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Beef quality attributes as affected by increasing the intramuscular levels of vitamin E and omega-3 fatty acids

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ABSTRACT

In order to investigate the effects of increasing beef n-3 fatty acid content and the protective effects of vitamin E antioxidant activity on meat quality characteristics, 80 feedlot steers were fed 4 different diets (control, high vitamin E, 10% ground flaxseed or high vitamin E–10% ground flaxseed). While dietary treatments had no effect ($P>0.05$) on meat composition or tenderness values, the increase in oxidation products was lower ($P=0.046$) in meat from vitamin E supplemented steers and higher ($P=0.006$) in meat from flaxseed fed animals. The increase in α-tocopherol tissue levels ($P<0.001$) in meat from animals fed flaxseed and increased dietary vitamin E resulted in the lowest drip loss values ($P=0.013$). As expected, display time had a large effect on retail traits in both steaks and patties ($P<0.001$). While retail traits of steaks were not affected by the dietary treatments ($P>0.05$), feeding flaxseed decreased ($P<0.05$) ground beef retail scores, which were not corrected by higher levels of dietary vitamin E. Finally, although no effect ($P>0.05$) was observed among treatments for sensory attributes in steaks, the correlations of a combined n-3:α-tocopherol ratio against retail and sensory attributes ($P<0.05$) suggest that increased n-3 fatty acids levels require increased dietary antioxidants, such as vitamin E to avoid negative effects on meat quality from a loss in oxidative stability.

1. Introduction

Lipid peroxidation in meat is an important factor limiting both the quality of meat and its consumer acceptability (Aalhus & Dugan, 2004). Peroxidation of lipids in meat becomes apparent to consumers by the development of rancid odours or flavours, and "warmed-over" flavour in previously cooked meats. Oxidation of meat pigments is recognisable by the development of brown discolouration replacing the normally acceptable bright cherry red colour. Typical lipid peroxidation in meat involves the phospholipid fraction (Frankel, 1998), located in the membranes and containing over 40% polyunsaturated fatty acids (PUFA). Due to their high level of unsaturation and their proximity to the haeme catalysts of the mitochondria and microsomes, they are susceptible to oxidation.

Despite the numerous known deleterious quality changes associated with oxidation of PUFA (Wood et al., 2004), there is considerable interest along the meat value chain in enhancing the PUFA content of meat so that niche products with health label claims can be marketed (Juárez et al., 2010; Ruxton, Reed, Simpson, & Millington, 2004). In this regard, dietary flax supplementation has been used by several authors in order to increase omega-3 (n-3) fatty acid content in beef (*e.g.* Bartoň, Marounek, Kudrna, Bureš, & Zahrádková, 2007; Juárez et al., 2011; Raes, De Smet, Balcaen, Claeys, & Demeyer, 2003; Scollan et al., 2001). However, as expected, some side-effects on meat quality, including early development of off-flavour and off-colour, have been reported (LaBrune, Reinhardt, Dikeman, & Drouillard, 2008). Consequently, increasing lipid stability by addition of elevated levels of antioxidant compounds could be a means of overcoming this problem, as observed in pork (Rey et al., 2001). Thus, vitamin E is widely used as an antioxidant in biological systems, and its accumulation in muscle has been shown to have a positive impact on colour and lipid stability of fresh and frozen beef (Liu, Lanari, & Schaefer, 1995).

The present study was undertaken to elucidate the effects of increasing beef total n-3 content and the protective effect of vitamin E antioxidant activity on meat quality characteristics.

2. Material and methods

Experimental design, animal handling, dietary treatments, slaughter process and sampling were previously reported by Juárez et al. (2011). Briefly, 80 feedlot steers were housed in 8 feedlot pens (2 pens per dietary treatment, 10 steers per pen, n = 20 steers per dietary treatment)

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and fed *ad libitum*. Steers (381 ± 7.10 kg) were stratified by weight and assigned to one of four diets in a 2 × 2 factorial experiment, with two levels of dietary vitamin E, with or without flaxseed: control (451 IU dl-α-tocopheryl acetate·head^{-1}·day^{-1}), high vitamin E (1051 dl-α-tocopheryl IU·head^{-1}·day^{-1}), flaxseed (10% ground flaxseed substituted for steam-rolled barley) and flaxseed–vitamin E (10% flaxseed and 1051 IU dl-α-tocopheryl acetate·head^{-1}·day^{-1}). Steers were on trial for 129 ± 3.2 days and finished to 571 ± 7.1 kg.

Steers were slaughtered at the Lacombe Research Centre in groups of 16, which included the two heaviest animals per pen per slaughter date, and all animals were slaughtered within 35 days. At slaughter the left *longissimus thoracis* (LT; rib-eye) temperature and pH at 45 min (Hannah HI9025C pH metre, Hannah Instruments, Mississauga, ON, Canada, equipped with an Orion Ingold electrode, Udorf, Switzerland) and 24 h, 24 h colour (Minolta CM2002; Minolta Canada Inc., Mississauga, ON, Canada) (CIE, 1978) were measured posterior to the grade site as described in Aldai et al. (2010). The left loin primal was removed from the carcass and one steak with the fat cap on from the posterior end (near the grade site) was removed and frozen (−80 °C) for subsequent fatty acid determination. The primal was then trimmed of subcutaneous fat and overlying muscles. Approximately 200 g of subcutaneous fat and 800 g of lean were labelled, individually vacuum packaged (Ultravac Model UV2100; Koch Instruments, Kansas City, MO, USA) and placed in a cooler at 2 °C for 6 days, for subsequent analysis. Another steak (25 mm) was removed from the posterior end of the LT, finely comminuted (Robot Coupe Blixir BX3; Robot Coupe USA Inc., Ridgeland, MS, USA) and samples (approximately 20 g) were placed into pre-labelled sterile sample whirl-pak bags (Fisher Scientific, Mississauga, ON, Canada) and stored at −80 °C for α-tocopherol level determination. Muscle levels of α-tocopherol were determined on the grind using normal phase HPLC with tocopherol acetate as an internal standard (Katsanidis & Addis, 1999), adapted for fluorescence detection (Hewavitharana, Lanari, & Becu, 2004). The remaining portion of the LT was labelled, vacuum packaged and stored in the cooler for 6 days, for subsequent meat quality analysis.

2.1. Meat quality analysis

Following a 6 day ageing period, five steaks (25 mm thickness) were removed from the LT muscle. The first steak was placed on a grill (Garland Grill ED30B; Condon Barr Food Equipment Ltd., Edmonton, AB, Canada) preheated to approximately 210 °C to an internal temperature of 35.5 °C, turned and cooked to a final temperature of 71 °C (Hewlett Packard HP34970A Data Logger; Hewlett Packard Co., Boise, ID, USA). Steaks were placed into polyethylene bags, sealed and immediately immersed in ice water to prevent further cooking. Cooked steaks were immediately transferred to a cooler and allowed to stand for a 24 h period. The following day, final steak weight was recorded for determination of cook loss and six 1.9 cm cores were removed parallel to the fibre grain and peak shear force was determined on each core perpendicular to the fibre grain using a TA-XT Plus Texture Analyzer equipped with a Warner–Bratzler shear head at a crosshead speed of 20 cm min^{-1} and a 30 kg load cell using Texture Exponent 32 Software (Texture Technologies Corp., Hamilton, MA, USA). Peak shear force was expressed as the average of the 6 cores. The second and third steaks were individually vacuum packaged and frozen at −35 °C until sensory evaluation. The fourth steak was placed into a polystyrene tray with a dri-loc pad (UZ Soaker Ultra Zap Pads, Paper Pak Industries Washington, GA, USA), over-wrapped with oxygen permeable film (8000 ml·m^{-2}·24 h^{-1} vitafilm choice wrap, Goodyear Canada Inc., Toronto, ON, Canada) and displayed in retail case at 1 °C for retail evaluation after 0, 1, 2 and 3 days, as described by Nassu et al. (submitted for publication). Following a 20 min period of exposure to atmospheric oxygen, objective colour measurements were collected across the fifth steak. To determine drip-loss, the steak was then pre-weighed, and stored on a polystyrene over-wrapped tray with a dri-loc pad for 4 days at 2 °C, and then a final steak weight was recorded, as described in Aldai et al. (2010).

The remaining portion of the LT was trimmed of all overlying connective tissue and ground three times (Butcher Boy Meat Grinder Model TCA22; Lasar Manufacturing Co., Los Angeles, CA, USA). Grind (100 g) was used to determine the proximate composition, as described by Aldai et al. (2010).

At 6 days after slaughter, the stored lean and subcutaneous fat was ground two times (Butcher Boy Meat Grinder Model TCA22, initially with a 0.48-cm grind plate followed by a 0.32-cm grind plate; Lasar Manufacturing Co., Los Angeles, CA, USA) to achieve an 80/20 lean to fat grind. A sub-sample (~50 g) was finely comminuted with a robot coupe and concentrations of thiobarbituric acid reactive substances (TBARS) (0 days in retail) were determined as described by Nielsen, Sorensen, Skibsted, and Bertelsen (1997). Briefly, after grinding the sample (10 g), it was mixed with 30 mL 7.5% trichloroacetic acid and filtered with Whatman #4 filter (Whatman, Maidstone, UK). The filtrate (2.5 mL) was mixed with the 2.5 mL of thiobarbituric acid solution (20 mM) and after heating at 100 °C for 40 min the absorbance was measured at 532 nm. The concentration (mg·kg^{-1}meat) was calculated by comparison with standard solutions. An additional 50 g of grind was placed on pre-labelled over-wrapped polystyrene tray (8000 ml/m^2· per 24 h vitafilm choice wrap; Goodyear Canada Inc., Toronto, ON, Canada), and placed in a retail display case to determine 3 day TBARS content. The increase in TBARS between days 0 and 3 (ΔTBARS) was then calculated. The remaining grind was used to form a 140 g patty (11.5 cm diameter × 0.63 cm thick) using a single patty hamburger press (Cabelas, Sydney, NE, USA). Patties were placed onto pre-labelled polystyrene trays, over-wrapped and placed into display case for retail evaluation at 0, 1, 2 and 3 days.

Intramuscular lipids were analysed as previously reported by Juárez et al. (2011). The concentration of n-3 fatty acids (% total fatty acids) was used to calculate the combined n-3:α-tocopherol ratio.

2.2. Retail and sensory evaluation

All samples were placed into a fan assisted, horizontal (chest type) retail display case (Hill Refrigeration of Canada Ltd., Barrie, ON) under fluorescent room lighting (GE deluxe cool white), supplemented with incandescent lighting directly above the display case (GE clear cool beam 150 W/120 V spaced 91.5 cm apart) resulting in an intensity of 1076 lx at the meat surface for 12 h per day (Jeremiah & Gibson, 2001). On each specific display time (0, 1, 2 and 3 days) three objective colour measurements were collected across both the steak and patties. Following objective colour measurements, the same steaks and patties were subjectively evaluated for retail appearance, lean colour score and percent surface discolouration by 8 trained panellists using an 8-point hedonic (1 = extremely undesirable and 8 = extremely desirable), an 8-point descriptive (1 = white and 8 = extremely dark red) and a 7-point descriptive (1 = 0% and 7 = 100% discolouration) scales, respectively.

Taste panel steaks were removed from the freezer and placed in a refrigerator to thaw for 24 h. Steaks were grilled and prepared for sensory analysis as described by Aldai et al. (2010). Attribute ratings from panellists were electronically collected with Compusense 5, release 4.6 computer software (Compusense Inc., Guelph, ON, Canada) using an eight point descriptive scale for initial and overall tenderness (8 = extremely tender; 1 = extremely tough), initial and sustainable juiciness (8 = extremely juicy; 1 = extremely dry), beef flavour intensity (8 = extremely intense; 1 = extremely bland), off-flavour intensity (8 = no off-flavour; 1 = extremely intense off-flavour) and amount of connective tissue (8 = none detected; 1 = abundant). Flavour desirability and overall palatability were rated on an eight point hedonic scale, (8 = extremely desirable; 1 = extremely undesirable).