EFFECTS OF CIMATEROL (CL 263,780) ON GROWTH PERFORMANCE AND CARCASS QUALITY OF BROILERS FED ON DIFFERENT LEVELS OF DIETARY PROTEIN AND ENERGY

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Summary

The present study was carried out to investigate the effect of cimaterol on growth performance, carcass quality and cellular functional activity of broilers as affected by the various protein and energy levels. In starter period (0-21 days) all chicks were fed the basal diet which contained approximately 23 % crude protein and 3200 kcal of metabolizable energy per kg of diet. The cimaterol was added during 22-49 days and during the period of 8th week the cimaterol was withdrawn. In finisher period (22-49 days), a 2 × 2 × 3 factorial arrangement consisting of 2 levels of cimaterol (0 mg/kg, 0.25 mg/kg), 2 levels of protein (19%, 17%) and 3 levels of energy (3200, 2900, 2600 kcal/kg) was used. In the finisher period, the body weight gain and feed efficiency was improved by the supplementation of cimaterol. The high protein and high energy level with supplementation of cimaterol had showned the highest body weight gain and feed efficiency, without significant difference.

The administration of cimaterol had no effects on percentage of abdominal fat content, giblet and neck. Eventhough the difference was not significant ($p > 0.05$), carcass yield was improved slightly by the administration of cimaterol. The effect of cimaterol on carcass composition was clearly demonstrated that protein content of broilers was not increased ($p > 0.05$) but fat content decreased significantly ($p < 0.05$). The utilization of nutrients in experimental diets was not significantly affected by feeding cimaterol compared to control group. The results of *in vitro* studies with liver and adipose tissue showed that cimaterol increased the lipolytic activities at 19% protein level whereas at 17% protein level this effect was variable. Lipogenic activities in liver and adipose tissue were not affected with the administration of cimaterol but the activities increased as energy decreased, particularly in liver tissue. In cell studies with acinar culture of liver tissues, cimaterol had no effect on protein synthetic activity but the parameter was increased at higher level of dietary protein and energy. Protein secretion in liver was increased by the supplementation of cimaterol. In addition, at high protein level the protein secretion was increased and has shown the highest values at medium energy level.

(**Key Words**: Cimaterol, Growth Performance, Carcass Quality, Protein and Energy Levels, Lipolytic and Lipogenic Activity, Protein Synthesis and Secretion)

Introduction

A major problem facing the livestock and poultry industries is the production of carcasses containing excess fat. Researchers are actively paying attention to alter the partitioning of nutrients away from adipose tissue deposition and towards muscle accretion (Etherton and Mescrole, 1982), because greater great quantity of energy is required to produce 1 kg of adipose tissue than muscle (van Es, 1977) and consumers are prefe ring leaner meats.

Overly fat animals used feed less efficiently than leaner animals of the same weight and age (Washburn et al., 1975). Nutritional factors that have been shown to modulate fat deposition in broilers include dietary fat level (Deaton et al., 1981), energy: protein ratios (Edwards, 1980), water: feed ratios (Pesti and Marks, 1983; Marks, 1983), feed restriction (Arafa et al., 1983). Various chemical treatments have also been studied to change body composition. Recently, it has been shown that the dietary administration of beta-adrenergic agonists such as cimaterol and clenbuterol improves animal growth performance and carcass composition in various animals (Baker et al., 1984; Dalrymple et al., 1984a,b; Beerman

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et al., 1985; Emery et al., 1984; Jones et al., 1985). The beta agonists could increase the rate of muscle growth and depress adipose tissue growth (Ricks et al., 1984). These compounds increased the yield of body protein contents (Kim et al., 1987) without increased feed intake or changes in slaughter weight. The magnititude of the effect in broilers, however, was smaller than that of cattle, sheep and pigs. According to Dalrymple (1984a), female tended to be more responsive than male. This greater response of female may be due to the fact that generally female have more deposited fat than male.

The objective of this study was to investigate the effect of dietary cimaterol on growth performance, carcass quality and composition, nutrient utilization, lipolytic and lipogenic activity in liver and adipose tissue, protein synthetic activity in liver of broilers when fed diets containing different levels of dietary protein and energy.

Materials and Methods

To investigate the effects of cimaterol on growth performances, carcass quality and cellular functional activity of broilers fed various levels of dietary protein and energy, an experiment with $2 \times 2 \times 3$ factorial arrangement was conducted. In this study the dietary treatments contained 2 levels of cimaterol (0 mg/kg, 0.25 mg/kg), 2 levels of crude protein (19%, 17%) and 3 levels of metabolizable energy (3200 kcal/kg, 2900 kcal/kg, 2600 kcal/kg) during the growing period of 4-7 weeks of age. All treatments in this experiment had 6 replicates with 8 birds in each replicate. Animals used in the present study were broiler chicks of Maniker strain and a total of 576 male birds were used.

The basal diet of starting period (0-3 week) was a practical-type corn-soybean meal ration, which met or exceeded the nutrient requirement of the starting chicks (1984, NRC). The basal diet was formulated to contain approximatly 23% crude protein (N × 6.25) and 3200 kcal of metabolizable energy per kg of diet for the starting chicks of 0-3 weeks of age. The basal formula of finishing diet are shown in table 1. The first groups contained 19% crude protein (N × 6.25) and corresponding levels of metabolizable energy (3200 kcal, 2900 kcal, 2600 kcal) per kg of diet (table 1). The other contained 17% crude protein (N × 6.25) and the same various levels of energy described above (table 1). Cimaterol (0 mg/kg, 0.25 mg/kg) was administered for the period of 4-7 weeks and the last week was withdrawal period of the cimaterol.

All birds were raised in battery cages made of steel wire and housed in a room with 24 hours illumination and air ventilation. Three-days old chicks had been fed the same experimental diets and tap water *ad libitum* throughout the experimental periods. Chicks grouped to have similar initial body weight were distributed into the respective experimental groups. Body weight and feed intake were recorded at 21, 42 and 49 days to final weighing and slaughter. During feeding trial, mortality was recorded for each group. To determine the nutrients utilizability of the experimental diets, a metabolic trial was carried out by total collection method for 7 d at the termination of feeding trial. To evaluate the carcass composition, carcass sample collection was done as follows. At 49th day, all birds were weighted and four chicks per treatment were randomly picked and then crated separately. The selected birds were carried to the slaughter facility, and slaughtered in group by pen. Slaughter procedure consisted of stunning, decapitation, bleeding, scalding and defeathering. The individual weight and chemical analyses of the carcass, giblets, neck, tarsometatarsuses from the carcass sampling was done for evaluating the yield of edible carcass and analyzing moisture, crude protein, crude fat and crude ash contents.

Liver acinar culture

(1) Preparation of acinar cell

Immediately after liver tissue was obtained, the tissue was bathed in sterile Balanced Salts Solution (BSS) containing antibiotics and calf serum. Liver tissue was trimmed free of pieces of connective, lymph, adipose tissues and blood vessels and minced with sterile scissors to less than 5 mm in a solution of 400 U/ml of collagenase (Type I), 400 U/ml hyaluronidase (Type I), 5% (V/V) Fetal Bovine Serum (FBS) and 0.15% (V/V) trypsin in 1X Mineral Essential Media (MEM). The liver tissue was injected with the collagenase-hyaluronidase solution to aid dispersion. This tissue was dissociated with the

TABLE 1. FORMULA AND CHEMICAL COMPOSITION OF THE BASAL DIET FOR FINISHING BROILER CHICKS (4-7 WEEK, %)

Protein level (%)	19			17		
ME (Kcal/kg)	3200	2900	2600	3200	2900	2600
Ingredients;						
Corn, yellow	65.3	54.9	38.7	67.1	56.6	41.7
Soybean meal	23.7	22.3	20.6	21.8	18.9	15.8
Fish meal	4.5	3.5	2.5	2.2	2.0	1.8
Sorghum	2.3	3.8	4.7	4.8	4.9	4.5
Wheat bran	0.0	13.0	31.0	0.0	14.8	33.4
Tallow	1.7	0.0	0.0	1.3	0.0	0.0
Tricalcium phosphate	1.8	1.8	1.8	2.1	2.1	2.1
Vit-min. mix.[1]	0.3	0.3	0.3	0.3	0.3	0.3
Salt[2]	0.3	0.3	0.3	0.3	0.3	0.3
Antibiotics[3]	0.1	0.1	0.1	0.1	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0
Chemical composition;						
Energy (ME, kcal/kg)[4]	3200.0	2900.0	2600.0	3200.0	2900.0	2600.0
Crude protein (%)	19.0	19.0	19.0	17.0	17.0	17.0
Calcium (%)	0.9	0.9	0.9	0.9	0.9	0.9
Phosphorous (%)	0.8	0.8	0.9	0.8	0.9	0.9
Lysine (%)	1.0	1.0	1.0	0.9	0.9	0.9
Methionine (%)	0.3	0.3	0.3	0.3	0.3	0.3

[1] Vit-min. mixture contains followings in a kg: Vitamin A, 2,000,000 IU; Vitamin D, 400,000 IU; Vitamin E, 900 IU; Vitamin K, 200 mg; Thiamin 100 mg; Riboflavin, 1,200 mg; Vitamin B_6, 200 mg; Vitamin B_{12}, 1,500 mg; Pantothenate 1500 mg; Niacin, 2,000 mg; Folacin, 600 mg; Choline, 3,000 mg; Iron, 4,000 mg; Copper, 500 mg; Zinc, 9,000 mg; Iodine, 250 mg; Cobalt, 100 mg; Dried yeast, 20,000 mg.

[2] Refined table salt.

[3] Zinc-bacitracin.

[4] Calculated value.

collagenase-hyaluronidase solution for 3 hours at 37℃ by continuous stirring. The cells were centrifuged at 1,000 g at 4℃ for 5 minutes, washed twice in BSS and resuspended in 1X MEM. This cell suspension was filtered through four layers of cheese cloth. The cells were plated on plastic tissue culture dishes.

(2) Culture medium

The basic medium were used Eagle's MEM (1959) as modified by Smith et al. (1982). Glucose and bovine serum were added to 1X MEM to final concentrations of 0.2% (W/V) and 5% (V/V), respectively. Antibiotics (Penicillin 10,000 IU, Amphotericin-B 25 mcg, Streptomycin 10,000 IU per 100 ml media) were added to all media. The pH of the media was adjusted to 7.4 by addition of 7.5 % sodium bicarbonate. The isotopes used most frequently for labeling the cell culture were [^{3}H]-lysine. Routinely, 0.5 μCi of the tracer was added to 1 ml media for the purpose of determining *in vitro* synthesis of protein ([^{3}H]-lysine).

(3) Protein synthesis

Liver tissues were collected in sterile BSS with antibiotics at the time of killing. Acinar cells were isolated by collagenase solutions. Acinar suspensions were incubated in 1X MEM containing [^{3}H]-lysine (0.5 μCi/ml) for 18 hour in a 5% CO_2 atmosphere at 37℃. The specific activity (dpm/mg protein × 10) of secreted and retained protein was determined as described previously (Choi et al., 1988).

Determination of lipogenic and lipolytic activity

(1) Measurement of lipogenic activity

Tissues (adipose and liver tissues) were sliced with scissors. The amount of tissue slices per vial and time of incubation was 10-20 mg and 120 minutes. Tissue slices were incubated for 120 minutes at 37℃ in 3 ml of medium under a gaseous atmosphere of 5% CO_2 in O_2. The incubation medium (Krebs Ringer bicarbonate buffer) also contained. 25 mM HEPES (N-[2-Hydroxyethyl] piperazire-N'-[2-ethanesulforic acid]), 5.0 mM glucose, 3% bovine serum albumin and 0.5 μCi [^{14}C]-glucose. Incubations were terminated by placing vials on ice. After taking out tissue slices from medium, total lipids in the tissue slices were extracted by the method of Dole (1957). The extracts were dried. Radioactivity incorporated into total lipid slices was determined in a liquid scintillation counter (LS 100C).

(2) Measurement of lipolytic activity

Lipolytic activity was measured in Krebs-Ringer bicarbonate buffer (KRB) with one-half the indicated Ca^{2+}, containing 4% fatty-acid-poor Fraction V bovine serum albumin and 5.56 mM glucose. Incubations were terminated by placing vials on ice. The medium was filtered through cheese cloth to remove the tissue and stored at −20℃ until analysis. Non-esterified fatty acids in the medium were extracted and titrated according to method of Kelly (1965).

Chemical and stastical analyses

All the proximate analysis of obtained samples were conducted by AOAC (1984) methods. Analysis of variance was carried out and means were compared by Duncan' multiple test (Duncan, 1955) using Proc Anova Procedure of SAS (1985) package program with IBM-PC compatible computer.

Results and Discussion

Growth Performance

Effects of cimaterol when fed various dietary energy and protein levels on body weight gain, feed intake and feed efficiency in overall period (3-7 week) were summarized in table 2. The data presented in table 2 showed that the highest body weight gain was obtained from 19%-3200 kcal group of cimaterol added (1634 g) and the lowest body weight gain was found from low protein and energy group (17%-2600 kcal) without cimaterol (1198 g) ($p < 0.05$). With the protein levels, body weight gain obtained from 19% group was superior to that of 17% group. With regard to the dietary energy levels, significantly increased body weight gain was found as the energy levels in the diets increased. Between the cimaterol levels, the body weight gain of cimaterol-fed group (0.25 mg/kg) was higher than that of the control group. This results agreed with previous studies performed by many investigators. Dalrymple et al. (1984) and Hanrahan et al. (1986) reported that the feeding of cimaterol in broilers was found to increase the body weight gain. They also suggested that the administration of cimaterol should be less than 1 mg/kg in diets.

Feed intake was not significantly affected by the level of protein and energy and also addition of cimaterol. This results agreed with Kim et al. (1987a) who also found that the administration of cimaterol in diet did not change feed intake. However, Jones et al. (1985) and Moser et al. (1986) reported that the administration of cimaterol in diet depressed feed intake in swine.

Feed efficiency of 19%-3200 kcal group with cimaterol group was significantly ($p < 0.05$) better than other groups while in 17%-2600 kcal group with no cimaterol had shown poor responses. Present data revealed that when the dietary protein levels increased the feed efficiency was also improved. Energy levels was very important factor in deciding the feed efficiency. When the energy level was higher (3200 kcal/kg) the feed efficiency was significantly ($p < 0.05$) better than those of medium (2900 kcal/kg) or lower (2600 kcal/kg) energy groups.

Carcass Characteristics

The effect of cimaterol on carcass characteristics was presented in table 3. There were no significant differences ($p > 0.05$) among experimental groups in weight of giblet, neck, abdominal fat, live weight, carcass weight and carcass yield with the administration of cimaterol. These results were similar to previous data of Dalrymple et al. (1984) who also found that in males the administration of cimaterol had no effect on abdominal fat content significantly. Eventhough

TABLE 2. EFFECT OF CIMATEROL ON BODY WEIGHT GAIN, FEED INTAKE AND FEED EFFICIENCY IN BROILERS FED VARIOUS ENERGY AND PROTEIN LEVELS (4-7 week)

Treatment	4th week weight (g)	7th week weight (g)	Body weight gain (g)	Feed intake (g)	Feed efficiency
19-3200 C[1]	399.5[NS3]	2034.4[a2]	1634.9[a]	3200.2[ab]	1.97[e]
19-2900-C	400.2[NS]	1771.0[cd]	1370.8[cd]	3162.1[ab]	2.31[abcd]
19-2600-C	400.7[NS]	1771.5[cd]	1370.8[cd]	3354.0[a]	2.45[ab]
17-3200-C	399.8[NS]	1896.7[abc]	1496.9[abc]	3315.3[a]	2.22[bcde]
17-2900-C	401.4[NS]	1792.0[cd]	1390.6[bcd]	3248.2[ab]	2.35[abcd]
17-2600-C	401.0[NS]	1691.7[de]	1290.7[de]	3125.1[ab]	2.48[ab]
19-3200	400.2[NS]	1935.8[ab]	1534.7[ab]	3205.8[ab]	2.09[de]
19-2900	399.6[NS]	1771.9[cd]	1372.3[cd]	3206.4[ab]	2.34[abcd]
19-2600	400.0[NS]	1754.8[cd]	1354.8[cd]	3303.3[a]	2.44[ab]
17-3200	402.7[NS]	1893.3[abc]	1490.6[abc]	3145.0[ab]	2.11[cde]
17 2900	399.6[NS]	1816.3[bcd]	1416.7[bcd]	3373.2[a]	2.39[abc]
17-2600	401.1[NS]	1599.2[e]	1198.1[e]	2987.7[b]	2.52[a]
Between protein levels					
19%		1839.9[a]	1439.6[a]	3238.6[a]	2.27[a]
17%		1781.5[b]	1380.6[b]	3199.1[a]	2.34[a]
Between energy levels					
3200 kcal		1940.0[a]	1539.3[a]	3193.6[a]	2.10[c]
2900 kcal		1787.8[b]	1387.6[b]	3247.5[a]	2.35[b]
2600 kcal		1704.3[c]	1303.5[c]	3216.6[a]	2.47[a]
Between cimaterol treatments					
0.25 mg/kg		1826.2[a]	1425.7[a]	3234.2[a]	2.30[a]
0 mg/kg		1795.2[a]	1398.5[a]	3203.6[a]	2.31[a]

[1] C added cimaterol.
[2] Mean values with different letters within the same column are significantly different ($p < 0.05$).
[3] NS means non-significant.

the difference was not significant ($p > 0.05$) carcass yield improved slightly with the administration of cimaterol. Among the protein levels there was no significant differences in all items except neck weight which was heavier with the increase of protein level. Among energy levels, carcass yield was higher in 2900 kcal/kg group than the others. Neck weight and abdominal fat decreased when the energy level decreased.

Carcass Composition

It had been known that the administration of cimaterol had an remarkable effect on the carcass composition such as protein and fat contents. The effect of cimaterol on carcass composition was summarized in table 4. Chemical analysis of carcass demonstrated that the administration of cimaterol did not affect the protein content but decreased the fat content significantly ($p < 0.05$).

Ash content also significantly ($p < 0.05$) decreased in cimaterol-fed group. And protein level did not affect the carcass composition ($p > 0.05$) protein contents of carcass were found to be high in medium energy group (2900 kcal) but fat contents were higher when dietary energy levels was increased. Moisture content showed no trend with energy levels. In contrast to these results, Dalrymple et al. (1984) and Ricks et al. (1983) reported that water content in carcasses associated with the protein content.

TABLE 3. EFFECT OF DIETARY CIMATEROL AT THE VARIOUS PROTEIN AND ENERGY LEVELS ON GIBLET, NECK, ABDOMINAL FAT AND CARCASS YIELD (% OF LIVE WEIGHT)

Treatment	Giblet	Neck	Abdominal fat	Carcass yield
19-3200-C[1]	4.1 ± 0.3^{bc23}	4.5 ± 0.2^{a}	2.7 ± 1.2^{a}	68.3 ± 1.0^{ab}
19-2900-C	4.0 ± 0.2^{c}	4.4 ± 0.6^{ab}	2.2 ± 0.4^{ab}	69.2 ± 2.6^{a}
19-2600-C	4.8 ± 0.6^{a}	$4.8 + 0.8^{c}$	$1.4 + 0.4^{b}$	67.3 ± 1.2^{ab}
17-3200-C	4.3 ± 0.2^{abc}	4.5 ± 0.7^{ab}	2.2 ± 0.8^{ab}	66.8 ± 1.7^{ab}
17-2900-C	4.1 ± 0.1^{bc}	4.2 ± 0.3^{ab}	1.7 ± 0.3^{ab}	68.4 ± 2.2^{ab}
17-2600-C	$4.5 + 0.4^{abc}$	4.2 ± 0.4^{ab}	1.4 ± 0.7^{b}	67.6 ± 2.0^{ab}
19-3200	4.5 ± 0.3^{abc}	4.7 ± 0.4^{a}	2.1 ± 0.5^{ab}	67.1 ± 0.4^{ab}
19-2900	4.4 ± 0.5^{abc}	4.3 ± 0.2^{ab}	2.1 ± 0.9^{ab}	67.7 ± 2.3^{ab}
19-2600	$4.8 + 0.6^{a}$	4.3 ± 0.7^{ab}	1.8 ± 0.8^{ab}	65.6 ± 2.9^{b}
17-3200	4.1 ± 0.5^{bc}	3.7 ± 0.2^{b}	2.2 ± 1.0^{ab}	$69.6 + 1.7^{a}$
17-2900	4.0 ± 0.1^{c}	4.2 ± 0.5^{ab}	2.1 ± 0.6^{ab}	68.2 ± 0.6^{ab}
17-2600	4.6 ± 0.3^{ab}	4.0 ± 0.4^{ab}	1.0 ± 0.7^{b}	67.2 ± 0.7^{ab}
Between protein levels				
19%	4.4 ± 0.5^{a}	4.5 ± 0.5^{a}	2.0 ± 0.8^{a}	67.5 ± 2.1^{a}
17%	4.3 ± 0.3^{a}	4.1 ± 0.5^{b}	1.8 ± 0.8^{a}	67.9 ± 1.7^{a}
Between energy levels				
3200 kcal	4.2 ± 0.3^{b}	4.3 ± 0.6^{a}	2.3 ± 0.9^{a}	67.9 ± 1.6^{ab}
2900 kcal	$4.1 + 0.3^{b}$	4.3 ± 0.4^{a}	2.0 ± 0.6^{a}	68.4 ± 2.0^{a}
2600 kcal	4.7 ± 0.4^{a}	$4.3 + 0.6^{a}$	$1.4 + 0.7^{b}$	66.9 ± 1.9^{b}
Between cimaterol treatments				
0.25 mg/kg	4.3 ± 0.4^{a}	4.4 ± 0.5^{a}	1.9 ± 0.8^{a}	67.9 ± 1.9^{a}
0 mg/kg	4.2 ± 0.5^{a}	$1.9 + 0.8^{a}$	1.9 ± 0.8^{a}	67.5 ± 2.0^{a}

[1] C: added cimaterol.
[2] Mean values with different letters within the same column are significantly different ($p < 0.05$).
[3] Values are means±SD.

Nutrient Utilization

The effect of dietary energy and protein levels on the utilization of the dry matter, protein, fat, total carbohydrate were summarized in table 5. Dry matter utilization was not affected by the administration of cimaterol and protein levels. Dry matter utilization tended to increase with dietary energy levels ($p < 0.05$). Protein utilization was not affected by the administration of cimaterol or dietary protein and energy levels except of 2600 kcal/kg group. Similar results were also reported by Kim et al. (1987a) that the improvement in dietary protein content did not affect the protein digestibility. Fat utilization and total carbohydrate was not affected by administration of cimaterol ($p > 0.05$).

Lipolytic Activity and Lipogenic Activity

Effects of cimaterol on lipolytic and lipogenic activity in liver and adipose tissue were compared in table 6. Lipolytic activity was found to be increased with the administration of cimaterol in liver tissue and adipose tissue at all energy levels of 19% protein level but at 17% protein level, this effects were reverse. These probably could be explained by the fact that at low protein level, the lipolytic activity could not be increased as the broiler's body used protein and energy for the body maintainance.

The lipogenic activity in the liver tissue when administered cimaterol at 19% protein level indicated that the activities declined as dietary level of energy decreased and also the same tendency was found in untreated diet with exception of

TABLE 4. EFFECT OF DIETARY CIMATEROL AT THE VARIOUS PROTEIN AND ENERGY LEVELS ON THE CARCASS COMPOSITION OF BROILERS (%)

Treatment	Moisture	Protein	Fat	Ash
19-3200-C[1]	65.1 ± 2.7[b2)]	18.8 ± 1.0[abc]	14.3 + 3.4[a]	0.9 + 0.2[ab]
19-2900-C	67.3 ± 4.7[ab]	18.5 ± 1.2[abc]	11.8 ± 3.7[abc]	0.7 ± 0.3[b]
19-2600-C	70.6 ± 2.5[a]	18.2 ± 2.2[abc]	9.6 ± 2.0[bcd]	0.9 ± 0.1[ab]
17-3200-C	68.0 ± 5.5[ab]	20.0 ± 1.6[a]	8.3 ± 3.1[cd]	0.9 ± 0.3[ab]
17 2900-C	69.0 ± 3.0[ab]	18.4 + 1.3[abc]	12.5 ± 2.5[ab]	0.9 ± 0.2[ab]
17-2600-C	70.7 ± 2.6[a]	19.1 ± 1.3[abc]	8.4 ± 1.9[cd]	0.8 ± 0.4[ab]
19-3200	67.0 ± 5.2[ab]	18.3 ± 2.2[abc]	14.3 ± 3.9[a]	0.9 ± 0.3[ab]
19 2900	70.6 ± 3.6[a]	17.4 + 2.0[c]	13.7 ± 4.7[a]	1.0 ± 1.3[ab]
19-2600	70.2 ± 2.5[a]	19.3 ± 0.8[ab]	7.3 ± 2.4[d]	1.3 ± 1.1[ab]
17-3200	68.4 ± 2.9[ab]	17.9 ± 1.6[b]	12.1 ± 4.3[abc]	0.8 ± 0.2[ab]
17-2900	68.6 ± 3.6[ab]	17.6 + 1.3[b]	14.4 ± 6.0[a]	1.1 ± 0.3[ab]
17-2600	69.8 ± 2.4[a]	19.1 ± 1.2[abc]	12.2 ± 3.4[abc]	1.5 ± 0.7[a]
Between protein levels				
19%	68.5 + 4.1[a]	18.4 ± 1.7[a]	11.8 ± 4.2[a]	0.9 ± 0.7[a]
17%	69.1 ± 3.4[a]	18.7 ± 1.6[a]	11.3 ± 4.2[a]	1.0 ± 0.4[a]
Between energy levels				
3200 kcal	67.1 ± 4.2[b]	18.7 ± 1.8[a]	13.1 ± 4.3[a]	0.9 ± 0.2[a]
2900 kcal	68.9 ± 3.8[b]	18.0 ± 1.5[b]	12.3 ± 4.3[a]	0.9 ± 0.7[a]
2600 kcal	70.3 ± 2.4[a]	18.8 ± 1.4[a]	9.4 ± 3.0[b]	1.1 ± 0.7[a]
Between cimaterol treatments				
0.25 mg/kg	68.5 ± 4.0[a]	18.8 ± 1.5[a]	10.8 ± 3.5[b]	0.8 ± 0.3[b]
0 mg/kg	69.1 ± 3.5[a]	18.3 ± 1.7[a]	12.3 ± 4.7[a]	1.1 ± 0.8[a]

[1] C: added cimaterol.
[2] Mean values with different letters within the same column are significantly different ($p < 0.05$).
[3] Values are means+SD.

2600 kcal level. At 17% protein level, the activities were varied in values. However, the activities were greater at 19% protein than that at 17% protein level of either treated or untreated with cimaterol. Mostly, in liver tissue, the activities were found to be greater than in adipose tissue with exception of 2600 kcal energy at 19% protein level. In addition, at 17% protein level, mostly, the activities were higher in liver tissue with an exception of 3200 kcal energy group which was found to be high. It indicated that either at high or low protein level the high activities occured in liver tissue than adipose tissue, with the particular suggestion that at 2600 kcal energy and 19% protein level, the adipose tissue had more activities than in liver tissue when added cimaterol. In conclusion, the decreasing of fat contents in broilers with the administration of cimaterol (table 9) was due to the increment of lipolysis rather than by inhibiting lipogenesis. In addition, in cimaterol fed on 3200 kcal energy group at 19 % protein level, either lipogenic or lipolytic activity were highel than others, this tendancy probably due to excessively high energy and protein in the diet (table 4). There were many reports that administration of beta-adrenergic agonist did not alter *in vivo* fatty acid synthesis, and agreed with the present study. Eadara et al. (1986, 1987) reported that feeding cimaterol to growing rats did not change lipogenesis in liver and adipose tissues. Yang and Firman (1986) also showed that L-640,033 fed to rats had no effect on lipogenesis in the epididymal fat pad.

TABLE 5. EFFECT OF DIETARY CIMATEROL AT THE VARIOUS PROTEIN AND ENERGY LEVELS ON THE NUTRIENTS UTILIZATION OF BROILERS (%)

Treatment	Dry matter	Protein	Fat	Total carbohydrate
19-3200-C[1]	77.6 ± 2.8[a a]	69.7 ± 3.2[NS 3]	81.2 ± 9.9[a b]	84.5 ± 2.7[a]
19-2900-C	74.5 ± 5.1[a b c]	78.9 ± 5.2[NS]	77.5 ± 3.8[a b]	77.8 ± 4.5[c d]
19-2600-C	65.8 ± 4.1[d]	64.6 ± 8.1[NS]	74.6 ± 4.0[b]	70.9 ± 1.9[e]
17-3200-C	78.4 ± 1.9[a]	70.7 ± 14.7[NS]	81.7 ± 2.0[a b]	85.7 ± 1.6[a]
17-2900-C	72.5 ± 0.5[a b c d]	72.0 ± 6.7[NS]	77.2 ± 3.1[a b]	77.5 ± 1.7[c d]
17-2600-C	68.4 ± 10.4[b c d]	64.1 ± 14.0[NS]	83.7 ± 4.0[a]	69.8 ± 4.2[e]
19-3200	76.9 ± 3.9[a b]	70.8 ± 7.1[NS]	83.0 ± 5.0[a b]	83.6 ± 1.6[a b]
19-2900	73.1 ± 1.8[a b c d]	70.6 ± 8.6[NS]	81.1 ± 2.0[a b]	79.4 ± 1.4[b c]
19-2600	68.4 ± 1.9[b c d]	62.0 ± 10.4[NS]	81.6 ± 4.2[a b]	74.3 ± 1.9[d e]
17-3200	78.8 ± 2.2[a]	74.7 ± 6.1[NS]	83.4 ± 4.0[a]	84.3 ± 1.2[a]
17-2900	75.3 ± 5.1[a b c]	67.8 ± 11.9[NS]	84.1 ± 2.1[a]	81.7 ± 2.4[a b c]
17-2600	67.0 ± 5.0[c d]	61.7 ± 12.0[NS]	80.2 ± 1.0[a b]	73.5 ± 3.0[d e]
Between protein levels				
19%	72.7 ± 5.3[a]	69.4 ± 8.3[a]	79.8 ± 5.4[a]	78.4 ± 5.4[a]
17%	73.4 ± 6.5[a]	68.5 ± 10.6[a]	81.6 ± 3.5[a]	78.7 ± 6.2[a]
Between energy levels				
3200 kcal	77.9 ± 2.5[a]	72.3 ± 8.4[a]	82.3 ± 5.2[a]	84.5 ± 1.8[a]
2900 kcal	73.9 ± 3.4[b]	71.5 ± 7.8[a]	80.0 ± 4.7[a]	84.5 ± 1.8[b]
2600 kcal	67.4 ± 5.4[c]	63.1 ± 9.7[b]	80.0 ± 3.9[a]	72.1 ± 3.1[c]
Between cimaterol treatments				
0.25 mg/kg	73.2 ± 5.4[a]	70.0 ± 9.6[a]	82.2 ± 3.2[a]	77.7 ± 6.7[a]
0 mg/kg	72.9 ± 6.4[a]	67.9 ± 9.4[a]	79.3 ± 5.4[a]	79.4 ± 4.6[a]

[1] C: added cimaterol.
[2] Mean values with different letters within the same column are significantly different ($p < 0.05$).
[3] NS means non-significant.
[4] Values are means±SD.

Retained Protein and Secreted Protein

Effects of cimaterol at the various protein and energy levels on retained and secreted protein in acinar culture of broiler were presented in table 7. Retained protein with the administration of cimaterol varied in values compared to untreated groups. The value found in 19 % protein at 3200 kcal energy level seems rather high, probably indicate that cimaterol affects to the retention of muscle protein when the diet contains high protein and energy level. The amount of secreted protein increased when fed cimaterol. It was surprising that at 2900 kcal energy groups showed high values in all protein levels with an exception of 17% protein group. In addition, at 19% protein levels the amount of secreted protein were higher than that of 17% protein level which was due to excess protein contents in the diets. It was concluded that the amount of secreted protein was affected by protein levels rather than energy levels. Certainly, the degradation of protein at 3200 kcal energy level was higher than that of 2600 kcal energy in all treatments. Both the amount of retained and secreted protein increased with the administration of cimaterol, thus providing that there was no effect on protein metabolism by adding beta-agonist. According to Forsberg et al. (1986) and Roeder et al. (1987), cimaterol had no effect on protein synthesis which was similar to present study showing irregular values among treatments. It was not clear if beta-agonists affected muscle protein metabolism directly via a receptor mediated event, or indirectly via other hormonal effectors.

TABLE 6. EFFECT OF DIETARY CIMATEROL AT THE VARIOUS PROTEIN AND ENERGY LEVELS ON LIPOLYTIC AND LIPOGENIC ACTIVITY IN LIVER AND ADIPOSE TISSUE INCUBATED *IN VITRO*.[1]

Treatment	Lipolytic activity[2]		Lipogenic activity[3]	
	Liver	Adipose	Liver	Adipose
19-3200-C	5.15	6.04	298.79	211.62
19-2900-C	4.53	5.39	231.42	90.47
19-2600-C	4.77	5.98	203.52	239.20
17-3200 C	4.27	4.11	191.43	805.42
17-2900-C	4.71	4.04	239.85	114.22
17-2600-C	3.77	4.81	166.96	125.27
19 3200	4.51	5.78	223.93	69.52
19-2900	4.28	5.15	194.04	96.15
19-2600	4.61	5.17	498.01	100.82
17-3200	5.00	4.97	215.91	82.55
17-2900	4.89	5.56	174.18	87.01
17-2600	4.43	4.01	156.57	103.67

[1] Each value represents the mean of four determinations.
[2] μeq nonesterified fatty acid (NEFA) released mg/cell in 120 minutes.
[3] n mole glucose incorporated into total lipid mg/cell in 120 minutes.

TABLE 7. EFFECTS OF DIETARY CIMATEROL AT THE VARIOUS PROTEIN AND ENERGY LEVELS ON RETAINED PROTEIN AND SECRETED PROTEIN IN ACINAR CULTURE OF BROILER LIVER.[1]

Treatment	Retained protein[2] (dpm/mg $\times 10^2$ protein)	Secreted protein[3] (dpm/mg $\times 10^2$ protein)
19 3200 C	46.49	4.18
19-2900-C	13.89	4.63
19-2600-C	8.79	3.07
17-3200-C	11.91	3.03
17-2900-C	24.64	4.20
17-2600-C	20.04	2.13
19-3200	21.02	3.97
19-2900	19.43	4.85
19-2600	32.36	3.17
17-3200	20.59	2.96
17-2900	14.20	0.90
17-2600	20.21	1.30

[1] Acinar cells from liver were plated and incubated for 18 hours in the medium; Each value represents the mean of four determinations (4 culture dishes/determination).
[2] The amount of retained protein was determined by the incorporation of [^{3}H]-lysine (0.5 μCi/ml) into acini.
[3] The amount of secreted protein was determined by the incorporation of [^{3}H]-lysine (0.5 μCi/ml) into TCA-insoluble material.

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