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

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Abstract— **The objective of the present study was to investigate the effects of increasing beef omega-3 fatty acid content and the protective effect of vitamin E antioxidant activity on meat quality characteristics. Eighty feedlot steers were fed 4 different diets (control, high vitamin E, 10% ground flaxseed or high vitamin E + 10% ground flaxseed) and meat quality characteristics were measured. 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 high vitamin E resulted in lower *longissimus thoracis* drip loss (*P*=0.013). As expected, ageing 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), ground beef from flaxseed fed steers had lower (*P*<0.05) retail scores, which were not corrected by higher levels of dietary vitamin E. Finally, although no effect was observed among treatments for sensory attributes in steaks, retail and sensory attributes were correlated with the n-3:α-tocopherol ratio (*P*>0.05). The results suggest the need to maintain a correct tissue balance between the recommended increase in n-3 fatty acids and the levels of endogenous antioxidants, such as vitamin E, in order to prevent negative effects on meat quality from a loss in oxidative stability.**

Keywords— **flaxseed, oxidation, tocopherol**

I. INTRODUCTION

Despite the numerous known [1] deleterious quality changes associated with oxidation of polyunsaturated fatty acids (PUFA), there is considerable interest in enhancing PUFA content in meat in order to market niche products with health label claims. Thus, dietary flax supplementation can be used in order to increase omega-3 (n-3) fatty acid content in beef. However, some side-effects on meat quality have been reported [2]. Increasing lipid stability by addition of antioxidant compounds, such as vitamin E, could be a means of overcoming this problem [3].

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

II. MATERIAL AND METHODS

Eighty feedlot steers were housed in 8 feedlot pens and fed *ad libitum*. Steers were stratified by weight and assigned to one of four diets: control (451 IU dl-α-tocopheryl acetate·head^{-1}·d^{-1}), VitE (1051 IU), Flax (10% ground flaxseed) and Flax-VitE (10% flaxseed and 1051 IU). Steers were on trial for 129±3.2 d (571±7.1 kg) and slaughtered at the Lacombe Research Centre in groups of 16 (4 animals per treatment).

The left loin primal was removed from the carcass and a 25 mm *longissimus thoracis* (LT) steak with the fat cap on was frozen (-80ºC) for subsequent fatty acid determination. Intramuscular lipids were analyzed as previously reported by Juárez et al. [8]. Approximately 200 g of subcutaneous fat and 800 g of lean were labelled, individually vacuum packaged and placed in a cooler (2°C) for 6 d, for subsequent analysis. A steak (25 mm) was removed from the posterior end of the LT for α-tocopherol determination using normal phase HPLC [4]. The remaining portion of the LT was labelled, vacuum packaged and stored in the cooler for 6 d. Five steaks were then removed from the LT . The first steak was cooked on a grill (210 °C) to an internal temperature 71°C and shear force analyses were carried out as described by Aldai et al. [6]. The second and third steaks were individually vacuum packaged and frozen at -35°C until sensory evaluation. The fourth steak was placed onto a polystyrene tray with a dri-loc pad, over-wrapped with oxygen permeable film and placed in a retail case at 1°C for retail evaluation. To determine drip-loss, the fifth steak was stored on a polystyrene over-wrapped tray with a dri-loc pad for 4 d at 2°C. The remaining portion of the LT was ground three times (3 mm?) and used to determine the proximate composition [6].

At 6 days after slaughter, the stored lean and subcutaneous fat was ground two times (3 mm?) to achieve an 80/20 lean to fat grind. A sub-sample (~ 50 g) was finely comminuted and concentrations of thiobarbituric acid reactive substances (TBARS) were determined [7]. An additional 50 g of grind was placed on pre-labelled over-wrapped polystyrene tray and placed in a retail display case to determine 3 d TBARS content. The increase in TBARS between d 0 and 3 (ΔTBARS) was then calculated. The remaining grind was used to form a 140 g patty, which was placed onto pre-labelled polystyrene trays, over-wrapped and placed into a display case for retail evaluation.

On each specific display time (0, 1, 2 and 3 d), three objective colour measurements were collected across steaks and patties. Following objective colour measurements, the same steaks and patties were subjectively evaluated for retail appearance and percent surface discolouration by 8 trained panellists [9]. Taste panel steaks were removed from the freezer and placed in a refrigerator to thaw for 24 h. Steaks were grilled and used for sensory analysis [6].

Statistical analyses were conducted using the MIXED procedure of SAS, including the fixed effects of dietary flax and vitamin E and their interaction, and kill as a random effect. For retail evaluation traits, day was included in the model as a fixed effect. The concentration of n-3 fatty acids (% total fatty acids) was used to calculate the n-3:α-tocopherol ratio. Correlations between the n-3:α-tocopherol ratio and subjective (retail and sensory) attributes were also determined.

III. RESULTS AND DISCUSSION

Meat composition (moisture, fat and protein content) was similar (*P* > 0.05) among dietary treatments (Table 1), as observed in previous studies when flax was included in beef cattle diets [10]. Although some authors [11] have reported an effect on tenderness with increasing dietary flax, the results from the present study showed no effect on tenderness (*P* > 0.05). For drip loss, an interaction effect was noted with meat from steers fed flaxseed and high levels of vitamin E having the lowest (*P* = 0.013) drip loss. α-Tocopherol preserves the integrity of muscle cell membranes, thereby preventing drip loss [12], but reasons for selective reductions in drip loss when feeding flax are not immediately apparent.

Table 1. Effect of dietary vitamin E and flaxseed on beef quality traits

	Diet				SEM	*P* value		
	Control	VitE	Flax	Flax-VitE		VitE	Flax	VitE*Flax
Moisture, $g \cdot 100g^{-1}$	72.4	72.1	71.7	71.8	0.413	0.699	0.139	0.599
Fat, $g \cdot 100g^{-1}$	5.56	6.04	6.27	6.23	0.493	0.579	0.257	0.516
Protein, $g \cdot 100g^{-1}$	21.2	21.0	21.1	21.2	0.151	0.318	0.888	0.305
Shear, kg	5.99	5.47	5.46	5.89	0.495	0.888	0.874	0.169
Drip loss, $mg \cdot g^{-1}$	40.7^a	39.6^a	43.7^a	34.9^b	1.812	0.002	0.556	0.013
α-Tocopherol, $\mu g \cdot g^{-1}$	2.03	3.16	2.25	3.25	0.130	<0.001	0.237	0.624
n-3:α-Tocopherol ratio	0.50	0.37	0.95	0.83	0.083	0.078	<0.001	0.941
ΔTBARS, $mg \cdot kg^{-1}$	0.42	0.22	0.64	0.49	0.135	0.046	0.006	0.809

^{a,b}Different letters indicate statistical difference (*P* ≤ 0.05) ;TBARS: thiobarbituric acid reactive substances

While increases in α-tocopherol levels (*P* < 0.001) were observed in meat from vitamin E and vitamin E plus flaxseed supplemented steers, including flaxseed in the diet resulted in greater n-3 fatty acid and n-3:α-tocopherol ratios ($P < 0.001$[8]. The increase in TBARS (ΔTBARS) between 0 and 3 d of ageing was lower ($P = 0.046$) in meat from vitamin E supplemented steers and higher ($P = 0.006$) in meat from flaxseed fed steers.

In steaks, the appearance ($P < 0.001$) scores, L^* ($P = 0.024$) and chroma ($P < 0.001$) values linearly decreased, and lean colour and surface discolouration, as well as hue values, linearly increased ($P < 0.001$) from d 0 to 3 for all groups (data not shown). Similar effects were observed for ground beef, with the exception of a quadratic effect ($P < 0.001$) on lean colour, due to a decrease after 3 d of ageing. The extent and rate of oxygen diffusion into the meat surface has been reported to increase during ageing due to continuous inactivation of oxygen-consuming enzymes [13].

Dietary addition of either vitamin E or flaxseed (Table 2) did not affect ($P > 0.05$) any of the subjective or objective retail attributes of steaks. In high-fat products (patties), several interactions between both treatments were observed. The scores for patty appearance decreased ($P = 0.043$) when flaxseed was included in the diet, and vitamin E supplementation did not show any protective effect. Lean colour scores increased ($P < 0.001$) and L^* values decreased ($P = 0.030$) when vitamin E was added to the control diet, but the opposite effect was observed in patties from flaxseed fed steers. Furthermore, patty hue values increased ($P = 0.041$) with the inclusion of both flaxseed and vitamin E in the diet and patty surface discolouration increased ($P = 0.003$) with flaxseed inclusion in the diets. The reasons these effects were observed in patties only is due to the disruption of cellular integrity; increased PUFA concentration at the same time antioxidant concentration is diluted and the increased exposure of the tissues to oxygen [14].

Only steaks were used for sensory evaluation and no effect of treatments ($P > 0.05$) was observed for any of the studied attributes (data not shown). Some authors have reported decreases in juiciness [11] and increases in off-flavour [2] when n-3 content is increased by inclusion of flaxseed in the diet. Increasing α-tocopherol levels has been reported to increase lipid stability and reduce off-flavour development in beef [15]. The lack of an effect in the present study may be due to the level of vitamin E in the control diet (451 IU dl-α-tocopheryl acetate$\cdot$head$^{-1}\cdot$d^{-1}) being within the norm used by Canadian feedlot producers, and apparently sufficient to counteract any potential negative effects on whole muscle beef palatability when feeding flaxseed.

Table 2. Effect of dietary vitamin E and flaxseed on evaluation characteristics of ground beef (20% fat)

	Diet				SEM	*P* value		
	Control	VitE	Flax	Flax-VitE		VitE	Flax	VitE*Flax
Appearance	5.69^{ab}	5.88^{a}	5.57^{bc}	5.42^{c}	0.550	0.808	<0.001	0.043
% Discoloration	1.64	1.51	1.81	1.92	0.150	0.959	0.003	0.221
L^*	54.1^{ab}	53.5^{b}	54.0^{ab}	55.0^{a}	2.370	0.570	0.049	0.030
Chroma	21.2	21.2	21.7	21.3	0.670	0.109	0.071	0.256
Hue	50.5^{b}	50.1^{b}	50.7^{ab}	51.5^{a}	1.490	0.518	0.014	0.041

^{a,b,c}Different letters indicate statistical difference ($P \leq 0.05$); Appearance (1=extremely undesirable and 8=extremely desirable) and % discolouration (1=0% and 7=100% discolouration).

Both treatments (dietary vitamin E and flaxseed) are known to have opposite effects on meat colour and lipid stability. Hence we were interested in determining if correlation analysis between beef quality traits and the n-3:α-tocopherol ratio would provide a more sensitive measure of the effects of increasing beef n-3 content and the protective effect of vitamin E on meat quality characteristics.

Several significant relationships ($P < 0.05$) were observed between the n-3:α-tocopherol ratio and retail characteristics of steaks. Appearance and hue were negatively correlated with this ratio ($r = -0.154$ and -0.268, respectively), while surface discolouration and chroma were positively correlated to this ratio ($r = 0.216$ and 0.142, respectively). Similar negative correlations were also observed between the n-3:α-tocopherol ratio and chroma and L^* values in patties (-0.143 and -0.193, respectively), together with a positive correlation with lean colour (0.176). Results indicate that higher levels of n-3 fatty acids and lower α-tocopherol tissue levels lead to an increase in negative retail characteristics, and clearly demonstrated the sensitivity of correlation analysis. Consistent with the enhanced sensitivity for finding differences in retail characteristics of steaks, all the sensory traits were negatively correlated with the calculated n-3:α-tocopherol ratio ($P < 0.05$; $r = 0.260$ to 0.374). Therefore, increasing the concentration of n-3 fatty acids, while decreasing the α-tocopherol level in beef, leads to tougher, less juicy meat with greater off-flavour intensity.

IV. CONCLUSIONS

The increase in oxidation observed in meat from flaxseed fed steers resulted in lower scores during the retail display for patties (20% fat), which were not corrected by higher levels of dietary vitamin E. Therefore, the only clear effect observed from increasing vitamin E in the diet was a decrease in drip loss. However, correlation analysis using the n-3:α-tocopherol ratio indicated that a balance between the desired increase in unsaturated fatty acids and the levels of endogenous antioxidants is necessary to avoid negative effects on beef colour and palatability.

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