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Resultant Effect of Early Endogenous Thermal Acclimatization on Performance of Heat-Stressed Broiler Finishers on Different Levels of Dietary Protein

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Abstract

The guarantee of a naturally stable thermal environment that will keep poultry birds within the zone of maximum comfort all year round in tropical and sub-tropical regions in the 21st century cannot be established. Therefore, it becomes necessary to look into stabilizing internal environment of vulnerable chicks, with the sole aim of re-exhibiting their masked potentials for fast growth and high yield. Crude protein (CP), though essential for growth and repair, dissipates more heat load than other nutrients during metabolism. Hence, it becomes imperative to investigate the effect of early endogenous thermal acclimatization on performance of heat-stressed broilers (HSB) at finisher phase. Using a total of 288, one day-old Arbor Acre broiler chicks, birds were randomly allotted to four dietary treatments (T1 – 21 % CP; T2 – 19 % CP; T3 – 17 % CP; and T4 – 15 % CP) at finisher phase with six replicate groups in a completely randomized design in order to evaluate the resultant effect of a 2 %, 4 % and 6 % reduction in dietary CP. Data were analysed using descriptive, ANOVA, regression and correlation statistics. Low crude protein diets improved performance of HSB at finisher phase. However, a 2 % dietary CP reduction (19 % CP) best enhanced performance of HSB at finisher phase. Some parameters that were supposed to strongly correlate were not as a result of the influence of early endogenous manipulation. Endogenous heat load reduction through dietary crude protein and electrolyte inter-play have resulted in a proportionate increase in feed intake, body weight gain, protein efficiency ratio and enhanced feed conversion ratio in HSB at finisher phase. The resultant effect of early endogenous thermal acclimatization on performance of heat-stressed broiler chickens at finisher phase has been beneficial.

Keywords: broiler finishers, crude protein, endogenous heat, heat stress, resultant effect.

1. Introduction

The extent of adaptation to heat stress conditions by poultry birds is dependent on the enhancing strategies adopted during thermal conditioning in chicks. Popoola et al. (2020a) affirmed that tropical regions with characteristic high environmental temperatures face more

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difficulty raising fast-growing meat type chickens because birds` health, performance and meat quality are adversely affected. Decuypere et al. (2001) also opined that adaptation to heat stress conditions can be enhanced by thermal conditioning in chicks, without impairing performance, as chicks regulate body temperature during early post-hatch periods more with proportionate increase in age (Debonne et al., 2008). However, the metabolism of crude protein ingested by chicks results in a greater increase in heat production than carbohydrates or fats and results in increased body temperature (Musharaf, Latshaw, 1999). A reduction of crude protein in rations fed to broilers under heat stress condition, with adequate amount of essential amino acids may improve performance (Zaman et al., 2008). Yahav (2000) suggested that early thermal manipulations in poultry may be useful in tropical regions with more vulnerability to heat stress, when the chicks` body temperature and feedback regulatory mechanisms are immature. Nichelmann, Tzschentke (2002) stated that early post-hatch period is more important where major developmental and physiological processes occur. Although, chicks anatomically seem complete post-hatch, yet some systems such as digestive, immune, and thermoregulatory systems need further development and maturation for optimum performance. Soleimani et al. (2012) opined that living organisms respond to thermal stressors by synthesizing a group of highly conserved proteins known as heat shock proteins as they function in modifying physiological stress response and stress tolerance acquisition. Tan et al. (2010) noted that heat stress during early post-hatch periods may result in greater adaptability to thermal stress even when endogenous heat production is higher. Since birds must maintain internal body temperature despite thermal oscillation, they do so at the expense of production, by diverting nutritionally beneficial molecules to homeostatic adjustments. The level of heat tolerance in poultry is dependent on the activation of heat loss mechanism and the ability to reduce the endogenous heat production (Nichelmann, Tzschentke, 2002). Also, Popoola et al. (2020b) noted that ideal DEB is prerequisite to blood acid-base balance and reduced incidences of hemodilution in heat-stressed broilers, and if supplied in adequate amount, there would be a substantial positive feedback. Azad et al. (2010) noted that heat stress affects metabolic processes, causing oxidative damage to skeletal muscles with impairment of functional properties of meat. Leterrier et al. (2009) noted that the growth of broilers have been improved by genetic selection. However, some visceral organs have not been genetically modified alongside traits of most importance, thereby creating a negligence in effective capacity of cardiovascular and respiratory systems for hyperventilation and heat loss. Yahav, McMurtry (2001) reported that pre-starter exposure of chicks to heat stress enabled them to withstand heat challenge at finisher phase when metabolic processes increased, with subsequent reduction in mortality as De Basilio et al. (2003) reported that chickens that did not survive heat challenge at 34 days of age had higher body temperatures of about 0.6 °C prior to heat challenge than those of the survivors. Although, the beneficial effects of early thermal-conditioning are known, yet the resultant effect of an internal adjustment of heat load in fast-growing broiler chickens on performance and protein utilization and the extent of deviation from the standard effect upon reduction of dietary crude protein have not been clearly established in heat-stressed broiler chickens and it is necessary as Popoola et al. (2020c) opined that poultry meat and feed quality deterioration; and loss of customers` preference to chicken meat exposed to heat stress conditions may persist in the 21st century poultry farming systems (Popoola, 2020).

2. Materials and methods

The study was carried out at the Teaching and Research Farm, University of Ibadan, Nigeria, after the experimental protocol was reviewed and approved by the Institutional Animal Care and Use Committee, through the Agricultural Biochemistry and Nutrition Unit of the Department of Animal Science. A total of 288, one day-old Arbor Acre broiler chicks with initial body weight of 41±3g were randomly allotted to four dietary treatments (CP, %: 23, 21, 19, 17) at pre-starter phase and 21, 19, 17 and 15 % CP at finisher phase with six replicate groups in a completely randomized design in order to evaluate the resultant effect of a 2 %, 4 % and 6 % reduction in dietary CP, and early endogenous thermal acclimatization on performance of heat-stressed broiler chickens at finisher phase. Feed grade potassium chloride and sodium bicarbonate, and the inherent potassium, sodium and chloride ions in feed ingredients were the electrolyte sources computed for determining the aggregate DEB using the equations derived by Popoola, Iyayi (2018). The derived equations were based on assumptions opined by Popoola et al. (2020c) for an ideal DEB, affirming that not more than 30 to 140 mEq/kg DEB are required from mineral sources, with about 115 to 210 mEq/kg DEB obtainable from feed ingredients.

The derived equation of DEB is $\sum$ DEB= $\sum (Na^+ + K^+) - \sum Cl^-$ ...[y] [c].................. (1)

Where [y] = mineral sources

and [c] = other macro ions (Ca, Mg, P, S etc) held constant.

$\sum$ DEB = ι DEB + ε DEB .... (2)

Where $\sum$ DEB = Aggregate DEB; ι DEB = Inherent DEB in rations and ε DEB = DEB in Electrolyte sources.

Feed intake was determined by giving a known quantity of feed to the birds and subtracting the left over for a given period from the quantity supplied. This difference was divided by the number of birds in a replicate group to estimate the feed intake per bird. Body weight gain of birds was determined by subtracting the initial weight for each week from the final weights with the aid of sensitive weighing scale.

The percentage deviation from the standard effect was calculated as described by the authors using the formula

$$\delta\,\% = \frac{(\dot{S}^{\hat{e}} - \hat{A}^{\hat{e}})}{\dot{S}^{\hat{e}}} \times 100$$

Where δ % = percentage deviation from the standard effect

$\dot{S}^{\hat{e}}$ = standard mean effect

$\hat{A}^{\hat{e}}$ = Actual mean effect for individual treatments

and the resultant effect (R) was calculated for each parameter as the difference between the initial and final standard deviations from the standard effect as

$R = {}^{f}\delta_{Tn} - {}^{i}\delta_{Tn}$

Where ${}^{f}\delta_{Tn}$ = final percentage deviation from the standard effect for each treatment

${}^{i}\delta_{Tn}$ = initial percentage deviation from the standard effect for each treatment

A total of 32 pens were used in this study in order to measure water intake in heat-stressed broiler chicks as described by Popoola et al. (2019). Maximum and minimum average ambient temperature and relative humidity were monitored on a daily basis using a digital hygro-thermometer. Rectal temperature was measured in the morning (06:00-08:00 h) and afternoon (13:00-15:00 h), with the use of a digital rectal probe. Two birds per pen with body weight closest to the class mean weight were identified for body temperature measurement. Proximate analysis of the feeds was determined according to AOAC (2005) procedure. Assay was conducted for sodium and potassium (Flame spectrophotometer), and chloride (titration) in diets fed to broiler chickens at different phases of growth (Lacroix et al., 1970). Data obtained were subjected to descriptive statistics, analysis of variance using SAS (2012) package, regression and correlation statistics. Means for treatments in the analysis of variance were compared using Duncan Multiple range test and all statement of significance were based on probability level of 0.05.

3. Results

Table 1 shows the chemical analyses of diets fed to heat-stressed broiler chickens at finisher phase. Although, the diets differed significantly in CP, yet they all met the optimum dietary electrolyte balance requirement for heat-stressed broiler finishers.

Table 2 shows the performance of heat-stressed broiler chickens fed diets with varying crude protein at finisher phase. Feed intake (FI) was highest ($P < 0.05$) in heat-stressed birds on 21 % CP (1777.33) compared to other dietary treatments. The lowest ($P < 0.05$) FI was observed in birds on 15 % CP (1462.08) and did not differ significantly from 17 % CP (1485.58). The body weight gain (BWG) observed in birds on 21 % CP (866.08) and 19 % CP (869.08) were similar and significantly ($P < 0.05$) higher compared to 17 % CP (757.50) and 15 % CP (623.08). However, the lowest ($P < 0.05$) BWG was observed in birds on 15 % CP. Birds on 15 % CP (2.35) had the highest ($P < 0.05$) FCR value compared to other dietary treatments. However, birds on 19 % CP (1.87) had the lowest FCR value at finisher phase. Gain to feed ratio was significantly ($P < 0.05$) higher in birds on 19 % CP (0.54) compared to 21 % (0.49) and 15 % CP (0.43), but did not differ significantly from 17 % CP (0.51). Protein intake (PI) was highest ($P < 0.05$) in birds on 21 % CP (373.24) and decreased significantly with decreasing dietary CP. However, protein efficiency ratio (PER) was significantly ($P < 0.05$) higher in birds on 19 % CP (2.83), 17 % CP (2.99) and 15 % CP (2.85) compared to 21 %

CP (2.32) at finisher phase. Water intake values observed in heat-stressed birds on 21 % (849.34), 19 % CP (851.03), and 17 % CP (838.39) were similar and significantly ($P < 0.05$) higher compared to 15 % CP (723.01).

Table 1. Analysed nutrients in diets fed to heat-stressed broiler chickens at finisher phase

Nutrients	21 % CP	19 % CP	17 % CP	15 % CP
Crude protein (%)	20.89	18.83	17.20	15.33
ME, kcal/kg	3038.90	3046.63	3083.08	3087.65
Ether extract (%)	3.84	3.80	3.81	3.78
Crude fibre (%)	3.49	3.28	3.08	2.93
Calcium (%)	1.03	0.99	1.02	1.02
Total phosphorus (%)	0.74	0.69	0.67	0.65
NPP (%)	0.43	0.42	0.41	0.40
Ca:NPP	2.39	2.36	2.49	2.55
Sodium (%)	0.23	0.27	0.31	0.35
Potassium (%)	1.15	1.13	1.07	1.05
Magnesium (%)	0.17	0.16	0.16	0.15
Chlorine (%)	0.54	0.58	0.58	0.63

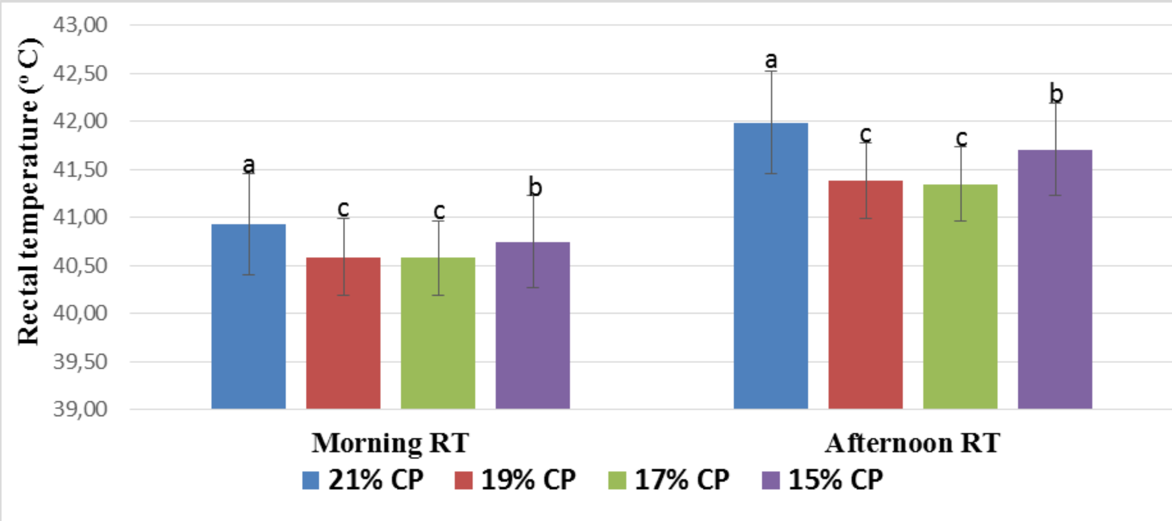
ME – Metabolizable energy, NPP – Non-phytate phosphorus, Ca – Calcium, CP – Crude protein

Table 2. Performance of heat-stressed broilers chickens fed diets with varying crude protein at finisher phase

Dietary treatments	FI (g/bird)	BWG (g/bird)	FCR (g/g)	Gain: Feed (g/g)	Protein Intake (g/bird)	PER (g/g)	Water intake (mL /bird/day)
21 % CP	1777.33^{a}	866.08^{a}	2.11^{b}	0.49^{b}	373.24^{a}	2.32^{b}	849.34^{a}
19 % CP	1617.83^{b}	869.08^{a}	1.87^{c}	0.54^{a}	307.39^{b}	2.83^{a}	851.03^{a}
17 % CP	1485.58^{c}	757.50^{b}	1.98^{bc}	0.51^{ab}	252.55^{c}	2.99^{a}	838.39^{a}
15 % CP	1462.08^{c}	623.08^{c}	2.35^{a}	0.43^{c}	219.31^{d}	2.85^{a}	723.01^{b}
SEM	24.63	40.57	0.10	0.02	4.25	0.12	36.21
P Value	0.00	0.00	0.02	0.02	0.00	0.01	0.05

^{abcd} Means of treatments along a column with different superscripts differed significantly ($P < 0.05$) using DMRT. FI – Feed intake, BWG – Body weight gain, FCR – Feed conversion ratio, PER – Protein efficiency ratio.

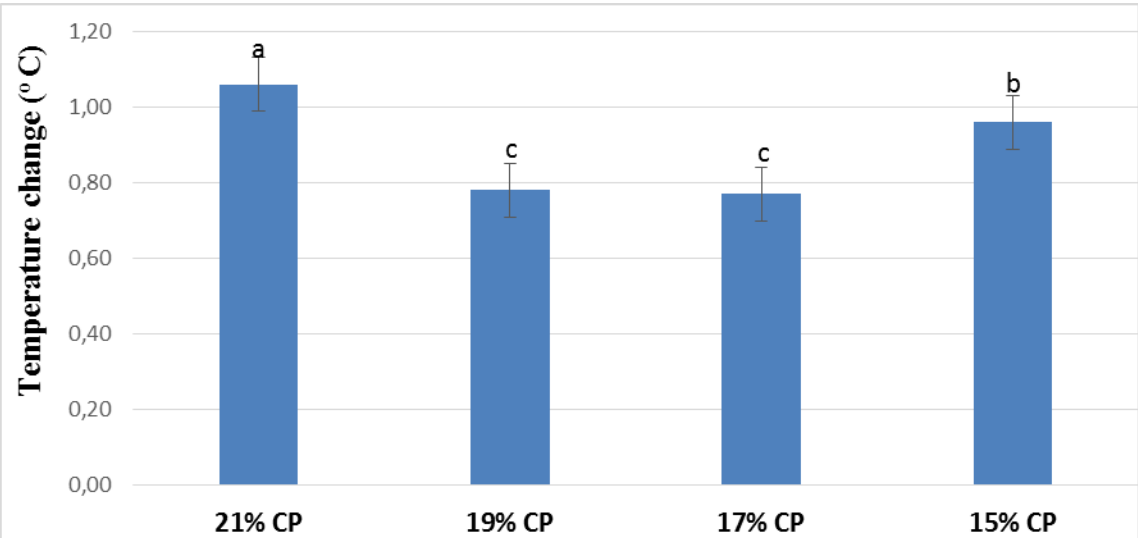
Figure 1 shows the rectal temperatures (RT) of heat-stressed broiler chickens at finisher phase. Higher ($P < 0.05$) morning RT was observed in birds on 21 % CP compared to other dietary treatments. However, birds on 19 % CP and 17 % CP had the lowest ($P < 0.05$) morning RT. Similar trend was observed in afternoon RT of heat-stressed birds on varying levels of dietary CP, though, it was at a much more elevated temperature range.



Bar means of treatments with different superscripts differed significantly (P < 0.05) using DMRT. RT – Rectal temperature; CP – Crude protein

Fig. 1. Rectal temperature of heat-stressed broiler chickens on different levels of dietary protein at finisher phase

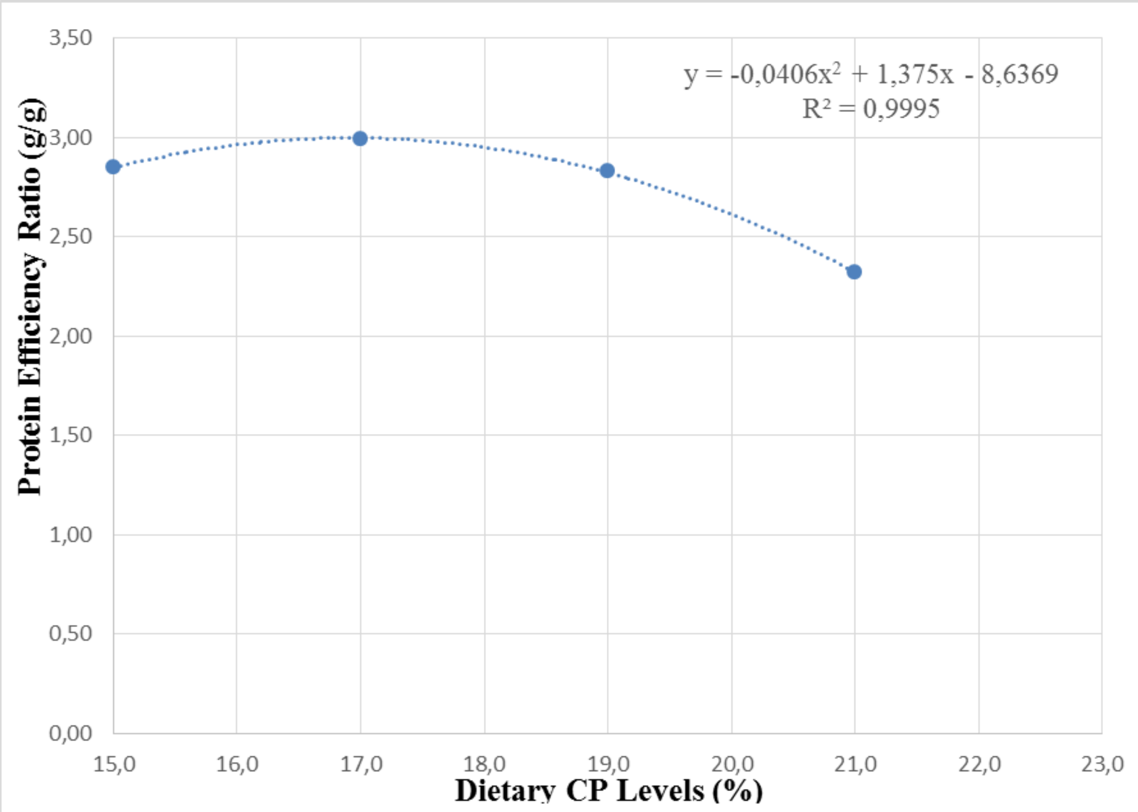
Figure 2 shows the temperature change in heat-stressed broiler chickens on different levels of dietary crude protein at finisher phase. It was observed that birds on 21 % CP (1.06) had the highest (P < 0.05) fluctuation in body temperature compared to other treatments. However, birds on 19 % CP (0.78) and 17 % CP (0.77) had the lowest (P < 0.05) body temperature change at finisher phase.



Bar means of treatments with different superscripts differed significantly (P < 0.05) using DMRT. CP – Crude protein

Fig. 2. Temperature change in heat-stressed broiler chickens on different levels of dietary protein at finisher phase

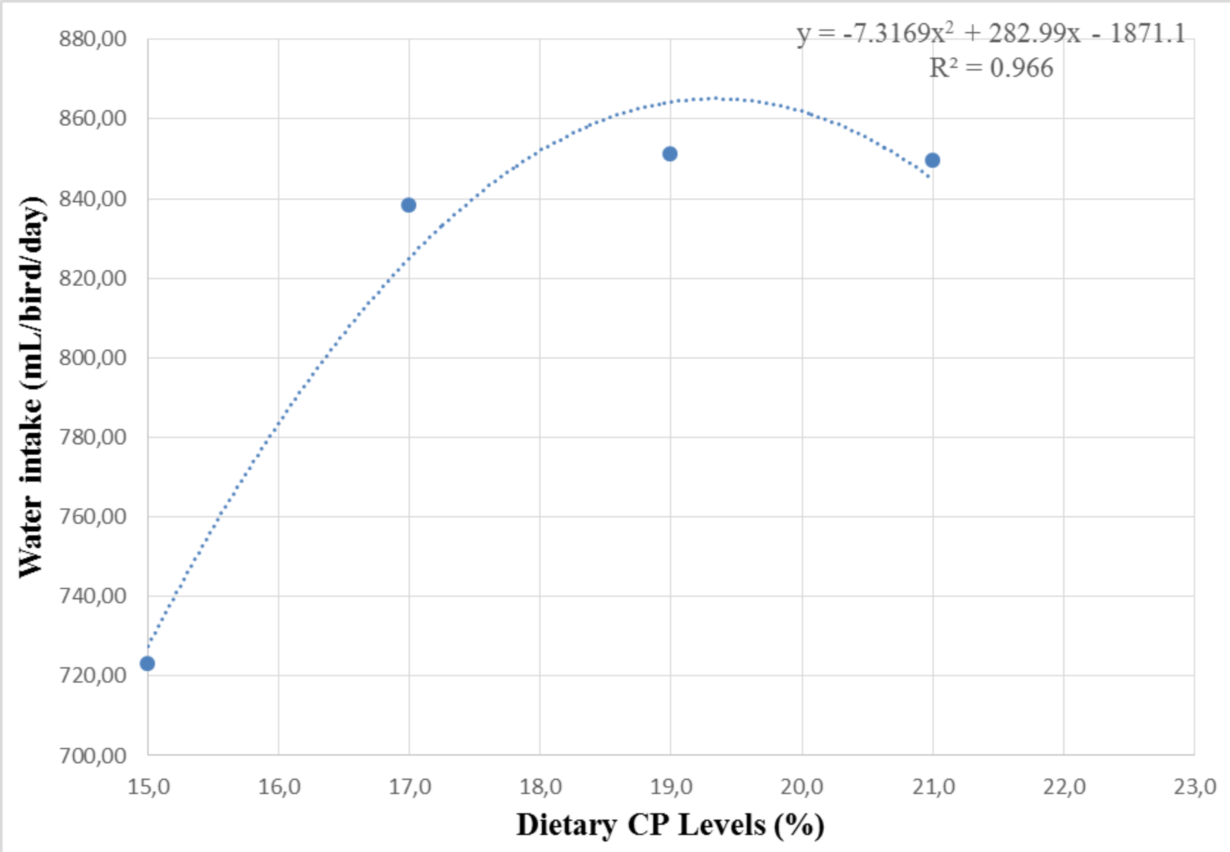
Figure 3 revealed the relationship between varying levels of dietary crude protein and protein efficiency ratio in heat-stressed broiler chickens at finisher phase. An optimum level of dietary CP was observed at 17 % in heat stressed birds and decreases significantly with increasing dietary CP under heat stress condition. The R^2 value (0.99) indicated that about 99 % of the observed changes in PER were as a result of dietary crude protein levels.



CP – Crude protein

Fig. 3. Relationship between dietary crude protein levels and protein efficiency ratio in heat-stressed broiler chickens at finisher phase

Figure 4 revealed the relationship between varying levels of dietary crude protein and water intake in heat-stressed broiler chickens at finisher phase. An optimum level of dietary CP was observed at 19.5 % in heat stressed birds and decreases significantly with increasing dietary CP under heat stress condition. The R^2 value (0.97) indicated that about 97 % of the observed changes in water intake of heat-stressed birds at finisher phase were as a result of dietary crude protein levels.



CP – Crude protein

Fig. 4. Relationship between dietary crude protein levels and water intake of eat-stressed broiler chickens at finisher phase

Table 3 revealed the percentage deviation from the standard effect and resultant effect of early endogenous thermal acclimatization on performance of heat-stressed broiler finishers. At pre-starter phase, a 2 % decrease in dietary CP resulted in a 4.45 % reduction in FI, while a 4 % dietary CP reduction resulted in 8.09 % reduction in FI. However, a 6 % dietary CP reduction resulted in about 19.90 % reduction in FI at pre-starter phase. A 2 % dietary CP reduction resulted in a 15.50 % reduction in BWG in pre-starter chicks, and 4 % dietary CP reduction resulted in about 13.52 % reduction in BWG, while 6 % reduction in dietary CP resulted in about 31.11 % reduction in BWG in heat-stressed pre-starter broiler chicks. A 13.61 % increase in FCR was observed in birds on 2 % dietary CP reduction, while those on 4 % dietary CP reduction had about 6.12 % increase in FCR. However, those on 6 % dietary CP reduction had about 17.01 % increase in FCR, at pre-starter phase.

Gain: feed ratio (feed efficiency) of pre-starter chicks on 2 % dietary CP reduction resulted in about 11.76 % reduction, while a 4 % dietary CP reduction resulted in about 5.88 % reduction in feed efficiency. However, a 6 % reduction in dietary CP resulted in about 13.24 % reduction in feed efficiency. A 2 % decrease in dietary CP resulted in about 12.76 % reduction in protein intake, while a 4 % decrease in dietary CP resulted in about 24.08 % reduction in PI. However, a 6 % decrease in dietary CP resulted in about 40.80 % decrease in PI at pre-starter phase. The PER value observed from a 2 % dietary CP reduction was about 1.48 % lower than the standard effect. However, a 4 % dietary CP reduction resulted in about 15.43 % increase in PER, while a 6 % dietary CP reduction resulted in about 23.15 % increase in PER of heat-stressed pre-starter chicks. A 2 % dietary CP reduction also resulted in about 9.87 % reduction in WI compared to the standard effect, while a 4 % dietary CP reduction resulted in about 1.51 % reduction in WI. However, a 6 % reduction in dietary CP resulted in about 9.20 % reduction in WI.

At finisher phase, a 2 % reduction in dietary CP resulted in about 8.97 % reduction in FI, while a 4 % and 6 % reduction in dietary CP resulted in 16.42 % and 17.74 % reduction in feed intake, respectively. A 2 % reduction in dietary CP resulted in about 0.35 % increase in BWG, while

4 % and 6 % dietary CP reduction resulted in 12.54 % and 28.06 % reduction in BWG, respectively. For FCR, a 2 % dietary CP reduction resulted in about 11.37 % reduction in FCR, while a 4 % reduction resulted in about 6.16 % decrease in FCR. However, a 6 % dietary CP reduction resulted in about 11.37 % increase in FCR value of heat-stressed broiler chickens at finisher phase. Feed efficiency in heat-stressed broiler chickens on a 2 % dietary CP reduction resulted in about 10.20 % increase compared to the standard effect. A 2 % reduction in dietary CP resulted in 17.64 % decrease in PI, while a 4 % and 6 % dietary CP reduction resulted in about 32.34 % and 41.24 % decrease in PI, respectively. A 2 % dietary CP reduction resulted in 21.98 % increase in PER, while a 4 % and 6 % reduction in dietary CP resulted in 28.88 % and 22.84 % increase at finisher phase, respectively.

A 2 % reduction in dietary CP at finisher phase resulted in 0.19 % increase in WI compared to the standard effect. A 4 % and 6 % dietary CP reduction resulted in about 1.29 % and 14.87 % decrease in WI of heat-stressed broiler chickens at finisher phase.

Resultant effect

Early endogenous thermal acclimatization resulted in about 4.52 % increase in FI of birds on a 2 % dietary CP reduction, while a 4 % reduction in dietary CP resulted in about 8.32 % increase in FI. However, a 6 % dietary CP reduction resulted in about 2.17 % reduction in FI. Early endogenous thermal acclimatization resulted in about 15.85 % increase in BWG at finisher phase, in birds on 2 % dietary CP reduction, while about 0.98 % and 3.05 % increase in BWG were observed in broiler finishers on 4 % and 6 % dietary CP reduction, respectively. Early endogenous thermal acclimatization resulted in about 24.98 %, 12.28 % and 5.63 % improvement in FCR of birds on 2 %, 4 %, and 6 % dietary CP reduction. Feed efficiency was improved at finisher phase in birds on 2 %, 4 % and 6 % dietary CP reduction in the order: 21.97 %, 9.96 % and 0.99 %, respectively. It was observed that early endogenous thermal acclimatization resulted in about 4.88 %, 8.26 % and 0.44 % increase in protein intake of heat-stressed broiler chickens at finisher phase. Early endogenous heat acclimatization resulted in about 23.47 %, 13.45 % and 0.30 % improvement in PER of heat-stressed birds on 2 %, 4 % and 6 % dietary CP reduction, respectively. Early endogenous thermal acclimatization resulted in about 10.07 % and 0.22 % reduction in WI of heat-stressed birds on 2 % and 4 % dietary CP reduction, respectively. However, birds on 6 % dietary CP reduction resulted in about 5.67 % increase in WI.

Table 3. Percentage Deviation from the standard effect and resultant effect of early endogenous thermal acclimatization on performance of heat-stressed broiler finishers

Phase	Treatments	δ % FI	δ % BWG	δ % FCR	δ % Gain :feed	δ % PI	δ % PER	δ % WI
	T1	0	0	0	0	0	0	0
Pre-starter	T2	4.45	15.50	-13.61	11.76	12.76	1.48	9.88
	T3	8.09	13.52	-6.12	5.88	24.08	-15.43	1.51
	T4	19.91	31.11	-17.01	13.24	40.80	-23.15	9.20
	T1	0	0	0	0	0	0	0
Finisher phase	T2	8.97	-0.35	11.37	-10.20	17.64	-21.98	-0.19
	T3	16.42	12.54	6.16	-4.08	32.34	-28.88	1.29
	T4	17.74	28.06	-11.37	12.24	41.24	-22.84	14.87
	T1	0	0	0	0	0	0	0
	T2	4.52	-15.85	24.98	-21.97	4.88	-23.47	-10.08
Resultant effect (R)	T3	8.32	-0.98	12.28	-9.96	8.26	-13.45	-0.22
	T4	-2.17	-3.05	5.63	-0.99	0.44	0.30	5.67

δ % – Percentage deviation from the standard effect; FI- Feed intake, BWG-Body weight gain, FCR-Feed conversion ratio, PI-Protein intake, PER- Protein efficiency ratio, WI-Water intake.

Table 4 shows the correlation between performance parameters and protein intake of heat-stressed broiler chickens at finisher phase. It was observed that feed intake had a strong and positive correlation with PI ($r = 0.99$; $P < 0.01$). Although, FI was also positively correlated to BWG (r = 0.81), gain: feed (r = 0.35), water intake (r = 0.62), morning RT (r = 0.65), afternoon RT (r = 0.60) and TC (r = 0.53), yet no significant relationship was found. The BWG was positively correlated to PI (r = 0.88), but was not significant. The FCR was negatively correlated to PI (r = -0.39) and their relationship was not strong. A negative, but weak relationship existed between gain: feed and rectal temperatures of heat-stressed birds at finisher phase. The PI was positively correlated to WI (r = 0.73), morning RT (r = 0.55), afternoon RT (r = 0.49) and TC (r = 0.41), and were not significant. The PER was negatively correlated to PI (r =-0.85), morning RT (r = -0.91), afternoon RT (r = -0.88), and TC (r = -0.83). The WI is positively correlated to BWG (r = 0.93) in heat-stressed broiler chickens at finisher phase, though not significant. Morning RT had a strong and positive correlation with afternoon RT (r = 0.99; P < 0.01) and TC (r = 0.99; P < 0.01). The TC was negatively correlated to PER (r = -0.83; P > 0.05).

Table 4. Correlation between performance parameters and protein intake of heat-stressed broiler chickens at finisher phase

Parameters	FI	BWG	FCR	Gain: feed	PI	PER	WI	Morning RT	Afternoon RT	TC
FI		0.81^{ns}	-0.27^{ns}	0.35^{ns}	0.99^{*}	-0.91^{ns}	0.62^{ns}	0.65^{ns}	0.60^{ns}	0.53^{ns}
BWG	0.81^{ns}		-0.78^{ns}	0.83^{ns}	0.88^{ns}	-0.49^{ns}	0.93^{ns}	0.09^{ns}	0.02^{ns}	-0.07^{ns}
FCR	-0.27^{ns}	-0.78^{ns}		-0.99^{**}	-0.39^{ns}	-0.15^{ns}	-0.88^{ns}	0.55^{ns}	0.60^{ns}	0.67^{ns}
Gain: feed	0.35^{ns}	0.83^{ns}	-0.99^{**}		0.47^{ns}	0.07^{ns}	0.90^{ns}	-0.48^{ns}	-0.54^{ns}	-0.61^{ns}
PI	0.99^{*}	0.88^{ns}	-0.39^{ns}	0.47^{ns}		-0.85^{ns}	0.73^{ns}	0.55^{ns}	0.49^{ns}	0.41^{ns}
PER	-0.91^{ns}	-0.49^{ns}	-0.15^{ns}	0.07^{ns}	-0.85^{ns}		-0.28^{ns}	-0.91^{ns}	-0.88^{ns}	-0.83^{ns}
WI	0.62^{ns}	0.93^{ns}	-0.88^{ns}	0.90^{ns}	0.73^{ns}	-0.28^{ns}		-0.11^{ns}	-0.19^{ns}	-0.28^{ns}
Morning RT	0.65^{ns}	0.09^{ns}	0.55^{ns}	-0.48^{ns}	0.55^{ns}	-0.91^{ns}	-0.11^{ns}		0.99^{**}	0.99^{*}
Afternoon RT	0.60^{ns}	0.02^{ns}	0.60^{ns}	-0.54^{ns}	0.49^{ns}	-0.88^{ns}	-0.19^{ns}	0.99^{**}		0.99^{**}
TC	0.53^{ns}	-0.07^{ns}	0.67^{ns}	-0.61^{ns}	0.41^{ns}	-0.83^{ns}	-0.28^{ns}	0.99^{*}	0.99^{**}	

*P < 0.05; ** P < 0.01, ns – not significant; FI – Feed intake, BWG – Body weight gain, FCR – Feed conversion ratio, PER – Protein efficiency ratio, WI – Water intake, RT – Rectal temperature, TC – Temperature change.

4. Discussion

Early endogenous heat manipulation has resulted in enhanced broiler performance at finisher phase, even in the face of thermal oscillation as observed in present study. Heat-stressed birds are characterized by a sharp neglect of feed or reduction in marginal feed intake. However, endogenous heat load reduction through dietary crude protein and electrolyte inter-play have resulted in a proportionate increase in feed intake at finisher phase where the effect of thermal stress is more felt due to increased metabolic processes and feathering. Contrarily, birds on a 6 % reduction in dietary CP from the standard exhibited about 2.17 % reduction in feed intake at finisher phase and this is symbolic to a clinical organism struggling to ensure thermal equilibrium. The result of present study is consistent with the report of Si et al. (2004) who also noted reduced appetite in birds fed low-CP diets. From current study, a 2 % reduction in dietary CP at pre-starter phase resulted in about 15.8 % increase in BWG. Early endogenous thermal manipulation resulted in about 25 %, 12 % and 5 % improvement in FCR for heat-stressed birds on 2 %, 4 % and 6 % dietary CP reduction as against the standard. Present findings were consistent with the assertions of Yahav, Hurwitz (1996) who noted that broiler chicks exposed to high temperatures at pre-starter period maintained higher rate of viability when challenged with higher temperatures at finisher phase, and concluded that such adaptive responses were due to previous exposure to heat stress. The results of present study were consistent with the assertions of Oliveira et al. (2006), who affirmed that performance decline in broilers under heat stress conditions resulted from the inability of birds to expel excess endogenous heat load. Current findings also contradicted the report of Cheng et al. (1997) who noted that the provision of higher crude protein in diets of heat-stressed broilers, in attempt to compensate for low appetite, is detrimental to production parameters. However, contrasting reports were documented by Temim et al. (2000), affirming that low-CP diets are not beneficial to poultry under heat stress conditions. Present findings have proven that extremely low CP diets are not indeed beneficial to heat-stressed broiler chickens at finisher phase as it appears that a dietary crude protein threshold exists for heat-stressed broiler chickens. Similar reports by Awad et al. (2014) affirmed present findings, as they reported a decrease in performance of broilers fed diets with low CP, even when all essential amino acid requirements are met. However, Popoola et al. (2020d) hypothesized that extremely low CP diets are unbeneficial to broilers in a state of thermal comfort, but when heat-stressed, these low CP diets become beneficial in reducing endogenous heat contribution and increasing the efficiency of nutrients. The results of present study are consistent with the reports of Buyse et al. (1992) who noted reduced growth performance in response to increased heat production in male broiler chickens, while affirming that the heat increment in broilers fed a lower protein diet was as a result of elevated plasma triiodothyronine (T3) concentration, which may consequently increase heat production. From current study, water intake was reduced in heat-stressed broiler chickens on reduced dietary CP, indicating a decline in overall heat load. This feedback showcases a significant relationship between dietary CP levels and water intake trend in heat-stress broilers. Soleimani et al. (2012) reported that performance of broiler chickens was negatively affected by dietary CP level reduction at both starter and finisher phases, regardless of feed-grade amino acid manipulation. Although, Aftab et al. (2006) established that the reduction of dietary CP will reduce both essential and non-essential amino acids, and could alter the balance of such in low-CP diets, with an aftermath on feed intake as the amount of ingested free amino acids into the blood stream increases in birds on low CP diets and may affect the balance of plasma amino acid profile. Waldroup (2007) noted that the reduced performance in broilers on low-CP diets could be associated with insufficient nitrogen for non-essential amino acid synthesis, because chickens on standard levels of dietary protein can synthesize the non-essential amino acids from excess essential amino acids, but when absent or in low supply, synthesis is reduced and performance decline is aggravated. Ali, Hossain (2010) stated that heat stress in broilers can be reduced by early-age thermal conditioning, as it is a sensitive process of induction of thermo-tolerant traits in immature neonatal chicks at an early age, by developing the hypothalamus, which is the thermo-regulatory centre, and has been proven to be the most appropriate age to exploit and induce thermotolerance in broiler chickens (Yahav et al., 2005).

5. Conclusion

Dietary CP levels of 17 % and 19 % enhanced protein efficiency ratio in heat-stressed broiler chickens at finisher phase. Low crude protein diets improved performance of heat-stressed broiler chickens at finisher phase. However, a 2 % dietary CP reduction (19 % CP) best enhanced performance of heat-stressed broiler chickens at finisher phase. Some parameters that were supposed to strongly correlate were not as a result of the influence of early endogenous manipulation. Endogenous heat load reduction through dietary crude protein and electrolyte inter-play have resulted in a proportionate increase in feed intake, body weight gain, protein efficiency ratio and enhanced feed conversion ratio in heat-stressed broiler chickens at finisher phase. The resultant effect of early endogenous thermal acclimatization on performance of heat-stressed broiler chickens at finisher phase has been beneficial.

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Conflicts of Interest

The authors declare no conflicts of interest as regarding the publication of this paper.

Ethical Approval

The study received the ethical approval of the Institutional Animal Care and Use Committee, through the Agricultural Biochemistry and Nutrition Unit of the Department of Animal Science, University of Ibadan, Nigeria.

Contributorship

I.O. Popoola designed, implemented and analyzed data; O.R. Popoola and I.O. Popoola drafted the manuscript. I.F. Olaleru, I.O. Busari, F.J. Oluwadele, O.M. Ojeniyi and Q.T. Alegbejo reviewed, contributed and approved the final draft of the manuscript.

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