Beef Quality and Oxidative Stability from Cattle Fed High Levels of Vitamin E

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Summary with Implications

Meat color is a major factor for consumer meat purchasing decisions. Aging beef, which can improve tenderness, has been shown to accelerate discoloration in fresh beef, shortening retail display time, and generating negative flavor attributes. The objective of this study was to evaluate supplementing cattle high levels (2,200 International Units/day) of Vitamin E to sustain meat quality during prolonged retail display in beef strip loins after 2 or 14 days aging compared to commercially-produced loins selected as controls. Results showed a treatment x age effect for Warner-Bratzler shear force and free calcium content, primarily due to aging. A dietary treatment x age x day interaction in redness (a) and subjective discoloration occurred. High vitamin E samples exhibited more acceptable color scores compared to Control samples throughout retail display. As aging increased (14 days vs 2 days), Vitamin E samples sustained color better than Control samples, as shown by delta E (overall color change) values. A dietary treatment x day effect in lipid oxidation occurred with Vitamin E samples having significantly less malonaldehyde than Control samples. No differences in slice shear force, moisture, fat, or ash content were found. Supplementing high levels of Vitamin E to cattle resulted in sustained meat color and oxidative stability compared to commercially-produced cattle.*

Introduction

Meat color is a major factor in initial meat purchasing decisions. Consumers prefer a bright, cherry-red color in fresh beef as it is a perceived indicator of freshness and wholesomeness. Fresh beef is often discounted at retail when surface lean exceeds 20% discoloration. It has been reported that 15% of retail beef is discounted due to discoloration, resulting in an economic loss of over $1 billion annually. In addition, the onset of lipid oxidation coincides with discoloration, generating flavor attributes associated with decreased palatability. Methods used to improve meat quality, such as postmortem aging, have been shown to accelerate the rate of discoloration and lipid oxidation. Maintaining beef color quality (color and lipid oxidation) can increase time in retail display for consumers to purchase product at its peak freshness. An effective method to retard oxidation of meat is supplementation of antioxidants, such as vitamin E, to cattle. However, the impact of high levels of Vitamin E inclusion in cattle rations on sustained color stability across extended retail display has not been well studied. Therefore, an investigation into cattle supplemented with and without high levels of Vitamin E in prolonged retail display is needed.

Procedure

Cattle (n=150) across 15 pens were grain-finished with 2,200 International Units (IU) of Vitamin E (α-tocopherol) per day for the final 100 days on feed. One Low-Choice strip loin (*Longissimus Lumborum*) was randomly selected from 9 of the pens. Nine Low-Choice strip loins were selected from commercial production at the packing plant as a control treatment, totaling nine loins per treatment (total n = 18). Loins were split in half and randomly assigned to wet age for 2 or 14 days postmortem under vacuum-packaging. After aging, loin sections were opened, and two 1-inch thick steaks were cut: one steak for tenderness measurements at 0 d of retail display, and one for instrumental color and subjective color analysis across 14 days of retail display. Four half-inch steaks were also fabricated, split in half, and randomly assigned to one of the following: 1) laboratory analysis including proximate composition and free calcium (Ca^{2+}) concentration or 2) assigned to 0, 4, 7, 10, 12, or 14 days retail display for lipid oxidation. After fabrication, all steaks used for retail display were placed on foam trays, overwrapped with oxygen permeable film, and placed under simulated retail display conditions up to 14 d at 37°F. The same fabrication scheme was used after 14 days of aging.

For all tenderness steaks, internal raw temperature and weight were recorded. Steaks were cooked to 80°F and turned over until they reached a target temperature of 160°F on an indoor electric grill (Hamilton Beach- 31605A, Hamilton Beach Brands, Glen Allen, VA). After cooking, internal temperature and weight were recorded. A single slice from the hot steak was removed parallel to the muscle fibers, and sheared using a Food Texture Analyzer with a Slice-Shear blade to determine slice shear force (SSF). The steak was then bagged and stored in the cooler (33°F) for approximately 24 hours. Six cores (1/2- inch diameter) were removed parallel to the muscle fiber orientation and were sheared with a Food Texture Analyzer with a Warner-Bratzler blade to determine Warner-Bratzler shear force (WBSF).

Free calcium was analyzed via inductively coupled plasma spectroscopy following high-speed centrifugation. Calcium concentration was quantified using an inductively- coupled plasma emission spectrometer (iCAP 6500 Radial; Thermo Electron, Cambridge, UK) with appropriate calcium concentration standards. Proximate composition (moisture and ash %) was measured via Thermogravimetric Analyzer. Fat content was measured via ether extraction using a Soxhlet apparatus, and protein content was calculated by differences. Lipid oxidation, or thiobarbituric acid reactive substance value (TBARS), was measured via the amount of mg of malonaldehyde per kg of muscle tissue subjected to retail display periods of 0, 4, 7, 10, 12, and

Table 1. Tenderness and Meat Quality Attributes from loins of cattle fed either Vitamin E or Control Diets.

Variable		Treatment	Days Aged 2	Days Aged 14	SEM[1]	*P*-Value
Tenderness (lbs of force)	Slice-Shear Force	Control	66.51	33.53	9.63	0.32
		Vitamin E	79.68	54.15		
	Warner-Bratzler Shear Force	Control	12.76[a]	8.71[b]	0.90	0.006
		Vitamin E	11.49[a]	10.10[b]		
Free Calcium (µm)		Control	50.85[ab]	59.07[a]	5.35	0.01
		Vitamin E	40.72[b]	59.70[a]		

Proximate Composition (%)	Control	Vitamin E	SEM[1]	*P*-Value
Moisture	71.43	71.68	0.65	0.07
Protein	20.84[A]	20.14[B]	0.27	<0.0001
Fat	6.61	7.08	0.65	0.38
Ash	1.13	1.10	0.03	0.92

[a-b] Means within the same variable with different superscripts denote dietary Treatment* days of Aging effect ($P < 0.05$).

[A-B] Means within the same variable with different superscripts denote dietary Treatment differences ($P < 0.05$).

[1] Standard Error of the Mean

14 days. Instrumental color was measured daily for 7 d using a Minolta Colorimeter (CR- 400, Minolta Camera Company, Osaka, Japan). The D65 illuminant setting and 2° observer with an 8 mm diameter measurement area were used. Color values were obtained by averaging 6 readings from various areas of the steak surface. Instrumental color was measured via colorimeter measuring L* (lightness), a* (redness), and b* (yellowness). Delta E (overall color change across two time points) values were calculated using the following equation: $\Delta E=[(\Delta L^{*2})+(\Delta a^{*2})+(\Delta b^{*2})]^{0.5}$. This value was calculated across day 0 and day 14 of retail display. Subjective discoloration was also evaluated daily during retail display by a panel of five trained panelists using a percentage scale where 0% meant no discoloration and 100% meant complete surface discoloration.

Proximate composition was analyzed as a completely randomized design for samples aged 2 d. Tenderness and calcium data were analyzed as a split-plot design, with dietary treatment as the whole-plot and aging period as the split-plot. Lipid oxidation (TBARS) data were analyzed as a split-split plot design with dietary treatment as the whole- plot, aging period as the split-plot and day of retail display as the split-split plot. The L*, a*, b* values and subjective discoloration data were analyzed as a split-split-plot design, with dietary treatment as the whole-plot, aging period as the split-plot, with day of retail display as the split-split-plot. Given measurements for color were evaluated on consecutive days on the same sample, days of retail display for L*, a*, b*, and subjective discoloration values were considered as a repeated measure. Loin was considered the experimental unit. Data were analyzed using the PROC GLIMMIX procedure of SAS with the LS MEANS statement. Statistical significance was determined at $P < 0.05$ with trends distinguished between 0.051–0.10.

Results

A dietary treatment x days of aging interaction ($P < 0.05$) was seen for Warner-Bratzler shear force. Increased days of aging lowered shear force values (more tender), regardless of dietary treatment (Table 1). At 14 days of aging, control samples had lower shear force compared to Vitamin E samples although difference was not statistically significant. No differences were found in SSF values across treatments or aging ($P > 0.05$). In addition, a dietary treatment x days of aging interaction ($P = 0.01$) was found in free calcium concentration, where 14-day aged samples had greater free calcium compared to 2 day aged vitamin E samples (Table 1). This was expected as calcium is released from organelles upon aging. However, minute differences did not result in different shear force values. There was greater ($P < .0001$) protein content in control loins compared to Vitamin E loins (Table 1). However, the numerical difference is of little practical importance. Differences in protein content may be due to calculated differences in proximate composition after determining moisture, fat, and ash content.

A dietary treatment x day of aging x day of retail display interaction ($P = .001$) was found in muscle redness (a*) values (Table 2). In general, redness values decreased as days of aging and days of retail display

Table 2. Analysis of Objective Redness (a*) scores and Subjective Discoloration during Retail Display.

Variable	Treatment	Age	Days of Retail Display								SEM	*P*-Value
			7	8	9	10	11	12	13	14		
a*[1]	Control	2	16.55^{b}	14.94^{c}	13.05^{c}	11.48^{d}	10^{e}	8.94^{f}	8.50^{f}	7.97^{g}	0.75	0.001
	Vitamin E	2	17.90^{a}	17.56^{a}	17.41^{ab}	17.03^{ab}	16.18^{b}	15.45^{bc}	13.89^{e}	12.60^{c}		
	Control	14	12.35^{cd}	10.10^{e}	8.21^{f}	7.23^{gh}	6.67^{h}	6.87^{h}	7.41^{gh}	7.88^{g}		
	Vitamin E	14	15.38^{bc}	13.91^{e}	12.48^{d}	11.13^{de}	10.92^{de}	11.46^{d}	11.55^{d}	11de		

	Treatment	Age	7	8	9	10	11	12	13	14	SEM	*P*-Value
Percent Discoloration (%)	Control	2	5.00^{mnop}	8.14^{lmno}	22.54^{ijk}	39.70^{h}	54.32^{g}	71.14^{f}	81.78^{cde}	87.60^{bcd}	5.44	<0.0001
	Vitamin E	2	0^{p}	0^{p}	0^{p}	0^{p}	0.01^{mnop}	7.58^{lmno}	20.68^{jkl}	35.42^{hi}		
	Control	14	21.79^{jk}	53.85^{g}	77.17^{def}	93.50^{abc}	98.07^{ab}	97.31^{ab}	97.61^{ab}	99.51^{a}		
	Vitamin E	14	14.10^{klm}	31.84^{hij}	54.61^{g}	66.18^{fg}	66.10^{fg}	72.45^{ef}	85.97^{bcd}	93.57^{abc}		

[a-p] Means within the same variable with different superscripts denote treatment*age*day interactions ($p < 0.05$).

[1] a*: Red to Green color space; + value (red),—value (green)

[2] SEM: Standard error of the Mean

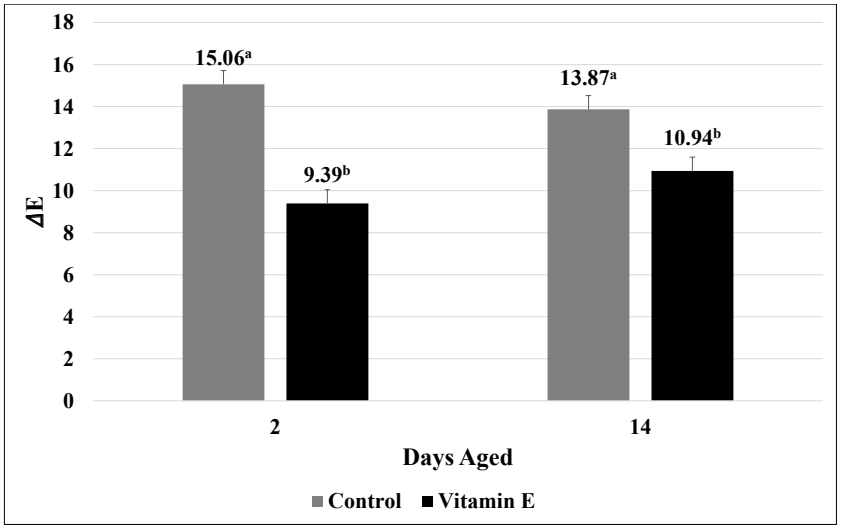

Figure 1. Delta E (ΔE) values of loins from cattle fed with or without Vitamin E [SEM: 0.92].

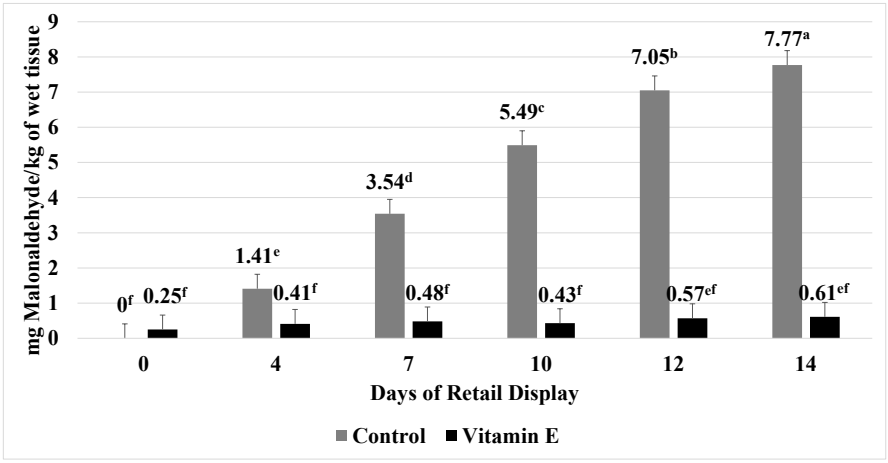

Figure 2. Thiobarbaturic Acid Reactive Substances (TBARS) of loins from cattle fed with or without Vitamin E [SEM (mg Malonaldehyde/kg wet tissue: 0.41)].

increased. At 0 d of retail display, there were no differences across treatments. As retail display time increased, however, control samples significantly decreased in a* values compared to Vitamin E loins, which maintained acceptable color throughout retail display after 2 d of aging. At 14 d aging, Vitamin E loins had a lower redness scores compared to 2 d aging, but maintained superior a* values when compared to control samples at 2 and 14 d aging. This is supported by a significant dietary treatment x days of age interaction ($P = 0.04$) in delta E values (gross color change from initial to end of retail display), as control loins had a greater overall change in color from the beginning of retail display compared to Vitamin E loins (Figure 1). There were no differences ($P > 0.05$) in L* or b* values. A dietary treatment x days of aging x days of retail display interaction ($P < .0001$) was found in subjective discoloration (Table 2). After 14 d of retail display, control samples aged 2 d had greater discoloration than Vitamin E samples aged 2 d. At 2 d of aging, Vitamin E loins did not surpass 20% (the threshold of discoloration meriting discounts) until day 13 of retail display, compared to control loins surpassing this discount threshold of discoloration at 9 days of retail display. After 14 days of aging, Vitamin E samples exhibited greater percent discoloration across fewer days of retail display but maintained noticeably lower percent discoloration compared to control loins. These data suggest that vitamin E supplemented beef, when aged,

is not as effective at retaining meat color under prolonged retail display as vitamin E supplemented beef aged just 2 d.

When examining lipid oxidation (Figure 2), a dietary treatment x day of aging interaction ($P < .0001$) was found. In general, lipid oxidation increased as days of retail display increased. Comparing dietary treatments, control samples showed exponentially (~11 times) greater malonaldehyde content compared to Vitamin E loins after retail display, as lipid oxidation remained relatively low in Vitamin E steaks throughout retail display (0.61 mg malonaldehyde/kg wet tissue).

Conclusions

Supplementing Vitamin E greatly reduced color and lipid degradation in meat, as only prolonged stages of retail display produced accelerated discoloration and lipid oxidation. Although Vitamin E supplementation did not enhance meat tenderness, it did not negatively impact meat tenderness. Vitamin E was shown to be an effective method at slowing the rate of discoloration in fresh beef, providing additional days of retail display for consumer purchasing after prolonged days of retail display. However, increased aging is shown to lower the efficacy of Vitamin E, as seen by prolonged retail display.

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