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Effects of Feed Restriction and Early Age Thermal Conditioning on Growth Performance and Carcass Characteristics of Meat-Type Chickens

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ABSTRACT

The research was conducted to find out the effects of feed restriction (FR) and thermal conditioning (TC) on growth performance and carcass characteristics of broilers. 216 broilers were studied using completely randomized design in a 2×3 factorial design arrangement. There were two levels of TC (31°C and 37±1°C for 12 h/day) within the first week and three levels of FR (*ad libitum* feeding; 10% less *ad libitum* and 20% less *ad libitum*), were applied after day 22 until day 49. Data were collected on growth performance, carcass characteristics, proximate composition of the meat and hematological composition. ANOVA was conducted and differences between means were determined using Tukey's Studentized Range Test at $p < 0.05$. Broilers on FR consumed less feed ($p < 0.05$) and had lower FCR and abdominal fat than those fed *ad libitum*. Meat from FR broilers contained higher proteins and moisture with low ether extract ($p < 0.05$). TC broilers had higher breast muscle, thigh, liver and heart weights ($p < 0.05$), as well as lower abdominal fat ($p < 0.05$) than their non-TC counterparts. In conclusion, both feed restriction (10% and 20% less feed) and early age thermal conditioning (37±1°C) improved growth and carcass traits in broilers.

Keywords: Feed restriction; early-age thermal conditioning; growth performance; carcass characteristics; broiler
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Introduction

The growth performance of broiler chickens over the last 30 years, has improved spectacularly. These uplifts have been attributed to the improvements in genetics, nutrition, and environment such that a broiler can reach a market weight of 2 kg within 33 days (Wilson, 2005). Broiler strains have been selected to utilize feed more efficiently and this help broilers to reach market weight in the shortest possible time and at a lower cost (Renema *et al*., 2007). This high growth of broilers in modern times is associated with a high appetite. Broilers accommodate the high metabolic loads of such quick growth rates, by mostly being fed *ad libitum*. The target weight for 6-week-old broiler chickens is over 2.5 kg. This bodyweight places a lot of negative impact on the welfare of the growing juvenile skeleton and cardiovascular system of the broiler bird. According to Mench (2002), this causes an increase in metabolic disorders, lameness, and heart disease in broilers.

In the tropics where ambient temperatures are constantly high, one of the challenges faced by modern breeds of broilers is heat stress due their high metabolic rate. Controlling heat stress in intensively raised broiler chickens has been very difficult particularly in the tropical and sub-tropical regions of the world. This is because these commercial and fast-growing broilers are developed in temperate regions and therefore have limited tolerance for hot climatic conditions. Also, poultry in general have problems adapting to higher environmental temperatures because of the absence of sweat glands and the high feather density. These factors subdue both sensible and evaporative heat losses since plumage temperature is dependent on not only the rate of heat loss from its surface, but also the total sensible insulation from the core of the animal to the environment (Smith, 1990; Lin *et al*., 2005).

Birds are more tolerant of cold stress than to heat stress and hence birds can recover after a reduction of about 20^{o}C in their normal temperature but when the normal temperature of these birds is raised by only 5^{o}C, they will die by heat stress (Smith, 1990). Previous studies reported that feed restriction and early age thermal conditioning as individual techniques helped eradicate some of these anomalies which occur as a result of feeding *ad libitum* and exposing broiler chickens to the high tropical temperatures (Zubair & Leeson, 1996; Kessler *et al*., 2000; Yahav & McMurtry, 2001; Yahav *et al*., 2005; Nawaz *et al*., 2021).

There is however, a dearth of information on the combination of these two techniques as a strategy to reduce heat stress in broilers within the sub-tropical region. Feed restriction exhibits a method of feeding where time, duration and amount of feed is limited (quantitative feed restriction) or the nutritional content is limited (qualitative feed restriction). Early age thermal conditioning on the other hand has to do with the inducing of the immature neonate chick with thermo-tolerance at an early age (within the first 7 days of its life) by exposing them to a high temperature of about 37±1^{o}C. This study was to investigate the effects of early-age thermal conditioning and feed restriction on the growth performance and carcass characteristics of meat-type chicken.

Materials and Methods

Experimental Birds and Design

The experimental design used was a 2×3 factorial arrangement; two thermal conditioning treatments and three feed withdrawal treatments. A total of 216-day old broiler chicks of commercial strain (Hubbard Flex F15) was obtained from a local hatchery and brooded for 3 weeks. Thermal conditioning was at two levels, No thermal conditioning at 31^{o}C (Non-TC, 31^{o}C) and thermal conditioning at a temperature of 37±1^{o}C (TC, 37±1^{o}C) while feed restriction was at three levels: no feed restriction (no FR), 10% restriction (10%FR)-broilers under this treatment were given 90% of the quantity of feed consumed by broilers on the *ad libitum* treatment- and 20% restriction (20%FR)-broilers under this treatment were given 80% of the quantity of feed consumed by broilers on the *ad libitum* treatment. There were three replicates under each treatment combination and each replicate had 12 birds. Thermal conditioning (37±1^{o}C) was administered by subjecting broilers under this treatment to a high brooding temperature of 37±1^{o}C during the first seven days for 12hr each day following the recommendation made by Yahav & McMurtry (2001). Non-thermal conditioning broilers were brooded under normal brooding temperature of 31^{o}C.

All birds were fed a standard broiler starter diet (2940.8 kcal of ME/kg; 21.6% CP) and finisher diet (2769.2 kcal of ME/kg; 20.34% CP) from day 1 to 28, and 29 to 49, respectively (Table 1). Water was given *ad libitum* and chicks were reared under continuous 24h lighting.

TABLE 1

Nutrient Composition of Starter and finisher diets fed to birds

Starter diet		Finisher diet	
Crude Protein (%)	21.6	Crude Protein (%)	20.34
Fat (%)	7.78	Fat (%)	8.94
Moisture (%)	10.6	Moisture (%)	10.30
Crude Fibre (%)	3.6	Crude Fibre (%)	3.4
Ash (%)	2.28	Ash (%)	2.61
NFE (%)	53.59	NFE (%)	54.419
Metabolizable Energy (kcal/kg)	2940.8	Metabolizable Energy (kcal/kg)	2769.2

Source: Agricare Company Limited, Ghana

The feed restriction phenomenon was employed from day 22 to day 49 (after brooding). Three dietary treatments were used and were identified as "no FR", broilers fed *ad libitum*; "10%FR", broilers fed 90% of the quantity of feed consumed by broilers under *ad libitum* and "20%FR", broilers fed 80% of the quantity of feed consumed by broilers under *ad libitum*. The quantity of feed given to broilers under 10%FR and 20%FR were calculated based on the previous 24 – hour feed consumption values of the control group (no FR - those fed *ad libitum*).

Management and data collection

The poultry house used for the experiment was an open-sided deep litter house. All birds were kept on a deep litter floor with wood shavings with an average ambient temperature of 29^{o}C during the day and 24^{o}C during the night. The relative humidity ranged from 65 to 75%. Initial weight, feed intake, water intake, weight gain and final body weight were measured on weekly bases. Feed conversion ratio (FCR) was calculated as the ratio of feed intake over weight gain. On day 49, one bird from each replicate was selected and slaughtered for carcass analysis from which the following parameters were measured: live weight, carcass weight, dressed weight, abdominal fat weight, breast muscle weight, liver weight, gizzard weight, heart weight, wing weight, and thigh weight. Chemical analysis was conducted to determine moisture, ether extract, crude fibre, crude protein, and ash of the raw meat from the experimental broilers using the procedures described by AOAC (1990). Blood samples were also taken from three birds under each treatment for hematological analysis to assess the health status of the birds. Mortalities were recorded as and when they occurred.

Statistical analysis

The data were subjected to two-way Analysis of Variance (ANOVA) using GenStat 12th Edition at $p < 0.05$ and significant differences between means were separated using Tukey's Studentized Range Test. The statistical module used for the data analysis is shown below:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \alpha_i\beta_j + \varepsilon_{ijkl}$$

Where;

Y_{ijk} = effect measured; μ = overall mean; α_i = main effect of early age thermal conditioning; β_j = main effect of feed restriction; $\alpha_i \beta_j$ = interaction of thermal conditioning and feed restriction; ε_{ijkl} =residual error term.

Results and Discussion

Growth performance parameters
Feed intake was higher ($p < 0.05$) in broilers fed *ad libitum* compared to those on 10%FR and 20%FR, but those on 10%FR ate more ($p < 0.05$) than those on 20%FR (Table 2). Feed Conversion Ratio (FCR) values were lower ($p < 0.05$) in broilers under the 20%FR treatment followed by those on 10%FR, and those fed *ad libitum* had the worst.

TABLE 2
Effects of feed restriction and early age thermal conditioning on the growth performance of broilers

Factors / Parameters	Initial weight (g)	Feed intake (kg)	Water intake (kg)	Weight gain (kg)	Final weight gain (kg)	FCR (feed/ weight gained)	Mortality (%)
Feed Restriction							
No FR (*Ad libitum feeding*)	42.00	5.20 [a]	6.74	2.02	2.06	2.59 [c]	1.14
10%FR (90% of feed consumed by $R_{100\%}$ broilers)	42.00	4.88 [b]	6.75	2.00	2.03	2.46 [b]	1.05
20%FR (80% of feed consumed by $R_{100\%}$ broilers)	42.00	4.52 [c]	6.00	2.40	2.77	1.88 [a]	1.24
SEM	5.170	0.0552	0.6120	0.353	0.619	0.0463	0.443
Thermal conditioning							
No Thermal Conditioning (Non-TC)	42.0	4.90	6.87	1.93	1.97	2.54 [b]	1.189
Thermal Conditioning (TC)	42.0	4.83	6.11	2.10	2.60	2.35[a]	1.098
SEM	4.220	0.0451	0.500	0.288	0.505	0.0378	0.361
P-Values							
Feed restriction	0.397	<.001	0.400	0.446	0.424	<0.001	0.661
Thermal conditioning	0.397	0.120	0.152	0.176	0.235	<0.001	0.593
FR×TC	0.397	0.602	0.429	0.493	0.450	0.281	0.913

[a-c]Means within the same column with different superscripts are significantly different ($p < 0.05$)

There were no differences ($p > 0.05$) in the initial chick weight, water intake, weight gain, and final body weight among broilers under the three feeding regimes (Table 2). Broilers that were thermally conditioned (TC) had lower ($p < 0.05$) FCR values than their non-thermal conditioning (Non-TC) counterparts. TC did not influence ($p > 0.05$) all the other growth parameters measured. There was no significant ($p > 0.05$) feed restriction × thermal conditioning interactions on all growth parameters measured (Table 2).

Carcass Characteristics

Feed restriction (FR) lowered ($p < 0.05$) the abdominal fat level in the broiler meat, however, those on 10% FR had a much lower abdominal fat ($p < 0.05$) than those on 20% FR. All other carcass parameters were not influenced ($p > 0.05$) by FR. TC increased breast muscle weight, thigh weight, liver weight, and heart weight, and also lowered the abdominal fat ($p < 0.05$). However, live weight, carcass weight, dressed weight, wing weight, and gizzard weight were not affected ($p > 0.05$) by TC (Tables 3 and 4).

TABLE 3

Effects of feed restriction and early age thermal conditioning on carcass characteristics of broilers

Factor/ Parameter[#]	LW, kg	CW, kg	DW, kg	BMW, kg	TW, kg	WW, kg	AFW, g
Feed Restriction							
No FR (*ad libitum*)	2.06	2.00	1.84	0.65	0.54	0.40	33.75 [c]
10%FR	2.05	2.00	1.84	0.64	0.56	0.40	30.17 [a]
20%FR	2.07	2.02	1.87	0.65	0.56	0.41	31.12 [b]
SEM	0.0773	0.0689	0.0828	0.0188	0.0193	0.0105	0.374
Thermal conditioning							
No TC	2.01	1.95	1.78	0.61[a]	0.51[a]	0.41	34.04 [b]
TC	2.11	2.06	1.92	0.67 [b]	0.59[b]	0.40	29.31 [a]
SEM	0.0631	0.0563	0.0676	0.0154	0.0157	0.00853	0.306
P-Values							
FR	0.534	0.939	0.893	0.935	0.985	0.534	<0.001
TC	0.075	0.082	0.059	0.003	<0.001	0.075	<0.001
FR x TC	0.708	0.619	0.292	0.906	0.274	0.708	0.370

[a-c]Means with different superscripts within the same column are significantly ($p < 0.05$); [#]LW = Live weight, CW = Carcass weight, DW = Dressed weight, BMW = Breast muscle weight, TW = Thigh weight, WW = Wing weight, AFW = Abdominal fat weight

TABLE 4

Effects of feed restriction and early age thermal conditioning on some organs of broilers

Treatments	Gizzard weight (full) (g)	Liver weight (g)	Heart weight (kg)
Feed Restriction (FR)			
No FR (*Ad libitum feeding*)	86.48	40.33	12.73
10%FR (90% of feed consumed by no-FR broilers)	78.62	40.33	12.43
20%FR (80% of feed consumed by no-FR broilers)	79.60	40.18	12.33
SEM	4.090	0.835	0.257
Thermal Conditioning (TC)			
No Thermal Conditioning (No TC)	79.00	34.87 [a]	11.98 [a]
Thermal Conditioning (TC)	84.20	45.61 [b]	13.02 [b]
SEM	3.34	0.682	0.210
P-Values			
Feed restriction (FR)	0.154	0.981	0.305
Thermal Conditioning (TC)	0.146	<0.001	<0.001
FR x TC	0.05	0.752	0.319

a-cMeans with different superscripts within the same column are significantly different ($p < 0.05$)

FR × TC interaction had no ($p > 0.05$) effect on all the carcass parameters measured except full gizzard weight which was influenced ($p < 0.05$) by FR x TC interaction (Tables 3 and 4) with the non-TC and full feeding combination having the highest gizzard weight than all the other combinations.

Chemical composition

Crude protein and moisture values in the meat of broilers under feed restriction were higher ($p < 0.05$) than those in the meat of broilers which were fed *ad libitum*; whilst ether extract was higher ($p < 0.05$) in the meat of *ad libitum* fed broilers than meat from broilers under feed restriction.

TABLE 5

Effects of feed restriction and early age thermal conditioning on the chemical composition of broiler meat on dry matter basis

Treatments	% Moisture	% crude protein	% Ether extract	% ash
Feed Restriction				
No FR (*Ad libitum feeding*)	75.56 [b]	76.28 [b]	25.40 [a]	4.350
10%FR (90% of feed consumed by no-FR broilers)	76.78 [a]	77.30 [a]	19.02 [b]	4.050
20%FR (80% of feed consumed by no-FR broilers)	76.37 [a]	76.99 [a]	21.25 [b]	4.050
SEM	0.0609	0.306	0.253	0.427
Thermal condition				
No Thermal Conditioning	75.539 [b]	75.87 [b]	26.62 [a]	4.26
Thermal Conditioning	76.928 [a]	77.85 [a]	17.16 [b]	4.04
SEM	0.0497	0.250	0.206	0.349
P-Values				
Feed Restriction (FR)	<0.001	0.016	<0.001	0.726
Thermal Conditioning (TC)	<0.001	<0.001	<0.001	0.556
FR x TC	<0.001	0.308	<0.001	0.698

a-cMeans with different superscripts within the same column are significantly different ($p < 0.05$)

Ash was not different ($p > 0.05$) in meat from the two groups of broilers (Table 5). Meat from broilers on thermal conditioning had higher ($p < 0.05$) crude protein and moisture levels, and had a lower ($p < 0.05$) ether extract level. Values for ash were not different in meat from thermal conditioned and non-thermal conditioned broilers (Table 5). There was no significant ($p > 0.05$) feed restriction (FR) × thermal conditioned (TC) interactions on crude protein and ash values but moisture and ether extract values were influenced by FR x TC interactions with TCx10%FR and TCx20%FR combinations having higher values ($p < 0.05$) of moisture and lower values ($p < 0.05$) of ether extract than all the other combination.

Haematological characteristics

The haematological parameters such as red blood cell, haemoglobin, mean corpuscular haemoglobin, and mean cell volume were different ($p < 0.05$) among the three feeding regimes.

TABLE 6

Effects of feed restriction and thermal conditioning on haematological parameters of broilers

Treatments[#]	RBC (µL)	HGB (g/dL)	MCH (p/g)	MCHC (g/dL)	MCV (μm^3)	WBC (µL)	PLT (µL)
Feed Restriction							
No FR (*ad libitum feeding*)	2.15×10^{6a}	8.05^{a}	37.65^{b}	29.37	127.60^{b}	235753	9333
10%FR	2.28×10^{6a}	8.50^{b}	37.65^{b}	29.25	128.20^{b}	245607	8000
20%FR	2.44×10^{6b}	8.83^{b}	36.03^{a}	28.95	124.80^{a}	254122	8000
SEM	68.3	0.181	0.555	0.409	1.187	8099	1089
Thermal conditioning							
No TC	2.234×10^{6}	8.14^{a}	36.98	29.28	128.39	240037	8889
TC	2.346×10^{6}	8.77^{b}	37.10	29.10	127.40	250284	8000
SEM	55.7	0.148	0.454	0.334	0.969	6613	889
P-Values							
FR	0.004	0.003	0.026	0.589	0.031	0.117	0.397
TC	0.069	0.001	0.792	0.604	0.317	0.147	0.397
FR x TC	0.531	0.253	0.034	0.330	0.101	0.523	0.397

[a-c]Means with different superscripts within the same column are different ($p < 0.05$). [#]Blood Haemoglobin (HGB), Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC), Mean Cell Volume (MCV), Platelet (PLT) and Red Blood Cells (RBC)

Mean corpuscular haemoglobin concentration, white blood cell, and platelets were not significantly influenced ($p > 0.05$) by the three feeding regimes. Haemoglobin was higher in TC broilers compared to the non-TC ones. All the other haematological parameters were not different ($p > 0.05$) between the two factors (Table 6). However, all the haematological parameters measured under the feeding regime and the temperature treatments were within normal ranges and therefore none of the factors studied affected the health of the birds negatively.

The higher feed intake of the birds that were fed *ad libitum* (no FR) might be as a result of the higher quantity of feed available to them. This agrees with the findings of Tumova *et al*. (2002) who reported that feed intake decreased by restrictive feeding. The lower FCR value for the birds fed restrictive feed is an indication that they utilized their feed more efficiently than the *ad libitum* group. This might be due to the levels of restriction and the duration of the restriction used in this study which was not too high. Lee & Lesson (2001) reported that quantitative feed restriction improves feed conversion ratio if the severity of restriction is not too high and the duration of the restriction is not too long.

The lower abdominal fat weight recorded in broilers that were restrictedly fed (10%FR and 20%FR) might be attributed to the fact that feed restriction enhances feed efficiency, due to the lower energy requirements for maintenance, which improves carcass quality and results in decreased fat deposition. This agrees with the findings of Crounch *et al*. (2002) who reported that birds that were fed restrictedly had lower abdominal fat than fully fed birds. Richards *et al*. (2003) also reported that feed restriction causes lower abdominal fat pad weight as well as a reduction in body weight in hens than *ad libitum* feeding.

The higher moisture content in the meat of birds that were restrictedly fed (20%FR and 10%FR) could be due to the lower rate of metabolic activities involved in the utilization of the feed. This agrees with the findings of Crounch *et al.* (2002) who reported that Large White turkey breeder hens that were exposed to feed restriction recorded significantly higher carcass moisture in their meat. The higher percentage of crude protein in the meat of the birds that were restrictedly fed (20%FR and 10%FR) can be attributed to the increased levels of enzymes associated with protein metabolism in restrictedly fed broilers.

Pinheiro *et al*. (2004), found that feed restriction increased and altered the functional development of the enzymes of protein digestion such as dipeptidase and aminopeptidase of broilers. The higher percentage of ether extract in the meat of the birds that were fed fully (no FR) could be due to the fact that feed was always at their disposal and so they consumed higher amounts of feed which may be above their maintenance and production requirements and which resulted in the higher deposition of fat. This agrees with the findings of Crounch *et al*. (2002) who reported that turkeys subjected to feed restriction during the raising period had lower carcass fat than the full-fed ones.

The lower FCR of the birds that were thermally conditioned could be attributed to the fact that the thermal conditioning positively affected the birds to adapt to the tropical temperature and influenced their feed efficiency positively. Tan *et al.* (2010) stated that heat stress during the first week enhances better adaptability of birds to high temperatures in their finishing periods where there is higher endogenous heat production as a result of the high metabolic rate of broiler chickens. The lower abdominal fat weight of birds that were exposed to early age thermal conditioning may be as a result of the adaptability of these birds to the tropical temperature conferred on them by the thermal conditioning, which resulted in the reduction of their basal metabolic activities. According to Rosa *et al.* (2007) broilers raised in hot environmental conditions had more fat accumulation which was attributed to the reduction in basal metabolism and physical activity.

This finding was also in agreement with that of Blahova *et al.* (2007) who reported a lower fat weight in birds raised in low environmental temperature. The higher mean liver, breast muscle, heart, and thigh weights of birds that were thermal conditioned (TC) could be attributed to their adaptability to the tropical temperature than their non-thermal conditioned counterparts. According to Rosa *et al.* (2007), exposing birds to high temperatures would result in a decrease in the weight of their liver. Aksit *et al.* (2006) also found that birds that were exposed to high temperature (34^{o}C) recorded a 1.5% reduction in their breast muscle weights. And they explained that it was due to an increase in physical activity of the breast as a result of increased frequency of respiration hence limiting the amount of glycogen available for breast muscle development since most of it would have been used in the respiration process.

The high percentage moisture levels in the meat of birds that were exposed to early age thermal conditioning were because heat load was reduced in these thermally conditioned birds and did not, therefore, use a lot of moisture to reduce heat stress since they were more heat tolerant as a result of the thermal conditioning. Aksit *et al.* (2006) reported that when chickens were subjected to a temperature of 34°C in their early life, the moisture content in their thigh was more than those raised in a temperature ranging from 22°C to 28°C. The lower percentage of crude protein levels in the meat of the birds that were not thermal conditioned was because these birds were unable to overcome the challenges associated with heat stress hence leading to increased protein degradation. This confirms the observation of Bianchi *et al.* (2007) that chickens raised in summer (hot environment) had lower protein levels in their thigh than those produced in winter because these birds were heat stressed. The higher ether extract in the meat of birds that were not exposed to early-age thermal conditioning (TC) may be due to heat stress in the birds which led to a slowdown in their metabolic activities. According to Rosa *et al.* (2007) broilers raised in hot environmental conditions had more fat accumulation which was attributed to the reduction in basal metabolism and physical activity.

Concusion and Recommendation

In conclusion, feed restriction reduced feed intake but improved upon the feed conversion ratio in broilers. Feed restriction also reduced the abdominal fat and ether extract in chicken meat whilst increasing the moisture and crude protein levels in the meat. Early age thermal conditioning improved the feed conversion ratio in broilers as well as carcass traits such as breast muscle and thigh weights. It also increased moisture and crude protein levels and reduced abdominal fat and ether extract in broiler meat. Early age thermal conditioning and feed restriction are recommended for broiler farmers in Ghana to improve growth and the quality of broiler meat while reducing the cost of producing broilers.

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