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Meat Science 71 (2005) 480–489
MEAT SCIENCE
www.elsevier.com/locate/meatsci

Colour stability, under simulated retail display conditions, of *M. longissimus dorsi* and *M. semimembranosus* from steers given long-term daily exercise and supplemented with vitamin E

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Received 12 December 2004; accepted 18 April 2005

Abstract

The objective was to determine if exercise has a negative impact on the colour stability of beef and if dietary vitamin E (VE) supplementation could counteract any negative effect. Steers were not exercised or were walked 4.41 km/day for 18 weeks. Within exercise treatment animals consumed, on average, either 450 or 1050 IU/day of VE. Muscle α-tocopherol increased ($P = 0.004$) from 2.35 to 3.15 μg/g with VE supplementation. Following ageing *M. longissimus dorsi* (LD) and *M. semimembranosus* (SM) steaks were packaged under 80%O_2:20%CO_2 and stored at 4 °C. The LD of exercised steers was more red and more saturated (both $P < 0.05$) after 0 and 2 days of storage than LD of unexercised steers. While redness of both muscles decreased over the display period, LD retained a higher redness than SM from day 2 to 7 ($P < 0.05$). Colour shelf-life of LD was extended by 0.75 days, to 3.25 days, due to VE supplementation.

Keywords: Colour; Exercise; Vitamin E; Steers; Muscle; Modified atmosphere

1. Introduction

In a retail environment, colour is a critical sensory characteristic of beef as it is experienced by consumers before tenderness or flavour and tends to be used as an indicator of perceived quality and freshness (Carpenter, Cornforth, & Whittier, 2001; O'Sullivan et al., 2002; Renerre & Labas, 1987). Colour is generally regarded as the first limiting factor in beef shelf-life (Smith, Belk, Sofos, Tatum, & Williams, 2000).

Exercise is reported to increase concentrations of reactive oxygen species (ROS) in vivo, which can cause oxidative damage to tissues, including muscle (Meijer et al., 2001; Singh, 1992; Witt, Reznick, Viguie, Starke-Reed, & Packer, 1992). In post-mortem muscle, oxidative reactions, particularly lipid oxidation, occur but it is unlikely that the defence mechanisms available to living muscle are available in the post-mortem condition (Morrissey, Sheehy, Galvin, & Buckley, 1998). Biochemical events accompanying the conversion of muscle to meat favour the promotion of oxidation (Kerry, Buckley, & Morrissey, 2000) and the resulting free radical intermediates of lipid oxidation, similar to ROS, are believed to contribute to oxymyoglobin oxidation leading to meat discolouration (O'Grady, Monahan, & Brunton, 2001). Therefore, it was hypothesised that exercise might increase post-mortem meat discolouration via lipid oxidation.

Consumption of supra-nutritional levels of vitamin E by cattle has been demonstrated to increase muscle vitamin E levels and improve muscle colour stability (Chan

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doi:10.1016/j.meatsci.2005.04.025

et al., 1996; Faustman, Chan, Schaefer, & Havens, 1998; Liu, Lanari, & Schaefer, 1995). Vitamin E, the collective generic name for "all entities that exhibit the biological activity of α-tocopherol" (Faustman et al., 1998), is believed to improve the colour stability of beef indirectly through its activity as a lipid antioxidant, whereby it prevents oxidation of unsaturated membrane lipids and decreases the production of lipid-derived free radicals and associated oxymyoglobin oxidation. The objective of this study was to determine if exercise has a negative impact on the colour stability of beef and whether any apparent negative effects would be counteracted by dietary vitamin E supplementation.

2. Materials and methods

2.1. Experimental design and animal management

Forty-eight continental crossbred steers of eighteen-months old (mean liveweight 526 [SD = 60.5] kg), were blocked on bodyweight and assigned, within block, to one of four treatments. Treatments were: (1) no imposed exercise, no supplemental VE (NOEX NOVE), (2) no imposed exercise, plus supplemental VE (NOEX VE), (3) imposed exercise, no supplemental VE (EX NOVE) and (4) imposed exercise, plus supplemental VE (EX VE). Steers were grouped into pens of six, according to treatment. Exercise was applied over a 4.41 km course, at an average walking speed of 5.2 km/h, 6 days per week for 18 weeks as described by Dunne, O'Mara, Monahan, and Moloney (accepted). For 20 weeks pre-slaughter, and 2 weeks prior to the commencement of the exercise regime, steers so designated were offered a concentrate containing supplemental VE while the unsupplemented steers continued to receive a basal concentrate.

The VE, as *dl*-α-tocopheryl acetate (vitamin E50, i.e., 50% w/w active vitamin, Roche Vitamins) was added to the mineral/vitamin mix at a rate of 40 kg of 'vitamin E50' per 1000 kg of mineral/vitamin mix so that the supplemented mix contained a target level of 20,000 IU of VE/kg, where 1 IU (international units) was equivalent to 1 mg of the acetate ester, *dl*-α-tocopheryl acetate. The composition of the supplemented mineral/vitamin mix is presented in Table 1. During concentrate manufacture, the supplemented mineral/vitamin mix was added to the concentrate designated as 'supplemented' at a rate of 25 kg per 1000 kg such that the target level was 500 IU of VE/kg. The ingredients and chemical composition of the concentrate were as described by Dunne et al. (accepted).

Concentrates were dispensed manually to each pen, 20 kg per pen each morning between 0900 and 1000 h and 16 kg per pen each evening, between 1400 and 1500 h for 140 days. Grass silage, containing straw at an inclusion rate of 60 kg per 1000 kg of silage (fresh weight), was fed on an ad libitum basis. The quantity of silage eaten per pen was recorded on a daily basis. Concentrate (both basal (−VE) and supplemented (+VE)) and forage samples were collected on a weekly basis and stored at −20 °C in the dark prior to chemical analysis. Concentrate samples were milled through a plate with 2 mm holes using a feed mill (Christy & Norris, Chelmsford, UK) prior to analysis.

Table 1
Ingredient composition of the supplemented mineral/vitamin mix

Ingredient[a]	(g/100 g)
Limeflour	67.0
Dicalcium phosphate	8.8
Sodium chloride	14.0
Additives (listed below)	10.16
Cobalt carbonate	9×10^{-3}
Calcium iodate	3×10^{-3}
Copper sulphate	0.2
Ferratlow® 30[b]	0.33
Manganese sulphate	2.0
Selenium	0.08
Zinc sulphate	3.33
Vitamin A/D3	0.1
Vitamin D3	5×10^{-3}
Vitamin E50	4.0
Tastetite® FP211[c]	0.1

[a] Ingredient concentrations are those used in product formulation.
[b] $FeSO_4$, 30% w/w.
[c] Flavour additive.

2.2. Blood sampling

During week 10 blood samples were collected by jugular veinpuncture from 24 steers on day 68 and 24 steers on day 70. On each sampling day, steers were sampled at 0800, 1030, 1230, 1530, 1800 and 2000 h. The concentrates were fed at 0830 h and again at 1600 h. Exercising steers were walked between 1030 and 1230 h. Steers were offered grass silage ad libitum after the 1230 h bleeding. The protocol was repeated during week 18, with 24 steers sampled on each of days 124 and 126. Blood was collected into duplicate 10 ml evacuated tubes containing lithium heparin as an anticoagulant. Blood samples were immediately centrifuged at 1500*g* for 20 min and stored at −20 °C for subsequent analysis. Plasma samples from 0800 h on week 18 were used for VE analysis.

2.3. Slaughter, muscle sampling and ageing

On each of three consecutive weeks, steers were weighed and transported 128 km to a commercial slaughter facility where they were slaughtered humanely. Samples of *M. longissimus dorsi* (LD), M. *semimembranosus* (SM) and *M. extensor carpi radialis* (ECR) for α-tocopherol analysis were recovered at 48 h post-mortem, as previously described by Dunne et al. (accepted)