Ionophore strategy affects growth performance and carcass characteristics in feedlot steers


*Department of Animal and Food Sciences, Texas Tech University, Lubbock 79409; and †Zoetis, Florham Park, NJ 07932

ABSTRACT: One hundred ninety-two steers (BW = 354 ± 23.5 kg) were used in a randomized block design to evaluate the effects of ionophore and ractopamine hydrochloride (RH) supplementation strategies on performance and carcass characteristics. Twelve pens of 4 steers were assigned to each of the following treatments: unsupplemented control (CON), laidlomycin propionate (12.1 mg/kg DM) with or without RH (LPRH and LP, respectively), and monensin sodium (36.4 mg/kg DM) with RH (MSRH). Steers were fed for 151 d, of which respective treatments received RH (Actogain; Zoetis, Florham Park, NJ) at a rate of 300 mg/(animal · d) for the final 32 d. Laidlomycin was removed from the LPRH treatment during this period, as no combination feeding has been approved. Upon harvest, carcass data were collected by trained personnel, and subsequent analysis of the LM was conducted to estimate tenderness using Warner-Bratzler shear force (WBSF). Prior to RH supplementation, both LP and LPRH had greater ADG (P ≤ 0.02) and G:F (P < 0.01) than CON, whereas MSRH was intermediate. During the final 32 d, MSRH improved G:F (P ≤ 0.02) compared to all other treatments and tended to increase ADG over unsupplemented controls (P = 0.05). Cattle receiving LP without RH had significantly greater BW at d 151 than CON (P = 0.02), whereas both RH treatments tended to improve final BW (P ≤ 0.09). Ionophores improved ADG (P ≤ 0.03) and G:F (P < 0.01) for the entire feeding period, and although LP-supplemented cattle had greater DMI for the final 32 d than both RH treatments (P ≤ 0.01), intakes for the 151-d trial were similar among treatments. Carcass weights were greater (P = 0.04) in cattle fed LP with no RH than CON, where cattle yielded an average of 12 kg more HCW. Ractopamine increased LM area in MSRH-supplemented cattle (P = 0.03) and tended to increase LM area for steers receiving LPRH (P = 0.07). Longissimus steaks of MSRH-supplemented cattle had greater WBSF values than CON (P = 0.04) after 7 d of postmortem aging and greater WBSF values than LPRH steaks after 28 d (P = 0.03). All other carcass and WBSF measurements were similar among treatments. The results of this study indicate that LP supplementation without RH may yield a performance similar to and carcass responses associated with the administration of a β-agonist. These results also suggest that performance and carcass characteristics for cattle fed LP are similar to those of cattle fed monensin throughout the feeding period.

Key words: beef cattle, beta-agonist, ionophore, laidlomycin propionate, monensin sodium

© 2016 American Society of Animal Science. All rights reserved.
million fed cattle, it was reported that 97.3% of clients used an ionophore in their finishing diets (Samuelson et al., 2016). Of those clients using an ionophore, 100% chose monensin as their source. A concurrently published meta-analysis (Cernicchiaro et al., 2016) examined the comparative effects of feeding laidlomycin propionate or monensin and indicated improved DMI, ADG, and HCW in laidlomycin propionate–supplemented cattle. Another study by Pritchard (1996) showed improved final BW and HCW, and Galanye et al. (1992) reported significant improvements in DMI when cattle were supplemented with laidlomycin propionate over monensin.

In addition to ionophores, other technologies are often implemented to maximize growth performance and feed efficiency of feedlot cattle. Beta-adrenergic agonists (βAA) are a class of feed additives that are used in approximately 85% of feedlot cattle (Samuelson et al., 2016) to improve ADG and HCW during the final 20 to 40 d on feed. Because they differ in their mechanism of action, it is common for βAA and ionophores to be fed simultaneously. Laidlomycin propionate, however, lacks combination approval with any available βAA. Consequently, no published research exists assessing management strategies for feeding these 2 compounds together during the finishing period. Therefore, the current study was conducted to evaluate growth performance and carcass characteristics when feeding laidlomycin propionate, with or without a βAA, compared to a standard supplemental feed additive program of monensin and the βAA ractopamine hydrochloride.

MATERIALS AND METHODS

All experimental procedures involving live animals were conducted at the Texas Tech University Burnett Research Center in New Deal, TX. Animals were handled in accordance with the regulations of the Institutional Animal Care and Use Committee (IACUC), and their use in this experiment was approved by the Texas Tech IACUC (protocol number 15003-01).

Animals

Two hundred and fifty crossbred steers (BW = 347 ± 33.2 kg) were received on August 25, 2015. On arrival, cattle were placed in receiving pens (n = 13) and provided ad libitum access to water, grass hay, and a 65% concentrate starter ration at 1% of incoming BW. For the 17 d prior to initiation of the trial, cattle were transitioned to the final finishing ration (Table 1). Three days after arrival (d −14), steers were processed and individually weighed (Silencer chute; Moly Manufacturing, Lorraine, KS; mounted on Avery Weigh-Tronix load cells, Fairmount, MN; readability ± 0.45 kg). Initial processing included the following procedures: application of a unique identification tag, vaccinations against viral (Bovi-Shield Gold 5; Zoetis, Florham Park, NJ), clostridial (One-Shot Ultra 7; Zoetis), and Mycoplasma bovis (Myco-Vac B; Texas Vet Lab Inc., San Angelo, TX) diseases; treatment for internal parasites (Dectomax Pour-On; Zoetis); and application of a trenbolone acetate + estradiol-17β combination implant (Synovex Choice; Zoetis).

Consecutive individual BW were captured on d −8 and −7. On d −7, 192 steers, which had been previously selected from the larger population based on uniformity of d −14 BW, were blocked by BW (n = 12 blocks; 16 animals/block) and returned to 12 receiving pens. On d 0, steers within each block were assigned to pen on the basis of the average of the consecutive weights recorded on d −8 and −7 in a method that

<table>
<thead>
<tr>
<th>Ingredient and analyzed chemical composition (DM basis) of diet</th>
<th>Value</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam-flaked corn</td>
<td>64.11</td>
<td>0.306</td>
</tr>
<tr>
<td>Wet corn gluten feed</td>
<td>19.71</td>
<td>0.273</td>
</tr>
<tr>
<td>Cottonseed hulls</td>
<td>4.10</td>
<td>0.038</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>3.97</td>
<td>0.033</td>
</tr>
<tr>
<td>Fat (yellow grease)</td>
<td>3.13</td>
<td>0.004</td>
</tr>
<tr>
<td>Supplement</td>
<td>1.94</td>
<td>0.010</td>
</tr>
<tr>
<td>Limestone</td>
<td>1.89</td>
<td>0.002</td>
</tr>
<tr>
<td>Treatment premix</td>
<td>0.65</td>
<td>0.003</td>
</tr>
<tr>
<td>Urea</td>
<td>0.52</td>
<td>0.002</td>
</tr>
</tbody>
</table>

1During final 32 d, 0.50% of the diet as steam flaked corn was replaced with a ractopamine hydrochloride (RH) supplement (95.74% ground corn, 4.26% Actogain 45; Zoetis, Florham Park, NJ) for laidlomycin propionate with RH (LPRH) and monensin sodium with RH (MSRH) treatments. An equal amount of untreated ground corn was supplied to the control (CON) and laidlomycin propionate without RH (LP) treatments.

2Supplement composition (DM basis): 67.789% cottonseed meal, 15.000% NaCl, 10.000% KCl, 4.167% ammonium sulfate, 0.986% zinc sulfate, 0.648% dicalcium phosphate, 0.500% Endox (Kemin Industries, Des Moines, IA), 0.333% manganese oxide, 0.196% copper sulfate, 0.158% vitamin E (500 IU/g), 0.125% selenium premix (0.2% Se), 0.083% iron sulfate, 0.010% vitamin A (1,000,000 IU/g), 0.003% ethylenediamine dihydroiodide, and 0.002% cobalt carbonate.

3Premix composition: CON = 100.00% ground corn; LP/LPRH = 96.319% ground corn, 1.501% Cattlyst 50, 2.180% Aureomycin 100 (Zoetis, Florham Park, NJ); MSRH = 95.604% ground corn, 2.512% Rumensin 90, 1.89% limestone 1.89, 0.65% Treatment premix 3, 0.52% Urea 1.89, 1.94% Treatment premix 3, 0.158% vitamin E (500 IU/g), 0.333% manganese oxide, 0.196% copper sulfate, 0.158% vitamin E (500 IU/g), 0.125% selenium premix (0.2% Se), 0.083% iron sulfate, 0.010% vitamin A (1,000,000 IU/g), 0.003% ethylenediamine dihydroiodide, and 0.002% cobalt carbonate.

4Composition from 13 composite samples analyzed at a commercial laboratory (Servi-Tech Laboratories, Amarillo, TX). DM calculated weekly (forced-air oven for 24 h at 100°C).
reduced variation in mean BW between pens within block. Upon trial initiation (d 0), steers were individually weighed (BW = 354 ± 23.5 kg) and sorted into 48 concrete, partially slotted floor pens (4 steers/pen; 2.9 × 5.5 m with 2.4 m of linear bunk space). Treatment was randomly assigned to pen within block, and the respective diets were introduced on d 0. All pens were fed to provide ad libitum access to feed once daily in the morning for the duration of the experiment.

Treatments and Experimental Design

Four treatments were used in a randomized complete block design. Treatments consisted of the following: 1) unsupplemented control (CON), 2) laidlomycin propionate (Cattlyst 50; Zoetis; targeted inclusion of 12.1 mg/kg DM) without a β-agonist (LP), 3) laidlomycin propionate (12.1 mg/kg DM) plus ractopamine hydrochloride (RH; Actogain 45; Zoetis) fed at a rate of 300 mg/(animal · d) for the final 32 d (LPRH), and 4) monensin sodium (Rumensin 90; Elanco, Greenfield, IN; targeted inclusion of 36.4 mg/kg DM) plus RH fed at a rate of 300 mg/(animal · d) for the final 32 d (MSRH). The antimicrobials chlortetracycline (Aureomycin 100; Zoetis; targeted inclusion of 350 mg/[animal · d]) and tylosin (Tylan 40; Elanco; targeted inclusion of 12.1 mg/kg DM) were fed concurrently with both laidlomycin propionate and monensin, respectively. Differences in the concurrently fed antimicrobials were due to corresponding combination approval with the selected ionophores. Laidlomycin propionate and chlortetracycline were removed from the diet for the final 32 d for the LPRH treatment, as no combination approval exists with the commercially applied β-agonist (Actogain; Zoetis). After accounting for the calculated DM of the diet and intake over the course of the study, laidlomycin propionate, chlortetracycline, monensin, tylosin, and RH were supplemented at 11.8 mg/kg, 343 mg/(animal · d), 35.3 mg/kg, 11.8 mg/kg, and 255 mg/(animal · d) on a DM basis, respectively.

Treatment Application and Routine Management

Diets were formulated to meet or exceed NRC (1996) requirements for growing-finishing beef cattle and were prepared at the Texas Tech Burnett Center Feed Mill. Feed bunks were evaluated at approximately 0730 h daily to estimate orts and adjust feed calls to ensure ad libitum access. The feed bunk management approach was to achieve ≤0.45 kg of dry orts in the bunk each day. Diets were mixed in a paddle-type mixer, transferred by drag chain conveyor to a tractor pulled mixer (Rotomix, Dodge City, KS), and delivered once daily beginning at 0900 h. To minimize residual contamination from different ionophores, feeding order was LP/LPRH, CON, and MPRH. During the RH supplementation period, clean out loads were delivered to spare cattle between ionophore and ractopamine rations.

All treatments were provided as supplemental premixes in a ground-corn carrier that was batched with the total mixed ration prior to delivery. All premixes were made on site, stored in labeled treatment receptacles, and delivered as needed to the appropriate bins on a commercial micromixer. For CON diets, a 100% ground corn placebo premix was fed at the same inclusion rate as ionophore-supplemented diets. Weekly diet samples were obtained directly from the feed bunk immediately following delivery and frozen for subsequent analysis. Following trial termination, samples were composited by diet within each interim period and submitted for proximate analysis (Servi-Tech Laboratories, Amarillo, TX) using AOAC (1995) procedures. Separate weekly diet samples were collected and dried in a forced-air oven at 100°C for 24 h to determine DM content, which was used to determine total DMI. Diet composition and chemical analysis can be found in Table 1.

Individual BW measurements were collected prior to feed delivery (0700 h) on d 0, 35, 70, 119, and 150. Before BW were collected, feed bunks were cleaned of residual feed, and orts were weighed and sampled for DM content. The DMI of each pen was adjusted to reflect the total DM delivered to each pen after subtracting the quantity of dry orts for each interim period.

Removal

Daily observations were conducted by trained study personnel. A total of 7 animals were removed during the course of the study. Four animals were removed from the CON treatment for coccidiosis (1), lameness (1), and symptoms consistent with Mycoplasma bovis (2). One animal was removed from the LP treatment because of lameness, and 2 animals were removed from the MPRH treatment for acute respiratory failure (1) and symptoms consistent with Mycoplasma bovis (1). For cattle removed from the experiment, feed intake up to the point of removal was subtracted from total feed delivered. It was weighted on a per animal, per day basis and applied total DMI calculations for the respective pens. One CON pen was removed entirely from the statistical analysis given that 2 of the removed animals came from that individual pen.

Carcass Evaluation

When study personnel deemed approximately 60% of the population to have an external fat cover sufficient to grade USDA Choice, all cattle were transported.
75 km to a commercial abattoir (JBS, Cactus, TX). Carcass measurements were collected by trained personnel from West Texas A&M University. During the harvest process, extra carcass trim and hide pulls of soft tissue ≥6.8 kg were noted. Individual carcass measurements (n = 181; 4 animals were excluded because of missing identification on harvest or missing data from carcass collection personnel) included HCW, 12th-rib fat depth, LM area, KPH percentage, marbling score, and evaluation for liver abscesses. Liver abscess data were collected using the Eli Lilly Liver Check System (Elanco) as described by Brown and Lawrence (2010), and yield grade was calculated using the USDA regression equation (USDA, 1997). A 3% shrink was applied to final live BW for calculation of dressing percentage.

Fabrication and Shear Force Analyses

Upon collection of individual BW on d 70, 2 animals from each pen were further evaluated using real-time ultrasound to answer an independent research question. The 2 steers selected for this analysis were identified as the intermediate animals within each pen based on d 35 BW. Strip loins (n = 85) were obtained from these previously selected carcasses on fabrication and transported to the Gordon Davis Meat Lab at Texas Tech University. Of the 96 animals selected, 11 were excluded because of removal from the trial or missing carcass identification on harvest. For Warner-Bratzler shear force (WBSF) analysis, 22 strip loins were collected from CON, LP, and MSRH treatments, whereas 19 strips were collected from the LPRH treatment. Three days postharvest, 1 steak was cut from the anterior end of each strip loin to level the cut surface. Four 2.54-cm thick steaks were cut from the anterior end and assigned to 1 of 4 aging periods (7, 14, 21, and 28 d) in rotating order to ensure each aging period was equally represented among anatomical position within the loin. Fabricated steaks were vacuum packaged within aging period and stored at 2°C. After the appropriate postmortem aging period, steaks were frozen at −20°C until further analysis.

Steaks (n = 340) were thawed at 4°C for 24 h prior to cooking. Steaks were cooked to an internal temperature of 74°C ± 2.2°C using a belt grill (Magigrill model TBG-60; Magi-Kitch’n Inc., Quakertown, PA) with a grill-plate temperature of 163°C. Individual steak temperature and weight were recorded immediately before and after cooking. Steaks were then cooled overnight to 2°C to 4°C. Warner-Bratzler shear force values were obtained by removing six 1.3-cm cores from each steak parallel to the muscle fiber. Cores were sheared once, perpendicular to the muscle fibers, using a WBSF analyzer (G-R Elec. Mfg., Manhattan, KS). The WBSF values from the 6 cores from each steak were averaged for statistical analysis.

Statistical Analysis

Data were analyzed using the GLIMMIX procedure of SAS (SAS version 9.4; SAS Inst. Inc., Cary, NC). For all growth performance and carcass characteristic analyses, pen was considered the experimental unit. Treatment was included as a fixed effect, and weight block was considered a random effect. For WBSF analyses, strip loin was the experimental unit, and treatment was included as a fixed effect. Postcook temperature was entered into the statistical model as a covariate but was dropped from the analyses when it was deemed insignificant. Results are reported as least squares means and were separated using the PDIFF option of SAS. For all analyses, an α level ≤ 0.05 was considered significant, and tendencies were declared for values between 0.05 and 0.10.

RESULTS

Feedlot Performance

Cattle fed LP for the duration of the experiment with no βAA had greater final BW (P = 0.02) than unsupplemented controls (Table 2). Both LPRH- and MSRH-supplemented cattle tended to have greater final BW than CON (P = 0.09 and P = 0.07), and numerical improvements of 15 and 16 kg were observed, respectively. Prior to RH administration, when LP and LPRH were treated similarly, laidlomycin-supplemented cattle had significantly greater ADG than CON (P ≤ 0.02), whereas MSRH was intermediate. The improved rate of gain observed in laidlomycin propionate treatments resulted in a pooled interim BW that was 14.5 kg greater for LP- and LPRH-supplemented cattle compared to CON (P = 0.03 and P = 0.08, respectively). Average daily gain for the first 118 d and interim BW were similar for all ionophore treatments. No differences were observed in DMI prior to RH administration (P ≥ 0.45); however, feed efficiency was significantly improved (P < 0.01) when cattle were fed laidlomycin propionate (LP and LPRH) compared to CON. Although the 2 treatments received the same diets for the first 118 d, LP had significantly greater G:F (P = 0.03) than MSRH, whereas LPRH cattle were not different (P = 0.14). Still, the pooled G:F for LP and LPRH treatments was 3% greater than for MSRH and represented a nearly 6% improvement over CON during the first 118 d. During this same period, MSRH supplementation also tended to improve feed efficiency (P = 0.10) over CON.

From d 119 to 151, LP had greater DMI than both RH treatments (P < 0.01), and although LP-supplemented
Table 2. Effect of ionophore feeding strategy and ractopamine hydrochloride (RH) supplementation on feedlot performance of steers

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment1</th>
<th>Treatment2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CON</td>
<td>LP</td>
</tr>
<tr>
<td>Initial BW, kg</td>
<td>355</td>
<td>354</td>
</tr>
<tr>
<td>d 119 BW, kg</td>
<td>571b</td>
<td>587a</td>
</tr>
<tr>
<td>d 151 BW, kg</td>
<td>618b</td>
<td>640a</td>
</tr>
<tr>
<td>d 0 to 118</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMI, kg</td>
<td>9.95</td>
<td>10.10</td>
</tr>
<tr>
<td>ADG, kg</td>
<td>1.82b</td>
<td>1.96a</td>
</tr>
<tr>
<td>G:F</td>
<td>0.183c</td>
<td>0.195a</td>
</tr>
<tr>
<td>d 119 to 151</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMI, kg</td>
<td>9.89b</td>
<td>10.48a</td>
</tr>
<tr>
<td>ADG, kg</td>
<td>1.46</td>
<td>1.64</td>
</tr>
<tr>
<td>G:F</td>
<td>0.148b</td>
<td>0.156b</td>
</tr>
<tr>
<td>d 0 to 151</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMI, kg</td>
<td>9.94</td>
<td>10.18</td>
</tr>
<tr>
<td>ADG, kg</td>
<td>1.74b</td>
<td>1.90a</td>
</tr>
<tr>
<td>G:F</td>
<td>0.176b</td>
<td>0.186a</td>
</tr>
</tbody>
</table>

Table 3. Effect of ionophore feeding strategy and ractopamine hydrochloride (RH) supplementation on carcass characteristics of steers

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment1</th>
<th>Treatment2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CON</td>
<td>LP</td>
</tr>
<tr>
<td>HCW, kg</td>
<td>392b</td>
<td>404a</td>
</tr>
<tr>
<td>Dress yield, %</td>
<td>63.38</td>
<td>63.09</td>
</tr>
<tr>
<td>LM area, cm²</td>
<td>87.61b</td>
<td>88.46b</td>
</tr>
<tr>
<td>12th-rib fat, cm</td>
<td>1.60</td>
<td>1.64</td>
</tr>
<tr>
<td>KPH, %</td>
<td>1.97b</td>
<td>2.03a</td>
</tr>
<tr>
<td>Marbling score²</td>
<td>412</td>
<td>430</td>
</tr>
<tr>
<td>Yield grade, calculated</td>
<td>3.40</td>
<td>3.52</td>
</tr>
<tr>
<td>Liver abscess³</td>
<td>6.71</td>
<td>4.17</td>
</tr>
</tbody>
</table>

a,bRow means that do not have common superscripts differ (P < 0.05).

1CON = negative control; LP = laidlomycin propionate (Cattlyst 50; Zoetis, Florham Park, NJ; 12.1 mg/kg DM); LPRH = laidlomycin propionate (Cattlyst 50; Zoetis; 12.1 mg/kg DM) and ractopamine hydrochloride (Actogain 45; Zoetis; 300 mg/animal · d) for final 32 d; MSRH = monensin (Rumensin 90; Elanco, Greenfield, IN; 36.4 mg/kg DM) and ractopamine hydrochloride (Actogain 45; Zoetis; 300 mg/animal · d) for final 32 d.

2As determined by trained personnel 300 = Slight00; 400 = Small00.

3Includes A+ = 1 or more large or multiple small active abscesses, with or without adhesions; A = 2 to 4 small, well-organized abscesses; A- = 1 or 2 small abscesses or scars.

cattle consumed approximately 0.60 kg more daily DM than CON, the 2 treatments were not different (P = 0.11). Monensin-supplemented cattle tended to have greater ADG (P = 0.06) than CON during the final 32 d, whereas LP and LPRH were not different. This resulted in a 15% improvement in G:F for MSRH cattle over LP (P = 0.01) for the final 32 d on feed and significantly greater G:F than CON and LPRH treatments as well (P < 0.01 and P = 0.02, respectively). The improved G:F for MSRH cattle during the final 32 d offset the lower G:F observed from d 0 to 118 compared to both laidlomycin treatments. This resulted in similar G:F for all ionophore-supplemented cattle for the duration of the feeding period and significant improvements (P ≤ 0.01) compared to CON. Because of this improved efficiency and similar DMI for the entire 151-d feeding period, all ionophore treatments had greater ADG than unsupplemented controls (P ≤ 0.03).

Carcass Characteristics and Warner-Bratzler Shear Force

Laidlomycin propionate–supplemented cattle that were not administered RH yielded significantly greater HCW (P = 0.04) than CON (Table 3), whereas LPRH tended to improve HCW (P = 0.07) and MSRH was not different (P = 0.12). Although greater carcass weights were observed in LP-supplemented cattle, LM area was not different than for CON. Laidlomycin propionate–supplemented steers that received RH tended to have larger LM area (P = 0.07), and MSRH cattle had significantly larger LM area than unsupplemented controls (P = 0.03). Although percentage KPH was significantly greater in LP cattle than MSRH (P = 0.03), the observed differences were small enough to have minimal biological importance. Following 7 d of postmortem aging (Table 4), LM steaks from MSRH-supplemented cattle had significantly greater WBSF values than CON (P = 0.04), whereas WBSF did not differ among ionophore treatments. After 28 d of postmortem aging, LPRH had significantly lower WBSF values than MSRH (P = 0.03), and both CON and LP were intermediate. There were no differences in estimation of tenderness using WBSF at 14 or 21 d of postmortem aging.

DISCUSSION

To our knowledge, this is the first published data evaluating the direct comparison of laidlomycin propionate fed with and without a βAA. Furthermore, we have provided additional data to expand on a relatively limited body of research directly comparing the efficacy of laidlomycin propionate and monensin. Because of facility and budget constraints, we were unable to include a treatment supplementing monensin for the duration of the study without the application of a βAA. The inclusion of this treatment would have likely different (P = 0.12).
improved our ability to interpret the observed differences. Nevertheless, this discussion will attempt to interpret the results we have presented and hopefully elucidate some of these novel findings.

Data from the current study failed to realize the depression in DMI that is commonly associated with monensin supplementation (Goodrich et al., 1984; Galyean et al., 1992; Duffield et al., 2012). In 1984, Goodrich et al. published a review of 228 trials evaluating the efficacy of monensin (31.8 mg/kg DM) in cattle and reported a mean reduction in feed intake of 6.5% with a 7.5% improvement in feed efficiency (FE). Duffield et al. (2012) conducted a similar review of 169 trials evaluating growth performance in cattle supplemented with monensin (28.1 mg/kg DM). The results indicated a 3% reduction in DMI when supplemented at 27.5 to 33 mg/kg and an improvement in FE of 6.4% compared to controls. In the present study, we observed similar DMI for MSRH and CON treatments, but FE was improved by 5.7% with MSRH supplementation. Duffield et al. (2012) further stratified all 169 trials by decade and revealed that although monensin improved FE by 8.1% in the 1970s, the effect was reduced to 6.4% in the 1980s and only 3% since 1990. It has been suggested that the lower response to monensin over time is a function of the simultaneous increase in the net energy of feedlot diets over the past several decades (NRC, 2016). Spires et al. (1990) summarized 6 trials that supplemented laidlomycin propionate (0 to 36 mg/kg DM) and ractopamine hydrochloride (Actogain 45; Zoetis; 300 mg/[animal · d]) for final 32 d; MSRH = monensin nitate (Cattlyst 50; Zoetis; 12.1 mg/kg DM) and ractopamine hydrochloride (Rumensin 90; Elanco, Greenfield, IN; 36.4 mg/kg DM) and ractopamine hydrochloride (Actogain 45; Zoetis; 300 mg/[animal · d]) for final 32 d.

Table 4. Effect of ionophore feeding strategy and ractopamine (RH) supplementation on Warner-Bratzler shear force (WBSF) of the LM

<table>
<thead>
<tr>
<th>Treatment1</th>
<th>CON</th>
<th>LP</th>
<th>LPRH</th>
<th>MSRH</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 d</td>
<td>3.07b</td>
<td>3.20a-b</td>
<td>3.26a-b</td>
<td>3.49a</td>
<td>0.144</td>
</tr>
<tr>
<td>14 d</td>
<td>2.79</td>
<td>2.76</td>
<td>2.90</td>
<td>3.02</td>
<td>0.114</td>
</tr>
<tr>
<td>21 d</td>
<td>2.66</td>
<td>2.55</td>
<td>2.51</td>
<td>2.72</td>
<td>0.093</td>
</tr>
<tr>
<td>28 d</td>
<td>2.52a,b</td>
<td>2.52a,b</td>
<td>2.40b</td>
<td>2.66a</td>
<td>0.082</td>
</tr>
</tbody>
</table>

a,b: Row means that do not share common superscripts differ (P < 0.05).

1CON = negative control; LP = laidlomycin propionate (Cattlyst 50; Zoetis, Florham Park, NJ; 12.1 mg/kg DM); LPRH = laidlomycin propionate (Cattlyst 50; Zoetis; 12.1 mg/kg DM) and ractopamine hydrochloride (Actogain 45; Zoetis; 300 mg/[animal · d]) for final 32 d; MSRH = monensin nitate (Rumensin 90; Elanco, Greenfield, IN; 36.4 mg/kg DM) and ractopamine hydrochloride (Actogain 45; Zoetis; 300 mg/[animal · d]) for final 32 d.

A recently published meta-analysis evaluated the comparative effects of laidlomycin propionate and monensin supplementation on performance and carcass characteristics of feedlot cattle (Cernicchiaro et al., 2016). The results showed a mean improvement of 0.05 kg in ADG when cattle were supplemented with laidlomycin propionate over monensin. Although in the current study we were unable to detect a significant difference in ADG, the numerical increase of 0.05 kg for the LP treatment compared to MSRH is consistent with these previously published results. A study by Domby et al. (2013), which was included in the aforementioned analysis, was the only report identified that presented a numerical decrease in ADG for laidlomycin propionate–supplemented cattle when compared to monensin-supplemented cattle. The remaining data sets included in the meta-analysis and other reviewed literature support the numerical increase in ADG observed in the current study (Pritchard, 1996; Kreikemeier, 1997; Cernicchiaro et al., 2016). This additional gain does not seem to be a function of improved efficiency, as Cernicchiaro et al. (2016) reported similar FE of both laidlomycin- and monensin-supplemented cattle, but is more likely a result of greater DMI.

In the current study, the numerical increase of 0.05 kg/d in ADG for LP- over both LPRH- and MSRH-supplemented cattle occurred in concert with greater DMI. Although the current study lacked the sensitivity to declare significance, the increase of 0.22 to 0.24 kg in DMI and similar FE observed in the LP treatment could provide substantial value if realized in a commercial setting. In a 6-trial summary by Spires et al. (1990), a linear reduction in DMI was observed with increasing levels of laidlomycin propionate (0 to 12 mg/kg DM). However, the majority of available literature suggests that laidlomycin does not affect intake when compared to unsupplemented controls. Further analyses by Spires et al. (1990) compared pooled DMI from cattle supplemented with laidlomycin propionate (6 to 12 mg/kg DM) to that of negative controls and reported similar intakes. In evaluating its efficacy compared to monensin, Cernicchiaro et al. (2016) reported that laidlomycin improved DMI by 0.29 kg/d, a magnitude similar to that detected in the current study where cattle fed LP consumed 0.23 kg more DM than cattle fed MSRH. Prior to RH supplementation, when LP and LPRH were treated similarly, both laidlomycin treatments had similar DMI, ADG, and
G:F. However, during the final 32 d on feed, laidlomy-
cin propionate and chlortetracycline were removed from
the LPRH diet as no approval exists for the simultane-
ous feeding of these products with RH. Therefore, the
observed differences in DMI during the final 32 d could
be the result of several potential processes.

First, the removal of laidlomycin propionate and
chlortetracycline for the LPRH treatment from d 119 to
151 may have caused a disruption in ruminal fer-
mentation, leading to digestive upsets that subsequently re-
duced intake. However, this hypothesis fails to explain
the similar reduction in DMI for MSRH-supplemented
cattle. For the final 32 d on feed, LPRH and MSRH
treatments saw reductions of 5.1% and 7.0% from pre-
vious levels of intake. Avendaño-Reyes et al. (2006) re-
ported a significant reduction in DMI during the final 33
d when steers were supplemented with 300 mg/(animal · d) of RH compared to controls, although the reduction
was less (1.6%) than was observed in the current study.
Conversely, Abney et al. (2007) reported similar DMI
when cattle were fed 0 to 200 mg/(animal · d) RH and
observed a linear increase in DMI for extended duration
of RH supplementation (28 to 42 d). Previous studies
by Scramlin et al. (2010) and Boler et al. (2012) also
reported similar DMI during the final 28 to 33 d in RH-
supplemented cattle (200 mg/(animal · d)), and Vogel et
al. (2009) observed significantly greater DMI in Holstein
steers supplemented at the same rate for the final 33
d before harvest. A summary of 48 trials presented by
Lean et al. (2014) calculated a weighted mean difference
in DMI of effectively zero (0.003 kg/d) between control
and RH treatments when RH was supplemented for the
final 31.8 ± 5.3 d. It is possible that the reduction in DMI
observed during the final 32 d of the current study could
be due to RH supplementation; however, the scientific
literature examining these effects is conflicting.

Although improved FE is a hallmark of ionophore
supplementation, the frequent reduction in DMI often
translates to similar final BW between monensin and
unsupplemented controls (Montgomery et al., 2009;
Felix and Loerch, 2011; Xu et al., 2014). Goodrich et
al. (1984) evaluated over 11,000 cattle that were fed with
or without monensin and reported final BW that were
nearly equal for the 2 groups (432 vs. 430 kg, respec-
tively). According to a recent survey of feedlot nutri-
tionists, U.S. beef cattle remain on feed for an average
of 201 d (Samuelson et al., 2016). If we consider this
information along with the mean improvement in ADG
(0.029 kg/d) reported in a 169-trial summary by Duffield
et al. (2012), we would expect final BW that were 5.8 kg
greater in monensin-supplemented cattle. This amount is
substantial; however, it is often difficult to detect in re-
search studies, and the majority of scientific publications
fail to realize a significant difference between final BW
of monensin and control cattle (Goodrich et al., 1984).
If we were to further extrapolate the additional data pro-
vided by Cernicchiaro et al. (2016; 0.05 kg/d increase
in ADG for laidlomycin-supplemented cattle compared
to monensin-supplement cattle), we would anticipate
an additional 10.1 kg of live BW gain when cattle are
supplemented with laidlomycin compared to monensin
and 15.9 kg more when compared to controls. These the-
etorical values are independent of RH supplementation
and have been extrapolated to 201 d on feed; however,
similar trends in final BW were observed in the current
study. In the 17 studies evaluated by Cernicchiaro et al.
(2016), the observed increase in gain resulted in signifi-
cantly greater carcass weights, as laidlomycin-supple-
mented cattle yielded approximately 5.4 kg more HCW
than their monensin counterparts. Still, multiple studies
included in this analysis included the administration of
a βAA, which may have influenced the observed results.

Ractopamine hydrochloride has been well estab-
ished for its impact on HCW; studies have shown
consistent improvements when fed at 200 to 300 mg/
(animal · d). Scramlin et al. (2010) reported HCW that
were 5.3 kg greater in steers supplemented with 200 mg/
(animal · d) compared to controls, and similar improve-
ments were reported by Brown et al. (2014), who real-
ized an 8.2-kg increase in steers fed 300 mg/(animal · d).
A 54-trial summary by Lean et al. (2014) supported these
observations, as RH supplementation improved HCW
by an average of 6.2 kg compared to unsupplemented
controls. Prior to the approval of RH in cattle, Pritchard
(1996) observed a 10.4-kg increase in HCW for laidlo-
ymycin propionate–supplemented cattle over monensin-
supplemented cattle. Unfortunately, in the current study,
the lack of combination approval between laidlomycin
and the commercially applied βAA limited our ability to
realize any potential additive effects on live performance
and HCW. Still, the significant HCW response in LP-
supplemented cattle over CON (+12 kg HCW) yielded
results similar to those associated with feeding a βAA.

Although βAA have consistently shown improve-
ments in performance and carcass characteristics, their
application has not been without scrutiny, and their
use has been associated with decreased consumer ac-
ceptance (Avendaño-Reyes et al., 2006; Woerner et al.,
2011; Bohrer et al., 2014). One measure of this con-
sumer acceptability is tenderness, and the application
of βAA has been reported to increase Warner-Bratzler
shear force values by Garmyn et al., 2014). Hilton et
al. (2009) reported increases of 7% to 17% in WBSF
when zilpaterol was fed for 30 d, whereas Scramlin
et al. (2010) reported increases of 32% to 39% across
multiple postmortem aging periods (3 to 21 d) when
cattle were supplemented with zilpaterol for the same
duration. Although ractopamine has a milder impact on
meat quality than zilpaterol, RH supplementation has still been shown to decrease estimation of consumer-perceived tenderness (Avendaño-Reyes et al., 2006; Howard et al., 2014). Platter and Chot (2008) analyzed several experiments that evaluated the effect of RH supplementation on WBSF and reported that, on average, RH increased WBSF by 0.2 kg. A meta-analysis by Lean et al. (2014) reported increases of 0.31 and 1.02 kg of shear force in LM steaks from cattle supplemented with zilpaterol and ractopamine, respectively. In the current study, RH supplementation increased WBSF values by an average of 0.31 kg over CON at 7 d of postmortem aging and only 0.01 kg after 28 d. Laidlomycin propionate supplementation did not affect estimations of consumer-perceived tenderness, and the greatest increase observed in WBSF was 0.13 kg between LP and CON at 7 d of postmortem aging (P = 0.50). According to Miller et al. (2001), steaks with a shear force under 4.3 kg were considered acceptable 86% of the time, whereas Shackelford et al. (1991) reported 100% consumer acceptance when steaks had a shear force value less than 3.9 kg of shear force. Longissimus steaks evaluated in the present study displayed very low WBSF values that all fell well below the threshold of consumer acceptability established in these previous publications.

**Conclusions**

In the face of scrutiny surrounding some of the beef industry’s most commonly utilized feed supplements, the opportunity exists to further explore existing alternatives. The results of this study indicate that LP supplementation without the use of a β-agonist may yield similar live performance and carcass responses associated with the administration of LH. These results also suggest that performance and carcass characteristics for cattle fed laidlomycin propionate are similar to those of cattle fed monensin throughout the entire feeding period.

**LITERATURE CITED**


