=8.76, p= 0.0126). Birds of the Cobb 500 strain were calmer during the grab test, compared to the Marshall and Noiler strains, which did not differ. The majority of the birds belonging to the Cob500 strain did not move during the grab test. The majority of the birds in the Marshall group walked away without vocalization, whereas the majority of the birds in the Noiler group walked away in addition to vocalization.

Table 5. Fear response of Noiler and broiler chicken strains based on touch and grab tests.

Test	Marshall	Cobb 500	Noiler	Chi-square	*p* Value
Number of birds touchable	2.67 ± 2.34 ^{c}	4.50 ± 0.97 ^{b}	7.83 ± 1.89 ^{a}	17.51	0.0002
Grab test (%)					
1	0	66.67	0		
2	66.67	3.33	33.33		
3	33.33	0	66.67		
Mean	2.10 ^{a}	1.33 ^{b}	2.67 ^{a}	8.75	0.0126

a b Means within the same row with different superscripts are significantly different at $p < 0.05$.

4. Discussion

The significance of thermal tolerance and climate adaptability in chicken breeding programs is paramount in the context of global warming. Identifying strains that exhibit resilience to heat and aridity through physiological, metabolic, and behavioral adaptations is crucial as climate variability intensifies. The semi-arid environment of Northern

Nigeria represents a primary agroecological zone for livestock production. For chickens, the challenges posed by this environment impact homeostasis and overall productivity. Differences in immune reactivity and genetic resilience to environmental stressors among chicken strains are well-documented in many chicken strains reared elsewhere [2,17]. Indigenous strains often demonstrate superior baseline immunological balance and adaptation, which may account for the maintenance of normal white blood cell (WBC) counts even under adverse conditions [18].

The slightly elevated, albeit statistically non-significant, rectal temperatures and respiratory rates observed in the Noiler breed, compared to exotic broilers, suggest functional similarity under mild stress and potentially greater preparedness for fluctuating environments. This observation is consistent with current scientific understanding that local breeds possess generalised adaptive traits, rendering them valuable genetic resources for resilience and food security in challenging agro-ecologies [19,20]. The rectal temperature observed in the birds was within the reference range for broiler chickens, but a lower respiratory rate was observed than the reference range [15]. However, both rectal temperature and respiratory rate in the current study are comparable to those reported in Marshall broiler birds reared under thermal and feed restriction stress in the rainforest agroecology of Nigeria [21]. Furthermore, a similar trend of decreasing values for rectal temperature and respiratory rate with increasing age of birds was evident in previous studies [13,21].

White blood cells are integral not only to chickens' defense against diseases but also as indicators of stress. Elevated WBC counts in Cobb 500 birds, particularly levels exceeding normal reference values, suggest susceptibility to environmental and physiological stressors, likely due to high metabolic rates that may activate immune responses [22,23]. This is likely stress-induced immune activation, which may result in leukocytosis if sustained. It may also indicate the presence of subclinical infections or immune challenges, to which fast-growing broilers could be more vulnerable due to reduced genetic diversity, intensive selection, and potentially compromised immune systems [24]. Given that all birds across the three strains were reared within the same pen and no clinical manifestation of disease was observed, the elevated WBC counts could have been triggered by an immune response likely caused by high metabolic stress in the Cobb-500 due to intensive selection for rapid weight gain and muscle deposition. Rapid growth and muscle deposition are often achieved at the expense of immune function and adaptability [25,26]. Previous studies have demonstrated that indigenous and locally adapted breeds often harbor alleles for enhanced disease resistance, which may lead to more balanced or efficient immune responses compared to commercial strains [27]. Elevated stress and immune activation are frequently associated with poorer welfare outcomes, including higher mortality rates, poor feed conversion, and lower meat quality [28]. In contrast, indigenous breeds are generally better adapted to harsh environments and exhibit less pronounced immune activation under similar conditions [27]. It is pertinent to state that lower concentration of hemoglobin (Hb), along with reduced MCV, MCH and MCHC observed in all the strains, may suggest the occurrence of microcytic hypochromic anemia in the birds. This type of anemia indicates that the red blood cells are smaller than normal and contain less hemoglobin [29,30], reducing their capacity to transport adequate oxygen to the body tissues. Although the diets fed to the birds meet the general nutritional requirements for energy and crude protein, the specific needs of Iron and other hematinic nutrients might not have been met.

The reduced AST activity observed in the Noiler strain indicates a diminished rate of hepatic and overall metabolic turnover compared to the Cobb-500 strain. This observation aligns with the inherently slower growth potential and reduces anabolic activity typical of indigenous genotypes such as the Noiler, which allocate more metabolic energy to maintenance and adaptation rather than rapid tissue accretion. Previous research has associated elevated AST activity with heat and metabolic stress in rapidly growing broiler strains [10,31]. An earlier study also reported lower AST activity in a slow-growing strain compared to its fast-growing counterpart at eight weeks of age [32], corroborating the findings of the present study. Although the specific metabolic function of ALP remains incompletely understood, the enzyme has been associated with intestinal lipid transport and bone calcification. The higher ALP activity observed in the Noiler strain in the current study suggests superior bone formation compared to the fast-growing broiler strains. Furthermore, elevated serum LDL concentrations in the Marshall strains indicate enhanced lipid mobilization and deposition efficiency [33,34]. This may reflect a metabolic predisposition towards fat storage, possibly in the Marshall strain. Previous studies have documented higher LDL levels in lean or slow-growing broiler strains compared to their fast-growing counterparts [34,35]. Similarly, elevated urea levels suggest increased amino acid catabolism and poor nitrogen efficiency, indicating that the indigenous chickens and Cobb 500 are less efficient converters of dietary protein into body tissue compared to the Marshall strain [36]. The serum metabolites and enzyme activities reported in this study generally fall within the range documented in previous studies [37,38], but are higher than those reported for Egyptian chickens [39]. However, the small sample collected from each strain represents an important limitation of these findings. These findings underscore critical metabolic trade-offs, wherein broilers exhibit rapid growth and efficient nutrient utilization, whereas indigenous birds prioritize resilience and survival under semi- intensive and extensive production environments.

Non-feeding activities such as locomotion are integral components of the normal ethological repertoire of chickens and are commonly used as indicators of comfort and environmental suitability [40]. The increased incidence of sawdust-bathing and locomotion observed in the Noiler and Marshall chickens suggests a better welfare status than the Cobb 500. The frequent expression of these activities indicates that the Noiler and Marshall birds experienced fewer physical constraints, better leg health, and a greater motivation to explore and engage with their surroundings. In contrast, the reduced activity levels observed in the Cobb-500 broilers could be associated with behavioral suppression resulting from intensive selection for rapid growth. Consequently, the increased expression of natural behaviors in the Noiler and Marshall strains reflects enhanced physical well-being, environmental adaptability, and psychological comfort, underscoring their relative resilience and welfare advantage under the rearing conditions. Previous studies have established a link between active behaviors and exploration tendencies with better health outcomes [41].

Furthermore, the number of birds that are touchable may indicate one of two possible scenarios: reduced fear or gait-related issues. Therefore, this measure should be interpreted with caution. In this study, the high number of birds within reach in Noiler chickens during the touch test may be due to behavioral adaptation, demonstrating more natural and adaptive coping strategies. In a related research, birds kept in environmentally enriched conditions were more reachable via the touch test than those in stressful conditions [14]. Furthermore, birds of the Noiler and Marshall strain may indicate greater reactivity and flight motivation, reflecting the behavioral profile of indigenous chickens and heightened awareness of their surroundings.

5. Conclusion

The findings of this study reveal a distinct trade-off between productivity and welfare in three chicken strains. The fast-growing Cobb-500 broiler chickens demonstrated elevated immune response (10.37 of WBC in Cobb 500 vs 8.23 in Noiler), yet exhibited limited natural behavioral expression In contrast, Noiler chickens had higher ALP (19.33 vs 16.50 in Cobb 500) and lower AST 98.67 vs 118.67 in Cobb 500), suggesting adaptive metabolic profiles, as well as increased expression of natural behavior (14.38 min/hr of locomotion vs 10.36 min/hr in Cobb 500). These results underscore the necessity of balancing genetic selection for production with the preservation of natural behaviors and physiological resilience to foster sustainable poultry welfare in a rapidly changing climate and escalating environmental stressors. However, there is a need to conduct a mechanistic study to verify these findings.

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