Dietary Vitamin E Supplementation Shifted Weight Loss from Drip to Cooking Loss in Fresh Beef Longissimus During Display

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ABSTRACT: Effects of dietary vitamin E supplementation on drip loss, cooking loss, and muscle fiber disruption in fresh beef loin steaks from Holstein and crossbred beef steers were studied. Nine Holstein steers and nine beef steers were fed a control diet and nine Holstein steers and eight beef steers were supplemented daily with 298 IU of vitamin E/kg of diet for 211, 232, or 252 d. Drip loss, cooking loss, cooking yield, and shear value were measured in each longissimus lumborum sample displayed in PVC film for 2, 6, 10, or 14 d. Dietary vitamin E supplementation produced meat that had smaller (P < .001) increases in drip loss during 14 d of display but higher (P < .01) cooking losses. Cooking yield was reduced (P < .05) by vitamin E supplementation. Vitamin E supplementation reduced (P < .01) muscle cell disruption in beef steak displayed for 14 d. These results indicated that dietary vitamin E treatment stabilized cell integrity and enhanced the ability of beef steak to hold sarcoplasmic components during display, although subsequent losses due to cooking were greater.

Key Words: Vitamin E, Beef, Drip, Water-Holding Capacity, Cooking Loss, Cell Structure

Introduction

Drip loss in fresh beef cuts is an important challenge to maintaining an attractive retail display of meat. Normally, fresh postmortem meat exudes fluid, or drip, from cut surfaces (Lawrie, 1991). Amount of drip from raw beef is influenced by the following factors: age, sex, diet, pre-slaughter stress, slaughter methods, storage time and temperature, and meat properties (especially pH and intramuscular moisture and fat contents) (Lawrie, 1991). If cell membrane integrity could be stabilized postmortem, sarcoplasm should be retained in muscle cells and thereby result in less drip loss and more weight retention during storage and display. Oxidative processes may contribute to the loss of membrane integrity. There is precedence for this suggestion: less drip loss was observed from thawed pork chops obtained from pigs supplemented with vitamin E (Asghar et al., 1991).

This study investigated the effects of dietary vitamin E supplementation on drip and cooking losses from fresh beef steaks. A parallel study with this meat described vitamin E's effects on color and lipid stability (Arnold et al., 1993b).

Materials and Methods

Dietary Vitamin E Supplementation

Eighteen Holstein steers and 17 crossbred beef steers were used in this study within the vitamin E treatments and slaughter groups of Arnold et al. (1993b). Animal management procedures and basal diet composition in terms of ingredients and nutrients have been reported previously (Arnold et al., 1993b). Nine Holstein steers and nine beef steers were fed a control diet and the other nine Holstein steers and eight beef steers received a diet formulated to contain 298 IU of vitamin E (DL-α-tocopheryl acetate, Hoffmann-La Roche, Nutley, NJ) per kilogram of diet. Steers were slaughtered after 211 d (slaughter group 1), 232 d (slaughter group 2), or 252 d (slaughter group 3) on treatment with three steers in each treatment × slaughter group combination, except that two beef steers represented the supplementation...
treatment in slaughter group 1. The ranges of age and live weight at slaughter of Holstein steers were 13 to 14 mo of age and 491 to 559 kg, and those of beef steers were 13 to 14 mo of age and 407 to 561 kg.

Steers were slaughtered at Packerland Packing Co., Green Bay, WI, and the left strip loin from each steer was removed at 24 h postmortem. These subprimal cuts were then vacuum-packaged and transported to the University of Wisconsin-Madison meat laboratory and stored for an additional 6 d at 4°C. The a-tocopherol concentrations were measured in duplicate samples of longissimus lumborum (LL) muscle at 2 d after slaughter by the method of Arnold et al. (1993b). The moisture contents in LL muscles were determined by drying samples at 105°C for 16 h. The fat contents were determined by Soxhlet extraction for 48 h with diethyl ether.

**Drip Loss, Cooking Loss, and Shear Value Analyses**

Longissimus lumborum muscles were sliced into 2-cm-thick steaks, and 2-cm × 5-cm × 5-cm steaks were cut from these sliced steaks. Samples were randomly allotted to four measurement days. All samples were individually placed on soaker pads (Dri-Loc Pad, Sealed Air Corp., Patterson, NC) to absorb drip fluid in a 100-mL disposable weigh boat, overlapped with PVC film (MW 4, P = 15,500 to 16,300 mL O2/m2/24 h at 23°C, Filmco Industries, Aurora, OH) and displayed under cool white fluorescent lights (2,475 lx) at 4°C for 14 d.

Duplicate samples were weighed at sampling day (7 d postmortem) and at measurement days (d 2, 6, 10, and 14), and drip loss percentage was determined as weight loss relative to the sampling day. Samples were then placed in a polyethylene bag, and cooked in water at 70°C. Internal temperature of samples was maintained at 70°C for 30 min with the use of a thermocouple probe inserted into the center of the monitored sample. After being cooled to room temperature, samples were weighed, and cooking loss was determined as percentage reduction at the measurement day. The cooking yield percentage was determined by the following calculation: cooked sample weight/fresh sample weight at sampling day × 100. The Warner-Bratzler shear values were determined with five to eight cores with 1.3-cm diameters obtained from each of the above cooked samples. Average shear values were calculated for each animal × day combination, prior to statistical analysis.

**Histological Analysis**

Muscle samples were histologically examined to assess the effect of dietary vitamin E supplementation on muscle cell structure. Two animals from each vitamin E × breed group combination were randomly chosen. A LL muscle sample from these eight steers was displayed at 4°C for 14 d, then frozen in liquid nitrogen and stored at −80°C. They were transversely sectioned at 10 μm in a cryostat (maintained at about −20°C) and the sections were placed on glass slides. Control (unfixed) and fixed (10% formalin) sections were then stained with Harris Hematoxylin (Humason, 1972) and mounted with glycerin jelly.

Morphological integrity of muscle sections was observed with a light microscope. About 1,000 cross-sectioned muscle fibers per sample were counted in randomly selected areas. Fibers were distinguished into intact or disrupted fibers by M. Mitsumoto, one of the authors. The percentage of muscle fibers disrupted was determined. Photomicrographs were taken with a Nikon Inverted Microscope Diaphot-TMD using Kodak 35-mm film (ISO 100).

**Statistical Analyses**

Different duplicate samples were used on each day for the drip loss, cooking loss, and cooking yield measurements. The total number of samples was 280 (35 animals × four measurement days × two steaks) for each analysis. Drip loss, cooking loss, cooking yield and shear value data were analyzed by the General Linear Models procedure of SAS (1985) as a split-split-plot design to account for the repeated measures aspect. Animal was designated as the main plot, muscle samples within animal as the sub-plot, and muscle samples within animal × day as the sub-sub-plot. Pairwise comparisons of means were analyzed by Scheffe's test (Snedecor and Cochran, 1980). Fiber disruption percentages were analyzed by least squares procedures (Harvey, 1988) to estimate the effects of dietary vitamin E and breed.

**Results and Discussion**

Least squares means for drip loss percentage and cooking loss percentage are shown in Figures 1 and 2, respectively. Relationships of two-way interactions (dietary vitamin E supplementation × day) for these measurements are presented in Figures 3 and 4, respectively.

**Dietary Vitamin E**

Beef steers consumed less vitamin E than Holstein steers because they consumed less diet than Holstein steers (Arnold et al., 1993b). During the last 179 d of the study, control and supplemented beef steers consumed 60 and 1,190 IU/d and Holstein steers consumed 80 and 1,460 IU/d, respectively. Vitamin E consumed in the control treatment was consumed as a-tocopherol, which was an endogenous component of the basal diet. The α-tocopherol concentration in LL muscles was increased (P < .001) by vitamin E supplementation (control, 1.1 mg/kg; supplemented,
The average α-tocopherol concentration tended to be lower \( (P < .10) \) in Holstein than in beef LL. Conversely, length of supplementation did not affect \( (P > .10) \) LL α-tocopherol concentration, which is consistent with Arnold et al. (1993a), who reported equilibration between LL α-tocopherol concentration and vitamin E intake after 12 - 18 wk. The α-tocopherol concentration did not correlate with moisture \( (r = .19; P > .10, \text{Table 1}) \) or fat content \( (r = -.12; P > .10) \) in LL muscles from both breeds.

Vitamin E-supplemented steers had lower drip loss \( (6.7\%; P < .001, \text{Figure 1}) \) and cooking yield percentages \( (66.8\%; P < .05) \) and higher \( (P < .01) \) cooking losses \( (28.4\%; \text{Figure 2}) \) than the control \( (7.5\%, 67.5\% \text{and } 27.0\%, \text{respectively}) \). Dietary vitamin E supplementation showed smaller \( (P < .001) \)
increases of drip loss (from 3.0% to 10.1%; Figure 3) during 14 d of display compared to the control (from 3.2% to 11.7%) and larger ($P < .01$) cooking losses (from 30.3% to 25.8%; Figure 4) during display compared to the control (from 29.3% to 23.2%). There was no relationship ($P > .10$) between dietary vitamin E supplementation and day on cooking yield percentages. Dietary vitamin E supplementation caused no difference ($P > .10$) in shear values, which were 2.9 kg and 3.0 kg for control and vitamin E, respectively. Arnold et al. (1992) also observed that vitamin E supplementation did not alter shear value of Holstein LL steak.

Concentration of $\alpha$-tocopherol was negatively correlated with drip loss at d 14 ($r = -.49; P < .01$, Table 1) but positively correlated with cooking loss at d 14 ($r = .56; P < .001$). Cooking yield and shear value at d 14 were not correlated ($P > .10$) with $\alpha$-tocopherol concentration. Dietary vitamin E supplementation shifted weight loss from drip to cooking loss. This implies that retailers may be able to sell more weight to consumers in packages that would be less prone to contain undesirable drip loss. The second implication of this finding is that water-holding capacity of the cooked LL was not affected by dietary vitamin E supplementation, but the drip loss effect presumably reflects a difference in integrity of fresh LL. Asghar et al. (1991) reported that pork from pigs receiving the higher level of vitamin E (200 IU/kg of feed for 14 wk; 4.7 mg $\alpha$-tocopherol/kg of meat) had less drip loss than pork from pigs receiving lower vitamin E levels (10 IU and 100 IU/kg of feed; .5 mg and 2.6 mg $\alpha$-tocopherol/kg of meat, respectively). They suggested that a higher $\alpha$-tocopherol concentration in meat minimizes drip loss from frozen meat upon thawing, because $\alpha$-tocopherol may preserve the fluidity of cell membranes (Asghar et al., 1991). Monahan et al. (1994) reported that the reduced exudation in fresh pork steaks from pigs fed supplemental $\alpha$-tocopherol (200 mg $\alpha$-tocopheryl acetate/kg of diet) did not seem to be directly related to oxidation-induced changes in membrane fluidity. Taylor et al. (1994) reported that vitamin E supplementation (2,500 IU/animal-d) for 40 d) reduced drip loss at the end of 7 d and 21 d storage and fat rancidity in bull LL.

The dietary vitamin E supplementation x breed interaction for muscle fiber disruption in LL samples displayed for 14 d is presented in Figure 5. Dietary vitamin E supplementation restricted ($P < .01$) muscle fiber disruption (25.4%) compared to the control (37.5%) and reduced the disruption percentages from 42.6% (control) to 25.5% (supplemented) in Holstein steers and from 32.4% (control) to 25.4% (supplemented) in beef steers. Since fixation caused artificial shrinkage of the cell (data not shown), staining without fixation allowed detection of a vitamin E effect. Figure 6 shows that vitamin E supplementation maintained cell structure of beef steak displayed for 14 d compared to the control. It seems that the fiber perimeter structure of the control muscle cells is more frequently absent. Also, large
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areas of the fibers in control muscle appear to have been dissolved or degraded.

Vitamin E acts as an antioxidant by reacting with free radicals (Schaefer et al., 1995) arising from oxidative reactions initiated in the phospholipid-rich membranes of meat (Buckley et al., 1989). Dietary vitamin E is absorbed by steers and incorporated into cellular membranes (Arnold et al., 1993a). The results of our study support the suggestion that membranal vitamin E probably restricted disruption of cell membranes by reacting with free radicals, thus preventing oxidative deterioration during display. Hence, dietary vitamin E stabilized myoglobin and lipid against oxidation (Arnold et al., 1993b) and improved the ability of beef steak to retain moisture during display.

Breed

Holstein LL had higher \( P < .01 \) drip loss (7.4%; Figure 1) and lower \( P < .01 \) cooking yield (66.7%) than beef LL (6.8% and 67.6%, respectively), but the two breeds did not differ \( P > .10 \) in cooking loss and shear values. Holstein LL muscles had higher \( P < .05 \) moisture content (73.0%) and lower \( P < .10 \) fat content (4.5%) than beef LL (71.7% and 6.0%, respectively). The effects of dietary vitamin E on drip loss and muscle fiber disruption (Figure 5) were greater \( P < .05 \) in Holstein than in beef steers. Dietary vitamin E supplementation seems to have greater impact on drip loss from Holstein beef than from meat derived from beef steers.

Further investigation of the vitamin E effect on drip loss is needed for muscles more prone to exude fluid than the LL. It would also be interesting to determine whether vitamin E affects the amount of exudate that occurs during meat storage in a vacuum package at 4°C.

Implications

Dietary vitamin E supplementation shifts fresh beef weight loss from drip during retail display to cooking loss. Muscle fiber membranes from vitamin E-supplemented feedlot cattle are less prone to disruption during retail display of fresh beef. The effect of dietary vitamin E on drip loss should be greater in Holstein steers than in beef steers. Since the postmortem addition of antioxidants to raw meat is not permitted now in most countries, dietary vitamin E supplementation would be an effective method for improving water-holding capacity in fresh beef, especially in Holstein steers.

Literature Cited


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