특강 Ⅲ

Effect of Antioxidants and Oxidized Fat on the Performance of Broiler Chicks

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항산화제와 산패지방이 육계의 생산성에 미치는 영향

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ABSTRACT

Five experiments were conducted to investigate the effects of antioxidants (Santoquin® and Oxiban®) using fresh or oxidized fat on the performance of broiler chicks. Day-old broiler chicks (except for Experiment 5 in which 6-d-old birds were given experimental diets for 10 d) were fed diets containing fresh or oxidized fat (animal-vegetable fat blend in Experiments 1, 4, and 5 and corn oil in Experiments 2 and 3) with or without graded concentrations of Santoquin® (0, 250, 500 ppm in Experiments 1 and 2 and 0, 100, 200, 300, 400, 500 ppm in Experiment 3) or of Oxiban® (0, 400, 800 ppm in Experiment 4 and 400 ppm with 0.1% lipase in Experiment 5) of 2 wk. In all experiments, birds fed fresh fat gained more weight, had better feed/gain, together with higher AME_n and apparent fat digestibility (Experiments 1 and

2) than birds fed oxidized fat (P < 0.05). There was no interaction among fat sources and antioxidants on the performance of chicks in any experiment. In Experiment 3, Santoquin® more than 200 ppm resulted in a reduction in weight gain and feed intake (P < 0.05). The livers of chicks fed oxidized fat in Experiments 2 and 5 had higher malondialdehyde (MDA) values (P < 0.05). Chicks fed oxidized fat with 250 ppm Santoquin® in Experiment 2 had lower liver MDA values, although this situation did not occur in Experiments 1, 4, and 5. These results indicate that antioxidant supplements can alleviate most deleterious effects of feeding oxidized fat and that supplementation of Santoquin® more than 200 ppm has a negative effect on the performance of broiler chicks.
(***Key words*** : antioxidants, Santoquin®, Oxiban®, rancidity, oxidized fat)

INTRODUCTION

Dietary fats are used to provide energy and essential fatty acids, and also aid in the assimilation of fat-soluble vitamins to animals. When fats are stored under adverse conditions, they may became oxidized. Oxidation of fats is known to produce undesirable results, including loss of fat-soluble vitamins in the diet and body, degradation of xanthophyll, reduced palatability, and impairment of subsequent bird health. Feeding oxidized fat has deleterious effects on growth and feed efficiency (Nakamura *et al.*, 1972; Reddy and Tappel, 1974; Cabel *et al.*, 1988). In contrast, L'Estange *et al.* (1966) reported no differences in weight gain and feed efficiency in broilers fed oxidized beef tallow compared with controls. Synthetic antioxidants are used in feed and feed ingredients to prevent oxidative losses of fat-soluble vitamins in unstabilized feed (L'Estange *et al.*, 1966; Najman *et al.*, 1976) and to prevent degradation of unsaturated fatty acids, particularly in unstabilized fat and byproduct meals. Synthetic antioxidants such as Ethoxyquin have been used for many years to enhance pigmentation (Romoser *et al.*, 1959; Waldroup *et al.*, 1960; Nakaue *et al.*, 1966) and prevent the oxidative destruction of dietary fats (Cabel *et al.*, 1988). However, in view of these findings, there is still considerable variation in use of antioxidants in commercial poultry feedings.

This situation raises some concerns because most feed grade fats now contain considerable quantities of recycled restaurant fats and oils, in which prior oxidation is more likely to have occurred than with conventional animal fats and vegetable oils. There is also current research interest in the use of lipase enzymes (AL-Marzooqi and Leeson, 1999; Kermaushahi *et al.*, 1998) in which liberation of free fatty acids may render fat more susceptible to oxidation. The objectives of the present studies were to evaluate the effect of using oxidized fats containing restaurant greases and lipase enzymes in broiler starter diets, and to determine the protective effect of antioxidants under such feeding conditions.

MATERIAL AND METHODS

Preparation of Oxidized Fat

Oxidized fat or oil used in experiments were prepared by bubbling air through the fat or oil at 90 C for 48 h.

Experiment 1

One hundred and forty-four 1-d-old male broiler chicks of a commercial strain were allocated at random to diets containing 5% fresh or oxidized animal-vegetable fat blend that contained restaurant grease with or without graded concentrations of Santoquin® (0, 250, and 500 ppm). Each treatment of 24 birds was represented by four replicate groups of six birds each housed in electrically heated cages. Feed and water were provided for *ad libitum* consumption. Weight gain and feed intake were recorded at 7 and 14 d. In order to determine AME_n, excreta was collected for 3 d following the main feeding trial and oven dried at 65 C for 72 h. After collection of excreta, four chicks per treatment were euthanatized by cervical dislocation in order to estimate malondialdehyde (MDA) content in liver.

TABLE 1. Composition of basal diet

Ingredients	(%)
Corn	52.03
Soybean meal (CP 48%)	28.79
Canola meal	10.00
Animal-vegetable fat blend[1] or corn oil[2]	5.00
Limestone	1.50
Dicalcium phosphate	1.37
Vitamin-mineral premix[3]	0.75
Salt	0.38
DL-methionine	0.18
Calculated analyses	
ME, kcal/kg	3050[1],3104[2]
Crude protein, %	22.00
Crude fat, %	7.27
Calcium, %	1.00
Total phosphorus, %	0.69

[1]Animal-vegetable fat blend for Experiment 1, 4 and 5 was added to the basal diet either fresh (MDA value 755 ng/g fat for Experiment 1, 3.05 meq/kg fat for Experiment 4 and 5) or oxidized(MDA value 1284 ng/g fat for Experiment 1, 59.45 meq/kg fat for Experiment 4 and 50.23 meq/kg fat for Experiment 5).

[2]Corn oil for Experiment 2 and 3 was added to the basal diet either fresh (MDA values, 8.89 ng/g fat for Experiment 2 and 26.26 ng/g fat for Experiment 3) or oxidized (MDA values, 2289 ng/g fat for Experiment 2 and 1970.79 ng/g fat for Experiment 3).

[3]Supplying per kilogram of diet: vitamin A, 8,800 IU; cholecalciferol, 3,300 IU; vitamin E, 40 IU; vitamin K, 3.3 mg; choline, 600 mg; riboflavin, 8.0 mg; pantothenate, 15 mg; vitamin B_{12}, 12 g; folic acid, 1.0 mg; niacin, 50 mg; thiamine, 4 mg; pyridoxine, 3.3 mg; maganese, 10 mg; iron, 60 mg; copper, 10 mg; zinc, 70 mg; selenium, 0.3 mg; iodide, 1.0 mg.

Experiment 2

Experiment 2 was carried out with the same design of Experiment 1 except that corn oil was used instead of the animal-vegetable fat blend.

Experiment 3

Two hundred and eighty-eight 1-d-old male broiler chicks of a commercial strain were allocated at random to diets containing 5% fresh or oxidized corn oil with or without graded concentrations of Santoquin® (0, 100, 200, 300, 400, and 500 ppm). Each treatment of 24 birds was represented by four replicate groups of six birds each housed in electrically heated cages. Feed and water were provided for *ad libitum* consumption. Weight gain and feed intake were recorded at 7 and 14 d.

Experiment 4

One hundred and forty-four 1-d-old male broiler chicks of a commercial strain were allocated at random to diets containing 5% fresh or oxidized corn oil with or without graded concentrations of Oxiban® (0, 400, and 800). Each treatment of 24 birds was represented by four replicate groups of six birds each housed in electrically heated cages. Feed and water were provided for *ad libitum* consumption. Weight gain and feed intake were recorded at 7 and 14 d. At the end of the feeding trial, four chicks per treatment were killed by cervical dislocation in order to estimate MDA content in liver.

Experiment 5

Experiment 5 was carried out in a 2 × 2 × 2 factorial design consisting of 5% fresh or oxidized corn oil with or without Oxiban® (400 ppm) or lipase (0.1% of diet). Lipase activity was 25 units USP/mg. Three hundred and eighty-four 1-d-old male broiler chicks of a commercial strain were fed a basal diet to 5 d of age. At 6 d of age, two chicks per cage were culled based on chicks having high or low weight. Each treatment was represented by six replicate groups of six chicks each. Feed and water were provided for *ad libitum* consumption. Weight gain and feed intake were recorded at 10 d. At the end of the feeding trial, four chicks per treatment were killed by cervical dislocation in order to estimate MDA content in liver.

Lipid Peroxidation and Chemical Analysis

Rancidity of fat or oil was measured by the method of Squires *et al.* (1991) measuring malondialdehyde (MDA) value in Experiments 1, 2, and 3 or by the method of AOAC (1990) measuring peroxide value in Experiments 4 and 5. The MDA value in liver was determined to measure liver lipid peroxidation (Squires *et al.*, 1991). Diets and excreta were assayed for gross energy by adiabatic bomb calorimeter, for nitrogen by Kjeldahl procedure, for crude fat by ether extraction, and for digest soap formation by ether extraction after hydrolysis with 25% HCl.

Statistical Analysis

Analysis of variance was analyzed using General Linear Models (GLM) procedure of SAS (SAS Institute, 1985) to determine the main effects and interactions of the kind of fats, antioxidant and lipase on the performance of broiler chicks, nutrient availability and MDA values. When significant differences among treatment means were found, means were compared using Duncan's multiple range test.

RESULTS

Experiment 1

Feeding oxidized fat caused a significant reduction in weight gain up to 2 wk of age (P < 0.05, Table 2). Over the 0 to 2 wk growth period, using oxidized fat caused a significant (P < 0.05) increase in feed:gain (Table 2). Santoquin® generally had no effect on bird performance. Diet AME_n was signifcantly (P < 0.01) reduced when oxidized fat was used (Table 3). In part this energy effect can be attributed to reduced digestibility of the oxidized fat (P < 0.01, Table 3). Chicks fed oxidized fat had a larger livers (P < 0.05, Table 3) although fat source had no effect on liver MDA levels. Santoquin® caused a reduction in diet AME_n although 250 ppm Santoquin® increased fat digestion (P < 0.05, Table 3). Diet treatments had no effect on digesta soap formation.

Experiment 2

Oxidized corn oil had a deleterious effect on weight gain and feed intake (P < 0.01, Table 4) and resulted in inferior feed efficiency in the 0 to 7d period. Oxidizing the corn oil resulted in reduced diet AME_n (P < 0.01) and fat digestion (P < 0.01, Table 5). The poorer performance with oxidized corn oil was associated with increase in liver size (P < 0.01) that contained higher levels of MDA (P < 0.01). Santoquin® reduced liver MDA levels in birds fed the oxidized oil but did caused increased liver weight (P < 0.05, Table 5).

TABLE 2. Weight gain, feed intake and feed/gain ratio of broiler chicks fed fresh or oxidized fat, Experiment 1

Fat	Santoquin®	Weight gain 0 to 1 wk	Weight gain 1 to 2 wk	Weight gain 0 to 2 wk	Feed intake 0 to 1 wk	Feed intake 1 to 2 wk	Feed intake 0 to 2 wk	Feed/gain 0 to 1 wk	Feed/gain 1 to 2 wk	Feed/gain 0 to 2 wk
	(ppm)	(g)								
Fresh	0	70.8	194.0	264.8	93.5	338.3	431.8	1.32	1.75	1.63
	250	71.3	195.0	266.0	90.3	326.0	416.3	1.27	1.67	1.56
	500	70.0	188.0	258.3	89.3	321.3	410.3	1.28	1.71	1.59
Oxidized	0	64.8	185.8	250.5	84.3	325.0	409.5	1.30	1.75	1.64
	250	63.5	175.0	235.5	83.3	310.8	393.8	1.31	1.83	1.69
	500	55.0	171.8	230.0	73.7	306.7	382.0	1.34	1.76	1.66
Pooled SEM		5.06	8.13	12.30	5.91	11.88	16.37	0.02	0.05	0.04
Main effect means										
Fat										
Fresh		70.7[a]	192.3[a]	263.0[a]	91.0	328.5	419.4	1.29	1.71	1.60[a]
Oxidized		61.6[b]	177.7[b]	239.5[b]	81.0	315.4	396.3	1.32	1.78	1.66[b]
Santoquin®										
0 ppm		67.8	189.9	257.6	88.9	331.6	420.6	1.31	1.75	1.63
250 ppm		67.4	183.4	250.8	86.8	318.4	405.0	1.29	1.75	1.62
500 ppm		63.3	182.4	246.1	82.6	315.9	398.1	1.31	1.73	1.62
		Probability								
Fat		0.0474	0.0460	0.0349	0.0586	0.2030	0.1086	0.1345	0.0963	0.0459
Santoquin®		0.6060	0.5740	0.5935	0.5172	0.3678	0.3672	0.4999	0.9647	0.9619
Fat × Santoquin®		0.6754	0.6494	0.7799	0.7763	0.9935	0.9809	0.1324	0.2827	0.2779

[a-b]Values within the same column with different superscripts differ significantly ($P < 0.05$).

TABLE 3. AME_n, fat digestibility, and liver characteristics of fed fresh or oxidized fat, Experiment 1

Fat	Santoqui®	AME_n	Fat digestibility	Soap formation	Liver weight	MDA
	(ppm)	(kcal/g)	(%)	(%)	(g/100g BW)	(ng/g liver weight)
Fresh	0	3044	86.01	34.47	3.1	298
	250	2979	86.36	32.24	3.6	326
	500	2966	84.60	34.41	3.4	325
Oxidized	0	2905	79.48	36.61	4.1	310
	250	2932	83.00	38.55	3.6	362
	500	2870	79.73	35.08	3.7	384
Pooled SEM		15.46	0.80	2.67	0.24	41.40
Main effect means						
Fat						
Fresh		2996^{A}	85.65^{A}	33.71	3.4^{b}	316
Oxidized		2905^{B}	80.83^{B}	36.90	3.8^{a}	349
Santoquin®						
0 ppm		2974^{A}	82.74^{b}	35.54	3.6	304
250 ppm		2955^{AB}	84.68^{a}	35.40	3.6	344
500 ppm		2925^{B}	82.51^{b}	34.70	3.5	350
		Probability				
Fat		0.0001	0.0001	0.1701	0.0380	0.3591
Santoquin®		0.0092	0.0175	0.9735	0.9961	0.4846
Fat × Santoquin®		0.0292	0.1725	0.5769	0.1408	0.8573

[a-b]Values within the same column with different superscripts differ significantly ($P < 0.05$).

[A B] Values within the same column with different superscripts differ significantly ($P < 0.01$).

TABLE 4. Weight gain, feed intake and feed/gain ratio of broiler chicks fed fresh or oxidized corn oil, Experiment 2

Corn oil	Santoquin®	Weight gain 0 to 1 wk	Weight gain 1 to 2 wk	Weight gain 0 to 2 wk	Feed intake 0 to 1 wk	Feed intake 1 to 2 wk	Feed intake 0 to 2 wk	Feed/gain 0 to 1 wk	Feed/gain 1 to 2 wk	Feed/gain 0 to 2 wk
	(ppm)	(g)								
Fresh	0	93.3	260.3	353.3	112.0	305.0	416.8	1.20	1.36	1.18
	250	85.8	244.8	330.5	103.5	288.8	391.8	1.21	1.35	1.19
	500	76.3	235.5	312.0	96.3	277.0	373.3	1.28	1.33	1.21
Oxidized	0	63.0	212.8	275.3	83.5	238.8	322.0	1.34	1.30	1.17
	250	68.3	212.8	281.0	89.8	247.8	337.3	1.31	1.32	1.20
	500	72.0	215.0	286.7	92.0	251.0	342.7	1.28	1.33	1.20
Pooled SEM		6.55	9.74	14.74	7.16	11.37	17.86	0.03	0.02	0.04
Main effect means										
Corn oil										
Fresh		85.1^{A}	246.8^{A}	393.9^{A}	103.9^{a}	290.3^{A}	331.9^{A}	1.27^{A}	1.34	1.19
Oxidized		63.9^{B}	210.4^{B}	324.1^{B}	84.2^{b}	240.2^{B}	274.1^{B}	1.34^{B}	1.30	1.18
Santoquin®										
0 ppm		78.1	236.5	369.4	97.8	271.9	314.3	1.27	1.33	1.17
250 ppm		77.0	228.8	364.5	96.6	268.3	305.8	1.26	1.34	1.19
500 ppm		68.4	220.6	343.1	87.8	255.5	289.0	1.31	1.31	1.19
		Probability								
Corn oil		0.0042	0.0004	0.0005	0.0123	0.0002	0.0008	0.0055	0.0795	0.7338
Santoquin®		0.4205	0.3202	0.3258	0.4673	0.4407	0.4357	0.4404	0.5797	0.8431
Corn oil × Santoquin®		0.6144	0.6447	0.5823	0.6779	0.5748	0.5981	0.8089	0.8503	0.7826

a-b Values within the same column with different superscripts differ significantly ($P < 0.05$).
A-B Values within the same column with different superscripts differ significantly ($P < 0.01$).

Experiment 3

Oxidized corn oil again resulted in reduced weight gain and feed intake ($P < 0.01$, Table 6). Santoquin® beyond 200 ppm had a deleterious effect on weight gain ($P < 0.05$, Table 3) and this was associated with reduced feed intake in the 0 to 1 wk period.

Experiment 4

Oxidizing the animal-vegetable blend fat in this study generally had few effects on bird performance (Table 7). Oxidizing caused a reduction in feed efficiency and Oxiban® improved feed efficiency over the 0 to 2 wk study ($P < 0.05$, Table 7). Liver weight and MDA values were unaffected by diet treatment.

Experiment 5

Feeding oxidized fat caused reduced weight gain and increased liver MDA levels ($P < 0.05$, Table 8). Adding lipase to the diet had no further effect on these parameters.

TABLE 5. AME_n, fat digestibility, and liver characteristics of fed fresh or oxidized corn oil, Experiment 2

Corn oil	Santoquin® (ppm)	AME_n (kcal/g)	Fat digestibility (%)	Liver weight (g/100g BW)	MDA (ng/g liver weight)
Fresh	0	3089	85.36	3.0	349
	250	3078	84.12	3.3	279
	500	3110	83.96	3.5	373
Oxidized	0	2936	78.59	3.7	815
	250	2982	78.52	4.1	494
	500	2841	81.89	4.3	569
Pooled SEM		70.75	1.82	0.23	29.12
Main effect means					
Corn oil					
Fresh		3092^{A}	84.48^{A}	3.3^{B}	333^{B}
Oxidized		2919^{B}	79.66^{B}	4.0^{A}	626^{A}
Santoquin®					
0 ppm		3012	81.97	3.3^{b}	582^{a}
250 ppm		3029	81.32	3.7^{ab}	386^{b}
500 ppm		2975	82.93	3.9^{a}	471^{ab}
		Probability			
Corn oil		0.0079	0.0044	0.0006	0.0001
Santoquin®		0.7394	0.6772	0.0883	0.0216
Corn oil × Santoquin®		0.4758	0.4237	0.8954	0.0848

$^{a-b}$Values within the same column with different superscripts differ significantly ($P < 0.05$).
$^{A\,B}$ Values within the same column with different superscripts differ significantly ($P < 0.01$).

DISCUSSION

Birds fed oxidized fat gained less weight, had poor feed efficiency and usually digested less fat and energy from the diet compared to birds fed fresh fat. These results substantiate earlier observation (Hussein am Kratzer, 1982; Lin *et al.*, 1989) that feeding oxidized fat or oils influence animal growth. The poor growth rate may be the consequence of the toxic effects of oxidized fats or oils (Century and Horwitt, 1959). Aldehydes, ketones, esters, and polymerized oils are direct products of oxidation and can result in reduced dietary energy values (Shermer and Calabotta, 1985). Bottje and Wideman (1995) reported that slower growth rates could lower oxidative stress by decreasing the amount of free radicals generated during metabolism. Engberg *et al.* (1996) reported that birds fed oxidized fat had lower weight gain, fat, and energy retention than did birds fed fresh fat. Santoquin® decreased AME_n in Experiment 1 and there was a similar tendency in Experiment 2 although this effect was not significant. Decreased AME_n is thought to be associated with the high concentration of Santoquin® in diets. This effect was confirmed in Experiment 3, in which birds fed more than 200 ppm Santoquin® showed lower weight gain.

There was no effect of Santoquin® on weight gain except in Experiment 3, in which corn oil was oxidized to a greater degree compared to other experiments. Therefore, concentrations of Santoquin® in diets beyond 250 ppm in Experiments 2 and 3 seemed to have a negative effect on performance of broiler chicks. Ohshima *et al.* (1996) observed increased weight gain and feed efficiency when less than 125 ppm ethoxyquin was used but not when more than 125 ppm ethoxyquin was used. Cabel *et al.* (1988) reported that the addition of ethoxyquin (62.5 and 125 ppm) had little or no effect either body weight and feed efficiency at low levels of peroxide (2 and 4 meq/kg).

TABLE 6. Weight gain, feed intake and feed/gain ratio of broiler chicks fed fresh or oxidized corn oil, Experiment 3

Corn oil	Santoquin®	Weight gain 0 to 1 wk	Weight gain 1 to 2 wk	Weight gain 0 to 2 wk	Feed intake 0 to 1 wk	Feed intake 1 to 2 wk	Feed intake 0 to 2 wk	Feed/gain 0 to 1 wk	Feed/gain 1 to 2 wk	Feed/gain 0 to 2 wk
	(ppm)	(g)								
Fresh	0	109.9	224.2	334.1	125.6	312.5	438.1	1.15	1.40	1.32
	100	106.3	229.0	335.3	121.5	301.0	422.5	1.15	1.32	1.26
	200	99.1	224.5	323.7	113.6	293.0	406.6	1.15	1.31	1.26
	300	97.8	227.5	325.4	111.4	285.0	396.5	1.14	1.25	1.22
	400	97.2	220.6	317.9	114.1	313.5	427.6	1.18	1.43	1.35
	500	98.4	218.6	317.0	107.7	280.0	387.7	1.10	1.28	1.25
Oxidized	0	94.8	214.1	308.9	106.4	289.1	395.5	1.13	1.35	1.28
	100	99.5	211.8	311.4	113.1	286.4	399.6	1.14	1.35	1.29
	200	100.8	218.4	319.1	113.6	285.0	398.6	1.13	1.31	1.25
	300	95.0	191.5	286.4	113.6	265.3	379.0	1.20	1.40	1.33
	400	78.6	186.2	264.8	94.9	256.0	350.9	1.21	1.38	1.33
	500	87.7	208.4	296.3	101.9	275.4	377.3	1.16	1.32	1.28
Pooled SEM		4.59	7.26	10.35	4.84	12.53	4.97	0.12	0.05	0.04
Main effect means										
Corn oil										
Fresh		101.5^{A}	224.1^{A}	325.5^{A}	115.7^{A}	297.5^{A}	413.2^{A}	1.14	1.33	1.27
Oxidized		92.8^{B}	205.1^{B}	297.8^{B}	107.3^{B}	276.2^{B}	383.5^{B}	1.16	1.35	1.29
Santoquin®										
0 ppm		102.3^{a}	219.1	321.5^{a}	116.1^{a}	300.8	416.8	1.14	1.37	1.30
100 ppm		102.9^{a}	220.4	323.3^{a}	117.3^{a}	293.7	411.0	1.14	1.34	1.27
200 ppm		99.9^{a}	221.5	321.4^{a}	113.4^{ab}	289.0	402.6	1.14	1.31	1.26
300 ppm		96.4^{ab}	209.5	305.9^{ab}	112.6^{ab}	275.2	387.8	1.17	1.32	1.27
400 ppm		87.9^{b}	203.4	291.4^{b}	104.5^{b}	284.8	389.2	1.19	1.40	1.33
500 ppm		93.1^{ab}	213.5	306.7^{ab}	104.8^{b}	277.7	382.5	1.13	1.30	1.25
		Probability								
Corn oil		0.0021	0.0001	0.0001	0.0038	0.0056	0.0015	0.2450	0.4677	0.3566
Santoquin®		0.0149	0.1138	0.0236	0.0311	0.3285	0.1541	0.1660	0.3190	0.1789
Corn oil × Santoquin®		0.2479	0.1786	0.2926	0.1138	0.3463	0.2072	0.3557	0.4151	0.3611

[b] [b]Values within the same column with different superscripts differ significantly ($P < 0.05$).

[A·B] Values within the same column with different superscripts differ significantly ($P < 0.01$).

TABLE 7. Weight gain, feed intake and feed/gain ratio of broiler chicks fed fresh or oxidized fat, Experiment 4

Fat	Oxiban®	Weight gain			Feed intake			Feed/gain			Liver weight	MDA
		0 to 1 wk	1 to 2 wk	0 to 2 wk	0 to 1 wk	1 to 2 wk	0 to 2 wk	0 to 1 wk	1 to 2 wk	0 to 2 wk		
	(ppm)	(g)									(g/100 g BW)	(ng/ g liver weight)
Fresh	0	108.9	220.1	329.0	122.6	282.1	404.6	1.13	1.28	1.23	2.92	402
	400	114.0	220.2	334.2	125.6	282.9	408.5	1.11	1.28	1.22	2.86	485
	800	108.8	234.2	342.9	116.9	297.1	414.0	1.08	1.27	1.21	2.30	390
Oxidized	0	98.5	216.5	315.0	114.4	281.9	396.3	1.17	1.30	1.26	3.30	387
	400	107.9	225.6	333.5	123.1	289.8	412.9	1.14	1.29	1.24	3.21	417
	800	107.3	221.0	328.3	121.1	286.8	407.9	1.14	1.30	1.24	2.86	542
Pooled SEM		5.38	6.41	11.00	5.31	8.77	12.12	0.03	0.04	0.02	0.14	30.41
Main effect means												
Fat												
Fresh		110.5	224.8	335.4	121.7	287.4	409.1	1.10^{B}	1.28^{B}	1.22^{B}	3.02	428
Oxidized		104.6	221.0	325.6	119.5	286.2	405.7	1.15^{A}	1.30^{A}	1.25^{A}	3.12	418
Oxiban®												
0 ppm		103.7	218.3	332.0	118.5	282.0	400.0	1.15^{b}	1.29	1.24^{a}	3.11	394
400 ppm		110.9	222.9	333.9	124.4	286.4	410.7	1.12^{ab}	1.28	1.23^{b}	3.03	451
800 ppm		108.0	227.6	335.6	119.0	292.0	411.0	1.11^{a}	1.28	1.23^{b}	3.08	421
		Probability										
Fat		0.0616	0.2765	0.1046	0.4494	0.7981	0.6172	0.0011	0.0062	0.0001	0.3864	0.7873
Oxiban®		0.1760	0.0964	0.1334	0.1820	0.2322	0.3531	0.0332	0.6540	0.0143	0.8513	0.2031
Fat × Oxiban®		0.5130	0.0993	0.5516	0.2136	0.3328	0.7102	0.7035	0.2218	0.2465	0.0116	0.1289

$^{a\text{-}b}$Values within the same column with different superscripts differ significantly ($P < 0.05$).
$^{A\text{-}B}$ Values within the same column with different superscripts differ significantly ($P < 0.01$).

TABLE 8. Weight gain, feed intake and feed/gain ratio of broiler chicks fed fresh or oxidized fat, Experiment 5

Fat	Oxiban®	Lipase	Weight gain	Feed intake	Feed/gain	Liver weight	MDA
	(ppm)	(%)	(g)			(g/100 g BW)	(ng/g liver weight)
Fresh	0	0	305	435	1.43	3.74	356
	0	0.1	312	441	1.42	3.74	338
	400	0.1	311	441	1.42	3.60	357
	400	0	309	435	1.42	3.66	384
Oxidized	0	0	295	422	1.44	3.66	513
	0	0.1	304	430	1.42	3.46	462
	400	0.1	300	426	1.42	3.67	600
	400	0	277	423	1.54	3.58	677
PooledSEM			8.29	8.90	0.03	0.17	57.83
Main effect means							
Fat							
Fresh			309[a]	438	1.42	3.69	359[B]
Oxidized			297[b]	427	1.44	3.59	563[A]
Oxiban®							
0 ppm			304	432	1.43	3.65	418
400 ppm			302	433	1.44	3.62	505
Lipase							
0 %			299	430	1.44	3.66	483
0.1%			307	435	1.42	3.62	440
			Probability				
Fat			0.0375	0.0814	0.2362	0.4441	0.0001
Oxiban®			0.7473	0.9037	0.5812	0.8341	0.0542
Lipase			0.1792	0.4752	0.2396	0.7272	0.3343
Fat × Oxiban®			0.5302	0.9899	0.3326	0.4649	0.1543
Fat × Lipase			0.5303	0.7764	0.1877	0.9055	0.6370
Oxiban® × Lipase			0.9779	0.6216	0.4885	0.6403	0.8491
Fat × Oxiban® × Lipase			0.6750	0.6417	0.2381	0.4692	0.9208

[A,B] Values within the same column with different superscripts differ significantly($P < 0.01$).

In this study as the peroxide level increased, ethoxyquin supplementation alleviated the deleterious effect of peroxide, especially when supplemented at 125 ppm level, although broilers fed diets containing 125 ppm ethoxyquin and 7 meg peroxide/kg feed exhibited similar feed efficiencies and weight gains to broilers fed 125 ppm ethoxyquin alone. In the present experiments, peroxide values (MDA value of 1,284 ng/g fat in Experiment 1, 2.94 meg/kg in

Experiment 4 and 2.51 meq/kg in Experiment 5) were lower than used in some other experiments (Cabel *et al.*, 1988; Ohshima *et al.,* 1996). Thus low rancidity of fat used in these study is thought to be associated with better weight gain. Wang *et al.* (1997) observed no differences in weight gain, feed intake, and feed efficiency of birds fed oxidized fat with or without 125 ppm ethoxyquin although birds fed fresh fat with or without ethoxyquin had a higher weight gain, suggesting that rancidity of fat used was too high to elicit the effect of ethoxyquin. Modern fats containing restaurant greases, therefore, do not seem particularly susceptible to oxidation induced by holding at high temperatures.

Feeding lipase results in a numerical increase in weight gain, although the effect was not significant. Poling *et al.* (1980) reported that supplementing lipase to diets containing 4% tallow did not affect weight gain and feed efficiency, although there was increased lipid absorption. Al-Marzooqi and Leeson (1998) showed variable response to lipase mainly due to associated effects of anorexia. Birds fed oxidized fat in Experiments 1 and 2 had heavier livers compared to birds fed fresh fat, suggesting some toxic effect of oxidized fat, but there were no differences among treatments in Experiments 4 and 5. Corn oil used for Experiments 2 and 5 had higher MDA values than did the animal-vegetable fat blend used in Experiment 1. The MDA values of liver in Experiments 2 and 5 were decreased by the antioxidants. Therefore, rancidity of fat used in Experiment 1 seems to be insufficient to impair liver peroxidation and Santoquin® can exert its effect at higher levels of rancidity.

Only birds fed oxidized fat in Experiment 5 showed higher liver MDA values although rancidity of fat used in Experiment 5 was similar to that used in Experiment 4. The result is thought to be associated with adaptation and age of birds to oxidative stress because livers were collected at different times after feeding for 17 d in Experiment 4, but only 10 d in Experiment 5. Faster growth rate may therefore make birds susceptible to oxidative stress. In the study of Izaki and Fujiward (1981) and Izaki *et al.* (1984) involving rats, when thermally oxidized rapeseed oil was fed to rats for 13 wk, the relative liver weight, relative kidney weight, liver peroxidation (TBA reactants), and glutathione content increased significantly in proportion to the degree of deterioration of the oils. Bailey *et al.* (1996) reported that when 500 and 1,000 ppm ethoxyquin in normal diets for cockerel were used, liver peroxidation (TBARS value) was decreased in both treatments compared to controls, although there was no significant difference between the two levels of ethoxyquin tested. They also reported that birds fed 1,000 ppm ethoxyquin had a heavier relative liver than did birds fed 0, 125, and 500 ppm ethoxyquin in the first experiment but there were no differences in liver weight of birds fed 500 and 1,000 ppm ethoxyquin in the second experiment in which diets were especially enriched with carotenoids. The effect of ethoxyquin on liver size therefore seems variable.

In conclusion, feeding oxidized fat or oil can reduce performance of broiler chicks and effectiveness of antioxidants depends upon the degree of rancidity of fat. The addition of 100 to 250 ppm Santoquin® to diets containing oxidized fat can alleviate deleterious effects of oxidized fat, while dietary lipase does not seem to pose any additional problems.

적 요

본시험은 산패지방을 사용시 항생화제 (Santoquin®와 Oxiban®)의 첨가가 육계의 생산성에 미치는 영향을 측정하기 위하여 실시하였다. 신선한 또는 산패된 지방 (실험 1, 4, 5에서는 동물성, 식물성 혼합지방, 실험 2, 3에서는 옥수수기름)을 함유한 사료에 실험 1과 2에서는 0, 250, 500 ppm, 실험 3에서는 0, 100, 200, 300, 400, 500 ppm의 Santoquin®을 실험 4에서는 0, 400, 800 ppm, 실험 5에서는 0.1% lipase + 400 ppm의 Oxiban®을 첨가 또는 미첨가하여1일령의 육계에 급여하였다. 모든 실험에서 산패한 지방을 급여한 병아리보다 신선한 지방을 급여한 병아리의 증체량이 높았고, 실험 1과 2에서는 사료효율이 개선되었으며 AME_n과 지방소화율이 높았다. 병아리의 생산성에 대한 항산화제와 지방공급원간의 상호작용은 없었다. 실험2에서 200 ppm이상의 Santoquin®을 급여시 증체량과 사료섭취량이 감소 하였다 (P < 0.05). 실험 2와 5에서 산패지방을 급여한 병아리의 간의 malondialdehyde (MDA)함량이 높았다 (P < 0.05). 실험 2에서 산패지방에 Santoquin® 250 ppm을 첨가한 구의 병아리의 간내 MDA함량이 낮았지만 실험 1, 4, 5에서는 처리간에 차이가 없었다. 결론적으로 항산화제의 첨가시 산패지방 급여에 의한 악영향을 완화시킬 수 있으며, 사료내 Santoquin®을200 ppm이상 첨가시 생산성 저하를 나타내는 것으로 보인다.

(색인어: 항산화제, Santoquin®, Oxiban®, 산패지방)

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