ABSTRACT: Twenty-eight Angus (289 ± 3.8 kg) steers were used in a completely randomized design to evaluate the effect of isocaloric supplementation of 2 different energy sources to steers rotationally grazing tall fescue pastures for 197 d in comparison to positive and negative controls. Steers were supplemented with either corn grain (0.52% BW on a DM basis; PC) or soybean hulls plus corn oil (0.45% BW on a DM basis + 0.10% BW on an as-fed basis; PO) using Calan gates for individual intake measurement. Negative, pasture only (PA), and positive, high-concentrate control diets (85% concentrate:15% roughage on DM basis; C) were also included in the study. Steers on PC, PO, and PA treatments were managed together under a rotational grazing system, whereas C steers were fed a high-concentrate diet for the final 113 d using Calan gates. Forage DMI and apparent DM and NDF digestibility for the grazing treatments were evaluated using Cr₂O₅ and indigestible NDF as digesta markers. Energy supplementation decreased (P = 0.02) forage DMI (% of BW) with respect to PA, but not (P = 0.58) total DMI. There were no differences (P = 0.53) among grazing treatments on apparent total DM digestibility. However, NDF digestibility was less (P ≤ 0.05) in PC than in PO and PA; the latter 2 treatments did not differ (P > 0.05). Overall ADG was greater (P < 0.01) in supplemented, regardless of type, than in nonsupplemented grazing treatments. During the final 113 d, ADG was greater (P < 0.01) in C than in the grazing treatments. Overall supplement conversion did not differ (P = 0.73) between supplement types and was less (P = 0.006) than C. Carcass traits did not differ (P > 0.05) between energy sources. Dressing percentage and HCW were greater (P < 0.01) in supplemented cattle than in PA. Fat thickness and KPH percentage for PA were less (P < 0.05) than for PO but did not differ (P > 0.14) from PC. Marbling score, LM area, and quality grade did not differ (P > 0.05) between grazing treatments. Hot carcass weight for C was heavier (P < 0.001) than for pastured cattle. Quality and yield grades of C carcasses were also greater (P < 0.001) than carcasses from pastured steers. Energy supplementation, regardless of source, to grazing steers increased ADG, dressing percentage, and carcass weight compared with PA steers; however, supplemented steers had less ADG, efficiency, dressing percentage, and carcass weight compared with high-concentrate finished steers.

Key words: beef, carcass, pasture

INTRODUCTION

Energy supplementation in cattle grazing high-quality forages often improves animal performance (Caton and Dhuyvetter, 1997). However, supplementation with starch-based energy supplements can depress forage intake as a result of negative associative effects on fiber digestion (Chase and Hibberd, 1987; Pordomingo et al., 1991; Doyle et al., 2005). In contrast, supplementation with high-fiber supplements, like soybean hulls (SBH), can lessen these negative associative effects (Anderson et al., 1988; Martin and Hibberd, 1990). Previous research has shown that corn oil plus cottonseed hulls can be used as a substitute for traditional high-starch energy supplements to meet production requirements in grazing systems and, at the same time, enhance meat fatty acid content (Pavan and Duckett, 2007; Pavan et al., 2007). Increasing quantities of corn oil supplementation to grazing cattle decreased fiber digestibility and forage intake in a linear manner but increased carcass weight and fatness (Pavan et al.,
Thus, corn oil could be used as a substitute for traditional high-starch energy supplements to meet production requirements in grazing systems. However, corn grain supplementation at isocaloric levels may result in a similar response as corn oil plus SBH, but this has not been tested or compared with high-concentrate or pasture-only finished. The objective of this study was to evaluate the effect of supplementing isocaloric levels of corn grain or corn oil plus SBH supplement to grazing steers on in vivo digestibility, animal performance, and carcass quality in comparison to negative, pasture-only control and positive, feedlot-finished control.

**MATERIALS AND METHODS**

The experimental procedures were reviewed and approved by the University of Georgia Animal Care and Use Committee.

**Study Site**

The experiment was conducted at University of Georgia Wilkins Beef Unit (Rayle) between November 2004 and June 2005. The soil types present in the plot were Enon and Mecklenburg fine sandy loam, with 2 to 6% slopes. The pasture was a 11.5-ha endophyte-free tall fescue (Festuca arundinacea Schreb cv. Jesup) plot subdivided into 15 paddocks of approximately 0.77 ha each for rotational stocking; paddocks were grazed more than once during the experimental period. Pasture was fertilized with 280 kg/ha of 20N-5P-10K in September and in March with 224 kg/ha of ammonium nitrate. Steers had ad libitum access to the paddock, fresh water, and vitamin-mineral premix (MAG-OPHOS Beef Mineral, Southern States Coop., Richmond, VA; 10.5 to 12.5% Ca, ≥5% P, 11.0 to 13.0% NaCl, ≥14.0% Mg, ≥0.35% K, ≥100 mg/kg of I, ≥250 mg/kg of Cu, ≥40 mg/kg of Co, ≥52 mg/kg of Se, ≥4,000 mg/kg of Zn, ≥3,700 mg/kg of Mn, ≥90,909 IU of vitamin A/kg, ≥6,818 IU of vitamin D/kg, and ≥50 IU/0.45 kg of vitamin E). Animals were removed from grazed paddocks when pasture height was decreased to approximately 6 cm (visually estimated by trained personnel). Every third paddock, pre- and postgrazing forage availabilities were estimated by harvesting 10 random samples (0.09-m² frame) at 1-cm height. The 10 samples from each cutting time were weighed and pooled, and a subsample was frozen at −20°C for subsequent chemical analysis. An additional subsample was oven-dried at 60°C for 48 h to estimate DM concentration.

**Animals**

Twenty-eight nonimplanted yearling Angus steers (289 ± 3.8 kg) obtained from the Northwest Georgia Experiment Station in Calhoun were randomly assigned to 1 of 4 dietary treatments. All steers were treated for internal and external parasites with ivermectin (Ivermectin Pour-On, Durvet Inc., Blue Spring, MO) on d 0, 42, and 84 and with doramectin (Dectomax, Pfizer Inc., Expon, PA) on d 105 and 147.

Two isocaloric supplementation treatments were evaluated: corn grain (PC) or SBH and corn oil (PO). The energy level was defined by setting corn oil level at 0.10% BW (as-fed basis) and SBH at 0.45% BW (DM basis), resulting in 3.05 Mcal of ME/kg of DM of supplement according to the beef NRC (1984) values. The level of corn oil supplementation was based on results from a previous study, which evaluated supplemental corn oil level on performance (Pavan et al., 2007) and tissue fatty acids profile (Pavan and Duckett, 2007). Corn oil and SBH supplements were individually mixed daily before feeding at 0800 h. Cracked corn grain (3.2 Mcal of ME/kg of DM) was supplemented at 0.52% BW (DM basis) to match the total amount of ME energy supplemented in the PO treatment. Negative (pasture only, PA) and positive [high-concentrate diet (C): 85% concentrate:15% chopped bermudagrass hay on a DM basis] controls were also included in the study. Concentrate used in C was formulated to contain 94.11% rolled corn, 2.91% soybean meal, 1.50% limestone, 0.95% urea, and 0.53% of trace minerals on a DM basis. Concentrate and bermudagrass hay were mixed before feeding and distributed with a Data Ranger (American Calan Inc., Northwood, NH). Supplements (SBH, corn oil, corn grain), concentrate, and bermudagrass hay samples were taken monthly, frozen at −20°C, and pooled for subsequent analyses.

Steers assigned to PO and PC were trained to use Calan gate feeders (American Calan Inc.) for 21 d before the beginning of the study, and in the last 5 d, steers were adapted to supplements. During adaptation, steers assigned to the grazing treatments (PA, PO, and PC) were allowed to graze the same pasture throughout the paddocks. Steers assigned to C grazed an adjacent endophyte-free tall fescue pasture for the first 84 d before moving to feedlot for high-concentrate finishing (d 85 to 197). During the first 21 d of finishing (d 85 to 105), steers were trained to use the Calan gate feeders, and dietary intake of the high-concentrate diet was gradually increased until steers approached ad libitum levels. Initial and final BW were recorded on 2 consecutive days at 0800 h and averaged at the beginning of grazing (d 0) for PA, PO, and PC or feedlot finishing period (d 85) for C, and all at the end of the experimental period (d 197). Individual BW was recorded before supplementation every 21 d and used to adjust the supplement level to the treatment BW average the following day.

When present, supplement refusals were removed and weighed daily to determine supplement intake (as-fed basis). The high-concentrate diet was offered to allow approximately a 10% refusal, orts were removed weekly, and daily intake (as-fed basis) was then calculated by difference.
Intake and Digestibility

Forage DMI and total dietary DM and NDF in vivo apparent digestibility were estimated using chromium sesquioxide as an external marker and indigestible NDF (INDF) as an internal marker (Lippke et al., 1986). On d 158, a controlled release fecal marker capsule (Captec, Cattle Chrome MCM for 300- to 700-kg cattle, active constituent: chromium sesquioxide 65% wt/wt; release rate 1.7 g of Cr$_2$O$_3$ per day; Nufarm Ltd., Auckland, New Zealand) was bolused to 5 steers in PA and to 3 steers in either PO and PC with ADG closest to the treatment mean. At the time of the study, Captec Cattle Chrome MCM controlled release fecal marker capsule availability was limiting due to environmental restrictions in New Zealand that discontinued production. Therefore, we selected 5 steers from PA and 3 steers from each of the PO and PC that were closest to the treatment mean to use in the digestion evaluation phase. Ten days later, fecal samples were collected from each steer twice daily at 0700 and 1700 h for 7 d. Fecal samples (25 g of wet weight) were pooled for each animal and frozen at −20°C for subsequent analyses. During the 7 d of fecal sample collection, samples of supplement refusals were collected for DM determination when present, and forage samples were obtained daily after the afternoon fecal collection by following and observing cattle grazing behavior and hand-plucking samples that closely resembled what the animals actually consumed (Cook, 1964). Samples were pooled on fresh weight basis and stored at −20°C for subsequent analyses of DM composition.

Forage, SBH, corn grain, and fecal samples were lyophilized, ground through a Wiley mill (Thomas Scientific, Swedesboro, NJ) equipped with a 1-mm screen, and stored at −20°C for subsequent OM, NDF, ADF, CP, and total fatty acid (FA) analysis. Organic matter was measured as the weight loss after combustion for 8 h at 500°C. Neutral detergent fiber and ADF were sequentially determined using an Ankom 200 fiber extractor (Ankom Technologies, Fairport, NY) according to the method of Van Soest et al. (1991). Crude protein concentration was determined by the combustion method using a Leco FP-2000 N analyzer (Leco Corp., St. Joseph, MI). Total FA percentage was also determined for corn oil samples. Fatty acids were methylated according to Park and Goins (1994) and separated by GLC according to Duckett et al. (2002). Forage, SBH, corn grain, and fecal samples collected during the fecal collection period were also analyzed for INDF. Briefly, samples were incubated in situ for 7 d (Lippke et al., 1986) in the rumen of a cannulated steer with ad libitum access to tall fescue hay. Samples were incubated using 6 F57 filter bags (Ankom Technology, Macedon, NY) with 0.5 g of DM of sample each; 6 empty filter bags were used as blanks. After ruminal incubation, filter bags were washed under tap water, dried at 60°C for 48 h, and NDF concentration of the residue was determined as described above. Chromium concentration was measured via colorimetric spectrophotometry (Beckman DU-6 spectrophotometer, Beckman Instruments, Palo Alto, CA) in the fecal samples (Fenton and Fenton, 1979). Forage DMI was calculated based on fecal output and indigestibility (Reis and Combs, 2000) with modifications. Fecal output was calculated based on chromium concentration in the feces, whereas indigestibility was determined based on forage, SBH, corn grain, and feces INDF excreted concentrations. Total forage INDF excreted was estimated by difference between total INDF excreted and total SBH or corn grain INDF. Forage DMI was then calculated as the ratio between total forage INDF excreted and INDF concentration in the forage sample. The DMI for each component of the diet was multiplied by the corresponding concentration of OM, CP, FA, NDF, and ADF that then was added to obtain total DMI and total OM, CP, FA, NDF, and ADF intakes. Total tract DM, OM, FA, NDF, and ADF digestibilities were estimated as the ratio between total tract disappearance (intake minus excretion) and intake.

Carcass Traits

In the Southeast United States, tall fescue forage quality declines in late spring, and animal performance is diminished. Therefore, all steers were finished to the same time endpoint and slaughtered in early June. Steers were transported 45 km to the University of Georgia Meat Science and Technology Center in Athens, and fasted BW were obtained after an overnight feed withdrawal with water access. After slaughter, HCW was recorded and carcasses chilled at −1°C for 24 h. At 24 h postmortem, adjusted subcutaneous fat thickness, LM area, marbling score, percentage of KPH, and skeletal maturity were determined on the left side of each carcass.

Calculations

Mean forage allowance per paddock was estimated as 0.5 × (pregraze + postgraze forage mass, kg of DM/ha)/(average BW, kg/steer × steer/ha) according to Fike et al. (2003). The added BW gain by the supplements (PO and PC) relative to BW gain for PA was calculated as follows: [(BW d 197 − BW d 0)PO or PC − (BW d 197 − BW d 0)PA], whereas the added BW gain by C was equal to the change in BW during the period when the high-concentrate diet was fed (BW d 85 − BW d 197). Individual supplement conversions for steers were calculated as follows: [(added BW change)/(total supplement intake, as-fed basis) for PO and PC or total diet intake (as-fed basis) for C].

The substitution rate of forage DMI by the supplements was calculated as the difference between average forage DMI in PA and individual forage DMI in PO or PC relative to the supplement intake (Bargo et al., 2003). The relative stocking density was defined as the approximate number of animals in PO and PC treat-
ments needed to utilize equal amounts of forage relative to PA. Relative stocking density was calculated as the ratio between the average forage DMI for PA and the individual forage DMI for either PO or PC. Carcass price was calculated according the following market values (AMS, 2005): base carcass price (Choice -, yield grade 3) = $133.32/45.5 kg; premiums: yield grade 1 $3.57/45.4 kg; lightweight carcass (<250 kg)−$12.87/45.4 kg; Select −$17.09/45.4 kg; Stan-

dard −$12.87/45.4 kg; discounts: Select −$7.41/45.4 kg; Stan-
grade 3) = $133.32/45.5 kg; premiums: yield grade 1 $3.57/45.4 kg; lightweight carcass (<250 kg)−$12.87/45.4 kg.

### Statistical Analysis

Performance, intake, digestibility, and carcass variables were analyzed as a completely randomized design using PROC MIXED (SAS Inst. Inc., Cary, NC) with dietary treatment as a fixed effect and animal as the random effect. Least squares means were generated and separated using the PDIFF procedure if the F-test was significant ($P < 0.05$).

### RESULTS

Pregrazing forage mass averaged $3,333 \pm 373$ kg/ha, and the postgrazing forage mass averaged $1,892 \pm 121$ kg/ha. On average, each paddock was grazed for 6.6 d with a mean forage mass of 25 kg of DM/100 kg of BW. The average DM chemical composition from pre- and postgrazing forage samples and for the pooled SBH, corn grain, concentrate, and bermudagrass hay samples collected throughout the trial are presented in Table 1.

Forage quality, as determined during the digestibility phase, was as follows: 15.4% CP, 57.4% NDF, and 29.5% ADF (DM basis). Total DMI did not differ ($P = 0.58$) among grazing treatments (Table 2). However, forage DMI (% of BW) decreased ($P = 0.02$) 34% with supplementation, regardless of supplementation type, compared with forage DMI of PA. Forage DMI did not ($P = 0.34$) differ between the 2 types of supplement evaluated. Similarly, forage substitution rate with supplementation was not affected ($P = 0.25$) by supplement type. Relative stocking density did not differ ($P = 0.18$) between supplements, but values were greater ($P < 0.01$) than one for both supplements. In vivo apparent digestibility of DM did not differ ($P = 0.53$) among grazing treatments; however, NDF and ADF digestibilities were less ($P < 0.05$) for PC than PO and PA, both of which did not differ ($P > 0.60$).

Average daily gains from d 0 to 84 were less ($P < 0.01$) for PA than either supplemental treatment (Table 3). During the first 84 d, steers receiving PC also had greater ($P < 0.01$) ADG compared with PO. However, during the final 113 d of grazing, ADG was greater ($P < 0.01$) for PO than PA with PC being intermediate. During the feedlot finishing phase (d 85 to 197), steers finished on a high-concentrate diet had greater ($P < 0.01$) ADG by 0.62 and 0.82 kg/d than supplemented or PA steers, respectively. Overall (d 0 to 197) ADG for supplemented treatments did not differ ($P > 0.05$) among sources and was 0.23 kg greater ($P < 0.01$) than for PA.

Total DMI (Table 4) of supplemental feed consumed during the 197 d of supplementation did not differ ($P = 0.84$) between PO and PC (1.9 kg/steer daily). Total supplemental DMI was greater ($P < 0.001$) for C than PC or PO and averaged 9.6 kg/steer daily. Cost of the supplemental feed per steer was greater ($P < 0.001$) for C than PC and PO ($124.27 and $124.27 greater, respectively); however, the added carcass value was also greater ($P < 0.001$) for C than PC and PO ($298.77). Cost of PO supplement was greater ($P < 0.001$) than PC ($31.68/steer). Added BW gain was greater ($P < 0.001$) for C than PC and PO (156 kg/steer). Supplemental conversion efficiency was greater ($P < 0.001$) for C than PO or PC; the latter 2 treatments did not differ ($P > 0.05$). The added carcass value obtained for supplemented treatments and C was greater than cost of supplemental feed in this experiment.

Hot carcass weight was 64 or 104 kg greater ($P < 0.001$) for C than PO and PC or PA, respectively (Table 5). Hot carcass weight did not differ ($P = 0.51$) between supplement types. Dressing percentage did not differ between types of supplement ($P = 0.51$; 56.4%). However, dressing percentage of supplemented steers was 3.4 percentage units greater ($P < 0.01$) and 4.9 less ($P < 0.001$) than that of PA and C, respectively. No treatment effect was observed for skeletal maturity ($P = 0.11$). Other carcass traits, LM area, fat thickness, marbling, and the percentage of KPH, were greater in

### Table 1. Chemical composition (% of DM) of pre- and postgrazed forage and feeds offered

<table>
<thead>
<tr>
<th>Item, % of DM</th>
<th>Pregrazing</th>
<th>Postgrazing</th>
<th>Soybean hulls</th>
<th>Corn grain</th>
<th>Concentrate</th>
<th>Bermudagrass hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>OM</td>
<td>92.63 ± 0.19</td>
<td>91.33 ± 0.70</td>
<td>94.68</td>
<td>98.62</td>
<td>96.74</td>
<td>93.87</td>
</tr>
<tr>
<td>CP</td>
<td>15.73 ± 0.65</td>
<td>15.05 ± 0.53</td>
<td>13.48</td>
<td>11.36</td>
<td>12.74</td>
<td>15.22</td>
</tr>
<tr>
<td>NDF</td>
<td>56.06 ± 1.05</td>
<td>61.18 ± 0.73</td>
<td>68.41</td>
<td>18.29</td>
<td>15.19</td>
<td>68.81</td>
</tr>
<tr>
<td>ADF</td>
<td>27.15 ± 0.68</td>
<td>30.27 ± 0.50</td>
<td>47.44</td>
<td>0.69</td>
<td>32.65</td>
<td>32.65</td>
</tr>
<tr>
<td>Total fatty acids</td>
<td>2.08 ± 0.10</td>
<td>1.73 ± 0.09</td>
<td>1.89</td>
<td>3.78</td>
<td>3.97</td>
<td>1.34</td>
</tr>
</tbody>
</table>

1 Least squares means ± SEM.
2 Pre- and postgrazing refer to samples taken at the beginning and end of grazing for every third paddock grazed throughout the 197-d study.

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C than in the grazing treatments \( (P < 0.01) \) and did not differ \( (P > 0.06) \) between type of energy source used in the supplement of grazing steers. Fat thickness and KPH percentages were greater \( (P < 0.05) \) for PO than PA with PC being intermediate. Marbling score, quality grade, and LM area did not differ \( (P > 0.05) \) among PA, PC, or PO. When LM area was expressed on a HCW basis, PA had the greatest \( (P < 0.05) \) and C had the least \( (P < 0.05) \) level. Yield grade was less \( (P < 0.001) \) for all 3 grazing treatments than for C, and for PA or PC than for PO \( (P < 0.05) \). Quality grade was also less for the grazing treatments than for C \( (P < 0.001) \), but no differences were observed across grazing treatments \( (P > 0.15) \). Regardless of the supplement type, supplementation of grazing steers increased \( (P < 0.05) \) unit price of the carcass and the total carcass value relative to PA steers. However, both unit price of the carcass and total value were greater \( (P < 0.001) \) for C steers than ones finished on pasture, regardless of supplementation.

**DISCUSSION**

The depression in forage DMI (% of BW) when cracked corn grain was supplemented agrees with results of others (Hess et al., 1996; Elizalde et al., 1998). Forage DMI was decreased when steers grazing an endophyte-free (Hess et al., 1996) or endophyte-infected (Elizalde et al., 1998) tall fescue were supplemented with 0.34 or 0.75% BW of cracked corn, respectively. In contrast, Brokaw et al. (2001) observed no changes in forage DMI when steers grazing a summer pasture were supplemented with less quantity of oil (0.0375% BW) and cracked corn (0.35% BW) or by Judkins et al. (1997) when supplemented steers grazing an endophyte-free tall fescue were supplemented with 0.4% BW of ground<br>

**Table 2.** Effect of supplementation with soybean hulls plus corn oil or corn grain to steers grazing endophyte-free tall fescue pasture on total and forage DMI, substitution rate, relative stocking density, and in vivo apparent total DM, NDF, and ADF digestibility

<table>
<thead>
<tr>
<th>Item</th>
<th>Dietary treatment²</th>
<th>PO</th>
<th>PC</th>
<th>PA</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steers, n</td>
<td></td>
<td>3</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>BW, kg</td>
<td></td>
<td>464 ± 16.8</td>
<td>455 ± 16.8</td>
<td>418 ± 13.0</td>
<td></td>
</tr>
<tr>
<td>DMI, % of BW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.58</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.61 ± 0.18</td>
<td>1.83 ± 0.18</td>
<td>1.84 ± 0.13</td>
<td>0.05</td>
</tr>
<tr>
<td>Forage substitution rate</td>
<td></td>
<td>1.09 ± 0.17( ^a )</td>
<td>1.33 ± 0.17( ^a )</td>
<td>1.84 ± 0.13( ^a )</td>
<td>0.02</td>
</tr>
<tr>
<td>Relative stocking density</td>
<td></td>
<td>0.53</td>
<td>0.50</td>
<td>—</td>
<td>0.02</td>
</tr>
<tr>
<td>In vivo apparent digestibility, %</td>
<td></td>
<td>67.2 ± 1.3</td>
<td>66.7 ± 1.3</td>
<td>68.5 ± 1.3</td>
<td>0.03</td>
</tr>
<tr>
<td>DM</td>
<td></td>
<td>69.8 ± 1.5( ^a )</td>
<td>64.2 ± 1.5( ^b )</td>
<td>69.5 ± 1.0( ^a )</td>
<td>0.046</td>
</tr>
<tr>
<td>ADF</td>
<td></td>
<td>88.5 ± 1.4( ^a )</td>
<td>72.6 ± 1.4( ^b )</td>
<td>83.6 ± 1.1( ^a )</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

\( ^a,b \) Within the same row, means without a common superscript differ \( (P \leq 0.05) \).

¹Least squares means ± SEM.

²PO = steers grazing tall fescue supplemented with 0.1% BW corn oil and 0.45% BW soybean hulls; PC = steers grazing tall fescue supplemented with 0.52% BW corn grain; PA = steers grazing tall fescue only.

³Body weight of the steers used for DMI and digestibility estimation as measured at the beginning of the sampling period.

⁴Substitution rate = \([\text{average forage DMI}\_\text{PA} - \text{(individual forage DMI)}_{\text{PO or PC}}]/\text{individual supplement DMI}\).

⁵Relative stocking density = \((\text{average forage DMI})_{\text{PA}}/(\text{individual forage DMI})_{\text{PO or PC}}\).

**Table 3.** Average daily gain of steers grazing endophyte-free tall fescue pasture without supplementation or supplemented with either cracked corn or soybean hulls plus corn oil and of steers on a high-concentrate diet (d 85 to 197)

<table>
<thead>
<tr>
<th>Item</th>
<th>Dietary treatment¹</th>
<th>PO</th>
<th>PC</th>
<th>PA</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steers, n</td>
<td></td>
<td>7</td>
<td>7</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.05</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>d 0 to 84</td>
<td></td>
<td>—</td>
<td>0.66( ^b )</td>
<td>0.85( ^c )</td>
<td>0.49( ^c )</td>
<td>0.06</td>
</tr>
<tr>
<td>d 85 to 197</td>
<td></td>
<td>1.79( ^a )</td>
<td>1.23( ^b )</td>
<td>1.12( ^c )</td>
<td>0.97( ^c )</td>
<td>0.04</td>
</tr>
<tr>
<td>d 0 to 197</td>
<td></td>
<td>—</td>
<td>0.99( ^b )</td>
<td>1.00( ^b )</td>
<td>0.76( ^c )</td>
<td></td>
</tr>
</tbody>
</table>

\( ^a,b \) Within a row, means without a common superscript letter differ \( (P < 0.05) \).

¹C = steers finished on a high-concentrate diet during the last 113 d of the trial; PO = steers grazing tall fescue supplemented with 0.1% BW corn oil and 0.45% BW soybean hulls; PC = steers grazing tall fescue supplemented with 0.52% BW corn grain; PA = steers grazing tall fescue only.
corn. Similarly, others have reported reductions in forage DMI with supplementation of cottonseed hulls plus corn oil (Pavan et al., 2007) or high-fiber supplements (Hess et al., 1996; Elizalde et al., 1998; Richards et al., 2006) to grazing steers. The lack of difference observed for forage DMI between supplements in this study may be due to the limited number of observations utilized for the DMI determination. In an earlier study (Pavan et al., 2007), stocking density could be increased by 62% relative to the stocking density without oil supplementation when supplementing steers with 1.5 g/kg of BW of corn oil.

The reduction in forage DMI with supplementation would result from negative associative effects between forage and supplement, which would decrease fiber digestion (Doyle et al., 2005) or decrease grazing time (Bargo et al., 2003). In our study, total tract NDF digestibility was decreased with corn grain supplementation.

### Table 4. Total supplemental feed DMI, cost, and conversion for the 197 d of supplementation or 113 d of high concentrate finishing

<table>
<thead>
<tr>
<th>Item</th>
<th>Dietary treatment 1</th>
<th></th>
<th></th>
<th>SEM</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Steers, n</td>
<td>C</td>
<td>PO</td>
<td>PC</td>
<td>PA</td>
<td></td>
</tr>
<tr>
<td>Total DMI, kg/head</td>
<td>1,080.4a</td>
<td>384.9b</td>
<td>375.4b</td>
<td>21.13</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cost, $/head</td>
<td>170.45</td>
<td>74.23e</td>
<td>46.16b</td>
<td>3.36</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Added BW, kg/head</td>
<td>202.3b</td>
<td>44.2b</td>
<td>47.3b</td>
<td>6.93</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Conversion</td>
<td>0.188a</td>
<td>0.115b</td>
<td>0.126b</td>
<td>0.014</td>
<td>0.006</td>
</tr>
<tr>
<td>Added carcass value, $/head</td>
<td>446.27</td>
<td>157.41b</td>
<td>137.58b</td>
<td>34.29</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

**Within a row, means without a common superscript letter differ (P < 0.05).**

1C = steers finished on a high-concentrate diet (from d 85 to 197); PO = steers grazing tall fescue supplemented with 0.1% BW corn oil and 0.45% BW soybean hulls; PC = steers grazing tall fescue supplemented with 0.52% BW corn grain.

2Supplemental feed cost (DM basis): corn grain, $111.83/ton; corn oil, $520/ton; soybean hulls, $99.08/ton; concentrate, $148.41/ton; bermudagrass hay, $118.50/ton.

3Added BW gain: C = BWd197 - BWd85; PC and PO = [(BWd419 - BWd0)PO or PC - (BWd197 - BWd0)PA].

4Conversion = (added BW)/(total DMI of supplemental feed).

5Added carcass value, $/steer = carcass valueC, PO, or PC - carcass valuePA.

### Table 5. Carcass traits of steers grazing endophyte-free tall fescue pasture supplemented with either cracked corn or soybean hulls plus corn oil compared with positive control (high-concentrate diet) or negative control (pasture only)

<table>
<thead>
<tr>
<th>Item</th>
<th>Dietary treatment 1</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Steers, n</td>
<td>C</td>
<td>PO</td>
<td>PC</td>
<td>PA</td>
</tr>
<tr>
<td>HCW, kg</td>
<td>319a</td>
<td>255b</td>
<td>248b</td>
<td>215c</td>
</tr>
<tr>
<td>Dressing, %</td>
<td>61.4a</td>
<td>56.8b</td>
<td>56.1b</td>
<td>53.1c</td>
</tr>
<tr>
<td>LM area</td>
<td>72.8a</td>
<td>62.3b</td>
<td>63.4b</td>
<td>59.4b</td>
</tr>
<tr>
<td>cm²:HWC</td>
<td>0.23a</td>
<td>0.25bc</td>
<td>0.26b</td>
<td>0.28a</td>
</tr>
<tr>
<td>FT, cm</td>
<td>1.25a</td>
<td>0.53b</td>
<td>0.41b</td>
<td>0.26c</td>
</tr>
<tr>
<td>Marbling score3</td>
<td>587a</td>
<td>424a</td>
<td>397a</td>
<td>367a</td>
</tr>
<tr>
<td>KPH, %</td>
<td>1.9c</td>
<td>1.3b</td>
<td>1.0bc</td>
<td>0.8c</td>
</tr>
<tr>
<td>Skeletal maturity4</td>
<td>161</td>
<td>166</td>
<td>154</td>
<td>159</td>
</tr>
<tr>
<td>Yield grade</td>
<td>3.2a</td>
<td>2.3b</td>
<td>2.0c</td>
<td>1.8c</td>
</tr>
<tr>
<td>Quality grade</td>
<td>5.6a</td>
<td>3.3b</td>
<td>2.7b</td>
<td>2.4b</td>
</tr>
<tr>
<td>Carcass price, $/45.4 kg</td>
<td>134.85a</td>
<td>116.85b</td>
<td>116.38b</td>
<td>105.80c</td>
</tr>
<tr>
<td>Carcass value, $/carr</td>
<td>948.52a</td>
<td>659.66b</td>
<td>639.83b</td>
<td>502.25c</td>
</tr>
</tbody>
</table>

**Within a row, means without a common superscript letter differ (P < 0.05).**

1C = steers finished on a high-concentrate diet during the last 113 d of the trial; PO = steers grazing tall fescue supplemented with 0.1% BW corn oil and 0.45% BW soybean hulls; PC = steers grazing tall fescue supplemented with 0.52% BW corn grain; PA = steers grazing tall fescue only.

2Supplemental feed cost (DM basis): corn grain, $111.83/ton; corn oil, $520/ton; soybean hulls, $99.08/ton; concentrate, $148.41/ton; bermudagrass hay, $118.50/ton.

3Added BW gain: C = BWd197 - BWd85; PC and PO = [(BWd419 - BWd0)PO or PC - (BWd197 - BWd0)PA].

4Conversion = (added BW)/(total DMI of supplemental feed).

5Added carcass value, $/steer = carcass valueC, PO, or PC - carcass valuePA.
Energy supplementation to grazing steers

...but not with SBH plus corn oil. The lack of oil supplementation effect on NDF digestibility contrasts with the linear decrease observed when increasing corn oil levels (0.075 and 0.15% BW) were supplemented to grazing steers in a previous experiment (Pavan et al., 2007). The difference between studies could be partially explained by the different fiber source used as oil carrier; lowly degradable cottonseed hulls were used in the first study versus highly degradable SBH in this study. Cottonseed hulls depress OM digestibility when supplemented to steers grazing wheat pasture (Lippke et al., 2000), whereas SBH did not alter (Richards et al., 2006) or increased NDF digestibility when supplemented to steers fed freshly clipped endophyte-infected tall fescue (Faulkner et al., 1994). Fieser and Vanzant (2004) observed that SBH supplementation improved total dietary NDF digestibility as tall fescue maturity advanced from vegetative to boot, heading stage, or mature stage, whereas, corn grain supplementation decreased NDF digestibility. Similar results were observed by Matejovsky and Sanson (1995) with lambs. In our study, the period of forage intake and digestibility determination was conducted while the pasture was in the heading stage. Thus, a greater NDF digestibility of the SBH with respect to the forage may have counterbalanced a possible negative effect of corn oil. A decrease in NDF digestibility was also observed when 0.054 to 0.099% BW of tallow fat was supplemented to bermudagrass hay (Hall et al., 1990) or when safflower seed were supplemented to bromegrass hay-based diets to provide 5% dietary fat (Scholljegerdes et al., 2004). According to our estimation of total DMI, total dietary fat provided by corn oil supplementation (0.10% BW) in our study represented 6.2% of DMI. Others have shown no changes in total dietary NDF digestibility when 0.0375% BW of soybean oil was supplemented to grazing heifers (Brokaw et al., 2001) or when 300 mL of soybean oil was infused intraruminally to heifers fed a grass-hay diet (Krysl et al., 1991).

The overall ADG for grazing steers without supplementation was within the 0.52 to 0.84 kg/d range reported in the literature for steers grazing endophyte-infected (Thompson et al., 1993; Elizalde et al., 1998; Beck et al., 2006) or endophyte-free (Hess et al., 1996; Judkins et al., 1997; Pavan et al., 2007) tall fescue pastures. In accordance with the forage DMI and digestibility results, SBH plus corn oil supplement provided a gain response similar to that observed with corn grain supplementation when supplemented at isocaloric levels. Greater ADG were obtained with corn grain than with wheat bran (Hess et al., 1996) or corn gluten fed (Elizalde et al., 1998), respectively, when both supplement types were supplemented at 0.34 or 0.5% BW. Likewise, ADG did not differ when 3 isonitrogenous and isocaloric concentrates containing different carbohydrate sources (starch, starch + fiber, or fiber-based) were supplemented to grazing steers (French et al., 2001). In our previous study (Pavan et al., 2007), corn oil supplementation to grazing steers increased ADG by 0.12 kg/d for each 0.10% BW of added oil. The reduced response to oil supplementation in the previous study could have been due to an indirect effect of oil supplementation on diet digestibility through an increase in the proportion of cottonseed hulls as mentioned above. When 3 and 6% of soybean oil (about 0.083 and 0.166% BW, respectively) partially replaced corn grain in isocaloric-formulated concentrate supplemented to prepuberal heifers fed a hay-based diet, no change in the ADG was observed (Whitney et al., 2000). In a second study using the same diets, ADG increased by 0.10 kg with the 3% oil inclusion, but no effect was observed with 6% inclusion (Whitney et al., 2000). Differences in ADG were not observed when vegetable oil (6.85% DM basis, equivalent to 0.056% BW) plus calcium carbonate replaced corn grain (8.2% DM basis) as the supplement of steers grazing common bermudagrass (Cynodon dactylon; Hall et al., 1990).

Supplemental feed conversion observed in the present study was less than that (0.20 and 0.16 kg/kg of supplement) observed by Hess et al. (1996) and Judkins et al. (1997) when supplementing corn grain (0.34 and 0.40% BW, respectively) to steers grazing endophyte-free tall fescue pastures. These differences may be related to the use of lighter animals (final BW <350 kg) in those studies versus the present study. In addition, variation in supplemental feed conversion efficiency between studies could be the result of differences of forage availability during supplementation. Supplemental feed conversion decreases as forage availability increases (French et al., 2001; Beretta et al., 2006). In our study, each paddock was grazed for an average of 6.6 d with mean forage mass during that period of 25 kg of DM/100 kg of BW. This could have resulted in high substitution rates throughout the grazing period limiting supplement conversions. Supplemental feed conversion efficiency was less (−0.068) for supplemented steers grazing forages than for C.

Carcasses from steers fed the high-concentrate diet were fatter than those from grazing treatments. Similar results were reported for fat score (French et al., 2001) and for intramuscular fat (French et al., 2003). Energy supplementation to grazing steers resulted in heavier carcasses than PA with relatively small differences in carcasses traits. Andrae et al. (2001) observed no changes in HCW, fat thickness, LM area, KPH, or yield grade when high-oil corn grain was used instead of conventional corn in a high-concentrate diet. Marbling scores and quality grades increased when the caloric density of the diet was increased by feeding high-oil corn but not when diets were offered in isocaloric quantity (Andrae et al., 2001). Others have shown no changes in carcass quality or yield with oil supplementation using 4% of corn oil (Gillis et al., 2004) or 5% of soybean oil (Beaulieu et al., 2002) to high-concentrate diets. Engle et al. (2000) reported reductions in HCW, fat thickness, KPH, marbling score, and quality grade when 5% soybean oil was added to a high-concentrate diet. In contrast, carcass weight and fat thickness were
linearily increased when grazing steers were supplemented with increasing quantity of corn oil (Pavan et al., 2007). Our present results confirm the positive effect of corn oil supplementation to grazing cattle on carcass fatness. Carcass weight was increased by energy supplementation, regardless of energy source used, to grazing steers.

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