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Effect of Different Levels of Dietary Fat on Broiler Performance and Production Cost with Emphasis on Calcium and Phosphorus Absorption

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Abstract: This experiment was conducted to investigate the effect of different levels of dietary fat on performance of broiler (Ross 308 strain) with emphasis on calcium (Ca) and phosphorus (P) absorption during a 56 days rearing period. A total of 360 1-day-old chicks randomly assigned to eight experiment groups, three replicates of 10 birds each. The birds with a 4 × 2 factorial design received either four levels of fat (0, 2, 4 and 6% of diet) or two levels of Ca (1 or 2 % of diet). Results showed that administration of different fat levels to broiler diets significantly ($P< 0.01$) increased food intake (FI), feed efficiency (FE), carcass weight (CW), abdominal fat (AF) and diet cost (DC). From the results of the present study, it was concluded that a combination of 2% of animal fat and 1 or 2 % of Ca provides the greatest performance in broiler chickens and this combination can be considered as a advantageous management practice in Ross 308 strains diets, with improving the Ca and P absorption; however, higher levels of fat intake may decrease absorption percentage.

Key words: Fat · Calcium · Phosphorus · Performance · Broiler chicks

INTERODUCTION

Growth performance of broilers can be affected by different fat origins supplemented to diets [1]. The effects of varying the dietary Ca and available phosphorus (AP) on chickens performance and Ca metabolism has been the topic of continuing research [2, 3]. Shafy and McDonal [2, 4] reported that increasing dietary calcium caused a defect in absorption of other minerals, particularly magnesium, manganese and zinc. Calcium react with fat in the digestive tract resulting in the formation of Ca soaps which are excreted [5, 6, 7]. The formation of insoluble soaps from divalent cations and fatty acids is an important aspect of poultry nutrition because it influences both fatty acid metabolism and availability of Ca. Hence, when adding fat to poultry diet is essential therefore, adding calcium to the dietary fat is essential for better efficiency on poultry performance. Inclusion of appropriate levels of calcium and phosphorus to diets improved feed conversion and weight gain in birds than groups had Ca shortage, which high calcium diet could reduced food intake, weight loss and delayed sexual maturation in broiler chickens [8].

The objective of presented experiment was evaluation of effect of different levels of animal fat on broiler performance with emphasis on calcium and phosphorus absorption.

MATERIALS AND METHODS

Birds and Diets: A total of 360 one-day-old broiler chicks [10] were used in the study. The birds were randomly assigned, according to their initial body weights, to eight treatment groups, three replicates of 15 birds each. The birds received a diet with either four levels of fat (beef tallow) (0, 2, 4 and 6% of diet) or two levels of Ca (1 or 2 % of diet) in a 4 × 2 factorial arrangement. Based on different levels of fat and Ca, diets of eight experimental treatments formulated using the UFFDA program [10]. Beef tallow and calcium were obtained from Iranian commercial companies.

The birds were fed a starter diet until 21 days of age, followed by a grower diet from day 21 to day 42 and finally a finishing diet from day 42 to day 56. Ingredients and chemical compositions of the diet are shown in Tables 1, 2, 3. The diets were formulated using NRC

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Table 1: Diet ingredients in starter period

Ingredients (%)	1[1]	2	3	4	5	6	7	8
Yellow corn	62.69	62.30	53.57	56.00	50.00	50.00	40.44	43.19
Soybean meal	30.33	30.00	31.00	30.31	30.88	32.00	30.58	32.89
Fish meal	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Beef tallow	0.00	0.00	2.00	2.00	4.00	4.00	6.00	6.00
Barley	0.00	0.00	7.00	3.00	3.85	5.00	10.00	7.77
Wheat bran	0.00	0.00	0.00	0.00	4.80	0.00	6.50	0.00
Dicalcium phosphate	1.50	4.10	1.29	4.11	1.29	4.00	1.23	3.60
Oyster shell	1.09	2.10	1.23	2.20	1.22	2.18	1.26	2.53
Salt	0.36	0.30	0.36	0.36	0.36	0.36	0.36	0.36
Vitamin/mineral premix[2]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Lysine	0.20	0.00	0.05	0.00	0.00	0.00	0.00	0.00
DL-Methionine	0.30	0.30	0.10	0.30	0.10	0.30	0.11	0.11
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutrient content								
ME[3] (Kcal/kg)	2900.00	2900.00	2900.00	2900.00	2900.00	2900.00	2900.00	2900.00
Crude protein (%)	20.85	20.85	20.85	20.85	20.85	20.85	20.85	20.85
Calcium (%)	1.00	2.00	1.00	2.00	1.00	2.00	1.00	2.00
Available P (%)	0.50	1.00	0.50	1.00	0.50	1.00	0.50	1.00
Sodium (%)	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Crude fiber (%)	3.50	3.40	3.70	3.60	4.00	3.60	4.30	3.70
Price of 1 kg diet (Rials)	2170.00	2160.00	2040.00	2120.00	1980.00	2110.00	1920.00	2020.00

[1] Treatments of 1,3,5 and 7 are considered for 1% calcium level and Treatments of 2, 4, 6 and 8 used for 2% Ca levels. [2]Composition of vitamin and trace element premix was as follows per kilogram of premix: vitamin A, 9,000,000 IU; vitamin D3, 2,000,000 IU; vitamin B1, 1,800 mg; vitamin B2, 6,600 mg; vitamin B3, 10,000 mg; vitamin B6, 3,000 mg; vitamin B12,15 mg; vitamin E, 18,000 mg; vitamin K3, 2,000 mg; vitamin B9, 1,000 mg; vitamin B5, 30,000 mg; vitamin H2, 100 mg; folic acid, 21 mg; nicotinic acid, 65 mg; biotin, 14 mg; choline chloride, 500,000 mg; Mn, 100,000 mg; Zn, 85,000 mg; Fe, 50,000 mg; Cu, 10,000 mg; I, 1,000 mg; Se, 200 mg. [3] ME= metabolizable energy

Table 2: Diet ingredients in grower period

Ingredients (%)	1[1]	2	3	4	5	6	7	8
Yellow corn	64.14	66.59	58.64	62.41	46.57	51.16	41.00	45.62
Soybean meal	21.24	22.02	20.96	23.34	20.65	23.10	20.40	22.75
Fish meal	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Beef tallow	0.00	0.00	2.00	2.00	4.00	4.00	6.00	6.00
Barley	5.00	0.00	5.00	1.27	15.00	10.00	15.00	10.00
Wheat bran	2.36	0.00	6.20	0.00	6.61	0.84	10.40	40.68
Dicalcium phosphate	1.40	4.12	1.40	4.10	1.35	4.07	1.33	4.06
Oyster shell	1.07	2.14	1.07	2.14	1.09	2.15	1.09	2.15
Salt	0.22	0.21	0.22	0.22	0.21	0.22	0.21	0.22
Vitamin/mineral premix[2]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Lysine	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00
DL-Methionine	0.01	0.08	0.02	0.02	0.02	0.02	0.02	0.02
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutrient content								
ME[3] (Kcal/kg)	2900.00	2900.00	2900.00	2900.00	2900.00	2900.00	2900.00	2900.00
Crude protein (%)	18.12	18.12	18.12	18.12	18.12	18.12	18.12	18.12
Calcium (%)	1.00	2.00	1.00	2.00	1.00	2.00	1.00	2.00
Available P (%)	0.50	1.00	0.50	1.00	0.50	1.00	0.50	1.00
Sodium (%)	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Crude fiber (%)	3.40	3.00	3.17	3.10	4.00	3.40	4.30	3.70
Price of 1 kg diet (Rials)	1930.00	2100.00	1880.00	1990.00	1820.00	1930.00	1770.00	1880.00

[1] Treatments of 1,3,5 and 7 are considered for 1% calcium level and Treatments of 2, 4, 6 and 8 used for 2% Ca levels. [2]Composition of vitamin and trace element premix was as follows per kilogram of premix: vitamin A, 9,000,000 IU; vitamin D3, 2,000,000 IU; vitamin B1, 1,800 mg; vitamin B2, 6,600 mg; vitamin B3, 10,000 mg; vitamin B6, 3,000 mg; vitamin B12,15 mg; vitamin E, 18,000 mg; vitamin K3, 2,000 mg; vitamin B9, 1,000 mg; vitamin B5, 30,000 mg; vitamin H2, 100 mg; folic acid, 21 mg; nicotinic acid, 65 mg; biotin, 14 mg; choline chloride, 500,000 mg; Mn, 100,000 mg; Zn, 85,000 mg; Fe, 50,000 mg; Cu, 10,000 mg; I, 1,000 mg; Se, 200 mg. [3] ME= metabolizable energy

Table 3: Diet ingredients in finisher period

Ingredients (%)	1[1]	2	3	4	5	6	7	8
Yellow corn	66.90	69.80	58.74	60.97	49.28	56.00	43.74	48.33
Soybean meal	17.19	19.23	16.90	19.27	16.30	19.00	16.34	18.72
Fish meal	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Beef tallow	0.00	0.00	2.00	2.00	4.00	4.00	6.00	6.00
Barley	5.00	0.50	9.00	7.63	15.00	6.74	15.00	10.00
Wheat bran	4.53	0.32	7.00	0.00	8.76	4.14	12.60	6.85
Dicalcium phosphate	1.40	4.12	1.40	4.10	1.35	4.07	1.33	4.06
Oyster shell	1.13	2.19	1.13	2.2	1.15	2.20	1.15	2.21
Salt	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Vitamin/mineral premix[2]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Lysine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DL-Methionine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutrient content								
ME[3] (Kcal/kg)	2900.00	2900.00	2900.00	2900.00	2900.00	2900.00	2900.00	2900.00
Crude protein (%)	16.30	16.30	16.30	16.30	16.30	16.30	16.30	16.30
Calcium (%)	1.00	2.00	1.00	2.00	1.00	2.00	1.00	2.00
Available P (%)	0.50	1.00	0.50	1.00	0.50	1.00	0.50	1.00
Sodium (%)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Crude fiber (%)	3.40	3.00	3. 7	3.10	4.00	3.40	4.30	3.60
Price of 1 kg diet (Rials)	1790.00	1890.00	1740.00	1850.00	1680.00	1800.00	1640.00	1750.00

[1] Treatments of 1,3,5 and 7 are considered for 1% calcium level and Treatments of 2, 4, 6 and 8 used for 2% Ca levels. [2]Composition of vitamin and trace element premix was as follows per kilogram of premix: vitamin A, 9,000,000 IU; vitamin D3, 2,000,000 IU; vitamin B1, 1,800 mg; vitamin B2, 6,600 mg; vitamin B3, 10,000 mg; vitamin B6, 3,000 mg; vitamin B12,15 mg; vitamin E, 18,000 mg; vitamin K3, 2,000 mg; vitamin B9, 1,000 mg; vitamin B5, 30,000 mg; vitamin H2, 100 mg; folic acid, 21 mg; nicotinic acid, 65 mg; biotin, 14 mg; choline chloride, 500,000 mg; Mn, 100,000 mg; Zn, 85,000 mg; Fe, 50,000 mg; Cu, 10,000 mg; I, 1,000 mg; Se, 200 mg. [3] ME= metabolizable energy

guidelines [11] and contained 20.85, 18.12 and 16.30% (starter, grower and finisher periods, respectively) protein and 12.11 MJ/kg (2900 kcal/kg) ME. Small amounts of the basal diet were first mixed with the respective amounts of calcium as a small batch, with a larger amount of the basal diet until the total amount of the respective diets were homogeneously mixed. The diets and fresh water were offered *ad libitum*.

Housing and Measurement: The experiment was conducted between 29 July and 23 September. At weekly intervals, feed intake and body weight were determined on group basis as replicates of each treatment. Body weight gain and feed efficiency of groups were then calculated. Food consumption for each replicate group was measured weekly.

At the end of the experiment, 12 birds (2 hens and 2 roosters of each cage) from each treatment group were randomly slaughtered for evaluation of carcass quality. The birds were not fasted before slaughter and carcasses were cleaned thoroughly, feathers (wet), feet and visceral organs were removed. Cold carcass weights were calculated after carcasses were kept at + 4°C for 18 h. Cold carcass yield was calculated as cold carcass weights divided by body weights at slaughter. Abdominal fat was removed, weighed and calculated based on carcass percentage. The results in the current study presented as a mean of both sex of birds.

Formulated diet and production costs were calculated according to the diet components and meat costs based on the Iranian markets.

Although, exact estimation of production cost from the markets was difficult because of more fluctuations in food prices, but it could be expected that the price of fat sources and also cost of fixed amount of energy supplied per kg of fat was cheaper than other sources.

The cost for feed intake per kg live weight for each of the experimental units was estimated by the following formula:

Feed Cost per Kg Live Weight: (C1×F1) + (C2×F2) + (C3×F3) / W1 + W 2 + W 3

C 1 = Cost per kg diet starter period.
C 2 = Cost per kg of diet during growing period.
C 3 = Cost per kg final diet period.
F 1 = FCR starter period.
F 2 = FCR growth period.
F = FCR final period.
W 1 = Initial period of weight gain.
W 2 = Weight growth period.
W 3 = Weight gain final period.

Unit cost of feed intake is based on Iranian Rial (IRR). For example for converting costs: 1 united state dollar (USD) in 2010 = 10500 ± 500 IRR.

Statistical Analysis: The data were analyzed by MSTAT-C statistical software [12] with fat and Ca as main effects.

RESULTS

A 2% dietary fat compared with that of other beef tallow levels resulted in a higher feed intake (P< 0.05), body weight change and feed efficiency (P< 0.01) (Table 4). Higher dietary Ca inclusions (1 vs. 2 % of diet) had not significant effect on improving FI, CW and FE (P>0.05). The interaction between Fat and Ca for feed intake, final body weight gain and feed efficiency was not significant.

Carcass weight improved to a higher extent by increasing dietary fat, but not changed when a higher dietary Ca level was fed. Feed efficiency significantly decreased to a lower extent by increasing dietary fat and the decline was not significant when a higher Ca level was fed.

Both dietary fat and Ca had significant (P<0.01) effects on abdominal fat measured at the end of the present study (Table 4). Abdominal fat content increased by both fat and Ca levels and higher AF was detected in 2% dietary fat group. The diet cost decreased by inclusion of both beef tallow and Ca to broiler diets when the price of a kg of various diet components was estimated by calculating the production cost of 1 kg weight gain, using food prices in the different markets. The interaction between Fat and Ca for diet cost was significant (P<0.05) and for abdominal fat was nearly significant (P=0.06).

The results showed that administration of different fat levels to broiler diets significantly increased feed intake (FI), feed efficiency (FE), carcass weight (CW), abdominal fat (AF), diet cost (DC) and also on Ca and P percentages of plasma, bone and ash (P<0.01) with the exception of bone ash (BA) percentage that was not significant. Inclusion of calcium levels on dietary fat significantly increased BWG, DC and Ca and P percentages of bone and ash (P< 0.01) and not significantly affected other mentioned parameters. There were no interactions detected for FI, FE, AF, BWG, ash P and bone Ca and P.

From the results of the present study, it was concluded that a combination of 2% of animal fat and 1 or 2 % of Ca provides the greatest performance in broiler chickens and this combination can be considered as a advantageous management practice in Ross 308 strains diets, with improving the Ca and P absorption; however, higher levels of fat intake may decrease absorption percentage.

Table 4: Effects of different levels of fat, Ca and their interactions on performance traits of broilers

Fat level (%)	**Feed intake (gr/bird/day)	**Feed efficiency (g:g)	**Abdominal fat (%)	**Carcass weight (gr)	**Diet cost (Rials)
0	691.79^{b}	1.93^{a}	2.275^{d}	2024^{c}	3850^{a}
2	72.06^{a}	1.85	2.783^{c}	2190^{bc}	3833^{a}
4	72.10^{a}	1.79	3.075^{b}	2264^{b}	3555^{b}
6	69.34^{b}	1.85	3.275^{a}	2455^{a}	3132^{c}
Total average	70.82±1.76	1.79±0.17	2.85±0.44	3233±202	3593±398
Ca level (%)	NS	NS	**	NS	**
1	71.15^{ns}	1.80^{ns}	2.704^{a}	2232^{ns}	3754.083^{a}
2	70.51^{ns}	1.78^{ns}	3.000^{b}	2235^{ns}	3432.667^{b}
Total average	70.82±1.76	1.79±0.17	2.85±0.44	3233±202	3593±398
Interaction	NS	NS	NS	NS	*
F1.C1[1]	69.39^{ns}	1.92^{ns}	2.017^{ns}	2023^{ns}	3903^{a}
F2.C1	72.93^{ns}	1.92^{ns}	2.650^{ns}	2130^{ns}	3883^{a}
F3.C1	72.26^{ns}	1.79^{ns}	3.050^{ns}	2267^{ns}	3917^{a}
F4.C1	70.01^{ns}	1.56^{ns}	3.100^{ns}	2507^{ns}	3312^{b}
F1.C2	70.19^{ns}	1.94^{ns}	2.533^{ns}	2025^{ns}	3797^{a}
F2.C2	71.20^{ns}	1.78^{ns}	2.917^{ns}	2250^{ns}	3783^{a}
F3.C2	71.95^{ns}	1.79^{ns}	3.100^{ns}	2262^{ns}	3200^{bc}
F4.C2	68.68^{ns}	1.60^{ns}	3.450^{ns}	2404^{ns}	2951^{c}
Total average	70.82±1.76	1.79±0.17	2.85±0.44	3233±202	3593±398

^{a,b,c,d} Means along the rows with no common superscript are significantly different (P<0.05). Values are means of twelve observations per treatment (2 hens and 2 roosters of each cage). [1]F1-F4= fat levels, C1-C4=calcium levels. P: NS= P>0.05; *= P<0.05; **= P<0.01

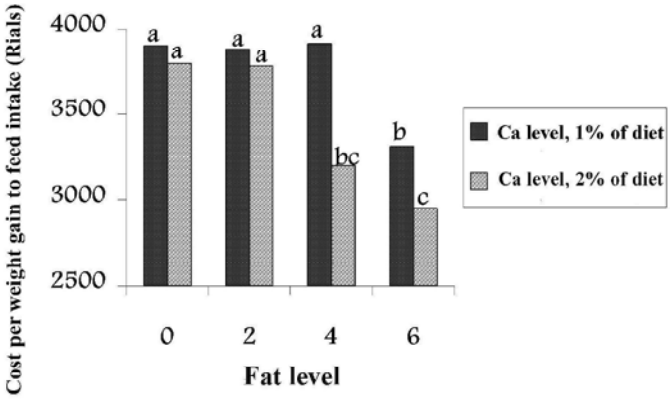

Fig. 1: Comparison to the feed cost per weight gain for the interaction of calcium and fat levels

DISCUSSION

The statistical analysis of crude data recorded from weekly performance of birds is shown in Tables 4 and Figure 1. The effect of different levels of fat on the food intake was significant. Based on the results, the most effective fats on increasing of FI were 4 and 2% levels (72.10 and 72.06, respectively) and the significant effect was detected with comparison of these effective groups and 6% dietary fat group.

Atteh and Leeson [13] reported that increase of fat content on food intake was not significant. Crespo and Esteve-Garcia [14] investigated the effect of diet supplementation with four types of fat (animal fat, olive oil, sunflower oil and flax oil) and two lipid levels (6 and 10 percent) on the male chicks and found that increasing dietary fat, significantly reduced food intake. Also, food efficiency was affected by different levels of fat. Because the younger birds to digest and absorb fat chicks have not evolved enough so they can not properly use the fat [15]. But, the adult broilers have the better system of digestion and absorption of fat, because of the higher physiological capacity of the digestion and absorption systems for fat accompanying with a increased rate in activity of bile and pancreatic lipase secretion [16, 17].

In the presented study, increasing levels of fat in the diet from 0 up to 6% caused o chicken to meet their energy needs and it can be concluded that 2% fat could well meet the energy needs. In the current project, the diets formulated based on equal energy amount. In addition, adding fat to diets improves the physical form of food and prevents waste of nutrients and increasing food intake in broiler diets.

Based on the results of current study in Table 4, the effect of different fat levels on feed efficiency was significant. The most effective lipid levels was related to 6% dietary fat and followed with other lipid levels, respectively. Hence, the final body weight gain was improved resulting FE improvements.

Results from current study are agreement with findings of Hulan *et al*. [18] and Crespo and Esteve Garcia [14]. The results of some studies have shown that the dietary fat improves feed conversion rate because of Cholcystokinin hormone secretion and prolonged gastrointestinal transit time of food and thus increasing the presence of enzymes in digestion and absorption canals and subsequently their further effects [18-20].

The effects of different levels of fat on the amount of abdominal fat was significant. Dale and Fuller [21] reported that although increasing dietary fat cause growth rate improvement in bird, but the carcass fat can increase by high dietary fat. Sanz *et al*. [22] found that the total amount of abdominal fat in broilers fed a diet rich in polyunsaturated fatty acids is lower than those fed saturated fats.

The amount of fat was significantly increased live weight. Crespo and Esteve Garcia [23] found that chickens fed dietary fat showed higher live weight in compared to birds fed with no supplemental fat [1]. In the present study, higher dietary fat, when used with a constant dietary calcium (1 and 2 % of diet), resulted in a increasing abdominal fat and decreasing diet cost, significantly, indicating a possible synergistic effect of fat and Ca especially on fat utilization in body. The results indicated that the interaction of calcium and fat levels on food intake, feed efficiency and live weight was not significant.

Smith *et al*. [24] investigated the effect of adding animal fat with different levels of calcium on the performance of poultry and found that consumption of animal fat with 1.5 % calcium decreased food consumption compared to those received 0.93 % calcium.

However, high consumption of animal fats containing large amounts of saturated fatty acids such as palmitic acid and stearic acid is associated with high intake of calcium causes a type of reaction between fatty acid and calcium which results in the formation of insoluble soap and non-use of nutrients by poultry and eventually will excreted through feces or it can deposited as abdominal fat. It could not significantly affected food intake in birds fed diet contain high levels of fat intake and calcium. Sibbald and Price [25] and Hakansson [26, 27] reported that they consume large amounts of the mixture of fat and calcium in the diet reduces abdominal fat and was reduced ME of diet. The interaction of different levels of fat and calcium on the cost of feed intake was significant. The average cost of feed intake on the interaction of 6% fat and 2% calcium (F4C2), was 2951 Rials that indicated lowest significant diet cost and followed by F3C2 dietary group (4% fat + 2% Ca = 3200 Rials). Also, interaction of F4 × C1 in compared to interactions with other levels of fat and calcium (F1C1, F2C1, F3C1, F1C2 and F2C2) showed a significant difference in the cost of feed intake (6% fat + 1% Ca = 3312 Rials).

Reduce feed costs can be interpreted that these birds due to increased fat and increased percentage of food containing calcium (powder shells and DCP) have consumed less food and therefore by the amount of food, their needs are resolved and thus the feed cost rate decreased.

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