Meat quality of vitamin E enriched beef

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***Abstract*—This study aimed to evaluate quality and sensory properties of 6 and 21 days aged beef (steaks and ground beef) from animals with different tissue levels of α-tocopherol. A total of 56 feedlot steers were fed a barley-based finisher diet with four vitamin E supplementation levels (340, 690, 1040 and 1740 IU dl-α-tocopheryl acetate·animal^{-1}·day^{-1}) for 120 days. The animals were then grouped based on their α-tocopherol (μg·g meat^{-1}) levels (<3 or low; 3 to 4 or low-medium; 4 to 5 or high-medium and >5 or high). *Longissimus lumborum* muscle and overlying subcutaneous fat were aged 6 days and then used to prepare steaks and 75/25 ground beef. Steaks aged for 21 days were also analysed. Although the increase in fatty acid oxidation over time was smaller (*P*<0.001) in the high-medium and high groups, tissue α-tocopherol levels did not affect (*P*>0.05) pH, proximate analysis, drip and cooking losses, and shear force of steaks. Similarly, α-tocopherol tissue levels had no effect (*P*>0.05) on sensory characteristics of 6 days aged steaks and ground beef. No effect of tissue α-tocopherol levels was found over the 6 days retail evaluation period for steaks, but with 21 days of ageing, a delay in formation of metmyoglobin (*P*=0.008) was observed with higher tissue levels of α-tocopherol. Similar results were found for ground beef (25% fat) prepared from 6 days aged meat. Higher α-tocopherol tissue levels protected ground beef ad long-aged steaks from discolouration and lipid oxidation.**

***Keywords*— α-tocopherol, steak, ground beef**

I. INTRODUCTION

Vitamin E is a widely used antioxidant in biological systems and has a positive impact on colour and lipid stability of fresh and frozen beef. The discolouration of beef from bright red to brown, which occurs during retail display, is a combined function of myoglobin and lipid oxidation, and supplementation of vitamin E can result in an increasing retail display life of beef by 1.6 to 5 days [1,2]. Several studies have reported positive effects of dietary vitamin E supplementation in reducing the oxidation of lipids and myoglobin in modified atmosphere packed beef [3,4] and steaks [5,6]. This study aimed to evaluate meat quality of steak and ground beef with different tissue levels of α-tocopherol over extended ageing times.

II. MATERIAL AND METHODS

A total of 56 feedlot steers were housed in eight feedlot pens (four diets; two pens per dietary treatment; seven animals per pen, n=14 animals per dietary treatment) at the Agriculture and Agri-Food Canada Lacombe Research Centre. Animals were fed experimental diets for an average of 120 days. All finisher diets contained 73% steam rolled barley and 22% barley silage. The control diet provided 340 IU dl-α-tocopheryl acetate/animal per·day. Increasing vitamin E levels (0, 350, 700 and 1400 IU dl-α-tocopheryl acetate/animal per·day) were top-dressed and mixed into the feed with a pitchfork to deliver four different treatments over the finishing period. One animal from the 700 IU group died during the experiment (n=13), reducing the total number to 55 feedlot steers. Animals were slaughtered over three slaughter dates within a one month period.

The left *longissimus thoracis* (LT) and right and left *longissimus lumborum* (LL) were removed from carcasses for this study. Initial colour, pH, proximate analysis (moisture, fat and protein), cooking loss and water holding capacity were measured in the steaks from LT at day 0. Muscle levels of α-tocopherol were determined using normal phase HPLC with tocopherol acetate as an internal standard as described by [7] and adapted for fluorescence detection by [8]. The remaining LT was vacuum-packaged and placed into a cooler at 2°C for 6 days. Following the ageing period, seven steaks (25 mm) were removed from the cut

surface of the LT and were used for 6, 14 and 21 day shear force, cooking loss determinations and retail study. Shear force analysis was conducted on cooked steaks as described by [9], using a TA-XT Plus Texture Analyzer equipped with a Warner-Bratzler shear blade at a crosshead speed of 200 $mm \cdot min^{-1}$ and a 30 kg load cell using Texture Exponent 32 Software (Texture Technologies Corp., Hamilton, MA). Cooking loss was determined through gravimetric weight difference of raw and final cooked weights of the same steaks prior to shear force analysis. From the left LL, approximately 300 g of subcutaneous fat and 900 g of lean were ground and ground beef with 75/25 lean to fat grind was prepared for retail study. Steaks and ground beef for retail study were pre-weighed onto a polystyrene tray with a dri-loc pad, over-wrapped with oxygen permeable film (8000 ml/m^{2} per 24 h permeability) and put into a fan assisted, horizontal (chest type) retail display case, supplemented with incandescent lighting directly above the display case to provide an intensity of 1076 lux at the meat surface for 12 h per day [10] at 1°C for evaluation after 0, 2 and 4 days of retail ageing. Following the 4 day objective colour measurements, the steaks were removed and final weights were recorded to determine driploss. During retail display, objective colour measurements using a Minolta CR-300 with Spectra QC-300 Software (Minolta Canada Inc., Mississauga, ON) were made at three locations across the surface of the 6 and 21 days aged steaks [11] and converted to hue and chroma. Spectral reflectance readings were also collected at the same time in order to calculate relative contents of metmyoglobin, myoglobin and oxymyoglobin [12]. For ground beef, thiobarbituric-acid reactive substances (TBARS) were determined as described by [13]. An eight-member trained taste panel assessed the 6 days aged steaks and ground beef samples. Attribute ratings were electronically collected with Compusense 5, release 4.6 computer software (Compusense Inc., Guelph, ON) using a nine point descriptive scale for initial and overall tenderness, initial and sustainable juiciness, beef flavour intensity and amount of connective tissue. The same attributes were used for ground beef, except residual mouth coating was rated instead of amount of connective tissue. Statistical analyses were conducted using the MIXED procedure of Statistical Analysis Systems Institute [14]. The model included as the fixed effect of vitamin E grouping, based on tissue α-tocopherol levels (<3 ug/g or low; 3 to 4 ug/g or low-medium; 4 to 5 ug/g or medium-high and >5 ug/g or high) for beef quality traits. Individual animal nested within group was included as a random effect. Group means were determined using the LSMEANS option and separated using the F-test protected LSD procedure ($P \leq 0.05$).

III. RESULTS AND DISCUSSION

In the present study, animals were grouped according to their tissue α-tocopherol levels, namely low (L), n=10 (<3 μg/g meat); low-medium (LM), n=20 (3 to 4 μg/g meat); high-medium (HM), n=11 (4 to 5 μg/g meat) and high (H), n=14 (>5 μg/g meat). A time of ageing by tissue α-tocopherol level interaction was detectected for TBARS ($P<0.001$) in ground beef (Figure 1). TBARS from animals with high-medium and high levels of α-tocopherol did not significantly increase between days 0 and 4 of ageing, while the low group, followed by the low-medium group, had increasing TBARS over time. Low and low-medium vitamin E groups had α-tocopherol concentrations lower than 4 μg/g meat, which explains the increasing TBARS over time. [15] reported that raw meat with less than approximately 2 mg α-tocopherol/g meat showed a very high degree of lipid oxidation measured by TBARS. Tissue levels of α-tocopherol had no effect on driploss ($P=0.838$) nor cooking loss ($P=0.528$) (Table 1), similar to results found by [16,17]. Initial colour and pH were also not affected by tissue α-tocopherol levels ($P>0.05$) (Table 1), as reported in similar studies [18,19]. As expected, fat content increased with α-tocopherol levels ($P=0.010$) (Table 1), as α-tocopherol is a fat soluble vitamin. The higher content of fat associated with higher α-tocopherol could have an effect on other meat quality traits, such as tenderness. In addition the use of antioxidants such as vitamin E could enhance tenderness in beef by preventing the inactivation of the calpain system [19]. However, although shear force from all groups decreased with ageing ($P<0.001$), no effect ($P>0.05$) of α-tocopherol tissue levels was found on shear force.

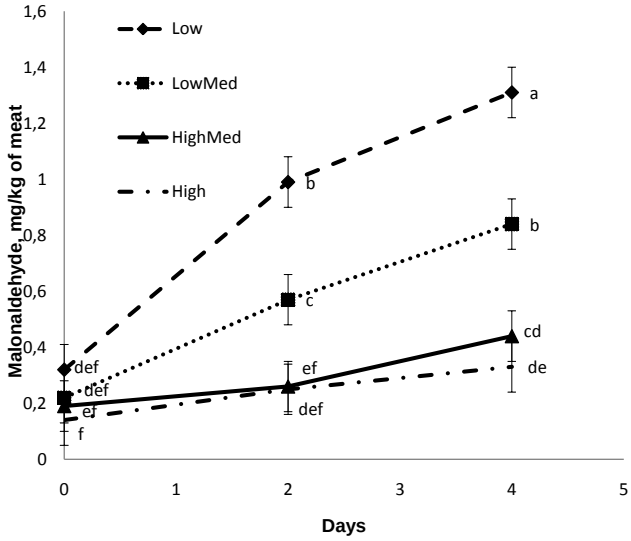

Fig.1. TBARS in ground beef (6 days of ageing) with different α-tocopherol tissue levels over 4 days of retail display. a,b,c,d,e,f: means with different letters are significantly different (P < 0.05)

Table 1. Effect of different tissue levels of α-tocopherol (μg/g meat) on *longissimus thoracis* quality

	α-Tocopherol tissue level[1]				
	L (n=10)	**LM** (n=20)	**HM** (n=11)	**H** (n=14)	***P* value**
Initial colour, 24 h					
*L**	36.3	36.2	35.4	36.2	0.718
Chroma	24.2	23.6	23.7	23.3	0.688
Hue	24.1	23.8	23.7	23.7	0.823
pH, 24 h					
pH	5.66	5.63	5.62	5.67	0.464
Temperature	2.87	2.40	2.43	2.18	0.657
Proximate Analysis, %					
Moisture	72.8[a]	71.9[a]	72.0[ab]	71.1[b]	0.010
Fat	5.38[b]	6.38[b]	6.27[b]	7.52[a]	0.010
Protein	21.0	20.9	21.0	20.7	0.187
Cooking Loss, mg/g[2]	192	185	181	179	0.528
Water Holding Capacity, mg/g					
Driploss[3]	42.9	41.0	42.9	42.5	0.838

[a,b]Means in the same row with different superscripts are significantly different ($P < 0.05$); [1] L=low(<3 μg/g meat); LM=low-medium (3-4 μg/g meat); HM=high-medium (4-5 μg/g meat); H=high (>5 μg/g meat). [2]Average values from 1, 6, 14 and 21 days of ageing. [3]From day 6 until day 10

For 6 days aged steaks and ground beef, vitamin E supplementation had no effect on sensory attributes (P>0.05) (data not shown), similar to studies by [6,18] who did not find any effects on steak texture and flavour attributes.

In the retail study, in steaks aged 6 (P=0.004) or 21 days (P<0.001), and ground beef (P<0.001), L* decreased over time (Data not shown). After a short ageing time (6 days), no effect (P>0.05) on retail evaluation was found among samples with different tissue levels of α-tocopherol. However, over time in retail display there was an increase in metmyoglobin (P<0.001) and decreases (P<0.001) in the content of myoglobin and oxymyoglobin. In contrast, with meat that had been aged for 21 days, increased tissue α-tocopherol levels protected against formation of metmyoglobin over time in retail display (P=0.008). The increase in metmyoglobin was smaller during retail display as α-tocopherol tissue levels increased. Oxymyoglobin levels on the last day of retail display were also higher (P=0.033) in meat with a higher content of α-tocopherol. Thus, chroma values of steaks with the high-medium and high levels of α-tocopherol were not affected by the time in retail display, in contrast to observations for steaks with lower α-tocopherol levels (P=0.016). A similar effect was found for the ground beef patties. An interaction between tissue α-tocopherol levels and days of retail display was observed for both oxymyoglobin (P=0.001) and metmyoglobin (P<0.001) in 21 days aged steaks; in low and low-medium α-tocopherol groups, oxymyoglobin decreased while metmyoglobin increased while values for high-medium and high α-tocopherol groups did not change. In addition, the increase in hue was smaller in samples with higher α-tocopherol tissue levels (P<0.001). In the present study, chroma decreased over time, meaning less intense colour in treatments with a lower level of tissue α-tocopherol. This protection with high α-tocopherol levels (P=0.016) in 21 days aged beef is practically significant, as the time before boxed beef as primal cuts and manufactured/ground beef are displayed in commercial retail cases in Canada ranges from 5 to 80 days and 2 to 56 days respectively [20]. Higher initial tissue α-tocopherol levels are more protective during long periods of ageing as its

concentration decreases over time [15]. Therefore, high tissue levels of vitamin E could lead to an improvement in colour and retail appearance of both lean and ground beef following long storage periods during distribution which are commonly found in industry and would be particularly valuable in assuring colour stability in transoceanic shipment of chilled meat.

IV.CONCLUSIONS

Increased tissue levels of α-tocopherol protected against retail discolouration and lipid oxidation in steaks after ageing 21 days, but had no influence in steaks after ageing only 6 days. A similar protective effect was observed in ground beef (25% fat) when prepared using lean and fat tissues aged 6 days. Shear force was not affected by tissue α-tocopherol levels. To obtain oxidative stability, this required >1040 IU supplementary vitamin E added to 770 IU estimated to be naturally available in the diet

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