Levels of α-tocopherol in beef from New Zealand pastures.

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INTRODUCTION

Consumers use the colour of meat as indications of quality and freshness, and base purchase decisions on these perceptions. Beef discolouration is primarily due to oxidation of red, ferrous, myoglobin pigments to brown, ferric metmyoglobin. Numerous papers have reported that addition of vitamin E, as tocopherol esters to corn based diets for cattle, delays metmyoglobin accumulation, and extends the shelf life of fresh, chilled and frozen beef. Liu *et al.* (1995) reviewed these dietary vitamin E supplementation studies.

Williams *et al.* (1993), and Arnold *et al.* (1993) reported that the critical factor in supplementation was achieving a minimum tissue concentration of 0.30 to 0.35 mg of α-tocopherol per 100 g meat, and that concentrations above these levels did not have any further benefit in terms of reducing metmyoglobin accumulation in fresh striploins. Liu *et al.* (1996 a, b) found that higher levels of tocopherol were required to achieve colour stability in beef after chilled storage. Also, the accumulation of tocopherol and colour stability differed between muscles. For various levels of vitamin E supplementation, the ranking of vitamin E concentration was gluteus medius (GM) > semimembranosus (SM) > longissimus lumborum (LL). However, the ranking based on metmyoglobin formation was also GM > SM >LL.

While there is a lot of information about grain-fed animals and dietary supplementation of vitamin E, there is very little information about vitamin E levels in pasture-fed beef. The present work was designed to establish vitamin E levels in New Zealand pasture-fed beef, to compare the colour stability of this beef with that of grain-fed beef, and to establish suitable procedures for raising levels of vitamin E by intramuscular injections of α-tocopherol.

MATERIALS AND METHODS

To establish average levels of vitamin E in New Zealand beef, striploin samples were analysed from prime steers and heifers presented for slaughter in early spring, mid summer and late autumn, from 38 farms, spread throughout the country. For farms in the Waikato area, autumn samples were also taken for the tenderloin, chuck tender and eye round cuts. Samples from three animals from each farm were used to form a composite, lean sample for chemical analysis.

For comparison of the effects of grain- and grass-finishing diets, twelve prime yearling steers, selected from a pasture-fed herd, were divided into two groups. One group was transferred to a feed-lot to receive a grain diet. These steers were conditioned to, and maintained on, a finishing diet of grain for 8 weeks, which included a 2 week diet adjustment period. The diet contained mainly maize, heat-treated soya and hay. The other six steers were grazed *ad libitum* on ryegrass / clover pasture for the same 8 weeks.

After the finishing period, the animals were slaughtered and processed in accordance with standard commercial practice. Carcasses were cooled to approximately 5 to 7°C overnight, and cold-boned the following morning. The next morning, two steaks were cut from the middle of the fresh striploin for "fresh" colour readings, and for chemical measurements. The remaining portions of the striploins were weighed, packed under vacuum in bags with a low oxygen permeability, stored in a chiller at -1°C for a week, then moved to a freezer, and held at -20°C for 7 or 19 weeks before they were thawed at 2°C. After thawing, the striploin pieces were drained, and reweighed to determine drip losses. Each piece was sliced into steaks 20 mm thick for simulated retail display and colour readings.

Steaks from the fresh and thawed striploins were placed, with freshly cut surfaces uppermost, on polystyrene trays, covered with an oxygen permeable film, and allowed to bloom at about 10°C for an hour before CIELAB **L*, a*, b*** colour readings were taken. Steaks from the thawed samples, were displayed at 2 to 4°C under cool white lights, and colour readings were taken at daily intervals.

Injectable d-α-tocopherol, containing 300 IU vitamin E per ml (Vital E -300 Schering-Plough Animal Health), was obtained for intramuscular injection trials. Twenty pasture-fed, cross-bred Angus steers were allotted to five balanced groups. Vital E -300 was injected into the neck muscles of these steers according to the schedule shown in Table 1. Blood samples for vitamin E determinations were taken by tail bleeding before the injections, as shown in the table. The steers were slaughtered in a commercial abattoir on day 30 of the trial. The carcasses were chilled overnight, then striploins and tenderloins were sampled for chemical tests. Vitamin E in blood and in lean tissues was determined by the methods of Baumgartner *et al.* (1993), and Pfalzgraf et al. (1995) respectively.

RESULTS AND DISCUSSION

Vitamin E levels in New Zealand beef

The average level of α-tocopherol in the lean tissues of striploin steaks from beef raised on farms throughout New Zealand was 4.96 mg/kg with a standard deviation of 1.66 mg/kg. On average, the ranking of levels between samples from different regions was Northland, 7.77 mg/kg, > Waikato, 5.39 mg/kg, > South Island, 3.71 mg/kg. These differences were significant ($p < 0.01$). Differences between seasons of the year were not significant ($p > 0.05$), but there were regional variations between seasons. The average levels of α-tocopherol in the lean tissues of different cuts from the same animals were ranked in the order; tenderloin, 7.6 mg/kg, > chuck tender, 6.1 mg/kg, > striploin, 4.8 mg/kg, > eye round, 4.4 mg/kg.

Table 1. Tocopherol injection and blood sampling plan.

Group no	Injection days	Injection volume, (ml)	Blood sampling days
1	1	1 x 15	1, 3, 5, 8, 15, 23, 29
2	1, 8, 15, 23	4 x 10	1, 3, 5, 8, 15, 23, 29
3	25	1 x 15	
4	27	1 x 15	
5	-	0	

Only 3 of the 38 striploin samples had an α-tocopherol level below 3.0 mg/kg. Two of these were from the South Island, and one was from a group young animals from a research farm. The data indicate that most New Zealand beef striploins contain adequate levels of α-tocopherol for fresh retail purposes. Those from the North Island, especially those from Northland, probably contain sufficient α-tocopherol for display after short periods of chilled storage. However, exact levels required for different storage regimes have not been determined.

Comparison of data for grain- and grass-finised steers

CIELAB **L*, a*, b*** colour coordinates, and the hue angle and chroma values derived from these coordinates, were not significantly different for fresh striploins from steers finished on grain or on grass (Table 2). There were also no initial differences in these data for samples thawed after frozen storage. However, after 7 and 19 weeks

frozen storage, and 3 or more days on display, the hue angle was significantly higher, indicating more discolouration, in the grain-fed samples. After both storage periods, **a*** values rose for the first 3 days on display, and subsequently fell. For the 7 week old samples, after 3 days on display, **a*** values were significantly higher in the grass-fed than in the grain-fed samples (Table 2), but **b*** values were not significantly different ($p > 0.05$). In contrast, after 19 weeks frozen storage, and 3 days on display, **b*** values for the grass-fed group were lower than those from the grain-fed samples, and **a*** values were not significantly different ($p > 0.05$). There were no significant differences or changes in **L*** values ($p > 0.05$).

Striploins from the grass-fed steers contained significantly higher levels of vitamin E (α-tocopherol) and fat than those finished on grain. Vitamin E to fat ratios (not shown) were also significantly higher in the grass fed beef ($p < 0.01$). However, drip losses were not significantly different between the groups after frozen storage ($p > 0.05$) (Table 3).

These data indicate that New Zealand grass-fed beef has greater colour stability than beef finished on grain without vitamin E supplements.

Effects of intramuscular α-tocopherol injections

The control steers, group 5, used to assess the effects of intramuscular injections had extremely variable levels of α-tocopherol in both the striploins and tenderloins. Levels of α-tocopherol in these cuts were not significantly different from those obtained from group 4 steers which were injected only 3 days before slaughter ($p > 0.05$) (Table 4). Steers in group 2, which had received 4 injections at weekly intervals, and those from group 3, which received a single injection 5 days before slaughter (Table 1), had significantly higher levels of α-tocopherol in both cuts than group 4 steers (Table 4). These results indicate that α-tocopherol injections into the neck muscles of grass-fed beef animals, 5 days before slaughter, could be used to boost α-tocopherol levels in meat cuts. This procedure might also be more economic than prolonged dietary supplementation.

Levels of α-tocopherol in blood (not shown) increased sharply within 2 days of injections, and subsequently fell to plateau values that were significantly higher than the pre-injection levels ($p < 0.05$). Njeru *et al.* (1992) obtained similar results after injecting sheep.

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Table 2. Colour values for striploins from grain-fed and grass-fed beef, displayed before and after frozen storage.

Storage, weeks	Display, day	Grain-fed					Grass-fed				
		L*	a*	b*	hue angle	chroma	L*	a*	b*	hue angle	chroma
0	1	41.5	10.3	8.3	39.1	13.3	40.6	10.6	8.5	38.6	13.6
7	1	36.6	13.1	9.5**	36.0	16.1	36.9	13.6	9.6**	35.4	16.6*
	3	37.5	13.7	11.3	39.4**	17.8	37.5	14.8 #	11.2	37.1 #	18.5
	5	37.3	12.5**	11.0	41.3**	16.6*	37.3	13.7 #	11.0	38.8**##	17.6
	7	38.5	11.2**	10.9	44.3**	15.6**	37.6	12.8**##	11.2	41.2**#	17.0* #
19	1	40.3	12.7	10.9	37.2	16.7	39.9	12.1**	9.7	35.6	15.5*
	3	41.7	13.2	11.9	38.6	17.7	41.2	13.5	10.5 #	35.0 ##	17.1
	5	41.5	11.5**	11.0	40.1*	15.9*	42.0	11.2**	9.7	37.5 #	14.8*
	8	40.7	10.8**	11.6	43.4**	15.9*	40.5	10.6**	10.0 #	39.8**#	14.5**

For samples from the 7 and 19 week storage trials, significant differences from the underlined readings on display day 3 are shown for L*, a*, b* and chroma readings, and significant differences from the underlined day 1 readings are shown for the hue angle. * = $p < 0.05$, ** = $p < 0.01$ Readings for grass-fed beef that differed significantly from those for grain-fed beef are indicated. # = $p < 0.05$ and ## = $p < 0.01$.

Table 3. Comparison of chemical data and drip losses for grain-fed and grass-fed beef striploins.

	pH	Fat, g/100 g	Vitamin E, mg/kg	Drip, % weight lost after frozen storage	
				7 weeks	19 weeks
Grain-fed	5.60	1.99	2.53	3.9	9.6
Grass fed	5.65	4.13	3.66	3.1	8.1

Differences in the fat and vitamin E levels were significant ($p < 0.01$).

Table 4. Average vitamin E levels in striploins and tenderloins from injected steers. (Data are mg/kg lean tissues).

Group	Striploin	Tenderloin
1	4.59*	5.05
2	5.57*	5.82**
3	5.32**	6.60**
4	3.61	4.05
5	4.78	3.66

Significant differences from levels in group 4 are shown. (* = $p < 0.05$, ** = $p < 0.01$)