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Effects of D-Thyroxine Hormone on Compensatory Growth and Carcass Characteristics of Broiler Chickens

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Abstract: An experiment was conducted to evaluate the effects of D-Thyroxine (T4) on compensatory growth of broiler chickens. The experiment was designed in a 2×5 factorial with 5 replicate pens of 12 male or female chicks each. Six hundred male and/or female day-old chicks were weighed and randomly allocated to 5 treatment groups of each sex. Five treatments including: A control (C, with no feed restriction and T4) and 4 restricted groups which were fed a mixture of 50:50 rice hulls and a starter diet with supplementation of trace minerals and vitamins from 4-11 days of age. All groups were fed similar diets from 11-56 days of age, with the exception that the diets of 4 restricted groups R0, R1, R2 and R3 were supplemented with 0, 1, 2 and 3 ppm T4 from 11-28 day, respectively. The lowered LBW of R0 birds was compensated at 42 day, whereas the LBW of R1, R2 and R3 treated birds was decreased as the level of T4 was increased. The LBW of R1 and R2 treated birds were similar at 49 day and this was lower than ($p<0.05$) the C and R0 birds. Among the T4 treated birds, only the R1 birds could complete a compensatory growth at 56 day. The LBW of R0 birds was numerically higher than of C birds at 56 day. The FI of birds with the exclusion of ground rice hulls was not different ($p>0.05$) among the C, R0 and R1 birds during 1-42 or 49 and/or 56 day but this FI value was significantly higher than obtained from R2 and R3 birds. The FCR of R0 birds was numerically better than of C or T4 treated birds, whereas all T4 treated birds exhibited a poorer FCR during 1-42 or 49 and/or 56 day. The performance parameters in male chicks were significantly better than of female chicks. Carcass fat content of the R0 treated birds was significantly lower than that of control or other treated birds ($p<0.05$). Carcass fat content of male chicks was lower than ($p<0.05$) that of female chicks. AFP of the R0 birds was lower than ($p<0.05$) that of control or T4 treated birds at 49 day, whereas all birds had a similar abdominal fat at 56 day. Therefore, compensatory growth in broiler chicks can be achieved at 42 day with diet dilution in early of life. The dietary T4 depressed performance characteristics. Serum Thyroxine was increased by feed restriction and reached to normal level when birds were re-fed.

Key words: Broiler; feed restriction, thyroxine, performance, carcass characteristics

INTRODUCTION

There has been an interest in using feed restriction programs to modify growth patterns of birds for many years. Generally the growth rate of broiler chickens fed *ad libitum* follows a sigmoid curve (Walker *et al*., 1995). A reduced growth rate is observed when birds are subjected to a feed restriction program as compared to full-fed birds. This decreased in growth rate reduces the bird's total maintenance requirements to market age and this improves feed efficiency (Leeson and Summers, 1997) and decreases incidence of metabolic disorders such as ascites, sudden death syndrome and skeletal abnormalities (Robinson *et al*., 1992). The goal of researchers in using feed restriction is to improve feed efficiency, decline in carcass fat content and abdominal fat pad size which is mainly due to hyperplasia and/or hypertrophy of adipocyte tissue (Plavnik and Hurwitz, 1991). The lower nutrient requirements of broilers after imposition of an early life feed restriction program may be due to a decline in heat increment, basal metabolic rate and specific dynamic action of food (Forsum *et al*., 1981). The response of broiler chickens to feed restriction will depend on the genetics and sex of birds. Gous *et al*. (1999) suggested that broiler genetic potential influences growth response and this affects their nutritrient requirements. Thus it is not surprising that discrepancies in the results concerning the response of broiler chickens subjected to under-nutrition programs has been credited to differences in genetics of birds (Yu and Robinson,

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1992; Fontana *et al*., 1992). However, other researchers have not shown a fat pad reduction or growth differences among strains in response to feed restrictions (Plavnik and Hurwitz, 1992). Generally male broiler chickens have a higher growth rate and leaner body composition than of female broilers. It has been reported that male broilers have a superior capacity to display growth compensation than of females after a feed restriction (Plavnik and Hurwitz, 1991; Santoso *et al*., 1993a,b), whereas Deaton (1995) showed that both male and female broilers attained complete compensatory growth. Different methods of feed restriction have been developed. Physical feed restriction programs for broilers have been extensively studied (Santoso *et al*., 1993b; Zhong *et al*., 1995). From the practical point of view, the physical feed restriction is not straightforward due to the problems of regularly weighing birds, calculating feed consumption on a daily basis, providing enough feeder, unequal growth and competition among restricted birds. It is known that a reduction in hours of light or intermittent light schedules may improve feed utilization (Apeldoorn *et al*., 1999). The broilers energy need for maintenance is lower during the periods of darkness (Buyse *et al*., 1996). However, broilers do learn to eat during the darkness when hours of lights are reduced (Morris, 1986). Many workers have used diet dilution as an alternative method of nutrient restriction because of the advantage of attaining a more consistent growth pattern within a flock. Diets are mixed with non-digestible ingredients such as rice hulls and so nutrient densities are reduced. Leeson *et al*. (1991) showed a complete compensatory growth in male and female broilers where growth was limited from 4-11 days due to a diluted diet containing up to 55% of rice hulls. In addition, there was no significant difference in the overall efficiency of feed utilization, although during the diluted period birds increased their feed consumption in an attempt to maintain their energy intake. The use of low protein or low energy diets is another means of achieving reduced growth rate. This is accomplished by lowering the dietary protein or energy levels. Plavnik and Hurwitz (1990) showed that broilers fed *ad libitum* with a 9% crude protein diet from 8-14 days markedly reduced their feed intake and weight gain by about 63 and 88%, respectively. Another method to depress the feed intake of broilers is the use of chemicals or pharmacological agents. Pinchasov and Jensen (1989) used 1.5 or 3% glycolic acid as an anorectic agent from 7-14 days in order to suppress the feed intake of chicks. Feed intake was severely reduced, resulting in 22 and 50% weight reduction with 1.5 or 3.0% glycolic acid inclusion, respectively. Body weight of these chemically restricted male broilers was not significantly different at 49 day from those fed *Ad libitum*. Oyawoye and Krueger (1990) utilized phenylpropanolamine hydrochloride and monensin sodium as appetite suppressants. Compensatory growth refers to the accelerated growth noted in animals of the same age and breed that were previously feed-restricted (Wilson and Osbourn, 1960). A complete compensatory growth and improved feed efficiency in broiler chickens under early feed restriction programs has been recorded by Plavnik and Hurvitz (1990), Santoso *et al*. (1993b), Zubair and Leeson (1994) and Deaton (1995). However, other workers have failed to obtain compensatory growth in broiler chickens under similar nutritional conditions (Fontana *et al*., 1992; Cristofori *et al*., 1997). Birds exhibiting such reduced growth during a restriction period have reduced plasma concentrations of Insulin-like Growth Factors (IGF-1 and II), (Leili *et al*., 1997), which may explain this lower growth. When normal feed availability is restored, chicks grow at a higher rate than normal in order to attain normal weight for age. This accelerated growth observed after a feed restriction period may be due to a higher concentration of Growth Hormone (GH) occurred in previously feed-restricted birds (Buyse *et al*., 1997). The mechanism(s) of compensatory growth has not been fully explored. Two theories have been proposed to explain how compensatory growth is regulated. First, compensatory growth mechanism may involve a set-point or reference for body size appropriate for age and that the control resides in the central nervous system (Wilson and Osbourn, 1960). Pituitary gland secretes more Growth Hormone (GH) is related to compensatory growth control but is not directly responsible for growth acceleration. The link between the compensatory growth control and GH release is regulated by photoperiod. Thus, after a period of undernutrition, the body tries to attain a size that is appropriate for age in the shortest possible time (Zubair, 1994). The second theory relates to so called "peripheral control" which suggests that tissues, per se, control body size through cell number or by the total content of DNA (Zubair, 1994). One of involving factors in accelerated growth may be hormonal change during this period. It has been reported that thyroid hormones concentration decreases after feed restriction period but increases and reaches to normal by re-feeding (Lauterio and Scanes, 1987; McMurtry *et al*., 1988). It seems that Thyroxine hormone supplementation after a feed restriction may induce compensatory growth in broiler chicks.

The objective of the present study was to investigate the Effects of early feed restriction and Thyroxine hormone supplementation after feed restriction on performance and carcass characteristics of broiler chickens.

MATERIALS AND METHODS

Six hundred male and/or female day old chicks of a commercial strain (Hybro) were randomly allocated to 1 of 5 treatment groups of each sex. The experiment was a 2×5 factorial design with two sexes and five dietary treatments. Each treatment consisted of 5 replicates of 12 birds each and placed in a (1.5×1 m) floor pen. All birds were fed *ad libitum* to 4 day of age using a conventional starter diet (Table 1), formulated to meet the nutrient requirements according to the NRC (1994). Lighting was provided 23 h day^{-1}. Room temperature was maintained at 30°C in d one and then gradually reduced according to standard brooding practices to reach 20°C on day 24. The experimental diets were formulated using maize, wheat, fish meal and soybean meal, as main ingredients (Table 1). Diet dilution was achieved by substitution of ground rice hulls with 50% of major ingredients in the diet. Five dietary treatments including: one control (C, with no restriction and T4 supplementation) and four restricted groups which were fed a mixture of 50:50 rice hulls:commercial starter diet from 4-11 days of age. The amount of trace minerals and vitamins in C and restricted diets (R) were remained similar. After this period, chicks were fed with a regular starter, grower and finisher diets up to 56 days of age (Table 1). All diets were formulated to meet the nutrient requirements according to NRC (1994). All groups were fed the same diets from 11-56 days of age with the exception of the 4 R diets, R0, R1, R2 and R3 which were supplemented with 0, 1, 2 and 3ppm T4 powder of 99% purity (Iran-Hormone Company, Karaj, Iran), respectively from 11-28 days of age. During the experiment Live Body Weight (LBW), weight gain, feed intake and feed conversion ratio were measured during 1-4, 4-11, 11-14 and then weekly till end of the experiment. Yield cost, body composition (crude protein, total fat, ash, moisture) organ weighs and abdominal fat pad size were determined at 49 and 56 days of age. Daily mortality was measured throughout the experiment. One bird with the average weight of pen weight was selected from each pen for carcass analyses at day 49 and 56 of age. After feed was withheld for 12 h, then the selected birds were slaughtered and processed. Viscera were manually removed and the abdominal fat pad and other carcass organs were weighed from slaughtered birds on day 49 and 56. The carcass, breast fillet, thighs, wings, abdominal fat pad (including fat adhering to the gizzard and proventriculus) were weighed. Carcasses were homogenized with an industrial blender and a sub-sample was taken and dried in oven for 24 h at 100°C and stored in room temperature for later analysis. Moisture content, total protein, lipid and ash in each sub-sample were determined with standard procedures (AOAC, 1980). Blood sample of one bird from each replicate was obtained by heart puncture at 4, 11, 28 and 49 days of age. The samples were stored at 2°C in refrigerator for 24 h and then were centrifuged at 1200 RPM for 30 min to separate the serum. The serum samples were stored at-20°C until hormone assay. Serum samples were analyzed for total T4 with radioimmunoassay described by May (1978, 1980) using commercial kit and using Automatic gamma counting system (Serono Inc., 607 Bolyston Street, Boston MA). Data of this experiment were analyzed by analysis of variance using General Linear Models (GLM) procedures of SAS (SAS Institute). The means were compared by Duncan's Multiple Range Test (SAS Institute). Percentage data for processing effects were converted to arcsin before analysis. The level of significance was reported at $p<0.05$.

Table 1: Composition of experimental feeds on percentage (as-is basis)

Ingredients (%)	0-21 day	21-42day	42-56day
Corn ground	53	39.9	50
Wheat ground	12.25	35.5	30.9
Soybean meal	26	19.5	11.9
Fish meal	5	2.2	5
Oyster shell	1.43	1.43	1.11
Mono calcium phosphate	1.12	0.7	0.5
DL-Methionine	0.07	0.025	-
Mineral Premix[1]	0.3	0.3	0.3
Vitamin Premix[2]	0.3	0.3	0.3
Vitamin E	0.2	0	0
Common Salt	0.33	0.23	0.135
Calculated analyses			
CP	20.82	18.12	16.81
ME (kcal kg^{-1})	2900	2900	2990
Calcium	0.92	0.816	0.75
Available phosphorus	0.47	0.32	0.33
Sodium	0.18	0.137	0.11
L-Arginine	1.37	1.13	0.98
L-Lysine HCL	1.21	0.92	0.85
DL-Methionine	0.46	0.34	0.33
Met+Cys	0.81	0.68	0.63
Linoleic acid	1.35	1.17	1.34

[1]Mineral mix supplied the following per kg of diet: Cu, 25 mg; Fe, 125 mg; Mn,100 mg; Se, 0.5 mg; Zn, 300 mg; Mg, 250 mg; Co, 0.5 mg; I, 2.5 mg; Cholin chloride, 2500 mg. [2]Vitamin mix supplied the following per kg of diet: vitamin A, 5000 IU; vitamin D_3, 2500 IU; vitamin E, 100 IU; vitamin K_3, 15 mg; vitamin B_1, 12.5 mg; vitamin B_2, 40 mg; vitamin B_6, 7.5 mg; vitamin B_9, 3 mg; vitamin B_{12}, 0.1 mg

RESULTS

The Effects of dietary nutrient dilutions, T4 supplementation after feed restriction and sexes on feed intake, body weight, feed conversion ratio, carcass characteristics and serum Thyroxine concentration are presented in Table 2-7, respectively.

Feed intake: As shown in Table 1, during the period of diet dilution (4-11 day) with exclusion of rice hulls, birds consumed significantly lower feed than C group and there

Table 2: Effect of Thyroxine hormone after feed restriction on daily feed intake (g/b/d) of broiler chickens in different ages

		Age (day)							
Treat		4-11[1]	14-21	0-21[1]	21-42	42-56	0-42[1]	0-49[1]	0-56[1]
Main effects									
T4	Control	25.4^{a}	67.1^{a}	40.5^{a}	131.6^{ab}	162.4^{a}	86.1^{a}	96.3^{a}	105.1^{a}
	0 ppm	20.8^{b}	65.0^{a}	37.9^{b}	131.0^{ab}	168.3^{a}	84.5^{a}	95.5^{a}	105.4^{a}
	1 ppm	-	59.9^{b}	35.8^{bc}	132.8^{a}	164.4^{a}	84.3^{a}	94.6^{a}	104.3^{a}
	2 ppm	-	58.0^{b}	34.7^{c}	126.9^{bc}	154.9^{b}	80.8^{b}	91.0^{b}	99.3^{b}
	3 ppm	-	56.3^{b}	34.0^{c}	124.9^{c}	150.6^{b}	79.5^{b}	88.9^{b}	97.2^{b}
SE		-	1.62	0.82	1.60	2.22	1.10	1.04	1.02
Sex	Male	21.6^{a}	61.8^{a}	36.7^{a}	131.9^{a}	167.9^{a}	84.3^{a}	95.6^{a}	105.2^{a}
	Female	21.9^{a}	60.7^{a}	36.5^{a}	126.9^{b}	152.3^{b}	81.7^{b}	90.9^{b}	99.4^{b}
SE		0.51	1.03	0.52	1.04	1.40	0.71	0.66	0.64
Interactions									
Male	Control	25.9^{a}	65.1^{abc}	40.1^{ab}	134.2^{ab}	165.4^{bc}	87.2^{a}	97.7^{ab}	106.7^{b}
Male	0 ppm	21.2^{b}	67.2^{ab}	38.9^{abc}	136.4^{a}	182.8^{a}	87.6^{a}	101.0^{a}	111.4^{a}
Male	1 ppm	-	58.6^{cde}	34.7^{d}	134.3^{ab}	169.6^{b}	84.5^{abc}	95.1^{bc}	105.8^{b}
Male	2 ppm	-	61.2^{bcde}	35.6^{cd}	128.4^{bc}	165.0^{bc}	82.0^{bcd}	93.5^{bcd}	102.8^{bc}
Male	3 ppm	-	56.9^{de}	34.3^{d}	126.2^{c}	156.7^{cd}	80.3^{bcd}	90.7^{cde}	99.4^{cd}
Female	Control	24.9^{a}	69.1^{a}	41.0^{a}	128.9^{bc}	159.4^{cd}	85.0^{ab}	94.8^{bc}	103.6^{bc}
Female	0 ppm	20.6^{b}	62.8^{abcd}	37.0^{bcd}	125.5^{c}	153.8^{de}	81.3^{bcd}	90.1^{de}	99.4^{cd}
Female	1 ppm	-	61.1^{bcde}	36.9^{bcd}	131.2^{abc}	159.1^{cd}	84.0^{abc}	94.0^{bcd}	102.8^{bc}
Female	2 ppm	-	54.9^{e}	33.8^{d}	125.3^{c}	144.8^{e}	79.6c^{d}	88.5^{e}	95.9^{d}
Female	3 ppm	-	55.8^{de}	33.8^{d}	123.6^{c}	144.4^{e}	78.7^{d}	87.1^{e}	95.1^{d}
SE		3.85	2.29	1.16	2.32	3.14	1.58	1.48	1.43

[1] feed intake with exclusion of rice hulls, ^{abcde} Means within each column and main effects or interactions with different superscripts are significantly different ($p<0.05$)

Table 3: Effects of Thyroxine hormone after feed restriction on live body weight of broiler chickens from 11-56 day of age

		Age (day)							
Treat		11	14	21	28	35	42	49	56
Main effects									
T4	Control	187.3^{a}	267.1^{a}	548.2^{a}	852.9^{a}	1309^{a}	1794^{a}	2170^{a}	2557^{ab}
	0 ppm	154.4^{b}	242.9^{b}	522.2^{b}	835.2^{a}	1274^{a}	1797^{a}	2208^{a}	2622^{a}
	1 ppm	-	225.9^{c}	478.8^{c}	758.4^{b}	1200^{b}	1674^{b}	2061^{b}	2478^{b}
	2 ppm	-	227.0^{c}	472.6^{c}	747.0^{b}	1177^{b}	1613^{c}	1998b^{c}	2390^{c}
	3 ppm	-	218.9^{c}	450.1^{d}	704.3^{c}	1132^{c}	1573^{c}	1936^{c}	2306^{c}
SE		-	3.54	6.96	9.20	12.54	16.22	22.41	30.10
Sex	Male	159.7^{a}	234.5^{a}	498.9^{a}	796.5^{a}	1252^{a}	1787^{a}	2205^{a}	2641^{a}
	Female	162.3^{a}	238.2^{a}	489.8^{a}	762.6^{b}	1184^{b}	1594^{b}	1944^{b}	2301^{b}
SE		1.55	2.24	4.23	5.82	7.93	10.26	14.17	19.04
Interactions									
Male	Control	186.2^{a}	258.9^{b}	547.9^{a}	871.2^{a}	1346^{a}	1888^{a}	2276^{b}	2689^{b}
Male	0 ppm	153.1^{b}	244.0^{c}	535.8^{a}	854.6^{ab}	1320^{ab}	1912^{a}	2371^{a}	2818^{a}
Male	1 ppm	-	220.0^{e}	473.5^{cd}	768.2^{c}	1230^{cd}	1766^{b}	2164^{c}	2631^{b}
Male	2 ppm	-	228.2^{de}	484.8^{bc}	770.2^{c}	1215de	1715^{bc}	2156^{c}	2610^{b}
Male	3 ppm	-	221.5^{e}	452.8^{d}	718.1^{de}	1115^{fg}	1651^{c}	2059^{d}	2425^{c}
Female	Control	188.4^{a}	275.2^{a}	548.5^{a}	834.6^{ab}	1272^{bc}	1700^{bc}	2064^{d}	2457^{c}
Female	0 ppm	155.8^{b}	241.7^{cd}	508.5^{b}	815.8^{b}	1227^{c}	1682^{cd}	2044de	2427^{c}
Female	1 ppm	-	231.9^{cde}	404.1^{e}	748.6^{cd}	1170^{ef}	1582^{d}	1958^{e}	2325^{c}
Female	2 ppm	-	225.8^{e}	460.4^{cd}	723.8^{de}	1139^{fg}	1511^{e}	1840^{f}	2171^{d}
Female	3 ppm	-	216.3^{e}	447.5^{d}	690.4^{e}	1113^{g}	1496^{e}	1813^{f}	2156^{d}
SE		1.61	5.00	9.46	13.00	17.7	22.9	31.7	42.6

^{abcdef} Means within each column and main effects or interactions with different superscripts are significantly different ($p<0.05$)

was not significant difference between male and female chicks. During days 14-21 when the T4 supplemented to the experimental diets, T4 receiving birds consumed feed significantly lower than C and R0 groups. At this period of the experiment also there was not significant differences either between sexes or sexes among interaction feed intake means. This trend for feed consumption was observed when the calculation was extended to period of 0-21 day but female R0 birds' feed intake was significantly lower than the males (Table 2). During 21-42 and 42-56 days of experimental periods, T4 treated birds showed lower feed intake and this result was observed during 0-42, 0-49 and 0-56 day. During the mentioned periods of the experiment there was not significant difference either between sexes or sexes among interaction feed intake means with exception that up to 56 days of age C male birds' feed intake was significantly more than females.

Table 4: Effects of Thyroxine hormone after feed restriction on feed conversion ratio of broiler chickens in different ages

Treat		Age (day)							
		4-11[1]	14-21	0-21[1]	21-42	42-56	0-42[1]	0-49[1]	0-56[1]
Main effects									
T4	Control	1.61^{b}	1.67^{a}	1.64^{a}	2.23^{b}	2.99^{a}	2.05^{b}	2.21^{b}	2.34^{ab}
	0 ppm	1.96^{a}	1.63^{a}	1.64^{a}	2.17^{b}	2.87^{a}	2.02^{b}	2.16^{b}	2.29^{b}
	1 ppm	-	1.65^{a}	1.70^{a}	2.35^{a}	2.89^{a}	2.17^{a}	2.29^{a}	2.40^{a}
	2 ppm	-	1.65^{a}	1.68^{a}	2.35^{a}	2.84^{a}	2.16^{a}	2.28^{a}	2.38^{a}
	3 ppm	-	1.70^{a}	1.72^{a}	2.35^{a}	2.91^{a}	2.18^{a}	2.30^{a}	2.41^{a}
SE		-	0.03	0.03	0.03	0.07	0.02	0.02	0.02
Sex	Male	1.90^{a}	1.64^{a}	1.66^{a}	2.15^{b}	2.77^{b}	2.02^{b}	2.16^{b}	2.26^{b}
	Female	1.88^{a}	1.69^{a}	1.69^{a}	2.42^{a}	3.03^{a}	2.21^{a}	2.34^{a}	2.46^{a}
SE		0.06	0.02	0.02	0.02	0.04	0.01	0.02	0.02
Interactions									
Male	Control	1.63^{b}	1.58^{b}	1.61^{a}	2.10^{de}	2.89^{abc}	1.96^{d}	2.13^{c}	2.24^{b}
Male	0 ppm	1.97^{a}	1.61^{ab}	1.63^{a}	2.08^{e}	2.84^{abc}	1.96^{d}	2.12^{c}	2.24^{b}
Male	1 ppm	-	1.62^{ab}	1.68^{a}	2.18^{cde}	2.78^{bc}	2.05^{c}	2.19^{bc}	2.29^{b}
Male	2 ppm	-	1.67^{ab}	1.67^{a}	2.19^{cde}	2.60^{c}	2.05^{c}	2.16^{c}	2.24^{b}
Male	3 ppm	-	1.73^{ab}	1.73^{a}	2.21^{cd}	2.76^{bc}	2.09^{bc}	2.20^{bc}	2.30^{b}
Female	Control	1.59^{b}	1.77^{a}	1.68^{a}	2.35^{b}	3.09^{a}	2.14^{b}	2.30^{b}	2.43^{a}
Female	0 ppm	1.95^{a}	1.65^{ab}	1.64^{a}	2.25^{bc}	2.90^{abc}	2.08^{bc}	2.20^{bc}	2.30^{b}
Female	1 ppm	-	1.69^{ab}	1.73^{a}	2.51^{a}	3.00^{ab}	2.28^{a}	2.40^{a}	2.52^{a}
Female	2 ppm	-	1.64^{ab}	1.67^{a}	2.51^{a}	3.09^{a}	2.27^{a}	2.40^{a}	2.52^{a}
Female	3 ppm	-	1.69^{ab}	1.72^{a}	2.48^{a}	3.06^{ab}	2.26^{a}	2.40^{a}	2.51^{a}
SE		1.89	0.05	0.04	0.04	0.09	0.03	0.03	0.03

^{abc} Means within each column and main effects or interactions with different superscripts are significantly different (p<0.05), [1]Feed conversion ratio with the exclusion of rice hulls

Live body weight: Live body weight data is shown in Table 3. As expected LBW of birds in diet dilution treatment was significantly lower than C group at 11 day. LBW of male and female chicks in both main effects and interaction means were not significantly different (p>0.05) at this age. Dietary T4 decreased the LBW of T4 receiving birds even 14 day after 3 days T4 receiving. At this age LBW of R1, R2 and R3 groups was significantly (p<0.05) lower than R0 group. LBW during 3 days after T4 supplementing was decreased as the level of T4 was increased in both main effects and interaction means (Table 3). This trend was observed up to 21, 28, 35, 42, 49 and 56 days of age. But, however, R0 birds were completely compensated their retarded growth at 42 day and even their LBW was numerically more than C group up to 49 and 56 day. As shown in Table 3, ppm males were heavier than C males but not R0 females in compare to C females. This result showed that the male chicks were more successful than females to compensate their retarded growth. After 28 day the LBW of male chicks were significantly (p<0.05) more than females (Table 3).

Feed conversion ratio: The Feed Conversion Ratio (FCR) of C group was significantly better than of diet diluted birds during 4-11 day (with exclusion of rice hulls). At this period of the experiment male and female chicks had similar FCR. C male and C female chicks had also same FCR that their FCR was significantly better than both R0 male and R0 female groups (Table 4). FCR during 0-21 day was similar among all groups. As shown in Table 4 during 21-42 day the C and R0 groups had similar FCR that was significantly better than R1, R2 and R3 groups. During this period, male birds showed better FCR than female chicks and among interaction means male birds showed better FCR than female chicks too. However, during 42-56 day there was not significant Effects among main effects and male chicks showed better FCR than females.

When FCR calculated for 0-42, 0-49 and 0-56 day, T4 receiving birds showed significantly poorer FCR than C and/or R0 groups in both main effects and interactions. During these Experimental periods, male chicks showed better FCR than females.

Carcass characteristics: Carcass fat content of R0 fed birds was significantly (p<0.05) lower than that in control birds but carcass fat in all T4 treated birds was similar to control birds (Table 5). The carcass fat in male broiler chickens was significantly lower than (p<0.05) of females at 49 day. As shown in Table 5 among the interaction means, by increasing the level of dietary T4, the carcass fat was increased in both sexes. Abdominal Fat Pad (AFP) in R0 fed birds was significantly (p<0.05) lower than of control birds at 49 day. Abdominal fat pad weight of T4 treated birds was not significantly different as compared to control or R0 treated birds at this age. Surprisingly, at 49 day, AFP among interaction means in male chicks was decreased by dietary T4 but in female chicks was increased as the dietary T4 was increased

Table 5: The Effects of Thyroxine hormone after feed restriction on carcass composition (% of carcass weight)

Treat		Moisture 49 day	Ash[1] 49 day	CP[1] 49 day	Fat[1] 49 day	AFP 49 day	AFP 56 day	Breast 49 day	Breast 56 day
Main effects									
T4	Control	59.2	3.35^{a}	26.9	50.8^{a}	3.24^{a}	3.48	18.7^{a}	18.9^{a}
	0 ppm	56.7	3.45^{a}	27.1	39.4^{b}	2.57^{b}	2.73	18.4^{ab}	18.6^{a}
	1 ppm	56.6	3.62^{a}	28.8	49.1^{a}	2.73^{ab}	2.89	17.2^{bc}	19.0^{a}
	2 ppm	58.5	3.85^{a}	26.4	50.4^{a}	2.69^{ab}	3.07	17.1^{c}	19.0^{a}
	3 ppm	58.3	4.21^{a}	25.7	50.4^{a}	2.67^{ab}	2.67	16.7^{c}	19.0^{a}
SE		0.92	0.16	0.54	0.91	0.33	0.47	0.315	0.25
Sex	Male	57.7	3.46^{a}	27.1	45.9^{b}	2.74^{b}	2.89	18.2^{a}	18.4^{b}
	Female	58.0	3.93^{a}	26.9	50.2^{a}	2.95^{a}	3.04	17.8^{a}	19.3^{a}
SE		0.58	0.25	0.34	0.57	0.21	0.30	0.20	0.16
Interactions									
Male	Control	59.1	3.60^{abc}	26.3	42.5^{cd}	3.46^{a}	3.65	18.4^{ab}	18.2^{a}
Male	0 ppm	54.9	3.67^{abc}	28.1	39.5^{d}	2.71^{abcd}	2.42	18.0^{ab}	18.3^{a}
Male	1 ppm	55.0	3.34^{bc}	29.1	49.1^{bc}	2.47^{bcd}	2.66	17.0^{ab}	18.7^{a}
Male	2 ppm	60.2	2.61^{a}	27.2	50.5^{abc}	2.33^{cd}	3.09	17.1^{ab}	18.2^{a}
Male	3 ppm	59.4	4.10^{abc}	24.7	48.0^{bcd}	2.07^{d}	2.67	16.6^{b}	18.9^{a}
Female	Control	59.3	3.10^{bc}	27.6	59.2^{a}	3.01^{abc}	3.31	19.0^{a}	19.6^{a}
Female	0 ppm	58.7	3.24^{bc}	26.1	39.3^{d}	2.42^{bcd}	3.03	18.8^{a}	18.8^{a}
Female	1 ppm	58.3	3.90^{abc}	28.4	49.1^{bc}	2.99^{abc}	3.13	17.4^{ab}	19.3^{a}
Female	2 ppm	56.8	5.09^{a}	26.2	50.3^{abc}	3.04^{abc}	3.06	17.1^{ab}	19.8^{a}
Female	3 ppm	57.1	4.32^{ab}	26.6	52.9^{ab}	3.28^{ab}	2.68	16.8^{b}	19.1^{a}
SE		1.3	0.56	0.77	1.28	0.47	0.67	0.47	0.36

^{abcd} Means within each column and main effects or interactions with different superscripts are significantly different ($p<0.05$), [1]On air dry basis

Table 6: Effects of Thyroxine hormone after feed restriction on carcass characteristics at 49 and 56 days of age

Treat		Wings 49 day	Wings 56 day	Tights 49 day	Tights 56 day	Carcass[1] 49 day	Carcass 56 day	Liver 49 day	Liver 56 day
Main effects									
T4	Control	8.3	8.1^{b}	21.5^{ab}	22.2^{b}	63.3	64.7^{b}	2.69^{a}	2.37^{a}
	0 ppm	8.4	8.6^{a}	21.6^{ab}	22.8^{ab}	63.5	65.0^{ab}	2.41^{a}	2.33^{a}
	1 ppm	8.3	8.6^{a}	21.3^{b}	23.2^{a}	61.9	65.8^{ab}	2.73^{a}	2.18^{a}
	2 ppm	8.6	8.7^{a}	22.3^{ab}	23.2^{a}	62.9	64.2^{ab}	2.64^{a}	2.14^{a}
	3 ppm	8.2	8.8^{a}	22.9^{a}	23.4^{a}	62.3	66.6^{a}	2.71^{a}	2.16^{a}
SE		0.14	0.14	0.33	0.18	0.31	0.35	0.25	0.20
Sex	Male	8.3	8.7^{a}	21.7^{a}	23.7^{a}	63.6	65.9^{a}	2.48^{b}	2.24^{a}
	Female	8.4	8.4^{b}	21.6^{a}	22.2^{b}	62.7	65.4^{a}	2.77^{a}	2.22^{a}
SE		0.09	0.09	0.21	0.11	0.20	0.22	0.16	0.13
Interactions									
Male	Control	8.2	8.7^{a}	21.9^{ab}	23.6^{ab}	63.6	65.5^{ab}	2.51^{ab}	2.41^{ab}
Male	0 ppm	8.2	8.6^{a}	22.0^{ab}	23.5^{abc}	63.4	64.6^{ab}	2.28^{b}	2.14^{ab}
Male	1 ppm	8.2	8.6^{a}	20.4^{b}	23.8^{a}	61.7	65.9^{ab}	2.41^{ab}	2.33^{ab}
Male	2 ppm	8.6	8.8^{a}	23.0^{a}	23.9^{a}	63.6	66.2^{ab}	2.67^{ab}	2.19^{ab}
Male	3 ppm	8.4	9.0^{a}	23.3^{a}	23.7^{ab}	62.1	67.1^{a}	2.68^{ab}	2.14^{ab}
Female	Control	8.4	7.6^{b}	21.1^{ab}	20.8^{e}	63.2	63.8^{b}	2.88^{ab}	2.34^{ab}
Female	0 ppm	8.6	8.6^{a}	21.2^{ab}	22.0^{d}	63.5	65.0^{ab}	2.53^{ab}	2.52^{a}
Female	1 ppm	8.4	8.5^{a}	21.6^{ab}	22.6^{bcd}	62.1	65.8^{ab}	3.06^{a}	2.02^{b}
Female	2 ppm	8.6	8.6^{a}	21.6^{ab}	22.5^{cd}	62.2	66.2^{ab}	2.61^{ab}	2.10^{ab}
Female	3 ppm	8.0	8.7^{a}	22.5^{ab}	23.0^{abcd}	62.4	66.1^{ab}	2.75^{ab}	2.09^{ab}
SE		0.20	0.20	0.46	0.25	0.44	0.50	0.35	0.28

[1]Carcass is without head, neck, feet and gut. ^{ab} Means within each column and main effects or interactions with different superscripts are significantly different ($p<0.05$)

(Table 5) although, the differences was not significant ($p>0.05$). However, all birds had a similar abdominal fat percentage at 56 day ($p>0.05$).

Among the main effects of the treatments on body composition (Table 5), only carcass fat content and AFP of restricted birds was significantly ($p<0.05$) lower than of control birds ($p<0.05$). Also, carcass fat content and AFP of male chicks was significantly lower than of female chicks ($p<0.05$). Breast yield of T4 treated birds was significantly lower than control at 49 day but not at 56 day of age. The breast fillet was significantly more in males than females at 56 but not at 49 day. Wings weight was not significantly different at 49 day but it was significantly ($p<0.05$) lower in control birds than R0 and T4 treated birds at 56 day. Thighs weight at day 56 was increased in T4 treated birds as compared to Control birds, whereas R0 fed birds showed similar thighs weight in compare to both C and T4 treated birds. The carcass yield was not significantly different ($p>0.05$) among control, R0 and T4 treated birds at 49 day. Dietary T4 significantly

Table 7: The Effects of feed restriction and sex on serum T4 concentration (μg/100ml) of broiler chickens fed diets containing 0, 1, 2 and 3 ppm T4 from 11 to 28 day of age

		Age (day)			
Treatments		4	11	28	49
Main effects					
T4	Control	-	2.30^{a}	2.74^{c}	2.33^{a}
	0 ppm	-	1.77^{a}	2.01^{c}	2.81^{a}
	1 ppm	-	-	10.8^{b}	253^{a}
	2 ppm	-	-	13.9^{ab}	1.97^{a}
	3 ppm	-	-	20.0^{a}	1.93^{a}
SE		-	0.21	2.02	0.39
Sex	Male	1.95^{a}	2.24^{a}	9.33^{a}	2.14^{a}
	Female	2.18^{a}	1.74^{a}	10.4^{a}	2.49^{a}
SE		2.07	0.21	1.28	0.25
Interactions					
Male	Control	-	2.52^{a}	-	-
Male	0 ppm	-	1.87^{a}	-	-
Female	Control	-	1.86^{a}	-	-
Female	0 ppm	-	1.67^{a}	-	-
SE		-	0.30	-	-

[abc]Means within each column and main effects or interactions with different superscripts are significantly different ($p<0.05$)

($p<0.05$) increased yield cost, whereas the R0 birds showed a markedly improved yield cost as compared to control group. Furthermore the feed cost per kg of LBW for male chicks was significantly ($p<0.05$) lower than of female chicks.

Serum thyroxine: Mean serum Thyroxine concentration in chickens is shown in Table 7. The serum Thyroxine concentration was not significantly ($p>0.05$) different between the sexes at day 4.

Serum Thyroxine concentration at day 11 in R0 fed birds was numerically lower than control ones and there was not significant Effects between sexes and interaction means. Serum Thyroxine concentration of C and R0 was not insignificantly different ($p>0.05$) at day 28 and it was increased significantly as the level of dietary T4 was increased, furthermore there was not significant difference between sexes at this age. At day 49 all groups had similar serum Thyroxine concentration (Table 7).

DISCUSSION

The objectives of the present study was to evaluate the potential of mild feed restriction and the use of dietary administration of T4 as a means of attaining compensatory growth, improving feed conversion while decreasing abdominal fat content in broiler chickens. Feed restriction and dietary T4 clearly affected performance, carcass characteristics and serum Thyroxine concentration (Table 2-7).

Birds attempted to maintain nutrient intake by consuming more feed during the period of diet dilution (Table 2). Although, birds increased their total feed intake when fed a diluted diet, they were not able to maintain normal energy intake. It should be noted the restricted birds encountering with diluted diet at the present study were losing the unfavorable diet from feeders and this was the responsible for poorer FCR for R0 birds than C birds during 4-11 day. We did not any attempt to correct the feed intake for the lost feed during the diet dilution period. If ground rice hulls is excluded from the calculation of feed intake (assumed indigestible) the feed intake of birds in restricted groups was about 82% of control birds. Osbourn and Wilson (1960) concluded that increased appetite following re-feeding is largely responsible for any improve in growth and feed conversion ratio which are associated with compensatory growth. In the present study, there was not an increase in feed intake immediately following under-nutrition. Mean daily feed intake (Table 2) was not significantly ($p>0.05$) affected by feed restriction even up to 42, 49 and 56 days of age ($p>0.05$). As seen in Table 4 the nonsignificantly improvement FCR in R0 fed birds was probably responsible for compensatory growth in the present study. Similar results have been reported by Deaton (1995) and Cristofori *et al.* (1997). The energy to support accelerated growth may come from a reduction in the overall maintenance energy needs (Yu and Robinson, 1992) and/or from a decrease in the basal metabolic rate as observed in feed-restricted birds (Zubair and Leeson, 1994). Cristofori *et al.* (1997) restricted the feed of broilers from 7-21, 7-28 or 21-35 day and showed that restricted birds did not compensate in final body weight. This is in contrast to the results obtained in current experiment where complete compensatory growth was attained by feed-restricted birds. These differences may have occurred due to the more severe degree of feed restriction applied by Cristofori *et al.* (1997) due to they allowed 1.5 Mcal ME/BW$^{.75}$/d. This indicates that the severity of feed restriction is as important as the duration of restriction for growth compensation in broilers.

Feed restriction from 4-11 day of age reduced weight gain (to 17.6% of that in the C broilers) during the restriction period. Such a reduction in body weight is in accord with results from Khantaprab *et al.* (1997), Roth *et al.* (1993) and Santoso *et al.* (1993a). Following the restriction period, compensatory growth was observed in the R0 birds. It seems that the severity of the feed restriction and restriction period allowed full growth compensation up to the marketing age, as was previously reported (Plavnik and Hurwitz, 1985; Plavnik and Hurwitz, 1988; Yu and Robinson, 1992; Plavnik *et al.*, 1986; Lee and Leeson, 2001). The present findings showed that better FCR in R0 birds than in C broilers coincided with greater weight gain over the whole production period. This finding is in agreement with those of previous studies, which reported improvements in overall feed conversion ratio as the most consistent result of early feed restriction studies (Plavnik and Hurwitz, 1985; Plavnik and Hurwitz, 1988; Plavnik and Hurwitz, 1991; Plavnik *et al.*, 1986; Lee and Leeson, 2001). In the present study the R0 birds were smaller by the age of 35 day probably they had used a lesser proportion of energy for maintenance than for growth. LBW of R0 birds was completely compensated on day 42 of age, corroborating previously reported results (Lesson *et al.*, 1991; Plavnik and Hurwitz, 1985; Zubair and Leeson, 1996). The LBW of birds fed R0 diet was numerically higher than C fed group this is in agreement with the results of Lee and Leeson (2001). However, other report by Pinchasov and Jensen (1989) did not revealed a significant compensatory growth for restricted birds. Although the difference between R0 and C fed birds was not significantly different from 28 day till end of experimental period. Compensatory growth has been achieved by broilers following short periods of undernutrition (Santoso *et al.*, 1993b; Deaton, 1995). Other workers, however, have failed to attain growth compensation in feed-restricted broilers from 4-7 or 7-14 days (Fontana *et al.*, 1992; Palo *et al.*, 1995a, b). The average LBW of male and female chicks were similar at 21 day whereas the males were significantly ($p<0.05$) heavier than females at 28 day or later ages (Table 3). In the present study performance characteristics of male chicks were significantly better than females that is in agreement of previous findings (Plavnik and Hurwitz, 1988).

Another response noted with broilers undergoing a period of feed restriction is reduced carcass fat at 42-56 days (Plavnik and Hurwitz, 1985). Plavnik and Hurwitz (1985) cited substantial reductions in the size of the abdominal fat pad of broilers that was not influenced by nutrition during refeeding. In the present study (Table 5) abdominal fat percent of restricted birds at 49 but not at 56 day of age was significantly ($p<0.05$) lower than of control birds. Early diet dilution may reduce adipocyte hyperplasia. Cherry *et al.* (1984) concluded that although hyperplasia proceeds during periods of nutrient restriction, the adipocytes remain smaller. Similarly Rosebrough *et al.* (1986) observed reductions in both liver size and lipogenesis in 12 day-old birds subjected to feed restriction from 6-12 days.

Feed intake was reduced by dietary T4 during 14-21 days of age ($p < 0.01$) when T4 was supplemented to the experimental diets from 11-28 day. The R0 fed birds had the highest feed intake among all groups and the feed intake of T4 treated birds was numerically lower than C or R0 treated birds. The FCR of C and R0 fed birds was similar ($p>0.05$) during 1-42 or 49 and/or 56 days of age, but this was significantly ($p<0.05$) better than T4 treated birds (Table 4). The FCR of R0 fed birds numerically improved as compared to C fed birds during the periods of 0-42, 0-49 and 0-56 days of age (Table 4). The FCR of R0 treated birds was significantly better ($p<0.05$) than T4 treated birds indicating the adverse effect of T4 administration on birds metabolism during all experimental periods or may the supplemented T4 level is more than birds' requirement and has been converted to T3 and caused toxic effects (May, 1980). Feed conversion ratio in the R0 and C treated birds was similar and all T4 treated birds exhibited a poorer feed conversion ratio during 1 to 42 or 49 day of experiment, but the FCR was only better in R0 treated birds than other treatments during the whole experimental period. With the exclusion of ground rice hulls from the calculation of feed intake the feed conversion ratio of R0 and control fed birds was significantly better than T4 treated birds up to 42, 49 and 56 days of age. Feed restriction during 4-11 day of age has improved feed conversion ratio of birds to the market age which is in agreement with the findings of Lee and Lesson (2001).

May (1980) reported that 1ppm or 0.1ppm dietary T4 did not significantly affect 0-28 day weight gain or feed efficiency. In another trail he showed that dietary T4 at 0.1 ppm resulted in poorer weight gain, but this observation was not consistent with his previous trail. In another trail he applied dietary T4 at 0.25 and 1 ppm, these levels of T4 did not significantly affect the 0-28 or 28-42 day body weight gain or feed efficiency but some of 14 day data suggested improved performance for low levels of T4 for 0-14 day period but results were variable. Low levels of T4 were used to further investigate (T4 at 0.05 or 0.25 ppm for 0-21 days). The dietary T4 at these levels did not affect performance too. Results of May (1980) showed differences in the response of chickens to T4. In the present study dietary T4 had a significant adverse effect on broilers performance and the results negatively were amplified as the level of dietary T4 was increased. It seems T4 at all used levels in the present study were toxic for the broilers. Plasma concentrations of T4 decreased during feed restriction at the present study, different from reports of no change in chickens during feed deprivation (Brake *et al.*, 1979). The rise at refeeding mimicked observations described in chickens by Brake *et al.* (1979). The declines for T4 receiving birds seen in the current study could also represent excess or potentially toxic accumulation of T3 because T4 converts to T3 (May, 1980).

Serum Thyroxine concentration at day 11 in R0 fed birds was numerically lower than control ones and its concentration was insignificantly lower than control group at day 28 indicating that under-nutrition may depress Thyroxine hormone secretion from thyroid glands. The serum Thyroxine was increased by feed restriction at day 11 (Table 7), but during re-feeding period (49 day) its level reached to the level in control birds which is in agreement with the results of Lauterio and Scanes (1987) and Mcmurtry *et al.* (1988). May (1980) full fed Broiler chickens with corn-soybean meal diets supplemented with either 3,5,3'-triiodothyronine (T3) or Thyroxine (T4). Chickens fed 1ppm of T3 had poorer weight gain and feed conversion ratio than controls, but feeding T4 at that same dosage did not adversely affect performance. Feeding diet containing 1ppm T3 or T4 resulted in respective serum T3 and T4 concentrations approximately three times than that of control birds. In the present study, the T4 administration at the level of 1, 2 and 3ppm after feed restriction significantly increased ($p<0.05$) the serum Thyroxine concentration approximately 5, 7 and 10 times than that of control birds, respectively at day 28 that is in agreement with findings of May, 1980. Liver weight was not significant among main effects at day 49 and 56. Liver weight of female chicks was significantly heavier than male birds at 49 day but not at 56 day.

CONCLUSION

With a period of moderate feed restriction in early of life, live body weight of birds was compensated at 42 day of age and at 56 day of age was numerically higher than control birds (2.5%). The T4 treated birds had a poorer body weight and other growth performances in overall period of experiment. Early life feed restriction caused a significant decrease in fat content of carcass and abdominal fat pad size. Male broiler chickens performance was better than females. Serum Thyroxine level was decreased by feed restriction but reached to normal level during compensatory growth period.

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