Effects of Maternal and Posthatch Dietary Oils and Vitamin E on Antioxidant Capability and Muscle Quality of the Progeny Broilers

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Effects of maternal and posthatch dietary oils and vitamin E (VE) on antioxidant capability and muscle quality of the progeny broilers were studied. Two-factor experiment was designed, there were two main effects, one was oil source, the other was VE level, diets were as follows: corn oil (CO) +20 mg/Kg VE, fish oil (FO) +20 mg/Kg VE, CO+ 100 mg/Kg VE and FO+ 100 mg/Kg VE. The results showed that: (1) FO in maternal and posthatch diets significantly reduced body weight of the progeny broilers at 42 d ($P<0.05$), significantly increased food/gain ratio ($P<0.01$) of 0–42 d, significantly increased lipid peroxides malondialdehyde (MDA) content of broiler serums at 10 d ($P<0.01$), 21 d ($P<0.01$), 28 d ($P<0.01$) and 42 d ($P<0.01$) respectively, there was also a substantial interaction ($P<0.05$) between oil sources and vitamin levels at 28 d, and also a trend at 42 d, the highest MDA content of serums was always observed in FO with 20 mg/kg VE group, the lowest MDA content of serums was occurred in CO with 100 mg/kg VE group. (2) FO inclusion in maternal and posthatch diet increased breast meat MDA content, decreased superoxide dismutase (SOD) activity of breast meat compared to corn oil treatment. (3) Addition of higher level of VE in maternal and posthatch diets significantly reduced MDA content of broiler serums at 10 d, 21 d ($P<0.05$), 28 d ($P<0.05$) and 42 d ($P<0.05$) respectively. (4) Higher level of VE in maternal and posthatch diets also significantly reduced drip loss of breast meat of the progeny broilers, but increased meat MDA significantly, decreased meat SOD activity significantly, besides, there was an interaction trend ($P=0.06$) between oil source and VE level on meat MDA, FO group with higher VE appeared the highest MDA content in breast meat. These findings suggest that diet with FO need more antioxidant to protect from oxidation, but FO oil with higher VE in maternal and posthatch diets may bring about meat deterioration to the progeny broilers.

Key words: breeder, corn oil, fish oil, progeny, vitamin E

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1. Introduction

In recent year, maternal effect of dam nutrition on the progeny has received considerable attention, specific ingredients and nutrients fed to hens will influence progeny growth, carcass attributes, enzyme functions, and immunity (Kidd, 2003). Studies indicated that vitamin E (VE) in breeder hen diet affected VE concentration in egg yolk and blood plasma of breeder pullet (Lin *et al.*, 2005), enhanced antioxidant status of offspring chicks (Surai, 2000; Lin *et al.*, 2005), which hint that maternal dietary VE is beneficial to protect the progeny from oxidative stress.

N-3 polyunsaturated fatty acid (PUFA) is welcome because of its beneficial effects on cardiovascular health (Siddiqui *et al.*, 2008), immunity (Wang *et al.*, 2000) and inflammatory diseases (Kremer, 2000). Fish oil rich in n-3 PUFA plays different immune function to corn oil, a source of n-6 PUFAs (He *et al.*, 2007), increases the content of n-3 fatty acids in poultry meat especially eicosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3) (Hulan *et al.*, 1988; Yang *et al.*, 2010). There are some studies of the two oils on broilers, but there is little information of the additive effects of the two oils in maternal and posthatch broiler diets on the progeny broilers. N-3 PUFA is highly susceptible to peroxidation (Meydani, 1991; Oarada *et al.*, 2008), dietary supplementation with n-3 PUFAs increases the levels of n-3 PUFAs, enhances the production of lipid peroxides (Song *et al.*, 2000), and needs protection of antioxidant such as VE, which may alleviate oxidant stress and optimize immune responses in poultry (Cherian, 2003),

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so the experiment was designed, the objective of the present study was to investigate the different additive effects of maternal and posthatch dietary oil sources and VE level on antioxidant capability, carcass and muscle quality traits of the progeny broilers.

2. Materials and Methods

2.1 Experimental Birds and Diets

2304 fertile eggs (576 per group) were collected from breeder hens fed diets containing corn oil (CO)+20 mg/kg VE, fish oil (FO)+20 mg/kg VE, CO+100 mg/kg VE and FO+100 mg/kg VE, dietary oil inclusion level in breeder was 2%. These eggs were incubated at 37.6°C and 61% relative humidity in a commercial incubator (EIXD2, Qing-Dao, China) with automatic egg turning. After 21 days incubation, 60 male broilers from each group breeders were divided into 6 replicates of 10 birds each feeding diets containing CO+20 mg/kg VE, FO+20 mg/kg VE, CO+100 mg/kg VE and FO+100 mg/kg VE, dietary oil inclusion level in the progeny was 4%. The basal diet composition was same. The breeder hen diets refer to An *et al.* (2010), the progeny diets are shown in Table 1, basal diets for starter period (0 to 3 week), grower period (4 to 6 week) were formulated to meet Feeding Standards of Chickens (Ministry of Agriculture of P. R.China, 2004). Feed and water were provided ad libitum throughout the experimental period. Other management was conducted according to the recommended guideline for the breeders and broilers.

2.2 Sample Collection and Analysis

2.2.1 Growth Performance of the Progeny Broilers

At 21d and 42 d of age, chickens of each replicate cage were weighed after 12 h feed deprivation, and the remaining feed was weighed. Performance indexes such as body weight (BW) gain, feed intake, and ratio of feed to gain were determined.

2.2.2 Antioxidant Capability of the Progeny Broilers

malondialdehyde (MDA) and activity of superoxide dismutase (SOD) of serum were detected to measure antioxidant capability of the progeny broilers. At 10 d, 21 d, 42 d of age, 6 healthy chickens (1 per replicate) were randomly chosen from each treatment, blood samples were collected from the wing vein and centrifuged at 3,000 g for 10 min at 4°C, then the serums were stored at -30°C until assay. Lipid peroxidation of serum was determined by thiobarbituric acid reactive substances (TBARS) expressed as MDA equivalents. SOD activity was assessed by xanthine oxydase and hypoxanthine system, one unit of SOD activity is defined as the amount of enzyme exhibiting 50% dismutation of the superoxide radical. MDA content and SOD activities were determined using commercial kits supplied by Nanjing Jiancheng Bioengineering Institute (China)

2.2.3 Carcass Composition and Muscle Quality Traits of the Progeny Broilers

At 42 d, birds were slaughtered after 12 h feed deprivation to test the carcass composition and meat quality. Abdominal fat, left thigh and left pectoral muscle were removed and weighed, all the indexes were expressed as percentage of 42 d live broiler BW before slaughter.

To judge muscle quality, pH value, drip loss, MDA content and SOD activity of pectoral muscle were detected. The methods were as follows: pH value of the breast pectoralis major was measured with a portable pH meter for two times, and expressed as the average value. Regarding drip loss of muscle, about 30 g of muscle from the same part with same surface area of the pectoralis major was taken and placed in a plastic bag with air, hanging from a hook, stored at 4°C for 24 h, then calculate the percentage of the loss weight to the initial muscle weight. MDA Content, SOD activity and protein concentration of pectoral muscle were detected according to reagent kits (Nanjing Jiancheng Bioengineering In-

Table 1. Composition and nutrient level of the progeny diets

Ingredients (%)	0-3 week	4-6 week	Calculated nutrient	0-3 week	4-6 week
Corn	51.61	58.17	ME (Mcal/kg)	2.95	3.05
Soybean meal	38.57	34.35	Crude protein (%)	21.00	19.50
Corn oil	4.00	4.07	Lysine (%)	1.15	1.01
Dicalcium phosphate	1.85	1.19	Calcium (%)	1.00	0.95
Zeolite	1.70	0.00	Available P (%)	0.45	0.35
Limestone	1.21	1.49			
Salt	0.35	0.30			
DL-methionine	0.25	0.08			
Choline chloride (50%)	0.16	0.10			
Lysine-HCL	0.05	0.00			
Antioxidants	0.03	0.03			
Vitamin premix ¹	0.02	0.02			
Mineral premix ²	0.20	0.20			
Total	100.00	100.00			

¹ Vitamin premix for broilers provided per kg of diet: vitamin A, 12500 IU; vitamin D3, 2500 IU; vitamin K3, 2.65 mg; vitamin B1, 2 mg; vitamin B2, 6 mg; vitamin B12, 0.025 mg; biotin, 0.0325 mg; folic acid 1.25 mg; pantothenic acid 12 mg; niacin 50 mg.

² Mineral premix for broilers provided per kg of diet: Cu, 8 mg; Zn, 75 mg; Fe, 80 mg; Mn, 100 mg; Se, 0.15 mg; I, 0.35 mg.

stitute, China), MDA content was measured by TBARS, SOD activity was assessed by xanthine oxydase and hypoxanthine system, protein was assayed by Coomassie brilliant blue method. MDA content of pectoral muscle meat was expressed as nmol / mgprot, meat SOD activity was expressed as U / mgprot.

2.3 Statistical Analysis

Two way analysis of variance was performed on all data using the General Linear Model (GLM) procedure of SPSS (SPSS 11.0), and Duncan's test was used to separate the means. A significance level was set at $P < 0.05$.

3. Results and Discussion

3.1 Growth Performance of Broilers

Growth performance indexes of broilers were influenced by oil source (Table 2), BW of broilers at 42 d was decreased, food/gain of 0-42 d increased in FO group compared to CO group. The results are similar as An *et al.* (2010) and Pappas *et al.* (2005), who found inclusion of FO in the maternal diet reduced the weights of the eggs and the newly-hatching chicks, moreover, maternal nutrition brings about an persistent effect on the progeny, Pappas *et al.* (2006) reported chicks hatched from hens fed FO were 11 g lighter than those hatched from hens fed soya oil at 14 d posthatch. In the present experiment, BW of chicks at 42 d of age in FO group was almost 100 g lighter than those in CO group, which suggests that there is an additive effect of maternal and posthatch diet on performance of broilers.

VE level also influenced broilers performance, food/gain of 0-42 d was significantly higher in group of 100 mg/Kg VE than that in 20 mg/Kg VE group, there was no significant effect of VE level on BW or food intake (FI). This phenomenon may be partly attributed to the lower egg weight and lower neonatal weight observed in the higher VE group (An *et al.*, 2010), this result indicated that higher level of VE in maternal and posthatch diet may have a negative effect on the growth performance of the broilers. However, there was no significant interaction between oil source and VE level on broiler performance indexes.

3.2 Antioxidant Capability in Serum of Broilers

3.2.1 Content of MDA

Study results indicated that different oil source played different antioxidant effect (Table 3). MDA contents in serums of broilers at 10 d, 21 d, 28 d and 42 d were substantially increased due to the replacement of CO with FO in maternal and posthatch diets. This effect was consistent with our previous finding in egg yolk, and also indicated that FO rich in n-3 PUFA is susceptible to peroxidation (An *et al.*, 2010).

100 mg/kg VE played an effective antioxidant effect, MDA concentration in serums of broilers at 21 d, 28 d and 42 d was significantly lower than that in 20 mg/kg VE group. These results were consistent with previous studies (Cherian *et al.*, 1996; Surai, 2000).

Except for the two main effects, there was a substantial interaction ($P < 0.05$) between oil sources and vitamin levels at 28 d, and also a trend at 42 d, the highest MDA content of serums was always observed in FO with 20 mg/kg VE group, the lowest MDA content was occurred in CO with 100 mg/kg VE group.

N-3 PUFA is highly susceptible to peroxidation, which may reduce tocopherol concentration in tissues and increase the need of antioxidant protection during periods of rapid growth (Cherian and Sim, 2003), α -tocopheryl acetate (VE), as a dietary lipophilic antioxidant, has been widely reported to be effective in protecting animal against the oxidative damage caused by free radicals. These results in the present study also remind us much more antioxidants should be applied when animal fed diets including oil rich in n-3PUFA than n-6PUFA to prevent the possible oxidative stress.

3.2.2 Activity of Total Superoxide Dismutase (T-SOD)

Activity of SOD is an indication of antioxidant capacity of the tissues, lipid peroxidation will be initiated when the generation of reactive oxygen species (ROS) such as H_2O_2 , the hydroxyl radical, and superoxide, or other free radicals exceed the antioxidant capabilities of cells or tissue, SOD plays an important role in protecting cells from damage caused by ROS, SOD converts superoxide to H_2O_2 and oxygen. In turn, H_2O_2 is reduced by Catalase (CAT) and Gluta-

Table 2. Growth performance of the progeny broilers

(n=6)

Oil source	V E(mg /Kg)	0 to 21d			0-42d		
		FI(g)	BW(g)	F:G	FI(g)	BW(g)	F:G
CO	20	753.46	542.10	1.49	2830.88	1757.20	1.65
CO	100	775.17	582.00	1.43	2894.55	1741.48	1.70
FO	20	743.83	564.44	1.42	2850.83	1704.50	1.72
FO	100	755.86	565.00	1.44	2789.46	1597.10	1.79
SEM		7.98	7.81	0.01	35.52	22.72	0.01
Oil source	CO	764.31	562.05	1.46	2862.72	1749.34	1.68
	FO	749.85	564.72	1.43	2820.15	1650.80	1.76
VE	20	748.65	553.27	1.46	2840.86	1730.85	1.68
	100	765.51	573.50	1.44	2842.01	1669.29	1.75
	P-value						
Oil source		0.38	0.87	0.19	0.56	0.05	0.00
VE		0.31	0.21	0.39	0.99	0.20	0.01
Oil×VE		0.77	0.23	0.07	0.40	0.33	0.46

Table 3. Content of MDA and activity of T-SOD in serum of the progeny broilers ($n=6$)

Oil source	VE	MDA (nmol/ml)				SOD (U/ml)			
		10d	21d	28d	42d	10d	21d	28d	42d
CO	20	3.23	4.29	2.82 ^b	3.78 ^b	98.82	120.95	153.07	133.45
CO	100	2.78	3.57	2.88 ^b	3.47 ^b	122.39	93.71	139.19	120.31
FO	20	4.74	7.94	5.70 ^a	8.83 ^a	94.50	87.15	166.11	122.78
FO	100	4.23	5.89	3.65 ^b	5.25 ^b	117.38	100.35	167.65	128.76
SEM		0.20	0.30	0.22	0.40	6.31	6.66	5.62	6.79
Oil source	CO	3.00	3.93	2.85	3.63	110.61	107.33	146.13	126.88
	FO	4.48	6.92	4.68	7.04	105.94	93.75	166.88	125.77
VE	20	3.98	6.11	4.26	6.31	96.66	104.05	159.59	128.11
	100	3.50	4.73	3.27	4.37	119.88	97.03	153.42	124.54
<i>P</i> -value									
Oil source		0.00	0.00	0.00	0.00	0.72	0.33	0.09	0.94
VE		0.26	0.04	0.049	0.03	0.09	0.61	0.59	0.80
Oil×VE		0.96	0.30	0.04	0.06	0.98	0.15	0.51	0.50

^{a,b} Means in the same column without common superscripts differ significantly ($P<0.05$).

Table 4. Carcass and meat quality of 42d-old progeny broilers (%) ($n=6$)

Oil source	VE	Carcass composition			Meat quality traits			
		Breast muscle	Thigh muscle	Abdominal fat	PH value	Drip loss	SOD (U/mg)	MDA (nmol/mg)
CO	20	9.06	10.24	1.47	5.64	2.51	134.52	10.32
CO	100	8.75	10.68	1.37	5.60	1.84	121.69	10.70
FO	20	8.65	10.35	1.33	5.58	2.68	112.91	17.51
FO	100	7.82	10.48	1.13	5.66	1.85	81.42	24.44
SEM		0.15	0.12	0.12	0.04	0.15	4.35	0.80
Oil source	CO	8.91	10.46	1.42	5.62	2.18	128.11	10.51
	FO	8.24	10.41	1.23	5.62	2.27	97.17	20.98
VE	20	8.86	10.29	1.40	5.61	2.60	123.72	13.92
	100	8.29	10.58	1.25	5.63	1.85	101.56	17.57
<i>P</i> -value								
Oil source		0.04	0.86	0.45	0.97	0.78	0.00	0.00
VE		0.07	0.28	0.55	0.85	0.03	0.03	0.04
Oil×VE		0.40	0.56	0.84	0.49	0.79	0.31	0.06

thione peroxidase (GPx) to H₂O and oxygen (Jones *et al.*, 1981).

From Table 3, we can find that activity of T-SOD in serum of broilers was not changed by different oil sources or different VE levels, this finding was consistent with Combs (1981), who reported that GPx, CAT, or SOD activities in liver or brain were not affected in chicks fed supplemental VE (100 mg/kg).

This results in our present study indicated that lipid peroxidation was prevented not mainly by mechanism of SOD activity improvement, but the higher VE level enhancement, the higher level VE may be the mainly mechanism of antioxidant defensive system in the experiment.

3.3 Carcass and Meat Quality Traits

Effects of diets on carcass composition and meat quality of broilers are shown in Table 4. Birds from FO group exhibited lower breast meat yield compared to CO group, besides, there was no obvious effect of oil source on thigh

muscle or abdominal fat yield. VE level also had no clear effect on carcass composition of the broilers.

Regarding breast meat quality traits, meat MDA was significantly increased in FO group compared to CO group (20.98 nmol/mg to 10.51 nmol/mg), the result was in good agreement with literature data (Song *et al.*, 2000). In addition, meat SOD activity was reduced significantly in FO group, different from that in serums (Table 3), because there was no significant effect of oil source on SOD activity of serums. The results attributed to different tissues of broilers and also partly to the cumulative effects of maternal and posthatch dietary treatment. There was no clear effect of oil source on pH value or drip loss of the breast meat.

However, contrary to our expectation, we observed a very interesting phenomenon happened about higher level of VE on breast meat quality, different from serums of the broilers, meat MDA was increased significantly, meat SOD activity was reduced significantly in 100 mg/kg VE group compared

to 20 mg/kg VE broilers, there was an interaction trend ($P=0.06$) between oil source and VE level on meat MDA, the FO group with higher VE appeared the highest MDA content in breast meat. The authors think this may be related to cumulative effect of maternal and posthatch dietary treatment. Chen *et al.* (1998) reported that VE had antioxidant activity at a low concentration and prooxidant activity at a high concentration (120 mg VE/kg diet) in laying hens. In our present study, progeny broilers from hens fed higher (lower) level of VE were still fed diets containing higher (lower) level of VE, the accumulation of long time feeding may produce an additive effect on meat antioxidant capacity, and also remind us of the possible prooxidation effect. Whether the rise of meat MDA and the decrease of meat SOD activity in broilers from higher VE was due to the prooxidant effect of higher VE for long time application need further study.

Higher level of VE significantly reduced drip loss of the breast meat. The result suggests that VE has the potential of improving water storage ability of the breast meat. Besides, there was no obvious difference of oil source or VE level on pH value of breast meat.

4. Conclusion

FO addition in maternal and posthatch diet significantly reduced body weight of broilers at 42 d, increased food/gain of 0–42 d, significantly increased MDA content of serums and breast meat, also decreased SOD activity of breast meat compared to CO group. Maternal and posthatch dietary 100 mg/Kg VE significantly decreased MDA concentration in serums of broilers, reduced drip loss of the breast meat, but the possible prooxidation to breast meat of high level VE for long time use should arouse more attention.

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