Vitamin E will improve the colour stability in lamb; a dose rate investigation

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Abstract

Whilst Vitamin E (VitE) is an antioxidant that can improve meat colour stability the dose rate required for lamb is not fully understood. In this study, mixed sex 6-8 month old crossbred lambs were fed for 8 weeks on either a grain diet supplemented with 30, 150, 275 or 400 mg α-tocopherol acetate/kg DM of feed, an annual green pasture or a dry summer pasture supplemented with lupin grain (400 gm/day). Retail colour was measured using the ratio of the percent reflectance of light at 630 nm to 580 nm (oxy/met). Increasing the muscle VitE concentration up to 3.5 mg α-tocopherol/kg tissue improved the oxy/met ratio over the retail display period. No further benefit was observed at concentrations above this, suggesting a VitE threshold concentration which may vary slightly between muscles. Most muscles with sufficient Vitamin E concentrations will reach 60 hours of retail display before an undesirable oxy/metmyoglobin ratio is reached (3.5 in our experience). Green pasture does supply sufficient vitamin E to the animal, however the shelf life of these animals was observed to be lower, possibly due to other nutritional differences. The muscle VitE threshold concentration of 3.5 mg α-tocopherol/kg tissue can be reached in 3 weeks by supplementing lambs with 165 mg α-tocopherol acetate/head/day.

Introduction

The surface colour of sheep meat will turn from red to brown over lengthy retail display periods. This change is due to the oxidation of the muscle pigment, myoglobin, from the red oxymyoglobin form to the brown metmyoglobin form. Meat with a bright red surface colour is more likely to be sold than meat that appears brown. Discounting meat after 48 hours display to avoid brown colour, results in a substantial economic loss.

It is well known that the rate of formation of metmyoglobin can be slowed by the use of antioxidants such as vitamin E (Wulf *et al.*, 1995; Faustman *et al.*, 1998). Vitamin E can be sourced nutritionally through green pasture or by supplementation in feedlot rations. The majority of studies have been in beef, where vitamin E supplied nutritionally has shown to improve the colour stability of meat (Faustman *et al.*, 1998). Although similar studies have been represented in sheep (Wulf *et al.*, 1995; Guidera *et al.*, 1997; Turner *et al.*, 2002), it is still unclear as to what dose rate is needed to improve colour stability in sheep meat.

In Australia, the lack of available green pasture, particularly throughout the summer season, can cause deficient Vitamin E levels in grazing lambs, as observed by increasing incidents of myopathy. Over these periods retailers have also observed a decline in colour stability of meat (Pearce *et al.*, 2005), possibly due to low levels of vitamin E in these animals. Many cuts would appear brown long before the retail shelf life bench mark of 48 hours is reached.

This study investigated the hypothesis that meat from sheep with deficient levels of vitamin E will have poor colour stability, while the addition of vitamin E nutritionally through supplementation or green pasture will improve colour stability and shelf life to 60 hours. We also aimed to investigate the dose rate required to improve colour stability, for use within the Australian sheep industry.

Materials and methods

Seventy mixed sex 6-8 month old crossbred lambs with a live weight of 38.0±0.38 kg (mean±sem) were used for this experiment. Lambs were sourced from a farm where they were grazing a dry senesced annual ryegrass pasture (*Lolium rigidum*) supplemented with lupin grain (*Lupinus angustifolius*) at the rate of 600g/hd/day. Lambs were sorted into 5 groups of 12 and one group of 10. The later group was sent to a commercial abattoir for slaughter to establish a basal colour stability level, while the remaining groups were drenched with Cydectin© anthelmintic that contained selenium and were fed for 56 days on different diets. 4 groups were fed a pelleted ration (11 MJ/kg ME and 18% crude protein) containing either 30, 150, 275 or 400 mg of added α-tocopherol acetate/ kg of feed (correlating to 18, 90, 165 or 240 mg of α-tocopherol acetate consumed/head/day, based on the feed intake of 600g head/day) and 1 group of animals were left to graze on a mixed sward irrigated pasture (kikuyu/clover/ryegrass). The clover contained 97mg/kg of vitamin E, the kikuyu grass pasture 127 mg/kg on a dry matter basis and no estimate was made for the ryegrass.

Muscle biopsies were performed at 14 day intervals for 6 weeks, to monitor the muscle VitE levels in the *m. semimembranosus* and *m. semitendinosus.* At the same time live weights were measured and venous blood was also taken from each animal for vitamin E analysis.

After 56 days the animals were then sent to a commercial abattoir for slaughter. All lambs were killed by exsanguination and processed on a commercial abattoir chain. Each carcase was divided into halves and 1 half was 1 half was packed fresh in air for 5 days before muscles were dissected.

Colour measurements were made using a Hunter Lab Mini Scan XE Plus (model No. 45/0-L, Hunter Associates Laboratory Inc., Reston VA, USA), using C set as the light source with an aperture set to 10. Measurements were taken every 12 hours for 96 hours. 5 muscles, *m.gluteus medius* (GM), *m.longissimus thoracis et lumborum* (LD), *m.semimembranosus* (SM), *m.semitendinosus* (ST) and *m.rectus femorus* (RF) were removed from the carcases. Each muscle was sliced into 3cm thick slices, trimmed of visible fat from the surface , placed on black styrofoam trays and over wrapped in polyvinyl chloride wrap. The meat was stored at 4^{o}C in a fridge fitted with fluorescent lights. Myoglobin oxidation was predicted from the ratio of light reflectance at 630 and 580 nm (oxy/met) (Hunt, 1980). A ratio score of 3.5 was used as a consumer discrimination point, below which the browning of meat becomes evident.

Data was analysed using a linear mixed effects model with display time as a covariate, diet and packaging type as fixed effects, and animal as a random term (SAS®). In a separate analysis, the oxy/met ratio at 48 for each individual was predicted by fitting an exponential equation. This allowed the use of a Linear mixed effects model (SAS®) to test muscle VitE concentration as a covariate on the predicted oxy/met, with animal as a the random term.

Results and discussion

Muscle vitamin E increased with increasing concentrations of dietary vitamin E ($P<0.05$) supplementation in all muscles (Table 1). Plasma vitamin E concentrations also increased with the time and level of supplementation ($P<0.05$; Table 1). Deficient levels of vitamin E (< 0.5mg/L) (Menzies *et al.*, 2004) were observed in the plasma from the basal lambs only.

Table 1. Vitamin E concentration within muscles and plasma within different diets (± sem)

Diet	GM	LD	RF	SM	ST	Plasma
basal	$1.64\pm0.05^{a\#}$	$1.31\pm0.05^{b*}$	$1.58\pm0.05^{a\#}$	$1.86\pm0.05^{c\#}$	$1.36\pm0.05^{b\#}$	$0.36\pm0.09^{\#}$
30IU	$2.02\pm0.26^{a\#}$	$2.12\pm0.18^{a\#}$	$1.87\pm0.26^{a\#}$	$2.38\pm0.18^{a\#}$	$1.93\pm0.18^{a\#}$	$0.85\pm0.13^{\wedge}$
150IU	$4.1\pm0.24^{ac+}$	$4.04\pm0.18^{ac+}$	$3.63\pm0.24^{ab+}$	$4.35\pm0.18^{c+}$	$3.51\pm0.18^{b+}$	$1.63\pm0.13^{*}$
275IU	$4.81\pm0.24^{a\wedge}$	$4.79\pm0.18^{a\wedge}$	$4.5\pm0.26^{ab\wedge}$	$5.07\pm0.18^{a\wedge}$	$4.12\pm0.18^{b\wedge}$	$2.32\pm0.13^{+}$
400IU	$5.99\pm0.24^{a*}$	$5.09\pm0.17^{b\wedge}$	$5.58\pm0.25^{ab*}$	$5.48\pm0.17^{ab\wedge}$	$4.6\pm0.17^{c\wedge}$	$2.49\pm0.13^{+}$
pasture	$4.24\pm0.26^{ab+\wedge}$	$3.68\pm0.18^{ac+}$	$4.35\pm0.26^{b\wedge}$	$3.98\pm0.18^{ab+}$	$3.35\pm0.18^{c+}$	$2.25\pm0.13^{+}$

Differences are denoted by letters between muscle types within diets; and by symbols between diets within muscles and plasma.

Oxy/met was significantly effected by diet and muscle type ($P<0.05$). The SM, RF and GM were classed as having poor colour stability, as they reached a ratio of 3.5 before 48 hours display. The LD and ST had good colour stability as the retail display colour was still satisfactory at 48 hours. These colour stabilities were improved with the addition of α-tocopherol acetate in the diet. All animals supplemented with α-tocopherol acetate had a consistently higher oxy/met than that of the basal animals over the retail display period (Figure 1a-SM only). SM from basal animals reached an unsatisfactory ratio of 3.5 about 15 hours before supplemented SM samples. Meat from animals consuming green pasture reached a ratio of 3.5 10 hours faster than basal SM samples, even though vitamin E levels were high, suggesting that a possible nutritional difference caused the poor colour stability. However this may also be attributed to a decline in vitamin E intake towards the end of the feeding period, observed by fortnightly biopsies.

By correlating muscle vitamin E concentration with colour stability, it appeared that a threshold level of 3.5mg/kg was present, whereby muscle vitamin E concentrations above this level produced no further colour stability benefit (Figure 1b-SM only). Faustman *et al.* (1989) and Arnold *et al.*(1993) reported similar threshold levels in beef; 3.0 and 3.3 mg α-tocopherol/kg tissue respectively. Large dose rates of α-tocopherol acetate and lengthy feeding periods were required to meet these thresholds in beef, where as the present findings show that this threshold level in lamb can be reached within 3 weeks at the calculated rate of 165 IU α-tocopherol/head/day. Meat from animals that have reached this threshold have a greater colour stability and most cuts would still have a satisfactory ratio above 3.5 after 48 hours retail display.

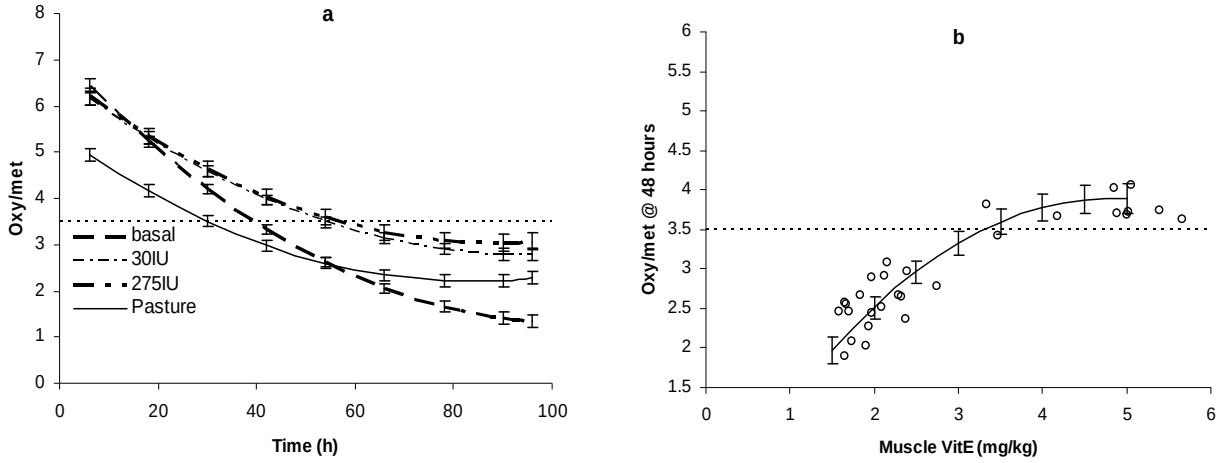

Figure 1. a) the oxy/met ratio of the SM over 96 hours retail display for basal, 30IU 275IU and pasture fed animals. **b)** the oxy/met ratio at 60 hours retail display for over the SM muscle vitamin E concentration.(± sem).

Conclusions

From the present study it is suggested that the retail colour stability of lamb can be improved if the animals are supplied with sufficient vitamin E via supplementation of grain feed. Lamb muscle has a colour stability threshold for vitamin E of 3.5 mg α-tocopherol/kg tissue; above this threshold level there was no added benefit observed. This threshold concentration can be achieved by supplementing lambs with 165 mg α-tocopherol acetate/head/day for a period of 3 weeks. Following these recommendations will result in a 60 hour retail display period for most muscles. Although green pasture is high in Vitamin E there appear to be other (potentially nutritional) factors that precipitate lower initial oxy/met ratios resulting in rapid browning, thus further work is required to clarify the mechanism of this effect.

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