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Effects of dietary vitamin E and organic selenium supplementation on the oxidative stability of lamb meat*

X. Han, J.G. Li[1], Y.X. Gao, Q.F. Li and Y.F. Cao

Department of Animal Science and Technology, Agricultural University of HeBei Baoding, 071001, P.R. China

ABSTRACT

A total of 72 healthy F_1 lambs (Suffolk♂ × Small Tailed Han sheep♀) were allocated to nine groups in a 3×3 factorial design to study the effects of dietary vitamin E (VE) and selenium supplementation on the oxidative stability of lamb meat. Dietary VE supplementation (500 or 1000 IU/d) increased α-tocopherol concentrations in serum and *longissimus* muscle ($P<0.01$). Se supplementation (0.2 and 0.4 mg/kg DM of concentrate) increased Se concentrations in serum and *longissimus* muscle ($P<0.05$), but no influence on the lipid oxidation, discolouration and water retention of muscle. VE supplementation at 500 and 1000 IU/d significantly decreased drip loss of *longissimus* muscle ($P<0.05$) and improved the oxidative stability of lamb meat during the whole period of storage ($P<0.01$). VE supplementation increased a* values of *longissimus* muscle at d 10-13 of storage at 4°C ($P<0.05$).

KEY WORDS: vitamin E, organic selenium, lamb meat, oxidative stability

INTRODUCTION

Vitamin E (VE) and selenium (Se) are important components of the antioxidant defence system of living tissues (Gerloff, 1992). These antioxidant functions are important because the oxidation of muscle lipids after slaughter can adversely affect the flavour and nutritive value of fresh, frozen, and cooked meat and meat products (Morrissey, 1998). Dietary Se supplementation did not affect significantly muscle Se levels, or susceptibility to lipid and oxymyoglobin oxidation in the presence or absence of VE. Dietary Se stimulated the biosynthesis yield of seleno-cysteine-proteins, e.g., the Se-dependent glutathione peroxidase (Combs, 1981).

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[1] Corresponding author: e-mail: jgli@hebau.edu.cn

It is well established that VE supplementation of the diets of meat-producing animals effectively elevates the concentration of VE in muscles, and lowers the susceptibility of muscle and, ultimately, meat products to lipid oxidation and the onset of flavour defects (Monahan et al., 1990; Guidera et al., 1997; Lauridsen et al., 1997). The concentration of Se in muscles has been shown to respond to dietary Se supplementation in pigs (Goehring et al., 1984) or beef cattle (Ekholm et al., 1991).

The objective of the present study was to determine the effect of dietary VE and Se on the oxidative stability of meat, and to examine potential interactions between the effects of dietary VE and Se.

MATERIAL AND METHODS

The vitamin E supplement used in the animal feed was supplied by DSM Co. Ltd. (China) and was stated by the supplier to contain 50% DL-α-tocopheryl acetate. Organic Se (Sel-Plex™) was obtained from Alltech China, and was stated by the manufacturer to contain about organic Se 1.000 mg/kg. The experiment was carried out on Fuhua Agri Husb LD Farm with F_1 lambs (Suffolk♂× Small Tailed Han sheep♀). A 3×3 factorial design was used to study the effects of dietary VE (0, 500 and 1000 IU/d) and organic Se (0, 0.2 and 0.4 mg/kg DM) supplementation on the oxidative stability of lamb meat. A total of 72 healthy F_1 lambs (age: 120±10 d, body weight: 22.0±2.4 kg) were randomly allocated to one of nine groups with 8 replicates. The lambs were fed maize silage (2 kg/d) and a base concentrate (55:45% roughage to concentrate) with different levels of VE and Se. After 60 days of feeding, 45 lambs were slaughtered as a sub-sample to evaluate the effects. Concentrate composition is shown in Table 1.

Table 1. Ingredient composition and major nutrient contents of basic concentrate

Ingredients, % DM		Nutrient contents	
Maize	60	Crude protein, *%*	17.00
Soya meal	24	DE, MJ/kg	13.45
Wheat bran	13	Ca, *%*	1.24
Premix[1]	3	P, *%*	0.57
		α-tocopherol, mg/kg	18.65
		Se, mg/kg	0.09

[1] Premix provided the following per kg of diet, IU: vit. A 1.900; vit. D 190; g: NaCl 4.4; mg: Mn 14; Fe 8.5; Cu 2.3; I 23; Co 24

Samplings, recordings and analysis

Lognissimus muscle samples (300 g), taken in the region of the last thoracic vertebra, were obtained 24 h post-mortem, vacuum-packed and stored at -20°C until

required for α-tocopherol and Se analysis, and lipid oxidation studies (less than 4 months). Fluorometric and high-performance liquid chromatographic (HPLC) determination were used separately to measure Se and α-tocopherol contents (Daniels et al., 2000; O'Grady et al., 2001). Drip loss was measured following the procedures of Sun Yumin. Discoloration and lipid oxidation of the samples were analysed on d 1, 3, 5, 10 and 13 in 4°C storage. The colour of the muscle (CIE L*, a*, and b*) was measured using a Minolta chromameter. The level of lipid oxidation was determined using the thiobarbituric acid reactive substances (TBARS) method by a commercial kit (Nanjing Jiancheng Bioengineering Institute, China).

The data were analysed by ANOVA using the general linear model procedure of SAS (SAS Inst. Inc., Cary, NC). Differences between treatment means at the 5% level were determined using the least significant different test.

RESULTS

Dietary VE supplementation (500 or 1000 IU per day) for 60 d led to an increase of α-tocopherol concentration in serum and *longissimus* muscle of lambs ($P<0.01$), but no statistical difference between the two levels ($P>0.05$). Se supplementation at 0.2 or 0.4 mg/kg DM also increased the Se concentration in serum and *longissimus* muscle ($P<0.05$; Table 2).

Table 2. The concentrations of α-tocopherol and Se in serum and *longissimus* muscle of lambs

Item	VE			Se			SEM	Se*VE	P
	0	500	1000	0	0.2	0.4			
α-tocopherol									
LM, μg/g	1.73^{B}	4.77^{A}	4.89^{A}	5.03	4.85	4.67	0.16	NS	<0.01
serum, μg/ml	2.61^{B}	5.90^{A}	6.05^{A}	3.74	3.89	3.77	0.15	NS	<0.01
Se									
LM, μg/kg	82.83	81.83	87.17	51.5^{B}	97.33^{A}	103.00^{A}	2.61	NS	<0.01
serum, μg/l	114.67	115.67	114.50	84.00^{C}	104.33^{B}	156.50^{A}	3.05	NS	<0.01

LM - longissimus muscle; ^{A,B,C} mean values in the same row with different superscripts are significantly different ($P<0.01$)

As shown in Table 3, from 5 d of storage, drip loss of *longissimus* muscle decreased significantly with dietary VE supplementation at 500 and 1000 IU/d ($P<0.05$). The TBARS value increased in all treatments during storage for up to 13 d. Dietary VE supplementation at 500 IU/d or 1000 IU/d was more effective in reducing lipid oxidation ($P<0.01$). Se supplementation had no significant effects on the lipid oxidation ($P>0.05$). The a* values (redness) tended to decrease with the expanded storage. Dietary VE supplementation increased a* value of *longissimus*

muscle after 10-13 d of storage at 4°C. Increasing dietary organic Se level had no effects on the discoluration of muscle during the storage period (P>0.05).

Table 3. The effects of dietary VE and Se on drip loss, lipid oxidation and discoloration of *longissimus* muscle of lambs during storage at 4°C

Item	VE			Se			SEM	Se*VE	P
	0	500	1000	0	0.2	0.4			
Drip loss, %									
1	0.66	0.67	0.59	0.63	0.65	0.65	0.03	NS	NS
3	1.76	1.60	1.39	1.50	1.71	1.55	0.17	NS	NS
5	4.11	3.58^{b}	3.53^{b}	3.76	3.79	3.67	0.17	NS	<0.05
10	7.72^{A}	6.61^{B}	6.64^{B}	7.05	6.99	6.93	0.18	NS	<0.01
13	12.35^{A}	10.56^{B}	10.39^{B}	11.17	11.10	11.03	0.17	NS	<0.01
TBARS values, nmol/mgProt									
1	0.25^{A}	0.15^{B}	0.16^{B}	0.19	0.18	0.19	0.01	NS	<0.01
3	0.34^{A}	0.24^{B}	0.23^{B}	0.27	0.28	0.27	0.02	NS	<0.01
5	0.64^{A}	0.43^{B}	0.45^{B}	0.51	0.51	0.5	0.02	NS	<0.01
10	1.05^{A}	0.66^{B}	0.65^{B}	0.78	0.78	0.78	0.02	NS	<0.01
13	1.24^{A}	0.84^{B}	0.85^{B}	0.97	0.99	0.97	0.02	NS	<0.01
*A**									
1	18.24	19.51	19.45	19.14	19.07	19.00	0.98	NS	NS
3	17.74	18.76	18.44	18.41	18.43	18.12	1.34	NS	NS
5	15.45	16.90	16.88	16.41	16.48	16.34	0.76	NS	NS
10	12.97^{b}	14.53^{a}	14.47^{a}	13.99	13.94	14.05	0.39	NS	<0.05
13	12.48^{b}	14.01^{a}	13.97^{a}	13.69	13.53	13.24	0.23	NS	<0.05

$^{A, B, C}$ mean values in the same row with different superscripts are significantly different (P<0.01)
^{a,b,c} mean values in the same row with different superscripts are significantly different (P<0.05)

DISCUSSION

Dietary VE supplementation led to an increase in serum α-tocopherol concentration after 60 d on the experiment diets. Increasing supplementation level from 500 to 1000 IU/d led to no further increase in serum α-tocopherol concentration (P>0.05). The results indicate that a saturation level of serum α-tocopherol was reached with 500 IU/d VE supplementation. Elevated bovine serum α-tocopherol concentration and its saturation following dietary supplementation have been reported also in bovines (Arnold et al., 1993). In agreement with the findings of Ekholm et al. (1991), muscle α-tocopherol concentrations were not significantly affected by dietary Se supplementation.

The effect of α-tocopherol on lipid oxidation in animal tissues is well established (Morrissey et al., 1998; Guo et al., 2006). There was no significant effect of dietary

Se on the oxidative stability of minced *longissimus* muscle, and no additional benefit. O'Grady (2001) reported that Se supplementation (0.3 mg/kg) in the beef cattle diets did not significantly affect glutathione peroxidase activity or susceptibility to lipid and oxymyoglobin oxidation in the presence or absence of vitamin E. The results were similar with given in this paper, but no similar reports were found in lambs. The oxidative stability of muscle lipid was improved by supplementation with 500 or 1000 IU of α-tocopheryl acetate/d after 10 d of storage ($P<0.05$), similar to the results reported (Arnold et al., 1992, 1993; Mitsumoto et al., 1993; Faustman et al., 1998, 1999). Avanzo et al. (2001) reported that α-tocopherol affected peroxidation of the mitochondrial membranes by one order of magnitude higher than Se, which also suggested that α-tocopherol, but not Se, is the factor that markedly affects the course of lipid peroxidation.

The surface meat colour of lambs, as expressed by a*, were not affected by different dietary Se supplementations. Monahan et al. (1994) reported that until 8 d of storage, a* values of chops from pigs fed 200 mg of α-tocopheryl acetate/kg of feed are significantly higher than those of chops from pigs fed a basal diet (10 mg/kg of feed), similar to the result of this study. In agreement with the results of Dufrasne et al. (2000), there were no significant difference of drip loss at d 1 and 3 of storage ($P>0.05$). From d 5 of storage, the drip loss tended to decrease with dietary VE supplementation ($P<0.05$). No carcass measurement benefit resulted from dietary Se levels (Mahan et al., 1999).

CONCLUSIONS

Organic Se supplementation of lambs affected muscle Se content, but no significant influence on the oxidative stability. Dietary VE supplementation at 500 or 1000 IU/d led to elevated α-tocopherol concentrations in serum and muscle and a decrease in the susceptibility of muscle tissue to lipid oxidation. The results suggest that adjusting dietary Se has limited potential, except perhaps when dietary Se is limiting, for increasing the oxidative stability of lamb or accentuating the stabilizing effect of VE.

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