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*Full Length Research Paper*

# Effects of transient hypo- and hyper-thyroidism on growth performance, organ weights and serum levels of thyroid hormones in broiler chickens

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**In order to investigate the effects of transient hypo- and hyperthyroidism on growth performance, organ weights and serum thyroid hormones of broilers, 120 one-day-old broiler chicks were randomly divided into four dietary treatments for six weeks. The dietary treatments included: 1) control, 2) hypothyroid (hypo; propylthiouracil (PTU)-treated), 3) hyperthyroid (HYPER; thyroxine ($T_4$)-treated) and 4) hypo-hyper ((PTU-$T_4$)-treated) groups. PTU and $T_4$ were administered between the ages of 14 to 28 days. Furthermore, a group of PTU treated birds were restored by administering $T_4$ between 28 and 35 days of age to form the hypo-hyper group. In the whole experiment, body weight gain and feed intake were significantly ($P < 0.01$) decreased by dietary inclusion of PTU and $T_4$ when compared with control birds. Induction of hyperthyroidism significantly impaired feed conversion ratio when compared with other groups ($P < 0.01$). The relative weight of liver was significantly greater for hypo and hyper when compared with control and hypo-hyper groups ($P < 0.01$). Induction of hyperthyroidism resulted in decreased abdominal fat when compared with other treatments ($P < 0.01$). Serum levels of $T_3$ and $T_4$ were significantly influenced by hypo- and hyper-thyroidism in 28, 35 and 42 days of age ($P < 0.01$). In conclusion, although serum levels of thyroid hormones were affected by dietary treatments, manipulation of thyroid status could not improve growth performance.**

**Key words:** Hypothyroidism, hyperthyroidism, performance, organ weight, thyroid hormones.

## INTRODUCTION

Many studies have been conducted in order to enhance quality and quantity of animals' product but few studies have been carried out on the importance of growth and metabolism control via endocrine glands in poultry than in mammals. In poultry and mammals, growth is dependent upon direct effects of thyroxine ($T_4$) and its active form, triiodothyronine ($T_3$) and also interactive effects between thyroid hormones and GH–IGF-I axis (Etherton et al., 1987). Thyroid hormones can influence specific mechanisms of body like metabolism of carbohydrates and lipids. These hormones can also increase basal metabolism, rate of respiration, motility of gastrointestinal tract and requirements for vitamins.

Decrease of body weight has excitatory effects on functions of central nervous system, muscles and other glands, which are some functional aspects of thyroid hormones. Hypothyroidism affects most avian body systems and cause abnormalities in metabolism of protein, lipids, carbohydrates and electrolytes. Furthermore, hyperthyroidism results in increased basal metabolism, urination and irritability, reduction in body weight, less resistance against heat and arrhythmias (Guyton and Hall, 2006).

Many studies have investigated the effects of hypo-

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and hyper-thyroid status in mammals and poultry. Howarth and Marks (1973) reported that using goitrogen propylthiouracil (PTU) (2 g/kg of feed) reduced growth rate in Japanese quails. They also concluded that reduction of growth rate could be recovered by injection of thyroid hormone. Prescription of low levels of thyroid hormone to intact animals could exert a slight stimulatory effect on growth (Ringer, 1976). Rosebrough et al. (2009) studied the effects of short term $T_3$ administration in hypothyroid broilers (induced by methimazole). They indicated that feeding methimazole decreased growth rate and increased obesity of the chickens. They also suggested that $T_3$ can reduce some deleterious results when birds are switched to a low protein grower diet from a starter diet. These researchers concluded that short term induction of hyperthyroidism in hypothyroid broilers by $T_3$, has beneficial impacts if they could overcome growth delaying effects of $T_3$. Wang et al. (2007) investigated changes of hepatic gene expression in young chickens in which their thyroid status was manipulated or were injected with growth hormone. Result of their study showed that administration of exogenous growth hormone could not solely reduce accumulation of abdominal fat, while supplementation of $T_3$ alongside the growth hormone but exerted a synergistic effect in reduction of abdominal fat.

Since the effects of transient hypo- and hyper-thyroid status on growth performance and serum thyroid hormones of broilers are still unclear and less evaluated, the aim of the present study was to investigate the effects of transient hypo- and hyper-thyroidism on growth performance, feed conversion ratio, inner organ weights and serum levels of $T_3$ and $T_4$ in broiler chickens.

## MATERIALS AND METHODS

Medications used in this study included sodium levothyroxine and 6-N-propyl-2-thiouracil (PTU), and were purchased from Iran Hormone Pharmaceutical Co. (Tehran, Iran). All other chemicals were of analytical grade or purer.

### Birds, diets and treatments

A total of 120 one-day-old Ross 308 male broiler chicks with an average initial body weight of 45.04 g were obtained from a commercial hatchery and used in a 42 days experiment. The birds were randomly allotted to 1 of 4 dietary treatments with three replicates of 10 chicks each. The average body weight of each group was similar. All birds were raised on identical floor pens (1 × 1.2 m) with concrete floors covered with wood shavings as litter. Pens were placed in an environmentally controlled house with continuous light. The temperature was maintained at 33°C for the first three days, after which the temperature was gradually reduced by 3°C per week until it reached 24°C for the rest of the experiment. Experimental birds were allowed access to feed and fresh water *ad libitum*.

Two basal corn-soybean meal diets for starter (one to 21 days) and grower (22 to 42 days) were formulated (Table 1). The diets were formulated to meet or exceed the NRC (1994) requirements for broilers. Experimental treatments were as follows: 1) control, 2) hypothyroid (hypo), 3) hyperthyroid (HYPER) and 4) hypo-hyper group. PTU and sodium levothyroxine ($T_4$) were used to induce hypo- and hyper-thyroidism, respectively. All birds received the same basal diets throughout the experiment. PTU and $T_4$ were administered at a level of 100 and 1 mg/L of drinking water for hypo and hyper groups, respectively (starting at days 14 to 28). Hypo-hyper group received PTU from days 14 to 28 (same as hypo group and with the same dosage) and was then restored by the administration of $T_4$ (1 mg/L of drinking water) from 28 to 35 days of age. Control group and all other treatments after the end of their medication period, received normal drinking water.

### Growth performance parameters

Chickens of each pen were weighed on a weekly basis, to determine average body weight gain. Feed intake of each pen was also recorded weekly, and feed conversion ratio was calculated subsequently. In addition, overall body weight gain, feed intake and feed conversion ratio were calculated for the whole duration of the experiment. Mortality was recorded daily.

### Organ weights

At the end of the experiment, six birds from each group (two per replicate) were randomly selected and killed by cervical dislocation. The gizzard, heart, liver, pancreas, spleen and bursa were excised and weighed. In addition, abdominal fat was removed and weighed individually. Relative weights of the mentioned organs and abdominal fat (calculated as % of carcass weight with giblets) were recorded.

### Serum levels of thyroid hormones

At 28, 35 and 42 days of age, nine chickens from each group (three per replicate) were randomly selected and 2.5 ml of blood samples were taken from the brachial vein into sterile syringes, following a 12-h feed withdrawal. Blood samples were then centrifuged at 10000 ×g for 10 min to obtain serum. The serum samples were stored at -20°C until needed for analysis. Afterwards, serum levels of $T_3$ and $T_4$ were determined by electrochemiluminescent immunoassays (ECLIA) (Sánchez-Carbayo et al., 1999) using commercial kits (LIAISON, DiaSorin Co., Ltd., Saluggia, Italy).

### Statistical analysis

Data were analyzed using the one-way ANOVA model in SPSS software (2009), and mean comparisons were made using Duncan's (1955) multiple-range test.

## RESULTS

### Growth performance

Since induction of hypo- and hyper-thyroid status started at 14 days of age, no significant differences were observed in associated parameters of growth performance, in first two weeks of the experiment. Induction of hyperthyroidism significantly decreased body weight gain in weeks three, four and six of age when compared with the three other treatments ( ($P < 0.01$) Table 2). In the

**Table 1.** Composition and nutrient levels of basal diets.

| Item | Starter (1 to 21 days) | Grower (22 to 42 days) |
|---|---|---|
| **Ingredient (%)** | | |
| Corn | 56.36 | 60.00 |
| Soybean meal | 36.00 | 32.00 |
| Soy oil | 3.00 | 3.26 |
| Limestone | 1.30 | 1.30 |
| Dicalcium phosphate | 1.80 | 1.90 |
| NaCl | 0.30 | 0.30 |
| DL-Methionine | 0.10 | 0.10 |
| Choline chloride | 0.14 | 0.14 |
| Vitamin-mineral premix[1] | 1.00 | 1.00 |
| | | |
| **Calculated nutrient content[2]** | | |
| ME (kcal/kg) | 2990 | 3010 |
| CP (%) | 20.94 | 19.80 |
| Crude Fat (%) | 5.43 | 5.79 |
| Lysine (%) | 1.20 | 1.05 |
| Methionine (%) | 0.54 | 0.47 |
| Cysteine (%) | 0.36 | 0.28 |
| Calcium (%) | 1.05 | 1.00 |
| Available phosphorus (%) | 0.51 | 0.45 |

[1]Supplied per kilogram of diet: Cu, 10 mg; Fe, 90 mg; Mn, 90 mg; Zn, 50 mg; Se, 0.2 mg; I, 0.4 mg; Co, 0.4 mg; vitamin A, 5,000 IU; cholecalciferol, 500 IU; vitamin E, 10 IU; riboflavin, 6.0 mg; pantothenic acid, 12 mg; niacin, 35 mg; cobalamin, 10 µg; biotin, 0.8 mg; folic acid, 0.8 mg; thiamine, 1.5 mg; and pyridoxine, 1.5 mg. [2]Based on NRC (1994) feed composition tables.

**Table 2.** Effect of dietary treatments on body weight gain of broilers (g/chick).

| Treatment | Age (week) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 0-6 |
| Control | 169 | 260 | 494[a] | 573[a] | 631[a] | 645[a] | 2772[a] |
| Hypo | 169 | 254 | 493[a] | 553[a] | 573[a] | 622[a] | 2664[b] |
| Hyper | 167 | 258 | 433[b] | 483[b] | 619[a] | 429[b] | 2390[c] |
| Hypo-hyper | 172 | 252 | 486[a] | 547[a] | 491[b] | 656[a] | 2604[b] |
| SEM | 1.863 | 3.575 | 4.059 | 9.555 | 19.956 | 27.053 | 23.674 |
| *P* value | 0.413 | 0.411 | 0.0001 | 0.001 | 0.004 | 0.001 | 0.0001 |

[a-c] Means on the same column with different superscripts are significantly different (P < 0.05).

fifth week of the experiment, hypo-hyper group had significantly lower body weight gain than control, hypo and hyper groups (P < 0.01). In the whole experiment, dietary inclusion of $T_4$ in hyper group resulted in a significant decrease in body weight gain when com-pared with other groups (P < 0.01).

Effect of dietary treatments on average feed intake of broiler chickens is shown in Table 3. Significant diffe-rences in feed intake were noted among treatments during the last four weeks (P < 0.01). Although in weeks three and four, hyper group had significantly lower feed intake when compared with the control, hypo and hypo-hyper groups (P < 0.05), was somewhat reversed in week five, whereas feed intake was significantly decreased in hypo-hyper group in comparison with the other groups (P < 0.01). In the last week of the experiment, HYPER group had significantly lower feed intake than other groups (P < 0.01). Furthermore, in the whole duration of the experi-ment, control birds had the highest amounts of feed intake among dietary treatments, while hypo-hyper group had significantly lower feed intake when compared with the three other groups (P < 0.01).

**Table 3.** Effect of dietary treatments on feed intake of broilers (g/chick).

| Treatment | Age (week) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 0-6 |
| Control | 127 | 374 | 709.6[a] | 980[a] | 1273[a] | 1351[a] | 4816[a] |
| Hypo | 127 | 373.7 | 716[a] | 984[a] | 1123[b] | 1318[ab] | 4642[b] |
| Hyper | 127 | 374 | 665.3[b] | 904[b] | 1266[a] | 1247[c] | 4584[b] |
| Hypo-hyper | 129.3 | 375.3 | 704.3[a] | 968[a] | 989[c] | 1308[b] | 4474[c] |
| SEM | 1.333 | 0.745 | 4.233 | 12.037 | 13.550 | 12.560 | 23.988 |
| *P* value | 0.545 | 0.448 | 0.0001 | 0.005 | 0.0001 | 0.002 | 0.0001 |

[a-c] Means on the same column with different superscripts are significantly different (P < 0.05).

**Table 4.** Effect of dietary treatments on feed conversion ratio of broilers (g/g).

| Treatment | Age (week) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 0-6 |
| Control | 0.753 | 1.439 | 1.437[b] | 1.711[b] | 2.027 | 2.106[b] | 1.738[b] |
| Hypo | 0.751 | 1.471 | 1.454[b] | 1.779[b] | 1.962 | 2.126[b] | 1.743[b] |
| Hyper | 0.761 | 1.449 | 1.535[a] | 1.874[a] | 2.046 | 2.920[a] | 1.918[a] |
| Hypo-hyper | 0.754 | 1.489 | 1.450[b] | 1.769[b] | 2.014 | 1.966[b] | 1.718[b] |
| SEM | 0.008 | 0.018 | 0.008 | 0.028 | 0.060 | 0.093 | 0.013 |
| *P* value | 0.848 | 0.286 | 0.0001 | 0.021 | 0.778 | 0.0001 | 0.0001 |

[a-b] Means on the same column with different superscripts are significantly different (P < 0.05).

**Table 5.** Effects of dietary treatment on relative organ weights of broiler.

| Treatment | Organ weights (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Bursa | Liver | Gizzard | Heart | Spleen | Pancreas | Abdominal fat |
| Control | 0.110 | 2.005[b] | 0.715 | 0.440 | 0.083 | 0.158 | 2.713[b] |
| HYPO | 0.107 | 2.748[a] | 0.753 | 0.411 | 0.103 | 0.132 | 3.419[a] |
| HYPER | 0.120 | 2.566[a] | 0.813 | 0.460 | 0.092 | 0.170 | 2.107[c] |
| HYPO-HYPER | 0.115 | 2.041[b] | 0.729 | 0.465 | 0.120 | 0.154 | 2.858[b] |
| SEM | 0.017 | 0.095 | 0.055 | 0.020 | 0.015 | 0.014 | 0.133 |
| *P* value | 0.947 | 0.001 | 0.625 | 0.272 | 0.381 | 0.361 | 0.001 |

[a-c] Means on the same column with different superscripts are significantly different (P < 0.05).

As shown in Table 4, with the exception of fifth week of the experiment in which feed conversion ratio was not significantly affected by the treatments, supplementation of broilers with $T_4$ in hyperthyroid group resulted in a significant increased feed conversion ratio when compared with the control, hypo and hypo-hyper groups in weeks three, four and six of age and also in the course of the whole experiment (P < 0.01).

## Organ weights

Table 5 shows the effect of hypo- and hyper-thyroidism on weights of inner organs. Apart from relative weights of liver and abdominal fat, those of bursa, gizzard, heart, spleen and pancreas remained unaffected by dietary induction of hypo- or hyper-thyroidism. The relative weight of liver was significantly greater for hypo and hyper when compared with control and hypo-hyper groups (P < 0.01). Moreover, hypo- and hyper-thyroidism had the highest and lowest amounts of abdominal fat, respectively. In this respect, feeding $T_4$ between 14 to 28 days of age resulted in broilers with decreased abdominal fat as compared to other treatments (P < 0.01).

## Serum levels of thyroid hormones

Serum levels of $T_3$ and $T_4$ at 28, 35 and 42 days of age are presented in Table 6. There were significant differences among the treatments,regarding serum levels of thyroid hormones (P < 0.01). In particular, induction

**Table 6.** Effects of dietary treatments on serum levels of thyroid hormones in broilers.

| Treatment | $T_3$ (ng/ml) | | | $T_4$ (ng/ml) | | |
|---|---|---|---|---|---|---|
| | Weeks of sampling | | | Weeks of sampling | | |
| | 4 | 5 | 6 | 4 | 5 | 6 |
| Control | 1.419[b] | 0.977[b] | 0.853[bc] | 31.7[b] | 35[b] | 34.0[a] |
| HYPO | 0.585[c] | 0.597[c] | 0.681[c] | 14[c] | 34.7[b] | 32.4[a] |
| HYPER | 2.190[a] | 1.583[a] | 1.437[a] | 369.3[a] | 16.7[b] | 31.7[a] |
| HYPO-HYPER | 0.670[c] | 0.958[b] | 0.940[b] | 15[c] | 120.7[a] | 13.3[b] |
| SEM | 0.069 | 0.055 | 0.059 | 4.356 | 7.821 | 2.121 |
| *P* value | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |

[a-c] Means on the same column with different superscripts are significantly different ($P < 0.05$).

of hyperthyroidism in broiler chickens, significantly increased serum levels of $T_3$ when compared with other groups at 28, 35 and 42 days of age, while hypothyroid status, resulted in a significant decrease in serum $T_3$ levels in the same periods of sampling ($P < 0.01$). As shown in Table 6, inclusion of $T_4$ in drinking water of experimental birds from 14 to 28 days of age, significantly increased serum levels of $T_4$ at 28 days of age when compared with control, hypo and hypo-hyper groups ($P < 0.01$). At 35 days, serum levels of $T_4$ were significantly higher in hypo-hyper group than other groups ($P < 0.01$). Results of the serum analysis for $T_4$ at 35 days were completely reversed in 42 days where hypo-hyper group had significantly lower levels of $T_4$ in their serum when compared with three other groups ($P < 0.01$).

## DISCUSSION

Rosebrough et al. (2007) studied the effects of hypo- and hyper-thyroidism on broiler chickens and in agreement with this study, indicated that control group showed better performance with regards to body weight gain and feed intake. Results of the present study show that induction of hyperthyroid status through administration of $T_4$ (1 mg/L of drinking water), significantly decreased body weight gain in the course of the whole experiment when compared with the control group. In this respect, May (1980) reported that supplementation of broilers with 1 mg/kg $T_3$ and $T_4$ resulted in decreased body weight gain and feed conversion efficiency. Results of the present study are in agreement with those of Leung et al. (1985) who reported that induction of hypothyroidism by using PTU decreased body weight gain as compared to the control group. Inconsistent with this study, Rosebrough and McMurtry, (2003) demonstrated that feeding $T_3$ to broilers which had previously received methimazole (recovery from hypo- to hyperthyroidism), had improved growth performance when compared with control and hypothyroid groups. In the present study, body weight gain in both hypo- and hyper-thyroid birds decreased in comparison with the control group. Similarly, Liu et al. (2007) reported that body weight gain, decreased in either hypo- or hyper-thyroid rats.

It has been shown that there is a negative correlation between levels of thyroid hormones and body fats in broilers (Stewart and Washburn, 1983) and pigs (Yen and Pond, 1985). Results obtained for abdominal fat and serum levels of $T_3$ in this study, are in agreement with those of Stewart and Washburn (1983), considering that abdominal fat is typically a good indicator of overall body fat in broilers. In particular, this negative correlation can be seen with respect to the amounts of abdominal fat and serum levels of $T_3$ in hypo and hyper groups. These researchers also suggested that hypothyroidism (induced by PTU) resulted in hepatic glycogen and triglyceride storage syndrome. Decuypere et al. (1987) observed that hypothyroidism (induced by methimazole) increased adiposity, while long term induction of hyperthyroidism (using $T_3$ or $T_4$) led to decreased weight gain and relative weights of abdominal fat, in broilers. They concluded that hormonal changes might be associated with the observed changes in growth and adiposity of broiler chickens and could also indicate negative correlation between $T_3$ and body fats. Wilson et al. (1983) reported that protamon as a hyperthyroidism inducer, reduced abdominal fat as well as feed conversion but did not exert any effect on slaughter weight in broiler chickens. In this study, the increase of abdominal fat in hypothyroid chickens (induced via PTU) was consistent with the results of Leung et al. (1985). It has been shown that exogenous growth hormone could not solely reduce accumulation of abdominal fat in young chickens, while supplementation of $T_3$ alongside the growth hormone, exerted a synergistic effect in reduction of abdominal fat (Wang et al., 2007). Similar to this experiment, Rosebroug et al. (2007) found that relative weight of liver in chickens which were subjected to methimazole (as a hypothyroidism inducer) from 14 to 28 days of age was significantly higher than that of control birds. Shibata et al. (2003) reported higher relative weight of liver in thyroidectomized chickens at 20 and 50 days of age. In this study, although relative weight of liver was significantly higher in hyperthyroid birds than the control ($P < 0.01$), no morphological changes were observed in this respect. Lack of morphological changes can be due to increased metabolism, higher blood flow and more activity of liver in hyperthyroid status. On the other hand, higher relative weight of liver in hypo group was concomitant with liver hypertrophy as a result of glycogen and lipid accumulation. Raheja et al. (1980) reported that induction of hypothyroidism by administration of PTU led to fatty liver syndrome in chickens. They also suggested that accumulation of glycogen in the liver of hypothyroid birds is mostly due to reduction of glucose 6-phosphatase activity in the glycogenolysis pathway.

In this trial, after two weeks induction of hyperthyroidism (1 mg $T_4$/L of drinking water), serum levels of $T_4$ reached 369.3 ng/ml which was 10 times higher than the control levels of serum $T_4$ but at 35 days of age (a week after withdrawal of levothyroxine in HYPER group), serum levels of $T_4$ were so low among the treatments (16.7 ng/ml). It has been mentioned in previous studies that poultry's response to exogenous thyroid hormones is faster than what is seen in mammals (Singh et al., 1968; Kittok et al., 1982). In this study, serum levels of $T_3$ and $T_4$ were affected by both hypo- and hyper-thyroidism. On the contrary, Akhlaghi et al. (2009) reported that although plasma levels of $T_4$ were affected by both hypo- and hyper-thyroidism, plasma levels of $T_3$ were only influenced by hypothyroidism.

## Conclusions

In conclusion, the present study indicates the important role of thyroid gland and its associated hormones in regulation of metabolism and growth performance of broiler chickens. Manipulation of thyroid status significantly decreased body weight gain. In particular, it was observed that induction of hyperthyroidism at the beginning of the growth phase led to increased basal metabolism, loss of energy and impaired growth performance. On the other hand, hypothyroidism resulted in decreased metabolism and higher amounts of abdominal fat. In addition, restoration from hypo- to hyper-thyroidism did not alter feed conversion ratio but reduced relative weight of abdominal fat in comparison with hypothyroid birds.

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