**Tasco-Forage: IV. Influence of a seaweed extract applied to tall fescue pastures on sensory characteristics, shelf-life, and vitamin E status in feedlot-finished steers**


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**ABSTRACT:** Tasco-Forage is an *Ascophyllum nodosum* seaweed-based product that has increased antioxidant activity in both plants and animals. Endophyte (*Neotyphodium coenophialum* ([Morgan-Jones and Gams] Glenn, Bacon, and Hanlin)-infected and uninfected tall fescue (*Festuca arundinacea* Schreb.) pastures in Virginia and Mississippi during 1997 were treated or not with 3.4 kg Tasco/ha in April and July. There were two replications of each treatment at each location. Forty-eight steers (6/replication) grazed pastures at each location (n = 96) from April to October prior to transportation to Texas Tech, Lubbock, for finishing during a 160-d period in the feedlot. Blood (ante-mortem) and liver (postmortem) samples were collected. After slaughter and chilling, the left strip loins (IMPS #180) were collected from three randomly selected steers from within each pasture replication (n = 48). Strip loins were vacuum-packaged and stored at 2°C. At postmortem d 7, 14, 21, and 28, strip loins were removed from packaging and fabricated into 2.54-cm steaks. Following each fabrication day postmortem, the strip loins were repackaged and stored at 2°C until the following postmortem time. After the prescribed fabrication, steaks were overwrapped with polyvinyl chloride film, subjected to simulated retail display at 2°C for up to 3 d, and subjective and objective color were evaluated daily by a trained panel. Steaks from Mississippi steers that had grazed Tasco-treated fescue retained higher (P < 0.05) CIE a* color scores throughout retail display. Steaks were more uniform and had less discoloration and less browning (P < 0.05) if they were from steers that had grazed Tasco-treated fescue, and the effect was greatest for steers from Mississippi (location × Tasco interaction; P < 0.05). The endophyte in tall fescue may decrease uniformity and increase lean discoloration and two-toning of beef steaks when removed from vacuum packaging on or beyond d 21 postmortem (endophyte × Tasco × postmortem day interaction: P < 0.05). Vitamin E in liver was increased (P < 0.06) and serum vitamin E was decreased (P < 0.09) in steers that had grazed the treated pastures. These experiments indicated that Tasco applied to tall fescue during the grazing season can improve color stability and extend beef shelf-life, particularly in cattle grazing infected tall fescue. The mode of action of Tasco is not clear, but antioxidants and specific vitamins may be involved.

Key Words: Aquatic Plants, Endophytes, Meat Characteristics, Vitamin E

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**Introduction**

In previous experiments, steers that grazed tall fescue (*Festuca arundinacea* Schreb.) infected with the endophyte fungus *Neotyphodium coenophialum* ([Morgan-Jones and Gams] Glenn, Bacon, and Hanlin; Glenn et al., 1996) had lower serum vitamin E and depressed monocyte immune function compared with steers that grazed low-endophyte tall fescue (Allen et al., 2001; Fike et al., 2001; Saker et al., 2001). In that research, application of Tasco-Forage, an extract from the brown seaweed *Ascophyllum nodosum* (Acadian Seaplants Ltd., Dartmouth, Nova Scotia, Canada) applied to infected and uninhibited tall fescue pastures was found to increase superoxide dismutase in the forage (Fike et al., 2001) and to reverse the depression in monocyte...
Materials and Methods

A 2-yr pasture and feedlot finishing experiment was conducted at Virginia Polytechnic Institute and State University, Mississippi State University, and Texas Tech University with 192 beef steers that grazed tall fescue pastures in Virginia and Mississippi from April to October during 1996 and 1997 followed by feedlot finishing in Texas. In each year, there were 48 steers from Virginia and 48 steers from Mississippi. A description of the steers and pasture treatments is provided by Saker et al. (2001) and the feedlot finishing by Allen et al. (2001); thus, only a brief description will be given here. In yr 2, effects of pasture treatments were measured on sensory characteristics and shelf-life of the finished beef. Additionally, pasture treatment effects on liver and serum concentrations of vitamin A and E and serum cholesterol were determined at slaughter on all 96 steers.

Angus and Angus × Hereford steers (initial BW 265 kg; SD = 5) in Virginia and 1/4 Brahman × 3/4 Angus steers (250 kg; SD = 2) in Mississippi grazed infected or uninfected tall fescue during 1997 that had been treated or untreated with Tasco, an extract from brown seaweed (*Ascophyllum nodosum*; Fike et al., 2001). Tasco was applied in water solution to the forage at 3.4 kg/ha in April and again approximately midsummer. At each location, there were two blocks that each contained all endophyte and Tasco treatment combinations. Thus, the pasture experiment was a randomized block design with a factorial arrangement of treatments. Six steers grazed in each pasture replication. At the end of the grazing season in October, steers from both locations were transported by truck to the Texas Tech Burnett Center for finishing on the feedlot (October 14 [Mississippi] and 15 [Virginia], 1997). No further treatments were imposed after the steers left the pastures. Steers were allotted to pens in the feedlot in a randomized block design with both locations and each of the four pasture treatments within each feedlot block. There were two blocks with eight pens per block. Steers grouped together on pasture remained as a group on the feedlot; thus, there were six steers per pen. All steers were fed a diet based on steam-flaked milo (*Sorghum bicolor*) and cottonseed hulls (*Gossipium hirsutum*; Allen et al., 2001). The diet included 0.38% vitamin A premix (734,700 IU vitamin A/kg of premix) and 0.09% vitamin E premix (17,633 IU vitamin E/kg premix). Steers were handled under an animal care and use protocol approved by the Texas Tech Animal Care and Use Committee.

At the end of the 160-d finishing period (March 23, 1998), steers were transported 74 km and slaughtered at Excel Corporation (Plainview, TX). Immediately prior to transportation, blood samples were collected via jugular venipuncture into 15-mL Vacutainer tubes protected from light by aluminum foil for determination of serum vitamins A (Dennison and Kirk, 1977, as modified by Stowe, 1982) and E (Widicus and Kirk, 1979). At slaughter, samples of liver were collected from the right hepatic lobe (lobus hepati dexter). Liver and blood serum were frozen (−20°C) until they were subsequently analyzed by the Michigan State University Animal Health Diagnostic Laboratory, Lansing using procedures listed above for blood serum. For liver, 1 mL of homogenate containing 1 g of liver in 5 mL of distilled water was added to 2 mL of ETOH and 2 mL of UV-grade hexane after vortexing for 5 min between additions. Samples were centrifuged at 400 × g for 10 min, the hexane had to be removed, and samples were filtered through a 0.45-μm Millipore filter. Alpha-tocopherol per milliliter of extract was determined by HPLC. The method of detection was UV absorbance at 291 nm.

Carasses were evaluated for quality grade and yield grade factors at 36 h postmortem. Three carasses from each pen of six steers (n = 48) were randomly selected and the left strip loins (IMPS #180) were collected, vacuum-packaged, and transported back to the Texas Tech University Meat Laboratory. Strip loins were vacuum-packaged and stored at 2°C. At postmortem d 7, 14, 21, and 28, strip loins were removed from packaging and fabricated into three 2.54-cm steaks for sensory, Warner-Bratzler shear (WBS) force, and color analysis. Following each fabrication day postmortem, the strip loins were repackage and stored at 2°C until the following postmortem time.

Steaks for sensory and WBS evaluation were vacuum-packaged and frozen at −29°C for later determinations. Steaks for color analysis were placed on styrofoam trays, covered with polyvinyl chloride film (PVC), and placed in a Tyler (model DGC6, Niles, MI) retail display case at 2°C for up to 3 d to simulate retail display conditions. The steaks were under 24-h exposure to 12, 35 SPX soft white fluorescent bulbs with 2,000 lm each. Two desk lamps with two 30 SPX bulbs with 1,000 lm each were placed above the display case. The illumination intensity was 1,880 lx at the surface of the steaks. During the 3-d period, the steaks were evaluated daily by a trained panel, consisting of at least six members, for beef color (8 = extremely bright cherry
red; 1 = extremely dark red), color uniformity (5 = extreme two-toning; 1 = uniform), surface discoloration (7 = 100%); 1 = 0%), and lean browning (6 = dark brown; 1 = none) according to AMSA (1991) color guidelines. Commission Internationale de l’Eclairage (CIE) L* (muscle lightness), a* (muscle redness), and b* (muscle yellowness) values were determined daily, through the overwrap, from three random readings on each steak with a Minolta colorimeter (Model C-200b, Minolta Corp., Ramsey, NJ) using illuminant D65 and a 1-cm aperture.

Steaks for sensory and WBS determinations were thawed overnight at 2°C and cooked on a gas grill (model 6124RCB, Star Mfg. Int., Smithville, TN). Steaks were flipped every 3 min, to prevent charring, until an internal temperature of 71°C was achieved. Steaks for sensory evaluation were cut into 1-cm³ cubes and stored in warming pans (approximately 5 min) until they were served warm (approximately 50°C) to the sensory panel. Samples were evaluated by a six-member sensory panel trained according to Cross et al. (1978). Steaks were evaluated for initial juiciness, sustained juiciness, initial tenderness, sustained tenderness, flavor intensity, beef flavor, overall mouthfeel (8 = extremely juicy, extremely tender, extremely intense, extremely characteristic beef flavor, extremely beef-like mouthfeel to 1 = extremely dry, extremely tough, extremely bland, extremely uncharacteristic beef flavor, extremely non-beef-like mouthfeel) and off-flavor (5 = extremely off-flavor to 1 = none). Steaks for WBS evaluation were placed on plastic trays and covered with PVC and chilled for 24 h at 2°C. Six cores (1.3 cm in diameter) were removed from each steak parallel to the muscle fiber orientation and sheared once with a WBS machine (G-R Elec. Mfg. Co., Manhattan, KS). The shear force determination for the six different cores within a steak were then averaged. Cooking loss percentages were calculated using a precooked steak weight and a postcooking steak weight.

For sensory characteristics, data were analyzed as a completely randomized block design with a split plot arrangement using a model that tested main effects of endophyte, Tasco, location, and all interactions; postmortem aging period and all interactions were represented in the subplot. For shelf-life and color characteristics, data were analyzed as a completely randomized block design with a split-split plot arrangement. The main effects and first subplot were as explained above and the second subplot tested effects of retail display day within aging period. Pen was the experiment unit. When data interacted with a treatment, subsequent analyses were completed within a given day of measurement.

Results

Sensory Characteristics

Changes in sensory characteristics and tenderness of beef due to postmortem aging were generally small and expected (data not shown). Meat tenderness, as indicated by Warner-Bratzler shear, and initial and sustained tenderness generally increased (P < 0.05) slightly due to aging, whereas juiciness decreased (P < 0.05) slightly with postmortem aging. In all cases, changes were small. Differences due to aging in flavor intensity, beef flavor, and overall mouthfeel were detectable statistically but were too small to influence consumer preference. Off-flavor was not influenced by postmortem aging.

Warner-Bratzler shear values were not influenced by Tasco (Table 1), but steers from Virginia exhibited slightly lower values if they had previously grazed infected rather than uninfected tall fescue (3.0 vs 3.4; SE = 0.10; location × endophyte interaction: P < 0.05), but little difference due to endophyte was observed in steers from Mississippi (3.3 vs 3.1 for infected and uninfected fescue, respectively). Cooking loss percentage was greater (P < 0.02) if steers had previously grazed the Tasco-treated pastures. Differences in cooking loss due to Tasco were larger in steers from Mississippi than in steers from Virginia (location × Tasco interaction: P < 0.07), perhaps due to breed effects. Little difference was observed in cooking loss due to the endophyte in steaks aged to postmortem d 7 and 28. Endophyte only affected cooking loss percentage in steaks aged d 14 and 21 postmortem, but the effect depended on location (location × endophyte × aging interaction: P < 0.05).

Beef steaks throughout these experiments were scored moderately juicy with little variation among treatments. No effects of treatments were observed for initial juiciness, but sustained juiciness was slightly higher (P < 0.05) in steers from infected tall fescue that had not received the Tasco treatment than from steers that had grazed the Tasco-treated, infected pastures (Table 1). No effect of Tasco on sustained juiciness was present in steers from uninfected tall fescue (Tasco × endophyte interaction: P < 0.05). Aging had no effect on sustained juiciness in steers that had grazed the Tasco-treated pastures, but aging decreased (P < 0.01) sustained juiciness in steers from the untreated pastures (Tasco × aging interaction: P < 0.05).

Initial tenderness was generally scored moderately tender (Table 1). Initial tenderness of meat from Tasco-treated fescue tended to be more tender than that from steers that grazed the untreated fescue on postmortem d 7, but by postmortem d 28 there was no difference in initial tenderness due to Tasco (Tasco × aging interaction: P < 0.07). Aging increased sustained tenderness in both Tasco-treated and untreated steers, but the effect tended to be greatest in steers that had previously grazed the Tasco-treated pastures regardless of endophyte status (Tasco × aging interaction: P < 0.06). In general, sensory tenderness measurement coincided with WBS forces with little to no treatment effects. Flavor intensity averaged moderately intense, although effects of Tasco tended to be influenced by endophyte status (Tasco × endophyte interaction: P < 0.07). No
Table 1. Sensory characteristics of beef longissimus steaks from steers that grazed endophyte-infected (E+) or endophyte-free (E−) tall fescue that was either treated (T+) or untreated (T−) with Tasco during the grazing season followed by feedlot finishing.

<table>
<thead>
<tr>
<th>Item</th>
<th>E+ T+</th>
<th>E+ T−</th>
<th>E− T+</th>
<th>E− T−</th>
<th>SEa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warner Bratzler shear, kgb</td>
<td>3.3</td>
<td>3.0</td>
<td>3.3</td>
<td>3.2</td>
<td>0.10</td>
</tr>
<tr>
<td>Cooking loss, %c</td>
<td>24.0</td>
<td>21.9</td>
<td>23.2</td>
<td>21.4</td>
<td>0.61</td>
</tr>
<tr>
<td>Initial juicinessbf</td>
<td>5.9</td>
<td>6.2</td>
<td>5.9</td>
<td>6.0</td>
<td>0.08</td>
</tr>
<tr>
<td>Sustained juicinessbf</td>
<td>6.0</td>
<td>6.3</td>
<td>6.1</td>
<td>6.0</td>
<td>0.07</td>
</tr>
<tr>
<td>Initial tendernessbf</td>
<td>6.1</td>
<td>6.4</td>
<td>6.3</td>
<td>6.2</td>
<td>0.20</td>
</tr>
<tr>
<td>Sustained tendernessbf</td>
<td>6.3</td>
<td>6.6</td>
<td>6.5</td>
<td>6.3</td>
<td>0.17</td>
</tr>
<tr>
<td>Flavor intensitybf</td>
<td>6.5</td>
<td>6.6</td>
<td>6.5</td>
<td>6.4</td>
<td>0.11</td>
</tr>
<tr>
<td>Beef flavorbf</td>
<td>6.5</td>
<td>6.6</td>
<td>6.6</td>
<td>6.4</td>
<td>0.05</td>
</tr>
<tr>
<td>Off-flavorg</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>0.13</td>
</tr>
<tr>
<td>Overall mouthfeelbf</td>
<td>6.1</td>
<td>6.3</td>
<td>6.1</td>
<td>6.0</td>
<td>0.13</td>
</tr>
</tbody>
</table>

aStandard error of the mean; n = 16 for each mean.
bEffect of aging (P < 0.05).
cEffect of Tasco (P < 0.02).
dTasco × endophyte interaction (P < 0.05).
eTasco × endophyte interaction (P < 0.07).
fEight-point scale; 8 = extremely juicy, extremely tender, extremely intense, extremely characteristic beef flavor, extremely beef-like mouthfeel to 1 = extremely dry, extremely tough, extremely bland, extremely uncharacteristic beef flavor, extremely non-beef-like mouthfeel.
gFive point scale; 5 = extremely off-flavor to 1 = none.

Objective Measurements. The CIE L* values were influenced only by day of retail display and were not affected by other treatments (Table 2). Because a postmortem aging × retail display day interaction was present for CIE a* and b* values, the data were analyzed separately by postmortem day. Tasco × location interactions were present (P < 0.05) for CIE a* values; thus, the data were further analyzed separately by location. The CIE a* values for cattle from Mississippi declined over retail display day, and the decline was greater during postmortem d 21 and 28 than during postmortem d 7 and 14 (postmortem aging × retail display day interaction; P < 0.01: Table 2).

Table 2. Main effects of Tasco and endophyte on lean color traits of beef longissimus steaks from steers that grazed endophyte-infected (E+) or endophyte-free (E−) tall fescue in Mississippi and Virginia that was either treated (T+) or untreated (T−) with Tasco during the grazing season followed by feedlot finishing.

<table>
<thead>
<tr>
<th>Trait</th>
<th>E+ T+</th>
<th>E+ T−</th>
<th>E− T+</th>
<th>E− T−</th>
<th>SEa</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIE L*b</td>
<td>44.1</td>
<td>44.6</td>
<td>44.0</td>
<td>44.2</td>
<td>0.44</td>
</tr>
<tr>
<td>CIE a*bcd</td>
<td>18.1</td>
<td>17.9</td>
<td>18.2</td>
<td>18.1</td>
<td>0.29</td>
</tr>
<tr>
<td>CIE b*bcd</td>
<td>7.9</td>
<td>8.0</td>
<td>8.0</td>
<td>7.9</td>
<td>0.15</td>
</tr>
<tr>
<td>Color scoresbde</td>
<td>5.7</td>
<td>5.6</td>
<td>5.4</td>
<td>5.6</td>
<td>0.20</td>
</tr>
<tr>
<td>Color uniformitybdef</td>
<td>1.6</td>
<td>1.7</td>
<td>1.7</td>
<td>1.8</td>
<td>0.06</td>
</tr>
<tr>
<td>Lean discolorationbdeg</td>
<td>1.6</td>
<td>1.9</td>
<td>1.8</td>
<td>2.0</td>
<td>0.10</td>
</tr>
<tr>
<td>Lean browningbdfh</td>
<td>1.6</td>
<td>1.9</td>
<td>1.8</td>
<td>1.9</td>
<td>0.08</td>
</tr>
</tbody>
</table>

aStandard error of the mean; n = 48 for each mean.
bEffect of retail display day (P < 0.001).
cEffect of postmortem aging (P < 0.01).
dInteraction of postmortem aging × retail display day (P < 0.001).
e8 = extremely bright cherry-red to 1 = extremely dark red.
f5 = extreme two-toning to 1 = uniform.
g7 = 100% surface discoloration to 1 = 0% surface discoloration.
h6 = dark brown to 1 = none.
interaction: $P < 0.05$; Figure 1). Application of Tasco to pastures resulted in steaks that were redder ($P < 0.03$) than steaks from untreated pastures. Effects of Tasco were consistent across endophyte and postmortem periods. The CIE $a^\ast$ values for cattle from Virginia responded similarly to those in Mississippi in response to postmortem aging and retail display day (interaction: $P < 0.05$; data not shown). For Virginia steers, a trend for a Tasco $\times$ endophyte $\times$ postmortem aging interaction ($P < 0.10$) was present. However, when effects of treatments were examined within postmortem ages, effects of Tasco and endophyte were not significant. The decline in CIE $b^\ast$ values became more rapid over days of retail display with increasing postmortem aging when removed from vacuum packaging (postmortem aging $\times$ retail display day interaction: $P < 0.01$) but was not influenced by other treatments.

**Subjective Measurements.** Color declined ($P < 0.01$) with increased days of retail display day during postmortem d 7, 14, and 21 but was not influenced by treatments during these periods. Color also differed ($P < 0.01$) due to day during postmortem period 28, but effects of both endophyte and Tasco depended on retail display day during this period (interactions of endophyte $\times$ day and Tasco $\times$ day: $P < 0.05$; Figure 2). On retail display d 3, there were trends for an effect of Tasco ($P < 0.18$) and a Tasco $\times$ endophyte interaction ($P < 0.16$). Steaks from steers that had grazed infected pastures seemed to have less desirable color than those from steers that grazed uninfected fescue, but the effect was reversed when infected pastures were treated with Tasco.

![Figure 1](image1.png)

**Figure 1.** CIE $a^\ast$ value of beef longissimus steaks during retail display following removal from vacuum packing on d 7, 14, 21, and 28 postmortem from feedlot-finished steers that had grazed endophyte-infected (E+) or uninfected (E−) tall fescue that was either treated (T+) or untreated (T−) with Tasco in Mississippi. aPostmortem aging by retail display day interaction ($P < 0.01$); beffect of Tasco ($P < 0.03$); cstandard error of the mean; n = 4 for each mean.

![Figure 2](image2.png)

**Figure 2.** Visual color values of beef longissimus steaks during retail display following removal from vacuum packing on d 28 postmortem from feedlot-finished steers that had grazed endophyte-infected (E+) or uninfected (E−) tall fescue that was either treated (T+) or untreated (T−) with Tasco in Virginia and Mississippi. aEffect of Tasco ($P < 0.18$); bTasco $\times$ endophyte interaction ($P < 0.16$); cendophyte $\times$ retail display day interaction ($P < 0.05$); dTasco $\times$ retail display day interaction ($P < 0.05$); estandard error of the mean; n = 4 for each mean.

Effects of treating pastures with Tasco on lean uniformity, discoloration, and browning were more obvious in steers from Mississippi than in those from Virginia (Tasco $\times$ location interaction: $P < 0.05$). For steers from Mississippi, treating fescue with Tasco prolonged shelf-life as measured by these parameters, and differences generally became greater with increasing postmortem aging and length of time on retail display (Figure 3). Treating pastures with Tasco improved ($P < 0.01$) lean uniformity and decreased lean discoloration ($P < 0.15$) and browning ($P < 0.05$) throughout the simulated retail display. Meat from steers from infected tall fescue seemed to remain more uniform with less discoloration and browning than meat from steers from uninfected tall fescue when steaks were aged to postmortem d 7 and 14. However, when steaks were removed from vacuum packaging on d 21 or 28, this effect of endophyte was either lost or reversed (endophyte $\times$ postmortem aging interaction: $P < 0.05$).

Uniformity, discoloration, and browning scores of steaks from Virginia steers were influenced by postmortem aging and by retail display day ($P < 0.01$). As was observed in steers from Mississippi, loss of uniformity and increased discoloration and browning occurred more quickly during retail display as postmortem aging increased (postmortem aging $\times$ retail display day interaction: $P < 0.01$). When the data were analyzed separately by retail display day, little effect of endophyte or Tasco was evident until the final postmortem period (Table 3). When removed from vacuum packaging on d 28, steaks remained more uniform with less discoloration and browning if they were from steers that had
grazed the Tasco-treated, infected pastures rather than untreated infected, pastures, but there seemed to be little response to Tasco application to uninfected tall fescue (Tasco × endophyte interaction: $P < 0.17$). By d 3, steaks from steers that grazed the untreated, infected fescue seemed to sustain the greatest loss in measures of color stability. There was less ($P < 0.05$) steak browning in all steers from Tasco-treated pastures on d 3 of retail display, regardless of the endophyte status.

Vitamins A and E and Cholesterol Status

Serum cholesterol was lower ($P < 0.02$) at slaughter in steers that had previously grazed infected compared with uninfected tall fescue pastures (Figure 4), but the effect of endophyte on serum cholesterol was only present in steers from Mississippi (endophyte × location interaction: $P < 0.07$; data not shown). Application of Tasco-Forage to infected pastures reversed the effect

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**Figure 3.** Uniformity, discoloration, and browning of beef longissimus steaks during 3 d of retail display following removal from vacuum packing on d 7, 14, 21, and 28 postmortem from feedlot-finished steers that had grazed endophyte-infected (E+) or uninfected (E−) tall fescue that was either treated (T+) or untreated (T−) with Tasco in April and July during the previous grazing season in Mississippi. *Effect of postmortem aging ($P < 0.01$); *b*effect of retail display day ($P < 0.01$); *c*postmortem aging × retail display day interaction ($P < 0.01$); *d*effect of endophyte ($P < 0.07$); *e*effect of Tasco ($P < 0.05$); *f*effect of endophyte ($P < 0.03$); *g*effect of Tasco ($P < 0.01$); *h*endophyte × Tasco × postmortem aging × retail display day interaction ($P < 0.05$); *i*Tasco × retail display day interaction ($P < 0.01$); *j*standard error of the mean; n = 2 for each mean.
Table 3. Effects of Tasco and endophyte on lean color traits of beef longissimus steaks during retail display day following removal from vacuum packaging on postmortem d 28 from steers that grazed endophyte-infected (E+) or endophyte-free (E−) tall fescue in Virginia that was either treated (T+) or untreated (T−) with Tasco during the grazing season followed by feedlot finishing.

| Trait and retail display day | E+  | E−  |  |  |
|-----------------------------|--|--|---|--|---|
| Uniformity<sup>b</sup> | T+ | T− | T+ | T− | SE<sup>a</sup> |
| 1<sup>cd</sup> | 1.0 | 1.1 | 1.2 | 1.0 | 0.017 |
| 2 | 1.5 | 2.1 | 1.9 | 1.7 | 0.191 |
| 3<sup>cd</sup> | 2.8 | 3.6 | 3.1 | 3.1 | 0.202 |
| Discoloration<sup>i</sup> | | | | |
| 1 | 1.0 | 1.0 | 1.1 | 1.0 | 0.042 |
| 2 | 1.6 | 2.0 | 2.1 | 1.8 | 0.314 |
| 3<sup>e</sup> | 3.6 | 4.4 | 4.0 | 3.4 | 0.382 |
| Browning<sup>j</sup> | | | | |
| 1 | 1.0 | 1.0 | 1.0 | 1.0 | 0.032 |
| 2<sup>e</sup> | 1.8 | 2.3 | 2.5 | 2.2 | 0.202 |
| 3<sup>cg</sup> | 3.2 | 4.6 | 3.9 | 4.1 | 0.231 |

<sup>a</sup>Standard error of the mean; n = 2 for each mean.
<sup>b</sup>Tasco × endophyte interaction (P < 0.01).
<sup>c</sup>Effect of Tasco (P < 0.05).
<sup>d</sup>Effect of endophyte (P < 0.06).
<sup>e</sup>Tasco × endophyte interaction (P < 0.17).
<sup>f</sup>Effect of Tasco (P < 0.15).
<sup>g</sup>Tasco × endophyte interaction (P < 0.08).
<sup>h</sup>Five-point scale; 5 = extreme two-toning; 1 = uniform.
<sup>i</sup>Seven-point scale; 7 = 100%; 1 = 0%.
<sup>j</sup>Six-point scale; 6 = dark brown; 1 = none.

of the endophyte, but applying Tasco to uninfected pastures seemed to result in lower (P < 0.07) serum cholesterol than in the steers that grazed untreated, uninfected fescue (endophyte × Tasco interaction: P < 0.02). Steers from Mississippi had higher (P < 0.05) serum cholesterol than steers from Virginia (201 vs 176 mg/dL, respectively, SE = 6). Serum vitamin E: cholesterol ratio was higher (P < 0.03) in steers from infected than in those from uninfected pastures, but this effect was negated by application of Tasco (endophyte × Tasco interaction: P < 0.02; Figure 4).

Serum vitamin E was lower (P < 0.09) in steers that grazed Tasco-treated tall fescue regardless of the endophyte status (Figure 5). Steers from Mississippi had lower (P < 0.05) serum vitamin E than steers from Virginia (1.95 vs 2.36 µg/mL, respectively; SE = 0.06). Serum vitamin A was not significantly influenced by either endophyte or Tasco (Figure 5), but steers from Mississippi had lower serum vitamin A than steers from Virginia (480 vs 539 ng/mL, respectively; SE = 20).

Liver vitamin E was higher (P < 0.06) in steers that grazed the Tasco-treated fescue (Figure 6). This effect was consistent across endophyte status and location of the pastures. Liver vitamin A concentrations were within normal limits, but Tasco and the endophyte seemed to interact (P < 0.10), resulting in the highest values in steers that had grazed the Tasco-treated, infected fescue and the lowest values in steers from untreated, infected fescue; the relationship was reversed in steers from uninfected fescue (Figure 6).

Discussion

Meat color greatly affects consumer purchases of meats (Faustman and Cassens, 1990). Deterioration in meat quality and color, caused by lipid and/or pigment oxidation, has a dramatic effect on consumer preference. Vitamin E plays a vital role in maintaining and protecting biological membranes and muscle pigments from oxidative damage (Rice and Kennedy, 1988; Arnold et al., 1993). Dietary supplementation of vitamin E has been shown to improve beef quality and color stability (Arnold et al., 1993; Sherbeck et al., 1995; Smith et al., 1996) and is thought to extend shelf-life through α-tocopherol accumulation in muscle that acts as an antioxidant and delays lipid and pigment oxidation.

Effects of the endophyte and Tasco on sensory characteristics seemed minimal and of little practical significance. However, effects of Tasco on cooking loss is of interest and should be further investigated. The increased cooking loss due to Tasco could be explained by greater initial moisture in the steak prior to cooking, although this hypothesis requires further investigation. All treatment differences in juiciness were small, but of all sensory traits measured, juiciness tended to be the most affected. Research conducted in our laboratory (unpublished data) suggests that Tasco treatments reduced cooler shrink in pork and that a greater percentage of water in the muscle was in bound and immobilized fractions with less free water present. Vitamin E
functions to stabilize plasma membranes and bind free radicals (Liu et al., 1995). This may in turn reduce protein degradation and muscle fiber disruption (Asghar et al., 1991; Mitsumoto et al., 1998), maintaining net charge and the binding capability of the meat. There is currently no available information to support or contradict our findings with Tasco in animals. However, Mitsumoto et al. (1995) showed that supplementing 298 IU of vitamin E/kg of diet to beef steers reduced drip loss but longissimus steaks had higher cooking loss. Taylor et al. (1994) found that supplementing 2,500 IU of vitamin E/d to two breeds of beef cattle had no effect on cooking loss.

Further evidence of effects of Tasco on membrane permeability was reported with plant research. Working with turfgrasses treated with Tasco, Yan (1993) found that the double bond index of polar lipid fatty acids was increased and that leaf water potential was higher in the treated grasses, regardless of soil moisture regimen. Kuiper (1985) suggested that the higher the double bond index, the more unsaturated the membrane lipids, and the more advantageous for drought adaptation because of improved osmotic adjustment.

The average postfabrication aging time of beef loins at the retail level in the United States was found to be 20 d (range of 3 to 90 d), and the majority of beef is sold between 10 and 30 d after fabrication (Morgan et al., 1991). Thus, differences in characteristics that appeared in the last two aging periods (21 and 28 d) in our experiment are important because much of the beef in the United States is aged to at least these periods. Our data strongly suggest that this would be important to meat from cattle that had grazed infected tall fescue. During the first two postmortem aging periods (d 7 and 14), steaks from steers that had grazed infected tall fescue seemed to have a longer shelf-life than steaks from steers that grazed uninfected tall fescue. However,
a shorter shelf-life due to the endophyte during aging periods 21 and 28 was measurable even though steers had been off fescue pastures and on the feedlot for 160 d prior to slaughter. It has been estimated that the endophyte in tall fescue results in a $600 million annual loss to the cattle industry alone in the United States (Fribourg et al., 1991). Our data suggest that this loss could be much greater if a shortened shelf-life of the product is a further consequence of the toxicity. It may be important to identify and market beef prior to 21 d postmortem if cattle have been exposed to the endophyte.

Conversely, Tasco treatment of infected fescue seemed to have a synergistic effect in extending the color stability throughout retail display. The reasons for the interaction between Tasco and presence of the endophyte in tall fescue are not known. The smaller but also significant effect of Tasco on extending shelf-life in steaks from steers that had grazed uninfected tall fescue suggests a mechanism that could have application to other forages as well. It is important to note that these effects were measured 160 d after the grazing season ended and 250 d after the last application of Tasco to the pastures.

Lean discoloration increases during retail display and aging due to oxidation of the meat pigment oxymyoglobin to a brown pigment metmyoglobin (Ledward, 1972; Renerre and Labas, 1987; Faustman and Cassens, 1990). Extensions of beef color and reductions in discoloration scores over postmortem aging have been found due to meat pigment stabilization (Ledward, 1991; Madhavi and Carpenter, 1993). Decreased discoloration across aging periods was shown in steaks from vitamin E-supplemented cattle (Faustman et al., 1989a,b; Arnold et al., 1992). In the present experiment, improved color stability as seen by increased color scores may be related to elevated antioxidants in the animal.

Tasco has been shown to increase a variety of plant antioxidant compounds when applied to forage grasses, including superoxide dismutase (Ayad, 1998; Zhang and Schmidt, 1999), glutathione reductase, ascorbate peroxidase (Ayad, 1998), β-carotene, ascorbic acid, and α-tocopherol (Zhang and Schmidt, 1999). Furthermore, increases in serum vitamin A and whole-blood Se in both lambs and steers in response to grazing Tasco-treated tall fescue suggested that antioxidant activity was also increased in the animal (Fike et al., 2001). Additionally, when the steers in the present study arrived at the feedyard in October, their blood serum vitamin E levels were depressed and their vitamin E:cholesterol ratios were higher if they had grazed infected tall fescue. The effect of endophyte on serum vitamin E was at least partially overcome if the pasture had been treated with Tasco (Allen et al., 2001).

Whether increased beef color stability in Tasco-treated animals is due to the same action as vitamin E (Liu et al., 1995, 1996), other antioxidant activity, or as yet unknown factors is still to be determined. All the steers were supplemented with approximately 15.9 IU of vitamin E/kg of feed (dry basis) during the finishing phase, or approximately 144 IU vitamin E/d (Allen et al., 2001). The vitamin E requirement for finishing steers has not been well established, but the level fed in this experiment was below recommendations for extension of shelf-life (NRC, 1996). The level of vitamin E fed in this experiment may not have been adequate to meet nutritional requirements. Liver vitamin E concentrations at < 10 μg/g were considered deficient (Michigan State University Animal Health Diagnostic Laboratory, Lansing; Puls, 1994).

Tasco seemed to modify vitamin E metabolism in steers and was associated with increased hepatic vitamin E concentrations. Vitamin E, initially transported in chylomicrons, is released to tissues or transferred to lipoproteins, but eventually much of the vitamin E returns to liver in chylomicron remnants (Sokol, 1996). Turnover of vitamin E is generally rapid in liver, and large amounts never accumulate because of the func-

![Figure 6](https://example.com/figure6.png)

**Figure 6.** Liver vitamins E and A at the end of the finishing period in steers that grazed endophyte-infected (E+) or endophyte-free (E−) tall fescue that was either treated (T+) or untreated (T−) with Tasco during the grazing season followed by feedlot finishing. *Effect of Tasco (P < 0.06); bTasco x endophyte interaction (P < 0.10); cstandard error of the mean; n = 4 for each mean.*
tion of tocopherol in transfer protein (Sokol, 1996). The turnover rate of vitamin E in liver has been estimated to be 5 to 20 d (Burton and Ingold, 1993). The differences in liver vitamin E in the present experiment are of interest because these cattle received the Tasco treatment only during grazing; thus, effects of pasture application of Tasco on liver vitamin E remained measurable over the 160-d feeding trial.

Cholesterol circulates in the blood as a component of serum lipoproteins and alterations reflect changes in serum lipoprotein dynamics. In our experiment, both cholesterol and serum vitamin E were influenced by the endophyte and by Tasco. Because of the high lipid solubility of vitamin E and its transport in lipoproteins, there is a high correlation of vitamin E with the total lipid concentration in plasma (Horwitt et al., 1972). It has been suggested that serum vitamin E levels should be normalized to the total plasma lipid level to determine tocopherol status (Horwitt et al., 1972). In our experiment, Tasco treatment lowered serum concentrations of vitamin E, but expressing this as the vitamin E:cholesterol ratio resulted in fewer treatment differences.

Lowered plasma cholesterol in response to the endophyte has been previously documented in both cows and steers during the grazing season (Stuedemann et al., 1985). These authors suggested a relationship of the endophyte with lowered plasma cholesterol, total lipids, and lipid metabolism. Our results are in agreement with Stuedemann et al. (1985) and suggest the effect is long-lasting, at least in the steers from Mississippi, in which the effect was measurable 160 d after the steers left fescue pastures. In our research, treatment of the infected fescue with Tasco reversed the effect of the endophyte on serum cholesterol such that it was not different from those that grazed the untreated, uninfected tall fescue pastures. It seems that both the endophyte and treatment of tall fescue with Tasco have potential to alter lipid metabolism. Whether differences seen here are due to Tasco treatment or Tasco treatment effects on vitamin E metabolism still remains unclear.

During these experiments, only one rate and timing of application of Tasco was tested (Fike et al., 2001). It is likely that rate and timing of application could be manipulated to enhance effects on the animal. It is assumed that results reported in this manuscript are due to effects on the forage that are reflected in the animal. However, effects of direct ingestion of Tasco by the grazing animal cannot be ruled out because Tasco was sprayed directly onto the plant canopy. It is possible that direct ingestion of A. nodosum-based products by cattle during the grazing phase could have potential effects on antioxidant activity, immune function, and carcass characteristics, and this is currently under investigation in our laboratory.

Implications

Length of time that steaks or cuts of meat remain in retail display is largely determined by visual changes in color. Steers that have grazed endophyte (Neotyphodium coenophialum)-infected tall fescue (Festuca arundinacea Schreb.) may have shortened shelf-life when placed on retail display after 21 d postmortem. This would add to the economic losses from this disorder. Tasco-Forage, an extract from the brown seaweed Ascophyllum nodosum, extended shelf-life, particularly in cattle exposed to fescue toxicity. Color stability may be related to effects on specific vitamins, including vitamin E. Increased color stability that resulted from treating fescue with Tasco-Forage could improve profitability for the retail meat industry. No negative effects of Tasco on sensory characteristics were detected. Thus, its use to improve meat quality and marketability seems promising.

Literature Cited


Montgomery et al.


