DIET AND VITAMIN E METABOLISM IN LAMBS: EFFECTS OF DIETARY SUPPLEMENTATION ON MEAT QUALITY

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Background

Dietary vitamin E is important not only for preventing deficiencies and improving animal health but also for increasing feedlot performance and improving meat quality in finished lambs. Nowadays, effective supplementation of the diet with enhanced levels of vitamin E is considered necessary in several species since it improves the shelf life of meat by delaying lipid and myoglobin oxidation (Faustman *et al.*, 1998; Wulf *et al.*, 1995). It is important to understand how vitamin E is metabolised and absorbed in order to improve the effectiveness of supplementation. However, there is contradictory data about the metabolism of vitamin E in the rumen. Some studies have shown that dietary vitamin E is not affected by ruminal fermentation (Leedle *et al.*, 1993) while others have shown substantial ruminal disappearance of vitamin E in lambs fed high concentrate diets (Alderson *et al.*, 1971). Previous studies in our laboratory (Enser *et al.*, 1999) have shown low tissue vitamin E concentrations in lambs fed on dry pelleted diets supplemented with supranutritional levels of the vitamin and this has caused us to question the influence of the basal diet on vitamin E metabolism.

Objective

The aim of this study was to determine the effect of basal diet on vitamin E metabolism in lambs in relation to meat quality.

Materials and methods

Four groups of eight Suffolk × Charollais wether lambs were individually penned and allocated according to their live weight to one of two diets (1) concentrates, (2) grass silage (first cut rye grass) supplemented with concentrates (mixed diet). Both diets contained two levels of vitamin E, 60 (low) or 500 (high) mg/kg DM. The low level is much higher than that normally used in concentrate based commercial diets. The pelletted concentrate was a mixture of wheat, molassed sugar beet pulp, soya bean meal and rapeseed meal. To obtain similar slaughter weights, the concentrate-fed lambs were started at an initial live weight of 25±1.6kg (SED) and lambs on the mixed diet were started at a higher initial live weight, 32±3.3kg (SED). Lambs were introduced to the diets, either concentrates *ad libitum* or silage *ad libitum* plus 400g/d concentrates, over a five-day adaptation period. Lambs fed the mixed diet were slaughtered after 56 days and concentrate fed lambs after 63 days. Blood samples were obtained at weekly intervals to monitor plasma α-tocopherol concentration (Burton *et al.*, 1985) and on days 0, 30 and 55 for creatine kinase (CK) and glutathione peroxidase (GSHPx) activity as indicators of oxidative stress in the animals. After slaughter, meat samples were removed at 24h. For assessment of colour during display and oxidative stability, 15mm thick leg steaks were aged for 6 days in vacuum at 0°C, repacked in modified atmosphere (O_2:CO_2, 0.75:0.25) and displayed under light (cool white fluorescent illumination with 700lx, 16hr on/8hr off) at 4°C for 6 days. M. *semimembranosus* colour was determined daily using CIELAB L*a*b* colour space and oxidative stability was determined as thiobarbituric acid reacting substances (TBARS) after 3 and 6 days of display (Vyncke, 1975). Vitamin E levels in m. *semimembranous* were determined by a modification of the method of Liu *et al.* (1996) and fatty acid composition of the same muscle was determined by the method of Whittington *et al.* (1986).

Results and discussion

Lambs fed the mixed diet grew more slowly than those on concentrates (daily liveweight gain 150g/d versus 309g/d) but neither dry matter intake no growth rate was significantly affected by the level of vitamin E supplementation. For lambs fed the mixed diet grass silage accounted for approximately 65% of the total DM intake. Mean live weights at slaughter were 40kg for lambs on both low vitamin E treatments, and 43 and 40kg for concentrate- and mixed diet-fed lambs on the high vitamin E treatment respectively. The lambs fed the mixed diet had higher plasma vitamin E on day 0 than the concentrate-fed lambs (Figure 1). During the trial, the plasma vitamin E of the concentrate-fed lambs on the low vitamin E diet fell 63% to less than 0.3 µg/ml, which is considered to be on the threshold between adequacy and deficiency (Rammell and Cunliffe, 1983; NCR, 1985). However, growth rate and plasma creatine kinase (CK) and glutathione peroxidase (GSHPx) activity did not indicate a deficiency state. In fact, CK and GSHPx indexes improved during the trial. In contrast, mixed diet-fed lambs on the same low vitamin E supplementation increased their plasma vitamin E levels approximately 36% during the trial and, on the high vitamin E supplementation plasma vitamin E rose 103% compared with 84% for the lambs fed concentrates. Muscle vitamin E concentrations were higher for lambs on the mixed diet for both supplementation levels despite their shorter feeding period. Vitamin E level in the feed had little effect on the colour of m. *semimembranosus* during simulated retail display but meat from lambs fed the mixed diet had a more intense red colour during the entire display period. Lipid oxidation expressed as TBARS was greater at the low levels of vitamin E and was very high for the concentrate-fed lambs. These values reflect the vitamin E concentrations in the muscle (Table 1). Lambs fed concentrates alone had high levels of 18:2 *n-6* (linoleic acid) in their muscle whereas feeding silage supplemented with concentrates produced high levels of 18:3 *n-3* (α-linolenic acid) and low levels of 18:2 *n-6* as shown from previous work in our laboratory (Fisher *et al.*, 2000). The lambs

on the mixed diet containing high vitamin E had higher levels of polyunsaturated fatty acids (PUFA) in the muscle than those fed the low level suggesting a positive protective effect of vitamin E on unsaturated lipids (Table 2).

Conclusions

The results confirm the problems of low vitamin E deposition in lambs fed concentrate diets and show that shelf life (colour and lipid oxidation) are closely related to the tissue vitamin E levels. Much higher supplementation levels of vitamin E than those normally used are required to overcome the effect of concentrate feeding. The results confirm the beneficial effect of grass feeding for muscle n-3 PUFA levels and vitamin E storage and show that even on grass-based diets supplemental vitamin E has beneficial effects on muscle fatty acid composition.

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Table 1. *Diet effect on plasma and muscle vitamin E concentrations at slaughter, muscle colour and lipid oxidation of m. semimembranosus (mean values). Concentrate (C) and mixed diet (M) fed lambs.*

	Vitamin E supplementation level (mg/kg DM)					Diet effect
	60 (C)	500 (C)	60 (M)	500 (M)	sem	significance
Plasma vitamin E (μg/ml)	0.22	1.56	0.98	1.93	0.124	**
Muscle vitamin E (μg/g)	1.01	3.41	2.88	4.67	0.178	***
Redness (a*) Display day 0	19.63	19.70	19.86	20.07	0.365	ns
Redness (a*) Display day 3	18.11	18.43	18.79	18.47	0.293	ns
Redness (a*) Display day 6	16.20	16.76	17.26	17.06	0.286	ns
TBARS Display day 3[1]	0.94	0.05	0.17	0.06	0.054	***
TBARS Display day 6[1]	1.98	0.07	0.24	0.09	0.093	***

[1] mg malonaldehyde/kg muscle **P<0.01; ***P<0.001; ns not significant

Table 2. *Mean values of fatty acid composition (mg/100g muscle) of m. semimembranosus*

	Vitamin E level (mg/kg DM)					Diet effect
Fatty acid	60(C)	500(C)	60(M)	500(M)	Sem	significance
C18:2*n*-6	119.2	118.4	58.1	74.3	3.754	***
C18:3*n*-3	14.6	13.7	18.1	22.4	0.864	***
C20:4*n*-6	41.1	37.2	27.9	32.3	1.113	***
C20:5*n*-3	19.8	19.7	24.6	29.5	0.995	***
C22:6*n*-3	6.9	6.0	6.7	8.0	0.321	ns

***P<0.001; ns not significant

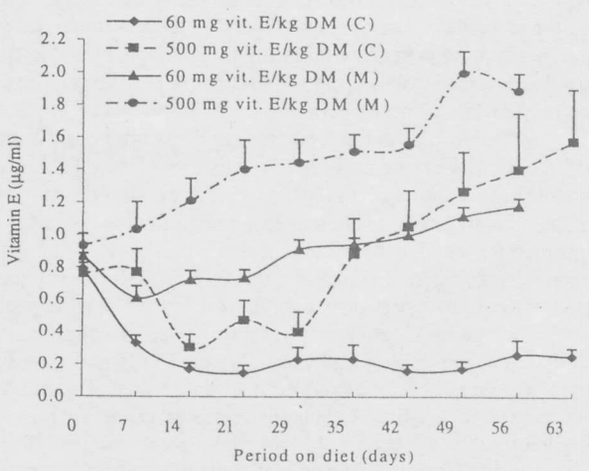

Figure 1. *Plasma vitamin E levels during the feeding period. Concentrate (C) and mixed diet (M) fed lambs.*