IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 15, Issue 9 Ser. I (September 2022), PP 21-30
www.iosrjournals.org

Effect of Quantitative Feed Restriction in the Hot Season (April, May and June) On Broilers' Response

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Abstract
180 day- old broiler chicks were used in a study designed to evaluate the effects of different levels of feed restriction at the growing period on the physiological response and performance of broiler chickens under the humid tropical conditions of hot season. The experiment consisted of four quantitative feed restriction treatment groups, each in three replicates of 15 birds per replicate. The treatments indicate the proportion of total daily allowance of feed restricted and offered to groups: T1 (0%), T2 (15%), T3 (30%) and T4 (45%). The experiment was framed in a Completely Randomized Design and was conducted in the hot season (April, May and June). Feed was restricted during the third, fourth and fifth weeks of age. Blood samples were collected from three birds in each of the replicates after two weeks of brooding just before the commencement of restricted feeding for the determination of baseline haematology and serum biochemical constituent values, and at the end of the fifth and eighth weeks. Results showed that the feed restriction experiments significantly ($P < 0.05$) reduced feed intake, weight gain, feed conversion ratio and water consumption. The serum biochemical constituents of the birds were also significantly ($P < 0.05$) reduced by treatments. Feed restriction, however increased the haematological profile of the birds, except for the heterophil: lymphocyte ratio which was increased during the restriction period but contrariwise was reduced during the refeeding period. Economic parameters were significantly ($P < 0.05$) affected by feed restriction. The highest revenue of production was obtained in the unrestricted treatment groups, while the best score of cost benefit ratio was obtained in the 30 % feed restriction group. Meteorological elements particularly ambient temperature and relative humidity were negatively correlated with broilers' response during the hot season. It was concluded that by restricting feed up to 30 % of ad libitum broiler chickens in the humid tropics would perform optimally during the hot season of rearing without compromising profitability. Recommendations to improve the overall performance of the birds were made.

Key words: *Feed, Quantitative, Hot season, Protein, Intake, Broilers*

Date of Submission: 22-08-2022 Date of Acceptance: 05-09-2022

I. Introduction

Feed restriction is a conventional strategy employed in modern broiler breeder industry to lessen fat accretion and avoid reproduction and health complications (Ge *et al.*, 2019) but not in modern broiler meat industry where feeding is *ad libitum*. However, *ad libitum* feeding has been implicated in mortality and health problems such as ascites, tibial dyschondroplasia, necrosis of the femoral head, angular and torsional long bone deformities, perosis, spinal deformities, obesity and Sudden Death Syndrome. Negative physiological effects include adrenal hypertrophy and persistent increase in corticosterone secretion after 24 h restriction or feed-off days (Mench, 1991).

Feed restriction also provides the opportunity to take advantage of compensatory growth. Compensatory growth classically refers to the period of rapid growth, relative to age, exhibited by mammals and birds after a period of nutritional restriction (Makinde, 2012; Chen, et al., 2018). The factors most critical to compensatory growth include the age at which the restriction is applied, the sex and genotype of the animal, the length and severity of the restriction and the quality and length of re-feeding of the re-alimentation diet (Ryan, 2012). Certain environmental factors like ambient temperature and season of the year have also been reported as factors that appear to influence post- restriction performance of broilers (Rao *et al.*, 2005). This experiment was therefore designed to study the effect of quantitative feed restriction in the hot season (April, May and June) on broilers' response.

Objectives

i. To determine the effect of quantitative feed restriction in the hot season on the performance of broiler chickens

ii. To determine the effects of quantitative feed restriction in the hot season on the haematological responses of broiler chickens

iii. To determine the effect of quantitative feed restriction in the hot season on the blood serum biochemistry of broiler chickens

iv. To determine the effects of quantitative feed restriction in the hot season on body temperature and respiration rate of broiler chickens

v. To determine the economics of production

II. Materials And Methods

Location and Description of Experimental Site

The trial was conducted at the Teaching and Research Farm of the Department of Animal Production, Kogi State University, Anyigba. Anyigba is located in the Derived Savannah of Nigeria on Latitudes 7^o15^1 and 7^0 29^1N of the equator and Longitudes 7^o11^1 and 7^032^1 E of the Greenwich meridian (Ifatimehin *et al., 2006*). The wet season spreads over a minimum of seven (7) months and it extends from late April to October with the dry season spanning from November to March with an approximate of five (5) months. Rainfall here is highly seasonal and September is the rainiest month with a short dry season (August break) in August with a mean annual rainfall ranging from 250mm to 1500mm. The area has a humidity of about 70 % on the average and a mean annual temperature of 27^0C (Kpado, 1985; Iji, 2007).

Experimental Layout and Procedure

A total of 180 day old broiler chicks were housed and brooded in open sided deep litter pens the floors of which were concrete basement, cleansed, disinfected, and covered with clean, dry wood shavings up to 5 cm thickness. Heat was provided from kerosene stoves placed under metal hoovers as described by Aduku (2004). The birds were vaccinated according to schedule against New Castle and Gumboro diseases (Goni, 1974). Other medications administered included proprietary antibiotics, coccidiostats and mineral- vitamins premix. Feed and water were provided *ad libitum.* At the end of two weeks stabilization period, the birds were randomly assigned to four quantitative feed restriction treatment groups each in three replicates of 15 birds per replicate. The quantitative treatments indicate the percentage proportion of total daily allowance of feed restricted or reduced from the amount of ration normally offered to groups corresponding to T1 (without reduction in ration), T2 (15% reduction in daily ration), T3 (30% reduction in daily ration) and T4 (45% reduction in daily ration). The experiment was framed in completely randomized design.

All the birds in the trial were fed and watered between 07:00 and 08:00 hours daily. Weighed amount of feed was given to each of the three replicates in the control and test groups. Feed intake per bird per day was determined by subtracting the quantity left over the following day from the quantity of feed given the previous day which was divided by the number of chicks fed. The restricted groups were quantitatively given 15, 30 and 45 % less of the previous day's feed consumption of the control group. In other words, when the control group consumed Y kg of feed quantitatively the previous day, the 15, 30 and 45 % restricted groups would receive 0.85Ykg, 0.70Ykg and 0.55Ykg of feed respectively. Feed was restricted during the third, fourth and fifth weeks of age, and thereafter all the chicks were fed *ad libitum* with a finisher ration containing 20% CP and 3000 Kcal ME/kg (Aduku, 2004) till the end of the eighth week. The ingredient composition of both the control and restriction diets is presented in Table 1.

Table 1. Ingredient Composition of the Control and Restriction Diets (%)

Ingredients	Control	Finisher
Maize	28.90	35.00
FFSB	27.00	28.00
Blood meal	7.40	4.00
Maize offal	32.50	29.70
Bone meal	3.00	2.30
Methionine	0.70	0.50
Salt	0.25	0.25
premix*	0.25	0.25
Total	100.00	100.00

Calculated Analysis

	Starter	Finisher
CP (%)	22.00	20.00
ME/Kcal/Kg	2929.00	3000.00
Ca (%)	1.24	0.98

P (%)	0.99	0.87
Methionine(%)	1.12	0.89
Lysine (%)	1.49	1.28

FFSB = Full fat soya beans ME = Metabolizable energy
*Contains the following/Kg of diet for 2.5 kg premix/tonne: Vit A - 13,340 I.U.; Vit. D3 - 2680 I.U. Vit. E - 10 I.U.; Vit K - 2.68 mg; Calcium Pantothenate - 10.68; Vit. B12 - 0.022 mg; Folic acid - 0.668 mg; Chloride - 400mg; Chlorotetracycline - 26.68mg; Manganese - 66.68mg; Zinc - 53.3 mg; Copper- 3.20mg; Iodine - 1.86mg; Cobbalt - 0.268mg; Selenium - 0.108mg.

Parameters measured and analytical procedures

Blood samples were collected after two weeks of brooding just before the commencement of restricted feeding for the determination of baseline haematology and serum biochemical constituent values and at the end of the fifth and eighth weeks. The analyses were done at the Biochemistry Laboratory of Kogi State University using the Randox Equipment test kits (Model: BT 29 4QY, UK.) for serum biochemical constituents and the Automated Abascus Junior Analyser for the haematological indices.

Haematological indices measured were:
Total erythrocyte count (RBC), total leucocytes count (WBC), haemoglobin (Hb), mean corpuscular hemoglobin concentration (MCHC), packed cell volume (PCV), heterophils, lymphocytes, eosinophils, basophils and monocytes.

Serum biochemical constituents measured were:
Glucose, total protein, albumin, globulin, urea, aspartate amino transferase (AST), sodium, calcium, potassium, alanine amino transferase (ALT), triglicerides, cholesterol and creatinine..

Body temperatur*e* was determined by inserting a clinical thermometer into the vent for a period of one minute using a stop watch.

Respiration rate was taken by counting the flank movement of the birds for an uninterrupted period of one minute using a stop watch

Body weight was determined by weighing the birds at the beginning of the experiment and weekly thereafter.

Feed consumption was determined on daily basis as already indicated in the feeding procedure.

Feed conversion ratio was computed as ratio of mean daily feed consumption to mean daily weight gain.

Water intake*:* A known quantity of water was supplied to each pen and the quantity left the following morning was determined by difference to obtain the apparent water intake. In order to correct for evaporative loses, another quantity of water of the same volume as the one supplied to each of the pens was kept in the pen. Any difference obtained the following morning was taken as the apparent water loss due to evaporation.

Environmental parameters: Data for the following environmental indices were obtained from the Kogi State University, Anyigba meteorological sub-station: (a) relative humidity (b) wind velocity (c) solar radiation and (d) rainfall. Data on ambient temperature was obtained in the poultry house using an ordinary thermometer.

Economic parameters were determined according to the methods of Orheruata *et al*. (2006) and Cam (2014) as follows:

Revenue**:** Final body weight × cost / kg live weight

Gross margin**:** Revenue – total variable cost

Cost benefit ratio: Total cost / Total revenue

STATISTICAL ANALYSIS

Data obtained were subjected to analysis of variance and descriptive statistics using the Statistical Package for Social Sciences (SPSS), Version 16 (2007). Significant differences among treatment means were separated at 5% level by Least Significant Difference (LSD).

III. Results

Meteorological data

The average meteorological data during the experimental period is presented in Table 2 while the correlation coefficients (r) between the meteorological elements during the experimental period are presented in Table 3. Mean meteorological values during the experimental period in the hot season were 23.57 ± 1.28 °C, 29.10 ± 1.26 °C, 25.23 ± 1.08 °C, 82.87 ± 0.92 %, 5.78 ± 0.25 hours/day and 3.60 ± 1.02 km/hr for ambient temperature, dry- bulb temperature, wet- bulb temperature, relative humidity, solar radiation and wind velocity respectively. Result of correlation coefficients (r) between meteorological elements showed that ambient temperature was positively correlated with dry- bulb and wet- bulb temperatures but negatively correlated with relative humidity, solar radiation and wind velocity. Wind velocity was positively and significantly correlated ($P < 0.05$; $r = 0.99$) with solar radiation.

Table 2. Mean values (±SE) of Environmental data during the study period

Season	Environmental Elements					
	AT	DBT	WBT	RH	RAH	WIND
Hot	23.57±1.28	29.10±1.26	25.23±1.08	82.87±0.92	4.06±0.25	3.60±1.02

AT = Ambient temperature (°C) DBT = Dry bulb temperature (°C)
WBT = Wet bulb temperature (°C) RH = Relative humidity (%)
RAH = Solar Radiation (hours/day) WIND = Wind Speed (km/hr)
SEM = Standard error of means

Table 3. Correlation coefficients (r) between environmental elements during the experimental period.

Parameters	Environmental Elements					
	AT	DBT	WBT	RH	RAH	WIND
AT	1:00					
DBT	0.70	1.00				
WBT	0.99*	0.79	1.00			
RH	–0.91	–0.34	–0.85	1.00		
RAH	–0.84	–0.98*	–0.90	0.54	1.00	
WIND	–0.81	–0.99*	–0.88	0.50	0.99*	1.00

* = Significant at P < 0.05 AT = Ambient temperature (ºC)
DBT = Dry bulb temperature (ºC) WBT = Wet bulb temperature (ºC)
RH = Relative humidity (ºC) RAH = Solar Radiation (hours per day).

Effects of quantitative feed restriction in the hot season on broilers

Performance parameters

The results of the effects of quantitative feed restriction in the hot season on broilers are presented in Tables 4, 5, 6, 7, 8, 9, 10 and 11. The results show significant treatment effects (P < 0.05) on all the performance parameters studied. Feed intake, weight gain and water consumption decreased progressively from the 0 % to the 45 % restriction groups (Table 4) and these differences were maintained till the end of the eight week. Feed: gain ratio was linearly depressed across treatments with the controls having the best ratio, and the 45 % restriction group having the least ratio. However, following refeeding, the best feed: gain ratio was obtained by birds in the 30% restriction group (1.76) followed by birds in the 15 % and 45 % restriction groups both of which had statistically similar (P < 0.05) feed: gain ratio of 1.99 and 2.00 respectfully (Table 6).

Physiological response

The physiological response of body temperature and respiration rates were not affected by treatments (P > 0.05). There were however significant treatment effects on blood haematology (P < 0.05). The heterophils: lymphocyte (H: L) ratio was similar for the full fed and 15 % restriction groups respectively and both groups were significantly lower (P < 0.05) than the 30 % and 45 % restriction groups respectively. The serum biochemical profile of birds showed varying responses during the restriction period. The triglycerides, globulin, cholesterol and potassium components were not affected by treatments during the restriction period (P > 0.05). After realimentation however, significant treatment differences were noticed among all the biochemical responses studied (Tables 9 and 10).

Economic parameters

Analysis of variance also showed significant treatment effects on the economic indices of performance (Table 11). The highest revenue of production of N1, 629.00 per bird was obtained in the full-fed group while the lowest revenue of N1, 144.00 was obtained in the 45 % restriction group. The best cost benefit ratio was obtained in the 30 % restriction group followed by the 15 % restriction group, and the lowest in the full– fed group.

Table 4. Performance of broiler chickens reared on restricted daily ration in the hot season

	Treatments (Levels of restriction)					
Parameters	**0%**	**15%**	**30%**	**45%**	**SEM**	**LOS**
Initial body wt (g)	340	342	338	339.5	1.21	NS
Final body wt (g)	1148[a]	995[b]	900[c]	751[d]	43.33	*
Weight gain (g)	808[a]	653[b]	562[c]	412[d]	43.32	*
Feed intake (g)	1450[a]	1232[b]	1015[c]	797[d]	43.32	*
Feed: gain	1.79[c]	1.89[b]	1.81[c]	1.94[a]	73.23	*
Feed cost/bird (₦)	140.89[a]	125.56[b]	103.33[c]	81.11[d]	6.99	*
Feed cost/kg gain (₦)	196[b]	193[a]	184[ab]	174[a]	3.40	*
Body temperature (^oC)	41.0	41.0	41.1	41.1	0.13	NS
Respiration rate (breath/min)	32.08	33.01	33.05	33.78	0.25	NS
Water consumption (ml)	1295[a]	1050[b]	875[c]	763[d]	12.21	*

a, b, c, d = Means with different superscripts on the same row differ significantly (P < 0.05)
NS = Not significant SEM = Standard error of means
LOS = Level of significance * = Significant at P < 0.05

Table 5. Performance of broiler finishers reared on recommended daily ration during the refeeding period in the hot season

	Treatments (Levels of restriction)					
Parameters	**0%**	**15%**	**30%**	**45%**	**SEM**	**LOS**
Initial body wt (g)	1148.27[a]	993.31[b]	902.13[c]	740.52[d]	44.60	*
Final body wt (g)	2172.54[a]	1950.73[b]	1830.40[c]	1517.88[d]	70.40	*
Weight gain (g)	1024.27[a]	957.42[b]	928.27[c]	777.36[d]	27.27	*
Feed intake (g)	2840.63[a]	1972.47[b]	1603.71[c]	1578.25[d]	153.99	*
Feed: gain	2.77[a]	2.06[b]	1.73[c]	2.04[b]	0.11	*
Feed cost/bird (₦)	291.04[a]	201.87[b]	164.22[c]	161.78[c]	15.78	*
Feed cost/kg gain (₦)	284.26[a]	211.62[b]	209.27[c]	177.23[d]	11.92	*
Body temperature (^oC)	40.90	40.10	40.05	41.10	3.18	NS
Respiration rate (breaths/min)	33.01	33.21	33.08	33.11	0.20	NS
Water consumption (ml)	1624.30[a]	1176.34[b]	945.42[c]	497.21[d]	124.45	*

a, b, c, d = Means with different superscripts on the same row differ significantly (P < 0.05)
NS = Not significant SEM = Standard error of means
LOS = Level of significance * = Significant at P < 0.05

Table 6. Overall performance of broiler chickens reared on restricted daily ration during the experiment (3 – 8 weeks) in the hot season

	Treatments (Levels of restriction)					
Parameters	**0%**	**15%**	**30%**	**45%**	**SEM**	**LOS**
Initial body wt (g)	340.32	342.61	338.24	339.51	1.21	NS
Final body wt (g)	2172[a]	1953[b]	1828[c]	1525[d]	70.40	*
Weight gain (g)	1832[a]	1610[b]	1490[c]	1185[d]	70.44	*
Feed intake (g)	4290[a]	3202[b]	2618[c]	2375[d]	22.26	*
Feed: gain	2.34[a]	1.99[b]	1.76[d]	2.00[b]	0.06	*
Feed cost/bird (₦)	431[a]	320[b]	267[c]	242[d]	21.91	*
Feed cost/kg gain (₦)	236[a]	205[b]	199[c]	180[d]	6.08	*
Water consumption (ml)	2919[a]	2226[b]	1820[c]	1260[d]	18.25	*
Body temperature (^oC)	41.70	41.07	41.90	41.27	0.17	NS
Respiration rate (breaths/min)	32.83	33.00	32.33	32.33	0.28	NS

a, b, c, d = Means with different superscripts on the same row differ significantly (P < 0.05)
NS = Not significant SEM = Standard error of means
LOS = Level of significance * = Significant at P < 0.05

Table7. Haematological indices of broiler chickens reared on restricted daily ration in the hot season

	Treatments (Levels of restriction)					
Parameters	**0%**	**15%**	**30%**	**45%**	**SEM**	**LOS**
PCV (%)	37.81^{c}	38.57^{b}	39.64^{a}	38.96^{b}	0.44	*
Hb (g/l)	157^{b}	186^{a}	188^{a}	185^{a}	6.67	*
RBC ($\times 10^{12/}$l)	6.95^{b}	7.91^{a}	8.61^{a}	6.67^{b}	0.50	*
WBC ($\times 10^{9/}$l)	7.69^{b}	8.45^{a}	8.55^{a}	7.00^{c}	0.34	*
MCHC (g/l)	231	230	243	238	4.85	NS
Heterophils (%)	47.11^{c}	49.44^{c}	54.45^{b}	59.22^{a}	2.41	*
Lymphocytes(%	46.78^{a}	44.78^{a}	37.67^{b}	46.33^{a}	1.85	*
H:L	1.04^{c}	1.11^{c}	1.49^{a}	1.30^{b}	0.09	*
Eosinophils (%)	1.00	0.78	0.78	0.33	0.20	NS
Basophils (%)	0.11^{c}	3.44^{b}	4.33^{b}	6.05^{a}	0.92	*
Monocytes (%)	3.33^{b}	4.30^{a}	4.44^{a}	1.78^{c}	0.52	*

$^{a, b, c, d}$ = Means with different superscripts on the same row differ significantly ($P < 0.05$)
NS = Not significant SEM = Standard error of mean
LOS = Level of significance * = Significant at $P < 0.05$
PCV = Packed cell volume Hb = Haemoglobin
RBC = Red blood cell WBC = White blood cell
MCHC = Mean corpuscular hemoglobin concentration
H: L = Heterophil: lymphocyte ratio

Table: 8. Haematological indices of broiler finishers reared on recommended daily ration during the refeeding period in the hot season

	Treatments (Levels of restriction)					
Parameters	**0%**	**15%**	**30%**	**45%**	**SEM**	**LOS**
PCV (%)	39.27	39.98	39.46	38.12	0.27	NS
Hb (g/l)	188.33^{b}	187.96^{b}	200.22^{a}	208.90^{a}	3.19	*
RBC ($\times 10^{12/}$l)	7.86	7.79	8.27	8.48	0.42	NS
WBC ($\times 10^{9/}$l)	6.54	6.46	6.90	7.45	0.27	NS
MCHC (g/l)	217^{c}	234^{b}	243^{b}	271^{a}	8.37	*
Heterophils (%)	53.00^{a}	48.00^{b}	48.00^{b}	44.61^{c}	1.24	*
Lymphocytes (%)	42.33^{c}	43.56^{c}	49.22^{a}	45.50^{b}	1.43	*
H:L	1.22	1.10	0.98	1.01	0.05	NS
Eosinophils (%)	0.56^{d}	0.67^{c}	0.78^{b}	0.89^{a}	0.06	*
Basophils (%)	0.22^{b}	0.22^{b}	0.33^{b}	0.44^{a}	0.05	*
Monocytes (%)	6.00^{c}	7.44^{b}	7.67^{b}	8.40^{a}	0.40	*

$^{a, b, c, d}$ = Means with different superscripts on the same row differ significantly ($P < 0.05$)
NS = Not significant * = Significant at $P < 0.05$
SEM = Standard error of mean LOS = Level of significance
PCV = Packed cell volume Hb = Hemoglobin
RBC = Red blood cell WBC = White blood cell
MCHC = Mean corpuscular hemoglobin concentration
H: L = Heterophil: lymphocyte ratio

Table 9. Serum biochemical constituents of broiler chickens reared on restricted daily ration in the hot season

	Treatments (Levels of restriction)					
Parameters	**0%**	**15%**	**30%**	**45%**	**SEM**	**LOS**
Total Protein (g/dl)	2.20^{a}	2.21^{a}	1.72^{b}	1.63^{c}	0.09	*
Albumin(g/dl)	0.92^{a}	0.80^{a}	0.73^{ab}	0.58^{b}	0.04	*
Globulin(g/dl)	1.28	1.073	0.99	1.52	0.07	NS
Glucose (mg/dl)	117^{a}	105^{ab}	93^{b}	78^{c}	4.71	*
AST (mg/l)	49.6^{a}	44.8^{b}	44.1^{b}	43.7^{b}	1.50	*
ALT (mg/l)	5.92^{a}	3.41^{b}	3.23^{b}	2.94^{c}	0.57	*
Triglycerides (mg/dl)	692	569	536	472	6.07	NS

Creatinine (mg/dl)	1.78^{a}	1.15^{b}	0.91^{b}	0.62^{c}	0.28	*
Urea (mg/dl)	3.12	3.09	2.84	2.67	0.27	NS
Cholesterol (mg/dl)	191	149	232	151	27.00	NS
Sodium (mg/dl)	9.25^{a}	9.02^{b}	8.79^{c}	8.70^{c}	0.06	*
Potassium (mg/dl)	0.67	0.67	0.56	0.56	0.04	NS
Calcium (mg/dl)	8.32^{a}	7.69^{b}	5.86^{c}	5.62^{c}	0.40	*

a, b, c, = Means with different superscripts on the same row differ significantly ($P < 0.05$)
NS = Not significant * = Significant at $P < 0.05$
SEM = Standard error of means LOS = Level of significance
AST = Aspartate amino transferase ALT = Alanine amino transferase

Table 10. Serum biochemical constituents of broiler finishers reared on recommended daily ration during the refeeding period in the hot season

	Treatments (Levels of restriction)					
Parameters	0%	15%	30%	45%	SEM	LOS
Total protein (g/dl)	3.83^{a}	3.34^{a}	2.67^{b}	2.64^{b}	0.19	*
Albumin (g/dl)	0.21^{a}	0.23^{a}	0.18^{b}	0.11^{b}	0.01	*
Globulin (g/dl)	3.62^{a}	3.11^{a}	2.50^{b}	2.53^{b}	0.18	*
Glucose (mg/dl)	125^{a}	118^{ab}	98^{b}	83^{c}	5.64	*
AST (mg/l)	51.97^{a}	51.87^{a}	47.23^{b}	44.33^{b}	1.14	*
ALT (mg/l)	6.87^{a}	5.93^{a}	5.13^{a}	3.77^{b}	0.48	*
Triglycerides(mg/dl)	7.64^{a}	713^{a}	605^{b}	501^{c}	46.44	*
Creatinine (mg/dl)	2.06^{a}	1.13^{b}	0.94^{bc}	0.78^{c}	0.29	*
Urea (mg/dl)	3.99^{a}	3.06^{b}	2.88^{b}	2.71^{b}	0.30	*
Cholesterol (mg/dl)	237^{a}	150^{b}	137^{c}	148^{c}	27.54	*
Sodium (mg/dl)	10.27^{a}	9.52^{b}	8.93^{c}	8.39^{c}	0.24	*
Potassium (mg/dl)	0.85^{a}	0.75^{b}	0.61^{c}	0.57^{c}	0.06	*
Calcium (mg/dl)	9.03^{a}	8.54^{a}	6.83^{b}	5.96^{b}	0.42	*

a, b, c = Means with different superscripts on the same row differ significantly ($P < 0.05$)
* = Significant at $P < 0.05$ SEM = Standard error of means
LOS = Level of significance AST = Aspartate amino transferase
ALT = Alanine amino transferase

Table 11. Economic performance of broiler chickens reared on restricted daily ration in the hot season

	Treatments (Levels of restriction)					
Parameters	0%	15%	30%	45%	SEM	LOS
Revenue (₦)	1629^{a}	1463^{b}	1373^{c}	1144^{d}	834.19	*
Cost per bird (₦)	217	217	217	217	-	-
Cost of day old (₦)	180	180	180	180	-	-
Variable cost(₦)	247	247	247	247	-	-
Feed cost/bird (₦)	431^{a}	320^{b}	267^{c}	242^{d}	22.03	*
Cost of production (₦)	679^{a}	568^{b}	515^{c}	490^{d}	21.91	*
Gross margin (₦)	583^{c}	612^{b}	625^{a}	571^{d}	6.64	*
Cost benefit ratio	0.417^{b}	0.388^{c}	0.375^{d}	0.42^{a}	0.01	*
Cost saving (₦)	-	111	164	189	-	-

a, b, c, d = Means with different superscripts on the same row differ significantly ($P < 0.05$)
NS = Not significant SEM = Standard error of means
LOS = Level of significance * = Significant at $P < 0.05$

IV. DISCUSSION

Performance Parameters

Performance of the restricted birds was affected during the restriction period due to reduced feed intake which led to low weight gain in the hot season. However, following realimentation in the finisher phase, there was an improvement in feed intake, body weight gain, feed: gain ratio and water consumption. This result is in agreement with the reports of Rezael *et al.* (2006), Tion *et al.* (2007), Ghazanfari *et al.* (2010) , Naser *et al.*

(2011) and Maynard *et al.*,(2019) that early age feed restriction significantly reduced feed intake, body weight gain and feed conversion ratio Zuprical *et al*. (1993) and Siegel (1995) attributed the reduction in body weight gain to the reduction in both feed consumption and true digestibility of proteins and amino acids. Yahav and Plavnik (1999) and Saxera *et al*., (2020) reported that plasma triiodothyronine concentration may decrease during periods of feed restriction and thermal challenge, suggesting a decline in metabolic status, digestive enzymes activities and heat production. This is confirmed by Leeson *et al*. (1992) who stated that high environmental temperatures stimulate the peripheral thermal receptors to transmit suppressive nerve impulses to the appetite centre in the hypothalamus causing the decrease in feed consumption. Thus fewer substrates become available for enzymatic activities, hormone synthesis and heat production, which minimize thermal load.

The higher feed intake and the improvement in feed: gain that occurred during the realimentation period was due to the hypertrophy of the gastro intestinal tract that occurs after the restriction period when the birds are fed *ad libitum* The improvement in feed efficiency noted with the use of feed restriction programs is due to reduced overall maintenance requirements (Payawal, 1996). This reduction seems to be due to a transient decrease in basal metabolic rate of the feed restricted birds (Zubair and Leeson, 1994) and is linked with a smaller body weight during early growth, leading to less energy requirement for maintenance. Reducing the amount of energy used for maintenance makes more energy available for other important tasks during development. Hence a reduction in metabolic processes has been interpreted as an adaptational response that enhances survival during poor feeding conditions (Ronning *et al*., 2009; Ge et al., 2019).

Physiological Response

The physiological indices of body temperature and respiration rates were not affected by treatments. The average rectal temperature range of 39.1 – 41.9 and respiration rates range of 31-34 obtained in this study agrees with values reported in literature for breeds kept in the tropics (Williamson and Payne, 1978 and Wilson and Vohra, 1980) This result could be a feature of the adaptability of the birds to the tropical environment of Nigeria where this experiment was conducted. Isidahomen *et al.* (2012) reported that rectal temperature, pulse rate and respiratory rates are the most important determinants in the adaptation of poultry to the tropical environment and that they determine to a large extent, the profitability of the poultry enterprise. It is apparent that feed restriction regimes could not alter the stability of the adaptive features of the birds that form the threshold of physiological adaptation to the hot tropical environment.

Generally, feed restriction increased the levels of haematological indices both during the restriction period and realimentation period, except for the Heterophil: Lymphocyte ratio (H: L) which was increased during the restriction period but contrariwise was reduced during the realimentation period. This result agrees with the works of Jang *et al.* (2009), Ronning *et al.* (2009) and Raghavan *et al.* (2012) that feed restriction improves blood haematology profile. The best Haematological response was obtained in the 30% quantitative restriction group. This observation suggests that these restriction levels may have haemapoietic and haematinic properties for the restricted birds. White blood cells and heterophils are involved in defence and phagocytic activities of the body against invading foreign bodies (Leigh *et al.*, 2010). The findings in this study suggests that restricting feed quantitatively up to 30% or qualitatively up to 20% could improve immune vigilance and enhance the birds' defenses against infections. The increase in eosinophils during realimentation could also be an indication of increased response against parasitic diseases.

Regarding the H: L ratio which has been used as a reliable indicator of the responses of the hypothalamic hypophyseal adrenal axis to the stressors in birds (Yalcin *et al*., 2003; Liu *et al.,* 2017; Hu *et al*., 2019), the findings of the present study indicate that feed restriction improved the physiological disposition of the birds and that the birds were in their most optimal physiological state at the 30 % quantitative feed restriction regime (Table 8) in the hot season. These results are in agreement with those reported by Mcfarlane and Curtis (1989), Mashaly *et al*. (2004) and Faisal *et al.* (2008) who found reduced H: L ratio in broiler chickens exposed to restricted feeding conditions.

Serum transaminase parameters of alanine amino transferase (ALT) and aspartate amino transferase (AST) were also reduced by treatments. ALT is present in the liver and other cells and is useful in measuring or assessing hepatic necrosis (Cornelius, 1989). An increase in serum AST is associated with cell necrosis of many tissues (Kaneko, 1989). The results of this study may therefore suggest improved liver and kidney function for the birds within the confines of feed restriction levels imposed.

Economic parameters

The best score of cost benefit ratio (cbr) of 0.375) was obtained for the quantity restricted birds at the 30% level of restriction followed by 0.388 at the 15% level of restriction with a cost saving of N164.00 and N 111.00 per bird for the birds in the 30% and 15% restriction groups respectively. This result is in agreement with the report of Yu and Robinson (1992) that economic performance with restricted feeding is always better than with full feeding as a result of improvements in feed conversion rates.

V. CONCLUSION AND RECOMMENDATIONS

Conclusion

The performance of the restricted birds, though affected during the restriction period leading to significant reduction in feed intake and weight gain improved during realimentation at the finisher stage. Though they could not attain the same body weight with the full fed group at eight weeks of age, they had better feed utilization index of conversion ratio.

Feed restriction improved the physiological disposition of the birds. Consequently, it appeared that the broiler chickens were in their most optimal physiological status at the 30 % quantitative feed restriction group.

The immune vigilance of the birds and their defenses against infections appeared to have been improved through feed restriction. Improved liver and kidney functions were also indicated for the broiler chickens. The broiler chickens used for this study seemed to be adapted to the humid tropical environment of Nigeria where the experiment was conducted.

Early age feed restriction gave an economic advantage over *ad libitum* feeding. This study showed that by restricting feed during the rearing period, cost of production of broiler chickens can be reduced, and it was lowest when feed restriction was 30 % of *ad libitum*.

Based on the findings of this study, it may be concluded that by restricting feed up to 30 % of *ad libitum*, broiler chickens in the humid tropics would perform optimally the hot season of rearing without compromising profitability.

Recommendations

From the result of this study it is hereby recommended that:

i. Feed restriction programmes of sufficient duration and severity should be practiced in the production of broiler chickens for improved overall performance of the birds.

ii. The age of the broiler chickens at which the restriction program should commence should not be earlier than two weeks to enable the birds to have stabilized before exposing them to the stress of feed restriction.

iii. The duration of feed restriction programme should not be more than three weeks to give the birds enough time to compensate for the loss in body weight.

ACKNOWLEDGEMENT

The Authors are grateful to the authorities of Kogi State University for providing the Facilities and the enabling environment for the successful conduct of this research work.

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