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The Effect of Quantitative Feed Restriction During the Starter Period on Compensatory Growth and Carcass Characteristics of Broiler Chickens

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Abstract: This study was conducted to evaluate the effect of early feed restriction on growth performance and carcass characteristics in broiler chickens. A total of 800 1-d old broilers were randomly allotted to *ad libitum* and 3 feed-restricted treatments, each of which was replicated 8 times (25 birds per replicate) in a randomized complete block design. Broilers were feed-restricted between 8 and 14 d of age, and fed either control *ad libitum* diet (F100), 50% feed intake (FI50), 65% feed intake (FI65), or 80% feed intake (FI80). Results showed that body weight and weight gain were significantly (p<0.01) greater for FI100 in contrast to restricted groups. Feed intake was significantly (p<0.01) higher for FI65 at 21 d, while FI100 had a superior feed conversion (p<0.01). Abdominal fat pad weight was significantly (p<0.01) lower for the FI50 compared to the other treatments, while the control diet had a significantly higher (p<0.02) liver and heart weight. No significant differences were observed with regard to carcass yield, dressing percent, or gizzard weight.

Key words: Quantitative, feed restriction, broiler, compensatory growth, carcass characteristics

INTRODUCTION

Intensive selection for high growth rate has provided the broiler industry with flocks that reach target weight for slaughter in shorter time periods. However, some undesirable selection responses correlated with rapid growth have occurred (Benyi *et al.*, 2010). Fast growth rate has been associated with greater susceptibility to metabolic disorders such as ascites and sudden death syndrome, and a high incidence of skeletal problems (Yu and Robinson, 1992; Garner *et al.*, 2002; Scott, 2002). Broiler chicken are given free choice feeding, therefore, they tend to consume energy in excess of their maintenance and production requirements and deposit this excess as fat (Summers and Spratt, 2000; Cuddington, 2004). Fat is an uneconomical and undesirable product that not only increases the occurrence of metabolic diseases and skeletal deformities, but also causes problems in feed efficiency, difficulties in meat processing, and rejection of meat by consumers for health reasons (Urdenta-Rincon and Leeson, 2002).

Consumer preferences for leaner meat have increased over the last two decades due to the corollary between human consumption of certain fats and cardiovascular disease. This has stimulated interest in reducing abdominal-fat deposition in broiler chickens and trend towards leaner carcasses (Cabel and Waldroup, 1990). It also sparked the interest in research on feed restriction and the concept of compensatory growth to correct metabolic problems and meet consumer demands for leaner carcasses (Zubair and Leeson, 1994).

Feed restriction, whether qualitative or quantitative, is denying birds a full access to nutrients that are required for their normal growth and development (Khetani *et al.*, 2009). Early feed restriction is practiced in broilers to induce compensatory growth, improve efficiency of feed utilization, and lower maintenance requirements in the grower and finisher phases (Teimouri *et al.*, 2005). This will ultimately lead to reduction in feed and production costs, thereby, producing a lean quality meat at cheaper prices (Zubair and Leeson, 1996; Navidshad *et al.*, 2006; Mahmud *et al.*, 2008).

Therefore, the aim of this research was to determine the effect of quantitative feed restriction during starter phase on growth performance, carcass traits and organ size at the end of the growing period.

MATERIALS AND METHODS

Experimental design: A total of 800 straight-run broiler chicks were randomly assigned to four dietary treatments in a 42-d quantitative (physical) feed restriction (FR) trial. Treatments consisted of a control (FI100) that provided 100% *ad libitum* and three test diets that provided 50% (FI50), 65% (FI65), and 80% (FI80) of *ad libitum* feed intake, respectively, during the starter period. Each diet was fed to 8 replicate pens of 1-d old Hubbard chicks for a total of 32 replicate floor pens (25 birds per pen). The experimental design was a randomized complete block design with 4 floor pens representing a block for a total of 8 blocks. Birds were weighed prior to the commencement of the trial and randomly allotted to replicate pens according to Bodyweight (BW) uniformity, such that, the average initial BW of birds was similar across pens.

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Birds and housing: Hubbard chicks, obtained from a local hatchery were reared from 1-d old and fed experimental diets during the starter period. All feed-restricted birds were offered F100 diet between 0 and 7 d of age and fed treatments FI50, FI65 and FI80 from 8 to 14 d of age, then put back on the control FI100 diet till 21 d of age during the starter phase. All birds were raised on regular corn-soybean diets till 42 d of age and given 24-h access to water for the duration of the trial. All diets were provided in mash form throughout the 6-wk experimental trial. Pens had a daily lighting regimen of 22 h of light and 2 h of dark. Room temperature was maintained at 35°C during the first week and reduced by 3°C per week thereafter, until maintained at 23°C. Birds were reared in an open-sided house on floor pens (2.5 x 1.85 m) and wood shavings were used as litter at a depth of 5 cm. All birds in this trial were handled in accordance with guidelines set forth by The Jordanian Society for Protection of Animals.

Diets: Diets were formulated in accordance with the breeders' management guide and to meet the requirements of the National Research Council (1994) for broiler chicken. The diets were standard corn-soybean meal diets formulated for starter (0-21 d), grower (22-35 d) and finisher (36-42 d) periods and were isocaloric and isonitrogenous for each feeding phase (Table 1).
During the period of FR (8 to 14 d), the starter diet was fed at 100% *ad libitum* or 50, 65 and 80% *ad libitum* feed intake. Thereafter, birds were returned to normal feeding regimen till the end of the trial.

Statistical analysis: Data was analyzed using the repeated measures analysis of SAS® (2007) (PROC MIXED) for a randomized complete block design. The data was tested for main effects of dietary treatments. The following general linear model was used:

$$Y_{ijk} = \mu + R_i + "_j + ß_{ijk}$$

Where:
Y_{ijk} = Measured response
μ = Overall mean
R_i = Block
$"_j$ = Dietary effect
$ß_{ijk}$ = Residual error
Level of significance used was p=0.05

Parameters measured

Production parameters: Production parameters measured on a weekly basis included Bodyweight Gain (BWG), Bodyweight (BW), Feed Intake (FI) and Feed Conversion Ratio (FCR). Mortality was observed and recorded daily and adjusted to both FI and FCR.

Table 1: Diet composition

Ingredient	Starter[1] (0-21 d)	Grower (22-35 d)	Finisher (36-42 d)
	----------	(%)	----------
Corn	58.50	62.30	67.05
Soybean meal (48% CP)	35.65	31.00	26.00
Palm oil	1.69	2.62	3.00
Limestone (ground)	1.84	1.79	1.68
Dicalcium phosphate	1.00	0.96	1.02
NaCl	0.41	0.41	0.42
DL-methionine (98%)	0.20	0.20	0.20
L-Lysine-HCl (98.5%)	0.11	0.12	0.13
Coccidiostat	0.10	0.10	-
Vitamin premix[1]	0.10	0.10	0.10
Mineral premix[2]	0.10	0.10	0.10
Choline Chloride (60%)	0.10	0.10	0.10
Antioxidant	0.10	0.10	0.10
Antifungal	0.10	0.10	0.10
Calculated nutrient composition			
ME, kcal/kg feed	3,000.00	3,075.00	3,150.00
Protein, %	22.00	20.00	18.00
TSAA, %	0.90	0.86	0.81
Methionine, %	0.54	0.51	0.50
Lysine, %	1.31	1.20	1.07
Threonine, %	0.84	0.76	0.68
Tryptophan, %	0.29	0.27	0.23
Ca, %	1.03	0.98	0.95
P, nonphytate, %	0.45	0.42	0.40
Na, %	0.18	0.18	0.18

[1]Starter diet was fed at 50, 65 and 80% of *ad libitum* feed intake during restriction period in treatments 2, 3 and 4.
[2]Vitamin premix provided per kilogram of diet: vitamin A, 120000 IU; vitamin D_3, 3500 IU; vitamin E, 40 mg; vitamin B_1, 2.5 mg; vitamin B_2, 8 mg; vitamin B_6, 5.0 mg; vitamin, riboflavin, 150 µg; B_{12}, 30 µg; biotin, 150 µg; folic acid, 1.5 mg; niacin, 45 mg; pantothenic acid, 13 mg.
[2]Trace mineral premix provided per kilogram of diet: Fe, 30 mg; Cu, 15 mg; Mn, 60 mg; Zn, 550 mg; I, 1 mg; Se, 0.80 mg

Carcass characteristics: At the end of the 42 d trial, 96 birds from each treatment (3 per pen) were randomly selected, weighed, and fasted for 8 h prior to slaughter. Slaughtered birds were scalded, feathers mechanically plucked and then carcasses eviscerated. Feet, shanks, neck and head were removed and carcasses were immediately weighed to obtain post-slaughter hot carcass yield without giblets. Giblets are the total yield of liver, heart and gizzard which were removed and weighed in addition to the abdominal fat pad. Carcasses were refrigerated for 24 h at 2-3°C and thereafter, chilled carcasses were weighed again to obtain cold carcass yield as % of live weight to calculate dressing percent.

RESULTS

Production parameters: Results showed that birds kept under *ad libitum* feeding (F100) significantly (p<0.01) gained more weight than those feed-restricted (FI50, FI65, FI80), post-restriction at 21, 28, 35 and 42 d of age (Table 2). At 21 d, birds fed FI65 had a significantly (p<0.01) higher BWG than other restriction treatments, though the difference was only numerical at 28, 35 and 42 d of age.

Table 2: Effect of quantitative feed restriction on bodyweight and bodyweight gain

	Treatments					
Parameters	FI100[1]	FI50[1]	FI65[1]	FI80[1]	SEM	p-value
Bodyweight gain (g/bird)						
Bird age (days)						
0-7 days	103.50	113.25	102.50	101.00	5.490	NS
0-14 days	303.75	387.00	293.00	275.25	12.953	NS
0-21 days	621.25^{a}	542.50^{b}	609.25^{a}	558.25^{b}	15.696	0.01
0-28 days	1114.00^{a}	889.50^{b}	920.50^{b}	897.25^{b}	21.993	0.001
0-35 days	1740.00^{a}	1489.50^{b}	1528.35^{b}	1460.75^{b}	24.769	0.001
0-42 days	2345.00^{a}	2095.00^{b}	2128.00^{b}	2093.50^{b}	43.202	0.001
Bodyweight (g/bird)						
Bird age (days)						
0-7 days	142.50	152.00	141.50	140.00	5.359	NS
0-14 days	342.75	326.00	332.00	314.00	12.855	NS
0-21 days	660.25^{a}	581.50^{b}	648.25^{b}	597.25^{b}	15.730	0.01
0-28 days	1153.00^{a}	928.00^{b}	959.50^{b}	936.25^{b}	21.970	0.001
0-35 days	1783.00^{a}	1528.50^{b}	1544.25^{b}	1499.75^{b}	19.956	0.001
0-42 days	2364.00^{a}	2154.00^{b}	2167.00^{b}	2132.50^{b}	43.044	0.001

[1]Dietary treatments designation: FI100 (100% feed intake), FI50 (50% feed intake), FI65 (65% feed intake), and FI80 (80% feed intake). [a-b]Means within rows with varying superscripts differ significantly (p<0.05)

Table 3: Effect of quantitative feed restriction on feed intake and feed conversion ratio

	Treatments					
Parameters	FI100[1]	FI50[1]	FI65[1]	FI80[1]	SEM	p-value
Feed intake (g/bird)						
Bird age (days)						
0-7 days	136.25	141.50	137.50	138.25	6.051	NS
0-14 days	304.00	457.75	435.50	398.00	20.898	NS
0-21 days	843.00^{c}	944.00^{bc}	1079.25^{a}	1001.25^{ab}	37.586	0.006
0-28 days	1595.25	1640.00	1767.50	1712.25	51.603	NS
0-35 days	3071.25	3099.50	3157.00	3098.25	57.354	NS
0-42 days	4428.25	4383.00	4562.75	4607.75	112.890	NS
Feed conversion ratio (g feed:g bodyweight gain)						
Bird age (days)						
0-7 days	1.33	1.26	1.53	1.37	0.0789	NS
0-14 days	1.26	1.60	1.50	1.46	0.0809	NS
0-21 days	1.36^{a}	1.74^{b}	1.77^{b}	1.79^{b}	0.0486	0.01
0-28 days	1.44^{a}	1.84^{b}	1.92^{b}	1.91^{b}	0.0571	0.002
0-35 days	1.79^{a}	1.98^{b}	2.01^{b}	2.07^{b}	0.0211	0.001
0-42 days	1.89^{a}	2.01^{b}	2.03^{b}	2.09^{b}	0.0214	0.001

[1]Dietary treatments designation: FI100 (100% feed intake), FI50 (50% feed intake), FI65 (65% feed intake) and FI80 (80% feed intake). [a-b]Means within rows with varying superscripts differ significantly (p<0.05)

At 21, 28, 35 and 42 d, BW was significantly (p<0.01) greater for birds fed FI100 in contrast to birds fed FI50, F65 and FI80, respectively (Table 2). There were no significant differences in BW among feed-restricted birds throughout the trial, even though, FI65 birds were the heaviest.

Table 3 shows the results for FI and FCR across 6 ages inclusive of the FR period (8 to 14 d). At 21 days of age, birds fed 65 and 80% of *ad libitum* FI had significantly higher (p<0.01) intake than those fed 50% and 100% of FI. Despite being nonsignificant, birds in treatments FI50, FI65 and FI80 exhibited a numerically higher feed intake over 42 d compared to the control diet (FI100). Among the feed-restricted birds, those in the FI80 treatment had the highest overall feed intake at 42 d. Birds fed the control diet had a significantly lower FCR (p<0.01) than restricted broilers, whilst, those fed 50% of *ad libitum* exhibited the lowest FCR at 21, 28, 35 and 42 d of age among restriction treatments, even though, the difference was only numerical.

Carcass characteristics: Carcass characteristics are shown in Table 4. No significant differences were found between control and feed restriction treatments for carcass yield and dressing percent, despite the control diet having a numerical advantage for both measurements. Abdominal fat pad weight was significantly (p<0.01) higher for FI100, FI65 and FI80 in contrast to FI50. The same was observed with regard to liver and heart weight with the FI100, FI65 and FI80 birds having a larger liver and heart weight in contrast to FI50. Among the feed-restricted birds, those fed 50% FI had

Table 4: Effect of quantitative feed restriction on carcass characteristics

	Treatments					
Parameters	FI100[1]	FI50[1]	FI65[1]	FI80[1]	SEM	p-value
Carcass yield (g)	1422.75	1414.13	1415.14	1331.63	66.061	NS
Dressing percent (%)	70.30	69.96	69.57	68.66	0.289	NS
Fat pad weight (g)	34.78[a]	29.88[b]	33.13[a]	33.63[a]	2.658	0.01
Liver and heart weight (g)	66.25[a]	59.63[b]	68.13[a]	64.13[a]	6.014	0.02
Gizzard weight (g)	35.63	32.50	32.00	30.62	2.525	NS

[1]Dietary treatments designation: FI100 (100% feed intake), FI50 (50% feed intake), FI65 (65% feed intake) and FI80 (80% feed intake). [a-b]Means within rows with varying superscripts differ significantly (p<0.05)

the lowest fat pad and liver and heart weights. Gizzard weight was nonsignificant among all treatments with control birds having numerically higher weights than restriction treatments.

DISCUSSION

In the present study, feed-restricted broilers (FI50, FI65 and FI80) gained less weight and were lighter than control group (FI100) following realimentation. It is clear that restricted birds failed to show any indication of compensatory growth during realimentation between 22 and 42 d of age. Congruent with our findings, various researchers have reported lower weight gains and market weights in feed-restricted vs. full-fed birds (Urdenta-Rincon and Leeson, 2002; Saleh *et al*., 2005; Zhan *et al*., 2007; Benyi *et al.*, 2010; Benyi *et al*., 2011). Contrasting results have been cited by others (Leeson and Zubair, 1997; Lee and Leeson, 2001; Mahmood *et al*., 2005; Mahmud *et al.*, 2008). Such inconsistencies in results may be attributed to the differences in levels and schedules of feed restriction used in these studies. McMurty *et al.* (1988) recommended that restricting broilers for a period no longer than 7 days, while Plavnik *et al.* (1986) found that broilers subjected to 12 days of restriction exhibited a significantly reduced market weight. It is important to note that Zubair and Leeson (1994) stated that under-nutrition in the early stages of life is more detrimental to the animal than under-nutrition at the latter stage. Our findings suggest that this statement is true as demonstrated by inability of feed-restricted broilers to regain weight losses incurred during restriction compared to control group during realimentation. Lanhui *et al*. (2011) reported that early restriction of broilers to levels of 70 and/or 80% of *ad libitum* for 7 and 10 days, respectively, decreased BW significantly in contrast to control birds. In our study, it is possible that the level of restriction was severe enough, especially with 50 and 65% of *ad libitum* FI, that it did not allow for complete recovery, thus, no compensatory growth occurred.

Our results showed that FI was only significantly affected by feed restriction at 21 d of age immediately after realimentation with FI80 and FI65 consuming more feed than FI50 and FI100. Though not statistically significant, feed restriction groups had a higher FI than control which is in accordance with findings by Jang *et al.* (2009) who reported an increase in feed intake of birds restricted at 70 and 85% of *ad libitum* FI. Contrasting to our results, several researchers have demonstrated a higher FI by control birds compared to restricted groups (Saleh *et al.*, 2005; Zhan *et al.*, 2007; Khetani *et al.*, 2009; Benyi *et al.*, 2010; Lanhui *et al.*, 2011). The differences in results among these trials may be due to the differences in the level of and duration of feed restriction regimens.

The superior FCR of control over the feed-restricted broilers observed in this trial during realimentation has been previously cited (Urdenta-Rincon and Leeson, 2002; Jang *et al.*, 2009; Khetani *et al.*, 2009). Others have reported better FCR values in feed-restricted birds (Yu *et al.*, 1990; Lee and Leeson, 2001; Saleh *et al.*, 2005; Mahmood *et al.*, 2007; Onbasilar *et al*., 2009). When birds are subjected to early feed restriction they exhibit slow growth followed by a period of rapid growth and weight gain as they approach market weight to compensate for the delayed growth during early restriction period (Gous and Cherry, 2004). This translates into reduced maintenance requirements and improved feed utilization potential by birds due to smaller body weights (Lippens *et al.*, 2000). The results in this study, however, show no indication of improved utilization by restricted birds, despite their significantly lower body weights compared to the control group. The reason for this discrepancy is due to the fact that feed-restricted birds consumed more feed in their attempt to compensate for the time they would have been deprived of feed, thus, birds were less efficient in feed utilization and in the process did exhibit compensatory growth (Khetani *et al*., 2009).

The weight of abdominal fat pad of restricted broilers was lower than that of *ad libitum* broilers, but not statistically significant, except for those restricted to 50% of *ad libitum* FI. In previous studies concerning early feed restriction, some cited a decreased trend in fat deposition (Jones and Farrell, 1992; Nielsen *et al.*, 2003), whereas others cited opposite results (Lippens *et al.*, 2000; Saleh *et al.*, 2005; Zhan *et al.*, 2007; Onbasilar *et al.*, 2009; Lanhui *et al.*, 2011). The discrepancies may be due to the metabolic programming, whereby, early malnutrition leads to adult life obesity. The metabolic programming is induced by nutritional experience during the critical period in development with consequences during adulthood (Patel and Srinivasan, 2002). The fact that there was no significant reduction in abdominal fat deposition in FI65 and FI80 birds in this experiment suggests that even feed-restricted-broilers are still overeating and that level of FI may control de novo lipogenesis (Rosebrough and McMurty, 1993). Rosebrough *et al.* (1986) reported that activities of lipogenic enzymes were depressed during the period of feed restriction, climaxed during the 1st week of realimentation and declined to below those of the control birds on subsequent birds. Santoso (2001; 2002) found that broilers restricted to 25% *ad libitum* FI for either 6 or 9 d significantly reduced abdominal fat compared to 50 *ad libitum*, 75% *ad libitum* and control and cited that the severity of early restriction affects fat accumulation in broilers. These findings are in agreement with results reported in the present trial, whereby, birds restricted to 50% *ad libitum* exhibited a decrease in abdominal fat when compared to unrestricted birds and other restriction groups (FI65 and FI80).

Heart and liver weight combined was significantly lower for bird in the FI50 in contrast to FI65, FI80 and FI100. Petek (2000) and Onbasilar *et al.* (2009) reported a significantly lower heart weight in feed restricted broilers when compared to the unrestricted control. However, McGovern *et al.* (1999) concluded that heart weight as a percentage of BW was significantly higher in feed-restricted broilers. This contrast in results may be attributed to the feed restriction program and slaughter age in these trials. Several previous studies (Saleh *et al.*, 2005; Mahmood *et al.*, 2007; Onbasilar *et al.*, 2009) have found no significant differences in liver weight between restricted and unrestricted broilers. Again the differences in results are likely to be related to feed restriction programs applied and slaughtering age of birds.

Conclusion: Early feed restriction is usually practiced to improve energetic efficiency of feed utilization by broiler chicken, produce a leaner carcass, and reduce production cost. In our study, birds subjected to feed restriction, gained less weight, were lighter and less efficient in utilizing feed compared to the control group. Except for FI50, feed-restricted broiler did not exhibit a reduction in abdominal fat pad weight in contrast to control. These results indicate that feed-restricted birds did not improve efficiency of feed utilization during restriction period, and overconsumed feed upon refeeding to compensate for slow growth during feed deprivation. The level of feed restriction may have been severe to allow for recovery and compensatory growth during realimentation.

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