EFFECTS OF DIETARY THYROXINE ON GROWTH PERFORMANCE AND CARCASS QUALITY OF BROILERS FED DIFFERENT LEVELS OF DIETARY PROTEIN

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Summary

To investigate the effects of crude protein and thyroxine on growth performance, nutrient utilizability, carcass composition, the content of total fat and cholesterol in leg muscle, breast muscle and liver, and caloric efficiency in broiler chicks. The experiment involved 3 levels of dietary crude protein (1-3 weeks: 20, 23, 26%; 4-6 weeks: 17, 20, 23%) and 3 levels of thyroxine (0.0, 1.5, 3.0 mg/kg).

In the starting period (1-3 weeks), body weight gain of chicks fed diets containing 26% crude protein and 1.5 mg/kg thyroxine was higher than any other groups, and among thyroxine levels, 3.0 mg/kg thyroxine groups were lower. The best feed efficiency was obtained at 26% crude protein with no thyroxine supplemented or 1.5 mg/kg thyroxine supplemented groups. In the finishing period (4-6 weeks) the highest body weight gain was obtained at 23% crude protein with no thyroxine supplemented group. Feed intake of 17% crude protein with 1.5 mg/kg thyroxine supplemented group was higher than those of the other groups. It was found that the utilizability of crude protein in the starting period, showed the best utilizability at 20% crude protein with 1.5 mg/kg thyroxine group. Increasing crude protein level from 17 to 23%, utilizability of crude fat was decreased. The carcass composition was significantly ($p < 0.05$) influenced by crude protein and thyroxine. Increasing thyroxine level from 0.0 to 3.0 mg/kg, crude protein content was increased whereas crude fat content was decreased. Chicks fed diet containing 1.5 mg/kg thyroxine showed the lowest total fat content in liver tissue. In breast muscle, it was significantly ($p < 0.05$) affected by crude protein and thyroxine. Present data revealed that the cholesterol content was increased for the chicks fed 3.0 mg/kg thyroxine. It the caloric efficiency, chicks fed a diet containing 20% crude protein with no thyroxine supplementation showed the highest caloric efficiency and the lowest efficiency was from 23% crude protein group with 1.5 mg/kg thyroxine.

From this study it may be concluded that crude fat content of carcass could be successfully reduced by dietary supplementation of thyroxine, whereas crude protein content was increased.
(**Key Words** : Thyroxine, Crude Protein, Broiler, Total Fat, Cholesterol, Caloric Efficiency)

Introduction

The thyroid hormones are necessary for normal growth, development and variety of metabolic functions including muscle protein synthesis and breakdown (Flaim et al., 1978; Brown et al., 1981; Brown and Millward, 1983; Hayashi et al., 1984), and growth hormone metabolism (Harvey, 1983), and heat production (Bowen et al., 1984), and O_2 consumption (Brown and Millward, 1983; Van Hardeveld and Clausen, 1984).

The growth rate of hypophysectomized or thyroidectomized chicks is greatly attenuated (King, 1969; King and King, 1973). The concommitant administration of thyroxine (T_4) to thyroidectomized chicks restores body and skeletal growth to normal. It is reasonable to conclude that T_4 is required for growth in the domestic fowl. However, unknown whether it is T_4 itself, or the T_3 that exerts an effect on growth.

Although, it is well established that thyroid hormones are required for normal growth, this is an argument that the administration of exogenous thyroid hormones can stimulate growth in intact birds. Low levels of thyroid hormone administration give little to moderate growth stimulation (Wentworth and Ringer, 1986). Singh et al. (1968) using doses ranging from 1-6 μg/100 g body weight/day, indicated that T_4 in small

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doses improved growth of chicken. May (1980) reported that the addition of T_4 to the diet had no major effect on growth rate and little influence on the plasma T_3 concentration, however, increase in the circulating concentration of T_4 and rT_3 (reverse T_3). Suthama et al. (1989) demonstrated that the abdominal fat content reduced, especially in female broiler chickens, and improved feed efficiency and muscle growth by dietary addition of T_4.

The objectives of the present studies were; 1) to determine the effect of the levels of dietary thyroxine and protein on growth performance, carcass quality and utilizability of nutrients in broiler, 2) to investigate the content of total fat and cholesterol in liver, breast and leg muscle, 3) to compare the effect of the thyroxine on body energy gain and caloric efficiency.

Materials and Methods

Animals

Animals used in this study were broiler chicks of Maniker produced by Chon Ho Breeding Farm. At 7 days of age, experimental animals were chosen to have similar initial body weight and fed the experimental diets for 6 weeks. All treatments in this experiment had 3 replicates with 8 birds in each replicate. All feeding trial, metabolic trial and chemical analysis of experimental feed and excreta were conducted in the Animal Nutrition Laboratory, Department of Animal Science and Technology, College of Agriculture and Life Sciences, Seoul National University located in Suweon, Korea. The feeding trial was initiated in November, 1991 and terminated in December, 1991.

Experimental Diets

In this experiment, birds were fed a commercial diet (CP: 23%, 3,200 kcal ME/kg) for a period of one week. The three basal isocaloric diets (3,200 ME kcal/kg) of starting period (1-3 weeks) were formulated to contain three different levels of dietary crude protein (20, 23, 26%). The three basal diets of finishing period (4-6 weeks) were formulated to contain three dietary crude protein levels (17, 20, 23%) with isocaloric density (3,200 ME kcal/kg). The formula and chemical composition of basal diets of starting and finishing diets are presented in table 1. Each basal diet used in each period was supplemented with three levels (0.0, 1.5, 3.0 mg/kg) of DL-thyroxine sodium salt produced by Sigma Chemical Company, St. Louis, USA. All the diets except crude protein were formulated to meet the National Research Council requirement (NRC, 1984).

Experimental Methods

All the birds were raised in battery cages made of steel wire and housed in a room with 24 hours light and air ventilation. During the pre-experimental period of 7 days, broiler chicks were fed on a commercial diet. Experimental diets and drinking water were provided *ad libitum* during the entire experimental period of 6 weeks. Chicks grouped to have uniform mean body weight were allocated into the respective experimental groups. Body weight and feed intake were recorded at 21 and 42 days on replication basis. Body weight gain were calculated by the difference between the initial body weight and final body weight. Feed efficiency was calculated by dividing the amount of feed consumed with the corresponding body weight gain. During the feeding trial mortality was also recorded.

To investigate the nutrient utilizability of experimental diets, the metabolizability coefficient was calculated by total fecal collection method during 7 days at the end of feeding trial. Three chicks per each treatment were selected for metabolic trial. Three chicks employed for the metabolic trial were caged in metabolic cages individually and experimental diets and water were fed *ad libitum*. After four days of preliminary period for adaptation, total excreta were collected four times a day for next three days to avoid the contamination of foreign materials such as feed, feathers and scales. Total excreta were pooled and one-third of these excreta was dried in an air-forced drying oven at 60℃ for 72 hours to gain constant dry weight. All the sample prepared in this way were ground with Wiley mill and analyzed for proximate composition and mineral content.

To evaluate the carcass composition sample collection was done as follows. At 22th day of each treatment, two chicks per treatment were sacrificed by cervical dislocation and frozen for determination of carcass composition. At 42th day of the experimental period, two chicks per treatment were sacrificed by cervical dislocation and frozen for determination of final carcass composition. The individual weight of liver, breast (pectoralis thoracica) muscle and leg (gastrocnemius peroneus) muscle was recorded. Carcass sample was freeze dried, ground and analyzed by AOAC (1990) methods.

TABLE 1. FORMULA AND CHEMICAL COMPOSITION OF THE BASAL DIETS

	Level of dietary protein (%)			
	17	20	23	26
Ingredients (%):				
Corn, yellow	69.50	62.50	54.00	45.00
Soybean meal	13.00	22.20	27.50	32.80
Fish meal	2.80	3.00	5.30	3.50
Corn gluten meal	4.20	4.20	4.50	8.62
Wheat bran	2.81	0.40	0.89	1.08
Tallow	3.80	4.34	5.53	6.30
Limestone	2.39	2.39	1.94	2.20
Tricalcium phosphate	0.30	0.08	0.00	0.00
Salt	0.20	0.20	0.20	0.20
Vitamin-mineral mix.[1]	0.25	0.25	0.25	0.25
Lysine	0.55	0.27	0.00	0.00
Methionine	0.15	0.12	0.04	0.00
Antibiotics	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00
Chemical composition:				
Energy (ME kcal/kg)	3,212.88	3,203.75	3,203.73	3,207.84
Crude protein (%)	17.15	20.07	23.03	26.02
Lysine (%)	1.20	1.21	1.23	1.32
Methionine (%)	0.50	0.51	0.50	0.50
Calcium (%)	1.13	1.07	1.02	1.03
Phosphorous, available (%)	0.47	0.45	0.52	0.50

[1] Vit.-mineral mixture contains followings in 1 kg: vitamin A, 10,000 IU; vitamin D_3, 1,500 IU; vitamin K, 5 mg; vitamin E, 15 mg; vitamin B_2, 8 mg; vitamin B_{12} , 0.008 mg; Ca-d-pantothenate, 8 mg; niacin, 25 mg; folic acid, 0.4 mg; biotin, 0.2 mg; choline, 500 mg; pyridoxine, 1 mg; B.H.T. 125 mg; Co, 0.85 mg; I, 1.29 mg; Zn, 100 mg; Mg, 600 mg; Mn, 60 mg; Cu, 8.75 mg; Se, 0.15 mg; Fe, 35 mg.

Chemical Analysis

Liver, breast (pectoralis thoracica) muscle and leg (gastrocnemius peroneus) muscle tissues sample for total fat and cholesterol assay were extracted by 2:1 (v/v) chloroform:methanol according to the method of Folch et al. (1957). Cholesterol was measured according to the method of Zlatkis and Zak (1969) with O-phthalaldehyde reagent and conc. H_2SO_4.

Proximate analysis and mineral composition of experimental diets, excreta and ether extract were conducted according to the methods of AOAC (1990). Experimental diets, excreta and freeze dried carcasses were prepared to determine the caloric values. Combustible energy value was measured in an Adiabatic Oxygen Bomb Calorimeter (Model 1241, Parr Instrument Co., Molin, IL).

Stastistical Analysis

Stastistical analysis for the present data were carried out by comparing means according to Duncan's multiple range test (Duncan, 1955), using General Linear Model (GLM) Procedure of SAS (1985) package program with IBM-PC compatible computer.

Results and Discussion

Growth Performance

1) Starting period (1-3 weeks)

Effects of dietary supplementation of thyroxine on body weight gain, feed intake and feed efficiency during starting period (1-3 weeks) are presented in table 2. The lowest body weight gain was observed in 23% crude protein with 3.0 mg/kg thyroxine groups. Among dietary crude protein levels, body weight gain of the 26% crude protein group was significantly ($p < 0.05$) higher than any other group, and among thyroxine levels, the 3.0 mg/kg thyroxine group was lower than any other group in body weight gain. As shown in table 2, interaction between dietary crude protein and thyroxine was not shown to be significant.

Feed intake showed significant ($p < 0.05$) difference among treatments. Chicks fed a diet containing 23% crude protein with 1.5 mg/kg thyroxine represented the highest feed intake. The lowest feed intake was shown in the treatment of 26% crude protein with 3.0 mg/kg thyroxine. Among thyroxine levels interaction between dietary crude protein and thyroxine was not shown to be significant.

TABLE 2. GROWING PERFORMANCES OF STARTER AS AFFECTED BY THE LEVELS OF DIETARY PROTEIN AND THYROXINE (1-3 WEEKS)

Crude protein (%)	Thyroxine (mg/kg)	Initial body weight (g)	Final body weight (g)	Body weight gain (g)	Feed intake (g)	Feed efficiency
	0.0	132.4	554.5±20.3[a1]	422.0±14.8[ab]	685.3±3.4[bc]	1.63±0.06[c]
20	1.5	125.7	510.0±20.6[bc]	375.3±21.2[cd]	698.3±3.2[a]	1.87±0.12[ab]
	3.0	125.5	475.1±16.6[c]	349.6±16.8[d]	698.0±3.2[a]	2.01±0.11[a]
	0.0	126.6	523.7± 6.5[ab]	397.1± 6.3[bc]	693.7±7.5[ab]	1.75±0.04[bc]
23	1.5	132.8	537.8± 5.8[ab]	405.1± 0.8[abc]	703.0±5.3[a]	1.74±0.02[bc]
	3.0	125.4	468.7± 9.4[c]	343.3± 9.4[d]	692.7±9.7[ab]	2.02±0.07[a]
	0.0	125.2	564.8± 9.1[a]	439.6± 8.9[ab]	673.3±3.8[c]	1.53±0.02[c]
26	1.5	126.4	569.3±19.1[a]	442.9±18.9[a]	676.7±6.2[bc]	1.53±0.06[c]
	3.0	125.5	530.7±13.2[ab]	405.2±13.5[abc]	671.3±4.6[c]	1.66±0.06[bc]
Among crude protein levels (%)						
20		127.9	510.2±15.1[b]	382.3±13.9[b]	693.9±2.69[a]	1.84±0.07[a]
23		128.3	510.1±11.2[b]	381.8±10.2[b]	696.4±4.19[a]	1.83±0.05[a]
26		125.7	554.9± 9.4[a]	429.2± 9.4[a]	673.8±2.62[b]	1.58±0.03[b]
Among thyroxine levels (mg/kg)						
0.0		128.1	547.7± 9.1[a]	419.6± 8.1[a]	684.1±3.9	1.64±0.04[b]
1.5		128.3	536.0±12.9[a]	407.8±12.8[a]	692.7±4.8	1.71±0.06[b]
3.0		125.5	491.5±11.9[b]	366.0±11.9[b]	687.3±5.2	1.90±5.20[a]
Probability (P);						
Crude protein			0.0015	0.0005	0.0002	0.0002
Thyroxine			0.0004	0.0004	0.1990	0.0007
Crude protein × thyroxine			0.1624	0.2671	0.6660	0.2239

[1] Values are mean±SE; n = 3.

[a,b,c] Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

Feed efficiency expressed as grams of feed consumed per grams weight gained is also recorded in table 2. The best feed efficiency was obtained at 26% crude protein with no thyroxine supplemented group or 1.5 mg/kg thyroxine supplemented group, respectively, and the lowest at 20% or 23% crude protein with 3.0 mg/kg thyroxine, respectively ($p < 0.05$). Among dietary crude protein levels, 26% crude protein group significantly ($p < 0.05$) improved feed efficiency compared to any other groups. Feed efficiency was improved at the level of no thyroxine supplemented group than 1.5 mg/kg thyroxine group even if there was no significant difference.

According to Suthama et al. (1989), during the period from 15 to 27 days, dietary inclusion of T_4 at the level of 0.4 and 1.2 mg/kg had no effect on the body weight gain of chickens. Feed intake was significantly ($p < 0.05$) lower and body weight/feed intake was significantly ($p < 0.05$) higher in male chickens when fed T_4 at the level of 1.2 mg/kg. Administration of 3.6 mg/kg T_4 produced significantly ($p < 0.05$) lower body weight gain and feed intake and significantly ($p < 0.05$) lower body weight/feed intake in the male chicken.

TABLE 3. GROWING PERFORMANCES OF FINISHER AS AFFECTED BY THE LEVELS OF DIETARY PROTEIN AND THYROXINE (4-6 WEEKS)

Crude protein (%)	Thyroxine (mg/kg)	Initial body weight (g)	Final body weight (g)	Body weight gain (g)	Feed intake (g)	Feed efficiency
	0.0	554.5	1,416.1±36.5^{bc1}	861.6±16.2^{bc}	1,876.9±46.8^{ab}	2.18±0.07^{ab}
17	1.5	501.0	1,320.8±51.2^{c}	819.8±35.8^{c}	1,953.1±56.8^{a}	2.39±0.10^{a}
	3.0	475.1	1,312.5±26.0^{c}	837.4±21.9^{bc}	1,807.0±49.9^{b}	2.16+0.09^{ab}
	0.0	523.7	1,429.2+61.4^{abc}	905.5±55.2^{abc}	1,806.1+26.2^{b}	2.01±0.10^{bc}
20	1.5	538.1	1,415.5±23.9^{bc}	877.4±23.3^{bc}	1,800.3±80.9^{b}	2.05±0.07^{bc}
	3.0	468.7	1,320.8±29.2^{c}	852.1±19.9^{bc}	1,824.3±15.8^{ab}	2.14±0.07^{ab}
	0.0	567.8	1,537.5±21.7^{a}	972.7+12.6^{a}	1,800.7± 4.4^{b}	1.85+0.03^{c}
23	1.5	597.4	1,514.3+16.0^{ab}	916.9±25.7^{ab}	1,851.8+48.9^{ab}	2.02±0.10^{bc}
	3.0	530.9	1,404.2±29.2^{bc}	873.3±16.6^{bc}	1,819.0±13.4^{ab}	2.08±0.04^{bc}
Among crude protein levels (%)						
17		510.2	1,349.8+25.7^{b}	839.6±14.3^{b}	1,878.9±32.2	2.24±0.06^{a}
20		510.2	1,388.5±27.3^{b}	878.3±19.8^{ab}	1,810.3±25.3	2.07±0.05^{b}
23		564.4	1,485.3±23.5^{a}	920.9±17.3^{a}	1,823.9±16.5	1.99±0.05^{b}
Among thyroxine levels (mg/kg)						
0.0		547.7	1,460.9±28.9^{a}	913.3±23.4^{a}	1,827.9±19.8	2.01±0.06^{b}
1.5		545.5	1,416.9±33.0^{a}	871.4±20.1^{ab}	1,868.4±38.9	2.15±0.07^{a}
3.0		491.6	1,345.8±20.3^{b}	854.3+11.1^{b}	1,816.8±13.5	2.13±0.04^{ab}
Probability (P);						
Crude protein			0.0007	0.0084	0.1536	0.0026
Thyroxine			0.0036	0.0518	0.3363	0.0857
Crude protein × thyroxine			0.6174	0.6993	0.4159	0.2507

[1] Values are mean±SE; n = 3.

[2] a,b,c Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

2) **Finishing period (4-6 weeks)**

Results obtained in finishing period are summarized in table 3. The highest body weight gain was obtained at 23% crude protein with no thyroxine supplemented group, and the lowest body weight gain was obtained at 17% crude protein and 1.5 mg/kg thyroxine supplemented group. Among dietary crude protein levels, 23% crude protein group improved body weight gain compared to any other groups.

Feed intake of 17% crude protein with 1.5 mg/kg thyroxine supplemented group was higher than those of the other groups.

The effect of dietary crude protein and thyroxine levels on feed efficiency during finishing period are shown in table 3. At the level of 23 % crude protein with no thyroxine supplemented group showed the best feed efficiency and the lowest was found from 17% crude protein with 1.5 thyroxine supplemented group. Among crude protein levels, 20 and 23% crude protein group improved feed efficiency more than 17% crude protein group.

3) **Overall experimental period (1-6 weeks)**

Table 4 summarizes effect of crude protein

TABLE 4. GROWING PERFORMANCES OF CHICKS AS AFFECTED BY THE LEVELS OF DIETARY PROTEIN AND THYROXINE (1 6 WEEKS)

Crude protein (%)	Thyroxine (mg/kg)	Initial body weight (g)	Final body weight (g)	Body weight gain (g)	Feed intake (g)	Feed efficiency
	0.0	132.4	1,416.1±36.5[bc1]	1,283.6±30.8[bc]	2,562.2±43.8[ab]	2.00±0.06[bc]
20-17	1.5	125.7	1,320.8+51.2[c]	1,195.2±51.6[c]	2,651.4±56.5[a]	2.22+0.07[a]
	3.0	125.5	1,312.5±26.0[c]	1,187.0±25.8[c]	2,505.0±43.6[b]	2.11±0.08[ab]
	0.0	126.6	1,429.2±61.4[abc]	1,302.5±61.2[bc]	2,499.8±20.4[b]	1.93±0.08[bcd]
23-20	1.5	132.8	1,415.5±28.9[bc]	1,282.7±22.9[bc]	2,503.3±86.2[b]	1.95±0.05[bc]
	3.0	125.4	1,320.8+29.2[c]	1,195.5±29.2[c]	2,517.0±17.6[ab]	2.11±0.06[ab]
	0.0	125.2	1,537.5±21.7[a]	1,412.3±21.5[a]	2,474.1± 1.9[b]	1.75±0.03[d]
26-23	1.5	126.4	1,514.3±16.1[ab]	1,387.9±15.7[ab]	2,528.4±44.0[ab]	1.82±0.03[cd]
	3.0	125.5	1,404.2±29.2[bc]	1,278.7±29.4[bc]	2,490.4±18.1[b]	1.95±0.04[bc]
Among crude protein levels (%)						
20-17		127.9	1,349.8±25.7[b]	1,221.9±24.4[b]	2,572.9±32.2	2.11±0.05[a]
23-20		128.3	1,388.5±27.3[b]	1,260.2±26.4[b]	2,506.7+26.2	2.00+0.04[b]
26-23		125.7	1,485.3+23.5[a]	1,359.6±23.5[a]	2,497.6±15.9	1.84±0.03[c]
Among thyroxine levels (mg/kg)						
0.0		128.1	1,460.9±28.9[a]	1,332.8±28.8[a]	2,512.0+19.1	1.89+0.05[b]
1.5		128.3	1,416.9±33.0[a]	1,288.6±32.6[a]	2,561.1±39.6	2.00±0.07[a]
3.0		125.5	1,345.8±20.3[b]	1,220.4±20.3[b]	2,504.1±15.1	2.06±0.04[a]
Probability (P);						
Crude protein			0.0007	0.0004	0.1010	0.0001
Thyroxine			0.0036	0.0035	0.2558	0.0122
Crude protein × thyroxine			0.6174	0.6431	0.4893	0.2258

[1] Values are mean+SE; n = 3.

[a,b,c,d] Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

and thyroxine on body weight gain, feed intake and feed efficiency in whole experimental period (1-6 weeks). The highest body weight gain was found when fed 26-23% crude protein with no thyroxine supplemented group.

Chicks received the diet containing 20-17% crude protein with 1.5 mg/kg thyroxine groups showed the highest feed intake. Among crude protein and thyroxine levels, there was no significant difference.

Feed efficiency showed the significant ($p < 0.05$) difference among experimental groups. Chicks fed a diet containing 26-23% crude protein with no thyroxine supplemented group showed the best feed efficiency, whereas the lowest feed efficiency was obtained 20-17% crude protein with 1.5 mg/kg thyroxine supplemented group. Among crude protein levels, 26-23% crude protein group showed the best feed efficiency ($p < 0.05$), and among thyroxine levels, the best feed efficiency was observed from no thyroxine supplemented groups. Interaction crude protein and thyroxine was not observed.

May (1980) reported that the T_3 or T_4 at 0.25 mg/kg or T_4 at 1.0 mg/kg used in experiment did not significantly affect the 0 to 28 day in body weight gain or feed efficiency. T_4 at 1.0 mg/kg did not significantly affect 28 to 42 day

TABLE 5. EFFECTS OF CRUDE PROTEIN AND THYROXINE ON NUTRIENT UTILIZABILITY OF BROILER CHICKS (%, 1-3 WEEKS)

		Nutrient utilizability				
		Dry matter	Crude protein	Crude fat	Crude ash	Total carbohydrate
Crude protein (%)	Thyroxine (mg/kg)					
	0.0	79.54 ± 1.56	67.12 ± 3.64^{abcd1}	96.99 ± 0.32^{a}	37.15 ± 7.70	85.25 ± 0.76^{abc}
20	1.5	$81.38+0.54$	$75.69+0.86^{a}$	97.78 ± 0.28^{a}	46.10 ± 1.46	$84.65+0.50^{bc}$
	3.0	82.51 ± 2.22	73.77 ± 4.13^{ab}	89.51 ± 1.04^{b}	47.11 ± 8.76	87.69 ± 1.24^{ab}
	0.0	79.65 ± 1.44	63.45 ± 1.69^{cd}	91.30 ± 0.90^{b}	45.26 ± 4.08	87.62 ± 1.19^{ab}
23	1.5	77.51 ± 2.61	66.54 ± 5.43^{abcd}	91.24 ± 0.93^{b}	36.52 ± 6.16	84.37 ± 1.76^{c}
	3.0	$78.09+1.17$	68.29 ± 2.26^{abcd}	$91.49+1.70^{b}$	40.44 ± 4.60	$84.01+0.97^{c}$
	0.0	78.29 ± 0.65	60.24 ± 0.85^{d}	91.93 ± 2.45^{b}	38.13 ± 2.79	88.20 ± 0.28^{a}
26	1.5	78.88 ± 0.03	71.43 ± 0.73^{abc}	88.97 ± 0.71^{b}	35.91 ± 2.23	85.02 ± 0.40^{abc}
	3.0	78.07 ± 1.10	64.47 ± 2.33^{bcd}	90.18 ± 0.53^{b}	41.61 ± 3.08	86.10 ± 0.58^{abc}
Among crude protein levels (%)						
20		81.14 ± 0.91^{a}	72.19 ± 2.07^{a}	94.76 ± 1.36^{a}	43.45 ± 3.74	85.86 ± 0.64
23		78.42 ± 0.98^{b}	$66.09+1.90^{b}$	91.34 ± 0.62^{b}	40.74 ± 2.81	$85.33+0.89$
26		78.42 ± 0.39^{b}	65.38 ± 1.79^{b}	$90.36+0.86^{b}$	38.55 ± 1.59	86.44 ± 0.52
Among thyroxine levels (mg/kg)						
0.0		$79.16+0.68$	63.60 ± 1.55^{b}	93.40 ± 1.18^{a}	40.18 ± 2.93	$87.03+0.61^{a}$
1.5		79.26 ± 0.95	71.22 ± 2.08^{a}	92.66 ± 1.37^{a}	$39.51+2.55$	84.68 ± 0.55^{b}
3.0		79.56 ± 1.08	68.85 ± 2.03^{a}	90.39 ± 0.66^{b}	43.05 ± 3.16	85.93 ± 0.72^{ab}
Probability (P);						
Crude protein		0.0552	0.0183	0.0006	0.5150	0.3922
Thyroxine		0.9428	0.0141	0.0157	0.6735	0.0272
Crude protein × thyroxine		0.5355	0.5685	0.0042	0.4890	0.0636

[1] Values are mean±SE; n = 3.

[a,b,c] Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

body weight gains or feed efficiencies, but T_3 at 1.0 mg/kg significantly ($p < 0.05$) reduced body weight gain of males and feed efficiency of females.

Nutrient Utilizability

1) Starting period (1-3 weeks)

The effects of crude protein and thyroxine on the utilizability of the dry matter, crude protein, crude fat, crude ash and total carbohydrate are summarized in table 5.

Crude protein utilizability showed significantly ($p < 0.05$) difference among treatment groups. The highest crude protein utilizability was found at 20% crude protein with 1.5 mg/kg thyroxine group. Among crude protein levels, 20% crude protein group showed the highest crude protein utilizability whereas, among thyroxine levels, the higher values were seen in 1.5 mg/kg thyroxine supplemented groups. However, there was no interaction between crude protein and supplemented thyroxine levels.

Crude fat utilizability was affected by the level of crude protein. At 20% crude protein group, crude fat utilizability was significantly ($p<0.05$) higher than any other groups. Among thyroxine levels, 3.0 mg/kg thyroxine group represented the

TABLE 6. EFFECTS OF CRUDE PROTEIN AND THYROXINE ON NUTRIENT UTILIZABILITY OF BROILER CHICKS (%, 4-6 WEEKS)

		Nutrient utilizability				
		Dry matter	Crude protein	Crude fat	Crude ash	Total carbohydrate
Crude protein (%)	Thyroxine (mg/kg)					
	0.0	72.19±2.03	55.40±5.05^{a1}	90.78+0.30^{abc}	46.91±9.64^{ab}	77.50+0.85
17	1.5	67.02±1.54	36.98±2.98^{c}	90.57±0.40^{abc}	43.06±3.39^{b}	75.60±1.10
	3.0	72.47±1.51	54.91±2.13^{ab}	95.16±0.72^{a}	18.29±6.01^{c}	79.46±1.23
	0.0	73.87±1.08	54.33±3.07^{ab}	92.08±1.72^{ab}	56.02±3.76^{ab}	80.13±0.87
20	1.5	70.20±2.42	51.05+4.18^{abc}	94.72+0.45^{a}	59.35±4.47^{ab}	75.64±1.90
	3.0	65.47±5.08	40.46±6.22^{bc}	82.04±4.84^{cd}	46.87±7.17^{ab}	74.11±4.74
	0.0	68.15±0.92	37.53±2.48^{c}	76.98±0.69^{de}	63.75±3.51^{a}	79.32±0.31
23	1.5	69.24±1.52	47.05±2.45^{abc}	84.43±0.64^{bcd}	49.08±2.05^{ab}	79.16±1.37
	3.0	68.50±3.26	43.64+7.80^{abc}	71.65+6.23^{e}	54.83±3.33^{ab}	79.26±2.33
Among crude protein levels (%)						
17		70.56±1.23	49.09±3.53	92.17±0.79^{a}	36.09±5.64^{b}	77.52±0.77
20		69.85±2.05	48.61±3.14	89.61±2.44^{a}	54.08±3.26^{a}	76.63±1.75
23		68.63±1.08	42.74±2.83	77.68±2.60^{b}	55.89±2.62^{a}	79.25±0.79
Among thyroxine levels (mg/kg)						
0.0		71.41±1.11	49.08+3.43	86.61±2.48^{ab}	55.56±3.98^{a}	78.98+0.53
1.5		68.82±1.05	45.03±2.66	89.91±1.52^{a}	50.50±2.94^{a}	76.80±0.95
3.0		68.81±2.06	46.34±3.67	82.95±4.10^{b}	40.00±6.24^{b}	77.61±1.79
Probability (P);						
Crude protein		0.6359	0.1778	0.0001	0.0004	0.3045
Thyroxine		0.3576	0.5327	0.0203	0.0067	0.4351
Crude protein × thyroxine		0.1962	0.0119	0.0211	0.0683	0.3546

[1] Values are mean±SE; n = 3.

[a,b,c,d,e] Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

worest crude fat utilizability. Interaction between crude protein and supplemented thyroxine was observed. Total carbohydrate utilizability was found to be the highest at 26% crude protein with no thyroxine supplemented group.

Utilizability of dry matter and crude ash was not affected by the levels of dietary crude protein or thyroxine.

2) Finishing period (4-6 weeks)

As shown in table 6, the utilizability of dry matter, total carbohydrate were not affected by dietary crude protein and thyroxine levels. Utilizability of crude fat was improved by 1.5 mg/kg thyroxine administration. It was found that the utilizability of crude fat was decreased, as dietary crude protein level increased from 17 to 23%. Interaction between crude protein and thyroxine was found in crude fat utilizability.

At 20% crude protein with no thyroxine supplemented level, crude ash utilizability was significantly ($p < 0.05$) higher than any other groups. As the level of crude protein increased, the crude ash utilizability was decreased, but the level of thyroxine affected adversely to the crude ash utilizability.

TABLE 7. EFFECTS OF CRUDE PROTEIN AND THYROXINE ON CARCASS COMPOSITION OF BROILER CHICKS (%)

		Carcass composition[1]				
		Crude protein	Crude fat	Crude fiber	Crude ash	NFE
Crude protein (%)	Thyroxine (mg/kg)					
	0.0	49.97 ± 0.58^{f2}	34.98 ± 0.68^{a}	0.94 ± 0.02^{ab}	6.78 ± 0.10	7.34 ± 0.21^{a}
20-17	1.5	$55.15 + 0.35^{d}$	30.85 ± 1.74^{b}	0.85 ± 0.04^{abcd}	6.90 ± 0.32	$6.25 + 1.11^{abc}$
	3.0	62.05 ± 0.47^{a}	21.87 ± 1.11^{f}	0.80 ± 0.03^{cd}	7.66 ± 0.65	7.63 ± 1.27^{a}
	0.0	52.68 ± 0.24^{e}	33.04 ± 0.30^{ab}	0.95 ± 0.02^{a}	6.59 ± 0.35	6.75 ± 0.42^{ab}
23-20	1.5	60.08 ± 0.32^{b}	25.62 ± 0.55^{cd}	$0.88 + 0.07^{abc}$	6.56 ± 0.45	6.86 ± 0.15^{a}
	3.0	63.08 ± 0.13^{a}	24.90 ± 0.06^{de}	0.90 ± 0.05^{abc}	$7.28 + 0.56$	$3.85 + 0.79^{c}$
	0.0	57.07 ± 0.10^{c}	28.08 ± 0.96^{c}	0.80 ± 0.03^{cd}	7.64 ± 0.29	6.42 ± 1.11^{abc}
26-23	1.5	62.22 ± 0.14^{a}	22.64 ± 0.34^{e}	0.81 ± 0.02^{bcd}	6.87 ± 0.08	7.48 ± 0.29^{a}
	3.0	$62.30 + 0.55^{a}$	$25.83 + 0.07^{cd}$	$0.73 + 0.04^{d}$	6.99 ± 0.09	4.14 ± 0.58^{bc}
Among crude protein levels (%)						
20-17		55.72 ± 2.22^{c}	29.23 ± 2.51^{a}	0.86 ± 0.03^{a}	7.11 ± 0.26	7.07 ± 0.51
23-20		$58.61 + 1.96^{b}$	27.85 ± 1.65^{a}	0.91 ± 0.03^{a}	6.81 ± 0.25	5.82 ± 0.67
26-23		60.53 ± 1.11^{a}	25.51 ± 1.03^{b}	0.78 ± 0.02^{b}	7.17 ± 0.17	6.02 ± 0.70
Among thyroxine levels (mg/kg)						
0.0		53.24 ± 1.32^{c}	32.03 ± 1.34^{a}	0.89 ± 0.03^{a}	$7.00 + 0.24$	6.84 ± 0.35^{a}
1.5		59.15 ± 1.33^{b}	26.37 ± 1.59^{b}	0.85 ± 0.03^{ab}	6.78 ± 0.16	6.86 ± 0.37^{a}
3.0		62.48 ± 0.27^{a}	24.20 ± 0.81^{c}	0.81 ± 0.03^{b}	7.31 ± 0.25	5.21 ± 0.87^{b}
Probability (P);						
Crude protein		0.0001	0.0012	0.0076	0.4833	0.1565
Thyroxine		0.0001	0.0001	0.0566	0.2684	0.0429
Crude protein × thyroxine		0.0001	0.0003	0.5394	0.3578	0.0748

[1] Dry matter basis

[2] Values are mean±SE; n = 3.

[a,b,c,d,e,f] Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

Carcass Composition

The effects of dietary crude protein and thyroxine on carcass composition are summarized in table 7.

Crude protein content of broiler chicks was significantly ($p < 0.05$) influenced by the level of dietary crude protein and thyroxine. Increasing thyroxine level from 0.0 to 3.0 mg/kg, crude protein content of carcass was increased whereas, crude fat content was decreased. Interaction between crude protein and thyroxine was found in crude protein and fat content. Crude ash content was not significantly affected.

Jackson et al. (1982) reported that a day-old broiler offered diet varying in dietary protein (16, 20, 24, 28, 32, 36%) to 49 days of age, significantly ($p < 0.01$) altered carcass composition. Increasing dietary protein generally produced carcasses that were lower in fat and higher in protein. This response appeared to plateau at the 28% level despite significantly ($p < 0.01$) increase in protein intake with high levels (Summers et al., 1965; Marion and Woodroof, 1966; Twining et al., 1978). Wilson et al. (1983) also demonstrated that the dietary inclusion of thyroactive iodinated casein was effective in decreasing abdominal fat pads and carcass fat of broilers. It is plausible to assume that the elevated level of T_4 induced by the iodinated casein in the diet increased muscle mass and decreased body fat content.

Total Fat and Cholesterol in Leg Muscle, Breast Muscle and Liver Tissue

TABLE 8. EFFECTS OF LEVEL OF DIETARY CRUDE PROTEIN AND THYROXINE ON THE CONTENT OF TOTAL FAT IN LEG MUSCLE, BREAST MUSCLE AND LIVER TISSUE (mg / g)

		Total fat		
		Leg muscle	Breast muscle	Liver
Crude protein (%)	Thyroxine (mg/kg)			
	0.0	215.70 ± 2.40[ab1]	78.35 ± 13.65	84.00 ± 6.80[a]
20-17	1.5	193.10 ± 13.30[bc]	72.90 ± 10.00	51.83 ± 2.37[bcd]
	3.0	215.80 ± 2.90[ab]	69.13 ± 5.74	63.70 ± 5.15[b]
	0.0	145.47 ± 16.60[d]	62.33 ± 9.43	65.85 ± 12.85[bc]
23-20	1.5	191.35 ± 1.45[bc]	75.30 ± 10.71	65.60 ± 10.60[bcd]
	3.0	224.70 ± 5.30[a]	69.70 ± 6.40	61.73 ± 6.66[ab]
	0.0	167.10 ± 8.70[cd]	66.03 ± 7.54	48.27 ± 6.71[d]
26-23	1.5	125.93 ± 3.26[e]	74.33 ± 3.29	42.80 ± 1.71[cd]
	3.0	156.50 ± 18.66[cd]	89.45 ± 1.95	61.60 ± 11.37[bcd]
Among crude protein levels (%)				
20-17		208.20 ± 5.96[a]	72.84 ± 4.56	64.33 ± 6.71[a]
23-20		181.21 ± 15.07[b]	69.04 ± 5.27	64.01 ± 1.71[a]
26 23		147.69 ± 9.17[c]	75.00 ± 4.38	50.89 ± 11.37[b]
Among thyroxine levels (mg/kg)				
0.0		171.71 ± 13.62[b]	67.73 ± 5.29	63.50 ± 5.22[a]
1.5		163.81 ± 13.77[b]	74.34 ± 4.14	51.89 ± 4.49[b]
3.0		192.93 ± 14.81[a]	75.10 ± 4.54	62.34 ± 4.75[a]
Probability (P);				
Crude protein		0.0002	0.2588	0.0042
Thyroxine		0.0023	0.6418	0.0693
Crude protein × thyroxine		0.0146	0.3897	0.1092

[1] Values are mean ± SE; n = 3.

[a,b,c,d,e] Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

The effects of dietary crude protein and thyroxine on the content of total fat and cholesterol in leg muscle, breast muscle and liver tissue of broiler chicks are presented in table 8 and table 9.

As shown in table 8, total fat content in leg muscle was the highest in chicks fed 20% crude protein with 3.0 mg/kg thyroxine. Among thyroxine levels, 3.0 mg/kg thyroxine group indicated to be higher than any other groups ($p < 0.05$). Interaction between protein and thyroxine was observed to be significant ($p < 0.05$).

Total fat content in liver tissue was different among thyroxine levels. Chicks fed the diet containing 1.5 mg/kg thyroxine showed the lowest total fat content. Protein and thyroxine had no effect on the total fat content of breast muscle and there was no significant difference was found.

As shown in table 9, the cholesterol content in leg muscle was highest in chicks fed 17% crude protein with 3.0 mg/kg thyroxine. Among thyroxine levels, 1.5 and 3.0 mg/kg groups were higher than no thyroxine supplemented group. Interaction between crude protein and thyroxine were observed cholesterol content of leg muscle.

With regard to cholesterol content in breast muscle, it was significantly ($p < 0.05$) affected by crude protein and thyroxine. At 3.0 mg/kg thyroxine level, cholesterol content was increased. Increasing thyroxine level from 0.0 to 3.0 mg/kg, the cholesterol content of breast muscle was increased. Interaction between crude protein and

TABLE 9. EFFECTS OF LEVEL OF DIETARY CRUDE PROTEIN AND THYROXINE ON THE CONTENT OF CHOLESTEROL IN LEG MUSCLE, BREAST MUSCLE AND LIVER TISSUE (mg/g)

		Cholesterol		
		Leg muscle	Breast muscle	Liver
Crude protein (%)	Thyroxine (mg/kg)			
	0.0	3.68 ± 0.18^{ab1}	3.33 ± 0.03^{a}	5.33 ± 0.04^{ab}
20-17	1.5	3.47 ± 0.18^{bc}	2.95 ± 0.07^{bc}	5.29 ± 0.02^{ab}
	3.0	3.89 ± 0.10^{a}	2.74 ± 0.03^{c}	$5.33 + 0.02^{ab}$
	0.0	3.82 ± 0.01^{ab}	2.17 ± 0.03^{c}	5.17 ± 0.11^{b}
23-20	1.5	3.92 ± 0.01^{a}	2.45 ± 0.04^{d}	5.33 ± 0.04^{ab}
	3.0	$3.76 + 0.14^{ab}$	3.35 ± 0.08^{a}	5.37 ± 0.04^{a}
	0.0	3.22 ± 0.12^{c}	2.76 ± 0.09^{c}	5.29 ± 0.02^{ab}
26-23	1.5	3.79 ± 0.12^{ab}	2.98 ± 0.03^{b}	5.35 ± 0.02^{ab}
	3.0	3.48 ± 0.05^{bc}	2.98 ± 0.11^{b}	5.21 ± 0.07^{ab}
Among crude protein levels (%)				
20-17		3.71 ± 0.10^{a}	3.10 ± 0.09^{a}	5.32 ± 0.02
23-20		3.83 ± 0.05^{a}	2.66 ± 0.18^{b}	5.29 ± 0.05
26-23		3.50 ± 0.10^{b}	2.91 ± 0.06^{a}	5.28 ± 0.03
Among thyroxine levels (mg/kg)				
0.0		3.56 ± 0.11^{b}	2.75 ± 0.17^{b}	5.26 ± 0.04
1.5		3.76 ± 0.08^{a}	2.80 ± 0.09^{b}	$5.32 + 0.02$
3.0		3.71 ± 0.08^{ab}	3.02 ± 0.10^{a}	5.30 ± 0.04
Probability (P);				
Crude protein		0.0037	0.0001	0.8516
Thyroxine		0.0934	0.0001	0.3000
Crude protein × thyroxine		0.0121	0.0001	0.1292

[1] Values are mean ± SE; n = 3.

[a,b,c,d] Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

thyroxine were found.

The cholesterol content in liver tissues was the highest in 20% crude protein with 3.0 mg/kg thyroxine, the lowest was detected in 17% crude protein with no thyroxine supplemented group. Among crude protein and thyroxine levels, there was no significant difference. Interaction between crude protein and thyroxine was not found to be significant.

Suthama et al. (1989) noted that breast muscle weight, liver weight and abdominal fat content were not affected by dietary inclusion of 0.4 mg/kg T_4, with the exception that the abdominal fat content in the female chicken was significantly ($p < 0.05$) lower. Administration of T_4 at the level of 1.2 mg/kg produced significantly ($p < 0.05$) higher breast muscle weight in males and lower abdonimal fat content in females. When the amount of T_4 was increased to 3.6 mg/kg, breast muscle weight, liver weight and abdominal fat content were significantly ($p < 0.05$) lower.

Caloric Efficiency

The effects of crude protein and thyroxine on caloric efficiency are presented in table **10**.

The calculation of ME intake was based on multiflied feed consumption by ME value of experimental diet during finishing period (4-6 weeks). Chicks fed the diet containing 20% crude protein with no thyroxine supplemented group showed the highest caloric efficiency, the lowest was 23% crude protein with 1.5 mg/kg thyroxine.

TABLE 10. EFFECTS OF LEVEL OF DIETARY CRUDE PROTEIN AND THYROXINE LEVELS ON ENERGY BALANCE (4-6 WEEKS)

Crude protein (%)	Thyroxine (mg/kg)	ME intake[1] (kcal)	Carcass gain (kcal)	Caloric efficiency (E gain/ME intake)
	0.0	6,028.4±150.3[ab2]	2,239.2±101.6[ab]	0.37±0.02[abc]
17	1.5	6,273.7±182.7[a]	2,158.2±111.9[abc]	0.35±0.03[bc]
	3.0	5,804.6±131.8[b]	1,926.0± 75.9[bcd]	0.33±0.01[cd]
	0.0	5,784.9± 83.4[b]	2,437.6±122.6[a]	0.42±0.02[a]
20	1.5	5,766.8±259.2[b]	1,965.3±120.0[bcd]	0.34±0.01[bc]
	3.0	5,843.6± 50.8[ab]	2,315.0± 43.9[a]	0.40±0.01[ab]
	0.0	5,767.8± 14.1[b]	2,153.2± 65.3[abc]	0.37±0.01[abc]
23	1.5	5,932.3±156.4[ab]	1,683.9±130.7[d]	0.27±0.03[d]
	3.0	5,827.6± 43.0[ab]	2,257.6± 9.4[ab]	0.39±0.01[abc]
Among crude protein levels (%)				
17		6,035.6±103.4	2,107.8± 67.7[ab]	0.35±0.01[b]
20		5,798.4± 80.8	2,239.3± 87.3[a]	0.39±0.01[a]
23		5,842.5± 52.8	2,031.6± 97.8[b]	0.35±0.02[b]
Among thyroxine levels (mg/kg)				
0.0		5,860.4± 65.2	2,276.6± 65.1[a]	0.39±0.01[a]
1.5		5,990.9±126.4	1,935.8± 91.7[b]	0.32±0.01[b]
3.0		5,825.3± 43.0	2,166.2± 65.7[a]	0.37±0.01[a]
Probability (P);				
Crude protein		0.1161	0.0261	0.0261
Thyroxine		0.3344	0.0012	0.0006
Crude protein × thyroxine		0.4148	0.0073	0.0497

[1] Calculated value (ME intake = Feed consumption × ME value of experimental diets).
[2] Values are mean±SE; n = 3.
[a,b,c,d] Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

Among crude protein levels, 20% crude protein group was higher than any other group, and among thyroxine levels, no thyroxine supplemented group was increased in caloric efficiency. Also, Carcass gain was similar to caloric efficiency. Interaction between crude protein and thyroxine was shown to be significant ($p < 0.05$).

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