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Effects of Dietary Supplementation of Betaine on Performance, Lipid Metabolic Parameters, and Blood and Ileal Osmolality in Laying Hens

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비태인의 급여가 산란계의 생산성과 지질대사 관련인자, 소화물의 삼투성에 미치는 영향

류명선 · 박재홍 · 신기형 · 나종삼[1] · 류경선[2]

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ABSTRACT : Two experiments were conducted to investigate the effect of betaine on egg production, lipid metabolism, and osmoregulation in 18- to 42-week-old ISA Brown laying hens. In experiment 1, three hundred and sixty one hens were fed a corn-soy basal diet containing 16% crude protein (CP), 2800 kcal/kg metabolizable energy (ME), 0.33% methionine, and 0, 300, 600, or 1200 mg betaine per kg diet. Egg production, egg weight, feed consumption, feed conversion, and egg quality were measured every eight weeks. Betaine concentration in liver and egg were determined along with serum cholesterol, abdominal fat, total serum protein and albumin levels. In experiment 2, twenty thirty-three-week-old laying hens were fed the same diets as those used in experiment 1 in individual cages and the amount of feed and water consumption were measured for two weeks. At the end of experiment 2, all birds were killed to determine blood plasma and ileal osmopressure, arginine vasotocin (AVT), and liver moisture content. In experiment 1, egg production between the treatments during the first eight weeks were not different, whereas the significant increment of egg production were noticed in the birds fed more than 600 ppm betaine after reaching the peak egg production stage ($P<0.05$). The egg weight was reduced significantly by the betaine supplementation for the first 8 weeks ($P<0.05$). Feed conversion tended to improve by betaine supplement. Egg quality was not enhanced by betaine supplementation. Liver betaine level increased with betaine feeding compared to the control but betaine concentration in eggs decreased with betaine supplementation. Betaine supplementation elevated the level of serum total cholesterol and triglycerides compared to the control. Abdominal fat content was increased by betaine supplementation, whereas liver fat content decreased. In experiment 2, water consumption significantly increased in hens fed diets containing 300 and 600 mg betaine/kg ($P<0.05$) and osmotic pressure of ileal digesta increased with betaine supplement. Liver moisture content was not affected by betaine, but AVT increased in hens fed betaine. The overall results suggested the possibility of using betaine as a feed additives in the laying hens because of its positive contribution to improving egg production and other metabolic parameters related to lipid metabolism.

(Key words : betaine, laying hens, egg production, blood lipid, osmolality)

INTRODUCTION

Betaine is known as an analogue of amino acid which do not directly associate with protein synthesis in nature but, has an

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undisclosed physiological function in cells. Several studies on betaine have been focused on its potentials to be used as a methionine replacer in birds (Schutte *et al.*, 1997; McDevitt *et al.*, 2000), and its effect on fat reduction and osmolality (Kettunen *et al.*, 2001b). Beli (1995) reported 12% reduction of the back fat thickness in swine fed betaine. Saunderson and MacKinlay (1990) reported the reduction of fat in chickens fed a diet containing supplementary betaine and methionine, but did not study the effect of betaine supplementation alone.

Betaine is also known to play a major role in modulating osmolality of kidney in mammals (Wunz and Wright, 1993; Ferraris *et al.*, 1996). Kidd *et al.* (1997) revealed the involvement of betaine in modulating the intestinal osmolality of chickens, and the latest study done by Kettunen *et al.* (2001b) using cultured epithelial cells of duodenum and ileum of chicken revealed its effect on controlling water absorption and osmolality of cells.

In spite of such important functions of betaine as in maintaining osmolality, many studies have failed to prove its effect on broiler production (Esteve-Garcia & Mack, 2000; Garcia Neto *et al.*, 2000). Moreover, the effect of dietary betaine supplementation on laying hens has not been clearly established. We attempted to prove the effect of dietary betaine supplementation on the performance, metabolic parameters related to lipid metabolism, and regulatory osmolality in ileal digesta of laying hens.

MATERIALS AND METHODS

1. Animals and Diets

In Expt 1, three hundred and sixty 18-week-old ISA Brown laying hens were divided into four groups each consisting of 5 replicates of 18 hens each and each group was fed diet containing 0, 300, 600 or 1200mg of betaine/kg for 12 weeks in cages. Composition of basal diet is shown in Table 1. Diets had free access to diets and water. The room was lighted for 18 hours a day and eggs were collected daily.

Expt 2 was done to determine the effect of betaine on water consumption and osmoregulation. Twenty 33-week-old ISA Brown laying hens were individually fed the same diet as in the experiment 1 for 4 weeks. Water consumption was monitored during the entire period of the experiment.

Table 1. Composition of experimental diet

Ingredient	(%)
Corn	57.74
Soybean meal	18.11
Corn gluten meal	3.88
Rape seed meal	0.50
Wheat	1.00
Wheat bran	6.02
Tallow	2.00
Limestone	8.44
Tricalcium phosphate	1.58
Salt	0.39
DL-methionine	0.14
Vitamin premix[1]	0.10
Mineral premix[2]	0.10
	100.00
Calculated chemical composition	
ME (kcal/kg)	2,800
CP (%)	16.00
Methionine (%)	0.32
Met+Sys (%)	0.67
Lysine (%)	0.75
Ca (%)	3.70
P (%)	0.40
Choline (mg/kg)	1,097

[1] Provided per kilogram of diet: vit. A, 5,500 IU; vit. D_3, 1,100 IU; vit. E, 11 IU; vit. B_{12} 0.0066 mg; riboflavin, 4.4 mg; niacin, 44 mg; pantothenic acid, 11 mg (Ca-pantothenate, 11.96mg); choline, 190.96 mg (choline chloride 220 mg); menadione, 1.1 mg (menadione sodium bisulfite complex, 3.33 mg); folic acid, 0.55 mg; pyridoxine, 2.2 mg(pyridoxine hydrochloride, 2.67 mg); biotin, 0.11 mg; thiamin, 2.2 mg(thiamine mononitrate, 2.40 mg); ethoxyquin, 125 mg.

[2] Provided in mg per kilogram of diet; Mn, 120; Zn, 100; Fe, 60; Cu, 10; I, 0.46.

2. Egg Production

Number of eggs produced per hen was calculated and egg weight of all collected eggs were recorded daily. Feed consumption was monitored during the 8 week period.

3. Egg Quality

Thirty eggs were collected from each treatment to evaluate the egg quality every 8 weeks. Eggshell strength was measured by using a eggshell destruction strength meter (FHK, Japan), and eggshell thickness using a micrometer (FHK, Japan) after removing egg shell membrane. Haugh unit and egg yolk color were measured by using egg quality measure system (QCM+, TSS, York, England).

4. Serum Cholesterol and Betaine Concentrations in Liver and Egg

Blood samples were collected from the jugular vein of ten birds from each treatment at the end of experiments and serum was collected. Triglyceride and total cholesterol were determined by using the enzymatic colorimetric method (Allain *et al.*, 1974). Total protein and albumin concentrations were measured by using automatic chemistry analyzer (ADVIA 1650, JEOL, Tokyo, Japan) and kits (Randox, Caerphilly, UK). The concentration of betaine in liver and in whole egg was determined by using the method described in Saarinen *et al.* (2001). Livers were collected from the five hens each treatment. Betaine was measured using a HPLC system (Sykam S1100, Gewerbering, Germany). The system used a Sugar-pak (6.5mm ~300mm) column housed in the column oven at 80℃. The column contained 0.004M $Ca(NO_3)_2 \cdot 4H_2O$ of mobile phase, and Infra Red (IR) detector (Waters 410, MA, USA) was used.

5. Water and Feed Consumption

In experiment 2, feed and water consumption were monitored daily (16:00 h) by measuring the residual amount of feed and water in each replicate pen and the intake was calculated at the end of the experiment.

6. Osmotic Pressure of Ileal Digesta

At the end of the experiment 2, 5 birds were killed by decapitation to measure the osmolality of ileum. The abdominal cavity was opened to collect ileal content. The collected samples were centrifuged at 6,000 g at 4℃ for 15 minutes, and the supernatant was recovered and the osmolality was measured by using a freezing point osmometer (Precision system Inc., USA).

7. Anti-diuretic Hormone (Arginine vasotocin)

Arginine vasotocin (AVT) level of ten birds from each group was determined using a arginine vasopressin radioimmunoassay kit (Buhlmann laboratories AG, Switzerland) which maintained 110% cross-reactivity against synthetic AVT (V-0130, Sigma Chemical Co., St. Louis, MO, USA).

8. Statistical Analysis

The analysis of variance of the data were performed by using the GLM procedure of SAS (1996). The statistical differences between treatment means were evaluated by using the Duncan's new multiple range test.

RESULTS AND DISCUSSION

1. Egg Production and Egg Quality

Egg production data (Table 2) that betaine supplementation during the 8 week period resulted in the loss of egg weight at all levels and the reduction of the egg weight was hightest ($P<0.05$) in the 1200ppm betaine-fed group. However, after 26 weeks, the maximum egg production was recorded with the reduction of egg weight in 600ppm betaine fed group. During this period, feed consumption increased, and feed conversion improved in hens fed betaine-added diets, but without significance compared to the control.

Improvement of growth in broilers fed betaine have been extensively discussed by previous studies done by McDevitt *et al.*(2000), Garcia Neto *et al.*(2000), Schutte *et al.*(1997), Esteve-Garcia and Mack (2000) and Matthews *et al.* (1998). All their studies did not mention dietary betaine's role in the broiler growth promotion and the study results regard on the performance in egg laying hens are even more scanty. Recently, Harms and Russell (2002) tried to prove the effect of betaine on egg production, but failed. Under such circumstance, our study results seemed to provide some meaningful result of betaine addition in improving egg production in laying hens.

Egg quality affected by the supplementation of betaine is shown in Table 3. Betaine supplementation tended to improve breaking strength of eggs collected during the period of 25 to 33 weeks, but decreased the shell strength of eggs collected at 42nd weeks. Throughout the entire period of experiment, egg shell maintained uniform thickness, and Haugh unit and egg

Table 2. Effects of dietary betaine supplementation on performance in laying hens[1] (Expt. 1)

Traits	Betaine (mg/kg diet)			
	0	300	600	1200
18~25 weeks				
Egg weight (g)	49.55 ±0.34[ab]	50.0 9±0.29[a]	48.59 ±0.48[bc]	47.80 ±0.47[c]
Egg production (%)	71.11 ±0.74[a]	70.30 ±1.31[ab]	71.82 ±1.39[a]	67.11 ±1.02[b]
Feedintake (g/bird/d)	94.95 ±0.64	92.58 ±1.12	94.19 ±1.32	95.17 ±0.89
Feed conversion (g/g)	2.658±0.044[b]	2.616±0.064[b]	2.627±0.029[b]	2.897±0.035[a]
26~33 weeks				
Egg weight (g)	57.50 ±0.16[a]	57.83 ±0.17[a]	56.94 ±0.17[b]	57.50 ±0.15[a]
Egg production (%)	91.03 ±0.82[c]	90.83 ±1.04[c]	95.99 ±0.45[a]	93.79 ±0.61[b]
Feedintake (g/bird/d)	109.93 ±0.49	109.87 ±0.96	110.77 ±0.86	111.44 ±0.94
Feed conversion (g/g)	2.104±0.049	2.102±0.087	2.027±0.018	2.068±0.033
34~42 weeks				
Egg weight (g)	62.13 ±0.11[bc]	63.04 ±0.12[a]	61.91 ±0.10[c]	62.37 ±0.12[b]
Egg production (%)	91.47 ±1.00[b]	92.56 ±0.44[b]	96.09 ±0.93[a]	92.28 ±0.86[b]
Feed intake (g/bird/d)	127.74 ±1.42	128.02 ±1.07	128.55 ±1.52	129.60 ±1.32
Feed conversion (g/g)	2.257±0.080	2.195±0.029	2.165±0.051	2.257±0.051

[1] Mean±SE of ninety birds.

[a-c] Means within a row with no common superscripts differ significantly (P<0.05).

Table 3. Effects of dietary supplementation of betaine on egg quality in laying hens[1] (Expt. 1)

Betaine (mg/kg diet)	Eggshell breaking strength (kg/cm^2)	Eggshell thickness (㎛)	Albumen height (mm)	Haugh unit	Yolk color index
		25 weeks			
0	3.957±0.159	401.1± 8.0	7.69±0.27	88.07±1.64	9.07±0.14
300	4.090±0.133	410.7± 7.1	7.26±0.23	86.27±1.29	9.07±0.14
600	4.393±0.160	407.7± 7.0	7.20±0.24	85.70±1.40	9.13±0.08
1200	3.977±0.193	400.4± 5.3	7.59±0.22	87.90±1.28	9.10±0.13
		33 weeks			
0	4.247±0.195	413.0± 5.1	8.15±0.24	89.00±1.45	7.50±0.12
300	4.027±0.178	398.0± 6.3	8.25±0.25	89.37±1.38	7.57±0.13
600	4.363±0.129	404.7± 6.1	8.02±0.27	88.07±1.64	7.17±0.14
1200	4.307±0.124	407.3± 6.0	8.40±0.22	90.60±1.18	7.33±0.10
		42 weeks			
0	4.073±0.136	414.0±15.4	7.17±0.22	82.87±1.51	8.97±0.13
300	3.687±0.155	393.3± 5.3	6.98±0.30	80.50±2.04	8.97±0.19
600	3.783±0.116	404.0± 4.4	6.78±0.27	79.37±2.03	8.70±0.14
1200	3.550±0.160	400.0± 5.4	7.10±0.24	82.33±1.87	8.70±0.13

[1] Mean±SE of thirty eggs.

yolk coloration were similar in all eggs collected during the experiment. In our previous study (Ryu *et al.*, 2002), betaine supplementation significantly improved eggshell breaking strength of eggs collected from 78-week-old birds fed diet containing 500 and 1000mg of betaine per kg diet in hot summer. However, Ryu *et al.* (2002) did not determine the effect of betaine on egg quality. These contrary results might have been explained by eihter the age of birds or the season when the experiment was conducted.

2. Betaine Level in Liver and Egg

Table 4 shows the concentration of betaine in liver and egg that were collected from betaine fed hens. It was proportionally elevated with the increment level of betaine in the feed, while the betaine concentrations in eggs were decreased. Previous study done by Ryu *et al.* (2002) and Garcia Neto *et al.* (2000) demonstrated the increased concentration of betaine in the liver that was collected from hens fed a diet with a high concentration of betaine, and the level of increment was significant at a lower level of crude protein. In this case, the low level of crude protein in the basal diet might have been contributed to stimulate the need of utilizable crude protein in the bird, which should have promoted the seeking of nitrogen substitutes, and correspondingly increased the securement or the accumulation of nitrogen substitute in the birds. So it is highly suggestive that the high betaine concentration in the hens' livers might have been caused by the accumulation of it through the betaine diet instead of synthesis. Contrary to the high accumulation of betaine in liver, betaine accumulation in the eggs was not significant.

Total serum protein and albumin concentrations increased in betaine-fed hens. Keyser *et al.* (1968) reported an increase in serum total protein with increasing level of dietary crude protein in pigs. Matthews *et al.* (1998) also reported that dietary betaine increased serum total protein and albumin concentrations in pigs. These reports suggest the crucial involvement of betaine in nitrogen utilization, strongly supported by Haydon *et al.* (1995) who reported the increment of average daily gain in pigs fed betaine with low crude protein diets. From our experiments, the total protein level was correspondingly increased as with the betaine level compared to control. This primarily suggests that the initial crude protein level, 16%, provided to the basal diet was not actually sufficient for egg production performance, and the fact might have been attributed to the birds to accumulate betaine as the next available protein substitute. Secondly, by the same reason, we were able to find out that the dietary betaine were actually well utilized to increase total protein level of birds fed betaine.

3. Serum Cholesterol, Abdominal Fat Pad and Liver Fat

The serum cholesterol, triglycerides, abdominal fat, and liver fat contents of hens fed a diet with supplementary betaine are shown in Table 5. Triglycerides and serum total cholesterol levels tended to increase in hens fed a betaine-added diet, and the highest increment was found in hens fed with 300ppm betaine supplemented diet. Abdominal fat contents of hens increased as dietary betaine levels increased, but the liver fat contents reduced in hens fed diet with 600 or 1200mg of betaine/kg.

Garcia Neto *et al.* (2000) reported an increase in abdominal, and a decrease in liver fat in hens fed diet with 650mg betaine/kg. Similar results were observed in our study. Usually, fat required for egg formation come from dietary fat or

Table 4. Effects of dietary supplementation of betaine on liver and egg betaine, serum total protein and albumin in laying hens[1] (Expt. 1)

Betaine (mg/kg diet)	Liver (μg/g)	Egg (μg/g)	Total protein (g/dL)	Albumin (g/dL)
0	726.06±244.03	168.88±44.52	5.22±0.22	2.22±0.08
300	731.83±151.58	125.80±19.78	5.80±0.18	2.46±0.04
600	737.70±125.42	124.60±26.62	5.58±0.17	2.40±0.06
1200	789.97±134.19	116.53± 7.43	5.94±0.24	2.40±0.08

[1] Mean±SE of ten birds.

carbohydrate in the liver (Dominique, 1997). Liver fat was decreased by betaine supplementation and egg production was increased. Considering the increments of serum total cholesterol and triglyceride in hens fed betaine, it strongly suggests that fat in the liver was not accumulated but rather transferred by cholesterol for egg formation. The residual fat might be accumulated in the abdomen. Thus, the reduction of liver fat and the increment of abdominal fat that were found in our data suggest that betaine caused hepatic fat to be transported to abdomen.

4. Water Consumption and Osmolality in Ileal Digesta

Changes in water consumption and osmolality of ileal digesta affected by the betaine supplementation are shown in Table 6. Water consumption significantly increased in hens fed diet with 300 or 600mg betaine/kg ($P<0.05$). Feed intake was not influence by betaine supplementation. However, the osmolality of the ileal digesta was elevated in all hens fed with betaine addition compared to the control. Previous study of McDevitt *et al.* (2000) reported an increased amount of water consumption in broiler chicks fed methionine-supplemented diet but not betaine-supplementated diet and explained this increment as the requirement of the water for the growth of the broilers. If the assumption is valid, the increment of water consumption noticed in our hens fed diet with 300 or 600mg betaine/kg might be closely related to their increased egg production performances. It can be supported by results of serum osmolality and hepatic moisture content, which was not changed by betaine supplementation in spite of increased amount of water consumption. Although the amount of water consumption was increased in the hens fed betaine, osmolality of the ileal digesta was higher in hens fed betaine compared to control. This could be explained by the results of studies done by Kettunen *et al.* (2001b) that reported the increased capacity of water absorption in the cultured chicken intestinal epithelial cells by the addition of betaine. Another study demonstrated the addition of betaine to the feed dramatically increased the betaine content of the

Table 5. Effects of dietary supplementation of betaine on serum cholesterol, triglyceride, abdominal fat pad and liver fat in laying hens[1] (Expt. 1)

Betaine (mg/kg diet)	Triglyceride (mg/dL)	Cholesterol (mg/dL)	Abdominal fat pad (%)	Liver fat (%)
0	567.22±104.52	72.57± 6.28	2.698±0.586	5.26±0.57
300	1143.58±243.37	88.56±12.34	2.720±0.488	5.40±0.66
600	716.85±230.83	79.74±17.46	3.144±0.633	4.97±0.20
1200	739.70±139.48	78.55± 7.97	3.534±0.681	4.83±0.72

[1] Mean±SE of ten birds.

Table 6. Effects of dietary supplementation of betaine on water consumption and ileal osmolality in laying hens[1] (Expt. 2)

Betaine (mg/kg diet)	Water consumption (mL/day/hen)	Feed consumption (g/day/hen)	Osmolality		Liver moisture (%)	Arginine vasotocine (pg/mL)
			Blood (mOsm/L)	Ileal digesta (mOsm/L)		
0	203±4.5[b]	116.8±2.2	322.8±2.3	515.0±29.3	74.06±0.51	24.16± 6.72
300	228±4.3[a]	115.3±2.2	322.0±1.5	618.2±26.6	74.15±0.45	31.83±10.33
600	231±5.6[a]	114.8±2.7	320.0±1.4	530.4±25.8	74.01±0.80	36.46± 8.73
1200	211±4.2[b]	116.6±3.6	319.5±1.2	552.8±30.9	74.05±1.50	38.94±13.52

[1] Mean±SE of ten birds.

[a,b] Means within a row with no common superscripts differ significantly ($P<0.05$).

ileal digesta (Kettunen *et al.*, 2001a). Our study result of the increased osmolality of ileal digesta in hens fed diet with betaine could be explained by the increased capacity of water absorption introduced by the accumulation of betaine in the ileum. Level of serum AVT, an anti-diuretic hormone, was expected to be elevated by increasing level of betaine supplementation. In other previous studies, AVT was released by the osmotic stress such as hypertonic feeding or dehydration (Koike *et al.*, 1977; Stallone and Braun, 1986; Muhlbauer *et al.*, 1992). Far from their experimental conditions, water consumption was increased by betaine supplementation. Thus, it seems that increase of serum AVT may have been introduced by factors other than osmotic stress. Another function of AVT is known to be related to the incidence of oviposition in the hens (Rzasa and Ewy, 1970).

From our layer experiments, we were able to find out several important roles of betaine incorporated to the feed. Most of all, addition of 600ppm of betaine to the feed improved the egg production performance, and effected to circumvent the accumulation of liver fat and to adjust the osmolality of ileum in laying hens.

Many studies attempted to elucidate the effect of betaine addition to animal feeds and factors regulating the role of betaine. Among these factors, the metabolic energy/protein ratio in diet (Garcia Neto *et al.*, 2000), choline (Harms and Russell, 2002), and methionine (McDevitt *et al.*, 2000; Esteve-Garcia and Mack, 2000) have been discussed, but all were unable to provide clear explanation on the effect of betaine addition. However, Haydon *et al.*, (1995) reported the addition of betaine to a swine feed that is low in crude protein increased daily weight gain, and Matthews *et al.*, (1998) reported the increased level of protein and betaine content in swine feed increased total serum protein and albumin contents in the swine. The results of our experiments, which suggest the betaine addition to the feed could be used to enhance the egg production performance in laying hens are similar to Mattews *et al.* (1998). As in our studies, where the content of crude protein in the feed might have been formulated to be low despite of high egg production performance. This implies that the addition of betaine to the basal diets could be practiced to improve the egg production performances of the hens and it is expected that the degree of improvement in egg production by betaine addition might vary by the amount of betaine added to the feed of hens. As in our experiments, 600ppm of betaine seemed to be the most ideal concentration of betaine to be added to the feed to improve the egg production performance of laying hens.

Addition of betaine to the basal diet of laying hens was also effective to reduce the accumulation of liver fat of the hens. This result is corresponding to the result of Garcia Neto *et al.* (2000) who reported the reduction of liver fat content of broiler chicks by betaine addition to the feed. However, our study revealed the increase of abdominal fat by adding betaine in laying hens, and this may be due to the activation of liver fat transport. Although the water consumption was increased in hens fed betaine, it caused an increase of digestal osmolality in ileum. In conclusion, dietary betaine supplementation in laying hens may be effective to increase egg production, decrease of liver fat and regulate the ileal osmolality.

적 요

비태인의 산란계 급여가 산란율과 지질 대사, 삼투압 조절에 미치는 영향을 구명하기 위하여 18주령 ISA Brown 산란계를 이용하여 42주령까지 두 번의 사양실험을 실시하였다. 실험 1에서, 산란계 360수를 공시하여 조단백질 16%와 대사에너지 2,800 kcal/kg, methionine 0.33%를 함유한 옥수수-대두박 위주의 실험사료에 비태인 0, 300, 600, 1200 ppm을 첨가 급여하였다. 8주마다 산란율과 난중, 사료섭취량, 사료요구율, 난품질을 측정하였으며 간과 계란의 비태인 함량과 복강지방, 혈중 cholesterol, total protein, albumin 함량을 측정하였다. 실험 2에서, 33주령 ISA Brown 산란계 20수를 케이지에 개체수용하여 2주간 사료와 물 섭취량을 측정하였으며 급여한 사료는 실험 1과 같다. 실험 종료후 산란계를 모두 희생시켜 혈청과 회장 내용물의 삼투압, arginine vasotocin (AVT), 간의 수분함량을 측정하였다.

실험 1에서, 초기 8주간은 산란율에 차이를 보이지 않았으나 산란율이 최고에 달한 이후 비태인 600ppm 이상 급여구에서 산란율이 현저히 증가하였다 ($P<0.05$). 그러나 난중은 초기 8주간은 현저히 감소하였으나 이후 차이를 보이지 않았다. 사료요구율은 비태인 급여구에서 개선되는 경향을 보였으나 난품질은 차이를 보이지 않았다. 간의 비태인 함량은 비태인의 급여로 대조구보다 증가하였으나 계란의 비태인 함량은 비태인의 급여로 감소하였다. 비태인의 급여는 혈

중 총콜레스테롤과 중성지방을 증가시켰으나 비태인 급여 수준에 따라서는 차이를 보이지 않았다. 복강지방 함량은 비태인의 급여로 증가하였으나 간 지방은 감소하였다. 실험 2에서, 음수량은 비태인 300과 600 ppm 급여구에서 현저히 증가하였으며 ($P<0.05$) 회장 소화물의 삼투압도 증가하였다. 그러나 간의 수분함량은 영향을 받지 않았으며 AVT는 비태인의 급여로 증가하였다. 이상의 결과에서 비태인의 급여는 산란율을 증가시키고 지질 대사를 개선할 수 있을 것으로 사료된다.

(색인어 : 비태인, 산란계, 산란율, 혈중지질, 삼투성)

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