Effects of supplemental phytomolecules on growth performance, carcass characteristics and liver abnormalities of finishing beef steers

Vinicius N. Gouvea, Glenn C. Duff, Consuelo A. Sowers and Michael L. Barnes

Department of Animal and Range Sciences, Clayton Livestock Research Center, New Mexico State University, Clayton, USA

ABSTRACT
This study was conducted to evaluate the growth performance and carcass characteristics of finishing steers fed diets containing different feed additives: control (CTL; no feed additives); monensin (26 mg/kg dry matter DM); a blend of cinnamaldehyde, eugenol, and capsicum (120 mg of a commercial product/kg DM; XT), or the combination of monensin and the blend of cinnamaldehyde, eugenol, and capsicum (26 mg/kg DM and 120 mg of a commercial product/kg DM, respectively; MON + XT). A total of 860 steers [initial body weight (BW) = 334 kg] were fed the basal diet (7% alfalfa hay and 93% concentrate; DM basis) containing the treatments during 154 days. Feed additives did not affect final BW, DM intake, average daily gain, and feed efficiency of finishing steers (P ≥ 0.12). Dressing percentage was lower for MON + XT than MON and XT (P = 0.01). Feeding XT tended to increase the percentage of the carcass with a small marbling score compared to MON (P = 0.09). The proportion of carcass grading premium choice tended to be greater for steers fed MON compared to XT (P = 0.07). The feed additives evaluated herein did not affect the growth performance of finishing beef steers and had little effects on carcass characteristics.

1. Introduction
Non-nutritional feed products (e.g. ionophores, β-adrenergic agonists, direct-fed microbials, exogenous enzymes, phytomolecules, and other feed additives) has been extensively used in cattle feeding operations to increase nutrient utilization and animal growth performance (Duffield et al. 2012; Khiaosa-ard and Zebeli 2013; Lourenco et al. 2020; Smith and Johnson 2020). According to Samuelson et al. (2016), more than 97% of the nutritionists in the United States provide some type of ionophore in the finishing diets, and the primary ionophore used by all these surveyed nutritionists (100%) is monensin. Feeding monensin for finishing beef cattle at the average concentration of 28.1 mg/kg DM increased feed efficiency (G:F) by 6.4%, decreased dry matter intake (DMI) by 3%, and increased average daily gain (ADG) by 2.5% in a meta-analysis conducted by Duffield et al. (2012). According to Ellis et al. (2012), the positive effects on the energetic efficiency of feeding monensin are a result of a shift in volatile fatty acids (VFA) profile in the rumen, increasing propionate, and decreasing acetate and butyrate production (Russel and Strobel 1989). However, some in vivo studies have failed to observe any appreciable effect of monensin on VFA molar proportions (Felix and Loerch 2011; Meyer et al. 2009; Montano et al. 2015).

Alternative feed additives, such as essential oils and some phytomolecules, can alter rumen fermentation characteristics and growth performance of feedlot cattle (Khiaosa-ard and Zebeli 2013; Khorrami et al. 2015), and has gained significant interest among ruminant nutritionists especially due to the increasing public concern about antibiotic residues and antimicrobial resistance (Yang et al. 2010). However, due to the great number of different phytomolecules and doses included in finishing diets, effects on cattle growth performance and feed efficiency are quite variable and deserve further investigation (Meyer et al. 2009; Khiaosa-ard and Zebeli 2013). Synergism and antagonism effects of combined phytomolecules (Burt 2004; Calsamiglia et al. 2007) and interactions between phytomolecules and monensin were also reported (Benchaar et al. 2006; Meschiatti et al. 2019).

The objective of this experiment was to evaluate the effects of supplemental phytomolecules (a blend of cinnamaldehyde, eugenol, and capsicum) and its interaction with monensin on performance and carcass characteristics of finishing beef steers.

2. Materials and methods

2.1. Study location
This experiment was conducted at the Clayton Livestock Research Center, New Mexico State University, in Clayton, NM, from December 2018 to August 2019. All procedures involving the use of animals were approved by the New Mexico State University Institutional Animal Care and Use Committee.

2.2. Animals and experimental procedures
A total of 860 yearling British × Continental crossbreed steers [initial body weight (BW) = 334 ± 23 kg] sourced from the regional auction market were used in this experiment. Steers...
were transported from Dalhart, TX, to the Clayton Livestock Research Center (39–40 steers/truck; ∼55 km and 1.5 h on truck).

Upon arrival, steers were individually weighted (off-truck shrink weight; Daniels Bud Box System; Model AH-10; Ainsworth, NE, USA), vaccinated against respiratory disease (2.0 ml s.c. injection of Vista Once SQ; Merck Animal Health, Millsboro, DE, USA) and clostridiosis (5.0 ml s.c. injection of Covexin 8®; Merck Animal Health), orally (2.5 ml/50 kg of body weight, Safe Guard®; Merck Animal Health) and injectable dewormed (7.0 ml s.c. injection of Dectomax®; Zoetis, Parsippany, NJ, USA), and received 80 mg of trenbolone acetate and 16 mg estradiol implant (Revalor IS®; Merck Animal Health).

Steers were allocated to 44 soil-surfaced pens (12 × 35 m) based on processing order (four pens each time; 20 heads/pen) and then treatments were randomly assigned to pens. One pen of each treatment contained 15 steers/pen. Pens were equipped with automatic water fountains (CattleMaster 480; Ritchie Inc., Conrad, IA, USA) and 11 m of feed bunk space.

Treatments consisted of a basal finishing diet fed as total mixed ration (TMR; Table 1) with or without the addition of either a single feed additive or a combination of additives on the diet DM basis: control (CTL; no feed additives were added to the basal diet); monensin at 26 mg/kg DM (MON; Rumensin®, Elanco Animal Health); a blend of cinnamaldehyde, eugenol, and capsicum (MON + XT; 26 mg/kg DM and 120 mg of a commercial product/kg DM); and the combination of monensin and the blend of cinnamaldehyde, eugenol, and capsicum (MON + XT; 26 mg/kg DM and 120 mg of a commercial product/kg DM, respectively).

Steers were adapted to the finishing diet during the first 19 days of the experiment using three step-up diets that gradually decreased the alfalfa hay from 33% (seven days), to 24.3% (seven days), and 15.4% (five days) of DM basis.

The basal diet (Table 1) was formulated to meet the nutrient requirements for finishing cattle (NASEM 2016) and contained 7% alfalfa hay and 93% concentrate. Each ration was mixed individually using a feed wagon (Roto-Mix 414-14, Dodge City, KS, USA) and delivered once a day at 0800 h. To prevent diet contamination, CTL was mixed prior XT, followed by MON and MON + XT, and the feed wagon was cleaned between loads. A flush diet with no feed additives was fed at the end of the day to cull animals not associated with the stud. Feed bunks were visually evaluated each day and feed delivery was adjusted so that feed bunks contained trace amounts of feed to no feed at 0630 h each day (Lopez et al. 2018). Treatments were added into diets during the entire experiment. Steers were re-implanted on day 55 (200 mg of trenbolone acetate and 20 mg estradiol; Revalor 200®; Merck Animal Health) and ractopamine hydrochloride (110 mg/steer daily; Optaflexx®, Elanco Animal Health) was fed for all animals during the last 28 days of the experiment. No tylosin was used in this trial.

During the study, animal health was evaluated daily by implementing a 4-point scale method (‘DART system’) based on depression, anorexia, respiration and temperature as described by Step et al. (2008) and Wilson et al. (2015). Calves with signs of morbidity based on the DART system were removed from their pens and further assessed to determine whether medical treatment was warranted as described by Lopez et al. (2018). Briefly, calves warranted medical treatment if they scored 2 or above using a severity score of 0 (no signs) to 3 (severe signs) for any of the DART system, had a rectal temperature ≥40.5°C or had a loss or no BW gain since their previously recorded BW. The first antibiotic treatment was a combination of florfenicol and flunixin meglumine (s.c. injection of Resflor Gold®; Merck Animal Health at 6.0 ml/45 kg BW). If a second medical treatment was warranted, steers received cefotiofur crystalline free acid (s.c. injection of Excede; Zoetis at 1.5 ml/45 kg BW). Steers were assigned to 5-day moratorium before a second antimicrobial treatment. Steers warranting further treatment were removed from the study, placed in a hospital pen and treated under the direction of a veterinarian.

The day before shipping, steers were fed 2/3 of the last 5 days’ average pen DMI. The final BW was recorded using a platform scale (pen weight; Survivor RS, Rice Lake Weighing Systems, Rice Lake, WI, USA) for two consecutive days to adjust for digestive tract fill. An independent certified scale company have checked the scales used in this trial before the beginning of the experiment. The ADG was calculated using the initial and final BW and feed efficiency (G:F) was calculated as the ratio of ADG to DMI. Steers were transported ∼230 km (3 h on truck) to a commercial abattoir (Tyson Fresh Meats, Inc., Amarillo, TX, USA), harvest in the following day and hot carcass weight (HCW) and liver score were collected. After 24 h of chilling, carcass data including marbling score, USDA quality grade, 12th rib fat depth, Longissimus Muscle (LM) area, kidney, pelvic, and heart (KPH) fat, and calculated yield grade were collected by trained personnel from the Beef Carcass Research Center.

### Table 1. Ingredient and chemical composition of experimental diets (DM basis).

| Item                              | Step1 | Step2 | Step3 | Finishing diet |
|-----------------------------------|-------|-------|-------|----------------|
| **Ingredients, %**                |       |       |       |                |
| Steam-flaked corn                 | 40.3  | 47.5  | 54.9  | 63.3           |
| Alfalfa hay                       | 33.0  | 24.3  | 15.4  | 6.93           |
| Wet corn gluten feed             | 22.5  | 22.5  | 22.5  | 22.5           |
| Starter supplement                | 4.20  | 4.70  | 5.17  |               |
| Finisher supplement               |       |       |       | 4.24           |
| Tallow                            | −     | 1.00  | 2.03  | 3.03           |
| **Analysed composition**          |       |       |       |                |
| Dry matter                        | 77.7  | 78.2  | 78.8  | 78.4           |
| Crude protein                     | 14.6  | 13.6  | 13.0  | 14.6           |
| Crude fibre                       | 13.6  | 10.9  | 8.19  | 6.10           |
| Ether extract                     | 3.26  | 4.73  | 6.20  | 8.03           |
| Ca, %                            | 0.87  | 0.77  | 0.67  | 1.01           |
| P, %                              | 0.44  | 0.44  | 0.44  | 0.46           |
| Total digestible nutrients        | 75.0  | 79.5  | 84.0  | 88.3           |
| Net energy maintenance            | 1.56  | 1.68  | 1.80  | 1.92           |
| Net energy gain, Mcal/kg          | 0.95  | 1.06  | 1.18  | 1.29           |

1 Steers were adapted to the finishing diet during the first 19 days of using 3 step-up diets: Step 1: fed during first seven days; Step 2: fed during seven days following Step 1; Step 3: fed during five days following Step 2.

2 Sweet Bran (Cargill Inc., Minneapolis, MN, USA).

3 Composed (DM basis) of 70 g/kg Ca, 6.1 g/kg P, 8.3 g/kg K, 7.9 g/kg S, 50 g/kg salt, 346,000 IU/kg vitamin A; 34,700 IU/kg vitamin D, 1388 IU/kg vitamin E, 92 g/kg NPN and trace minerals to meet the requirements specified by NASEM (2016).

4 Composed (DM basis) of 136 g/kg Ca, 3.5 g/kg P, 5.1 g/kg K, 6.7 g/kg S, 50 g/kg salt, 110,670 IU/kg vitamin A, 11,070 IU/kg vitamin D, 110 IU/kg vitamin E, 403 g/kg NPN and trace minerals to meet the requirements specified by NASEM (2016).

5 Estimated using tabular values (NASEM 2016).
Table 2. Effects of supplemental phytomolecules (a blend of cinnamaldehyde, eugenol, and capiscum) on growth performance of finishing beef steers.

| Item                        | Treatments1 | Orthogonal contrasts, P-value2 |
|-----------------------------|-------------|--------------------------------|
|                             | CTL        | MON    | XT     | MON + XT | SEM2 | 1  | 2   | 3 |
| Initial body weight, kg     | 335        | 337    | 333    | 333      | 7.30 | 0.92 | 0.71 | 0.88 |
| Final body weight, kg3      | 614        | 622    | 616    | 631      | 6.13 | 0.15 | 0.90 | 0.12 |
| Dry matter intake, kg       | 8.80       | 8.88   | 8.90   | 8.77     | 0.082 | 0.60 | 0.80 | 0.23 |
| Average daily gain, kg      | 1.92       | 1.96   | 1.94   | 2.03     | 0.090 | 0.58 | 0.87 | 0.48 |
| Feed efficiency4            | 0.218      | 0.220  | 0.218  | 0.230    | 0.010 | 0.68 | 0.85 | 0.31 |

1CTL, no feed additive; MON, sodium monensin (Rumensin®, 26 mg/kg DM, Elanco Animal Health, Indianapolis, IN, USA); XT, Xtract Ruminant® 7065 (120 mg of commercial product/kg DM, Pancosma SA, Geneva, Switzerland).  
2Pooled standard error of the mean, n = 11 pens for CTL, 10 pens for MON, 12 pens for XT and 11 pens for MON + XT.  
3Orthogonal contrast: 1, CTL vs. others; 2, MON vs. XT; 3, average of MON and XT vs. MON + XT.  
4Average of two consecutive days.  
5Average daily gain to dry matter intake ratio (G:F).

Table 3. Effects of supplemental phytomolecules (a blend of cinnamaldehyde, eugenol, and capiscum) on carcass traits of finishing beef steers.

| Item                        | Treatments1 | Orthogonal contrasts, P-value2 |
|-----------------------------|-------------|--------------------------------|
|                             | CTL        | MON    | XT     | MON + XT | SEM2 | 1  | 2   | 3 |
| Hot carcass weight, kg      | 376        | 380    | 376    | 376      | 3.04 | 0.64 | 0.43 | 0.61 |
| Dressing percent4           | 61.2       | 61.1   | 61.1   | 59.6     | 0.484 | 0.24 | 0.96 | 0.01 |
| Ribeye, cm²                 | 95.0       | 92.9   | 94.2   | 92.3     | 1.27 | 0.67 | 0.45 | 0.44 |
| Fat, mm                     | 11.2       | 11.5   | 11.0   | 11.2     | 0.310 | 0.62 | 0.28 | 0.98 |
| KPH5, %                     | 2.99       | 2.98   | 2.99   | 2.99     | 0.010 | 0.76 | 0.64 | 0.85 |
| Marbling score6             | 43.8       | 45.0   | 44.4   | 44.4     | 0.560 | 0.21 | 0.44 | 0.66 |
| Moderate, %                 | 2.51       | 4.69   | 2.22   | 2.45     | 1.23 | 0.76 | 0.20 | 0.61 |
| Modest, %                   | 19.7       | 21.0   | 16.0   | 16.3     | 2.71 | 0.52 | 0.19 | 0.51 |
| Small, %                    | 46.5       | 43.2   | 52.0   | 58.1     | 3.63 | 0.28 | 0.09 | 0.02 |
| Slight, %                   | 29.6       | 29.8   | 27.0   | 22.0     | 3.78 | 0.43 | 0.61 | 0.17 |
| Preliminary yield grade (PYG)| 3.07       | 3.08   | 3.04   | 3.07     | 0.029 | 0.79 | 0.34 | 0.88 |
| Yield grade                 | 2.44       | 2.60   | 2.46   | 2.58     | 0.079 | 0.25 | 0.20 | 0.64 |
| Quality grade               | 0.505      | 1.05   | 1.78   | 0.975    | 0.703 | 0.41 | 0.54 | 0.68 |
| Prime, %                    | 29.7       | 30.3   | 27.0   | 21.8     | 3.12 | 0.44 | 0.55 | 0.14 |
| Select, %                   | 22.2       | 25.8   | 18.2   | 18.5     | 2.86 | 0.64 | 0.07 | 0.35 |
| Premium choice, %           | 46.5       | 42.6   | 52.0   | 57.6     | 3.62 | 0.32 | 0.08 | 0.03 |
| Choice, %                   | 5.11       | 5.13   | 5.09   | 5.10     | 0.031 | 0.99 | 0.36 | 0.96 |

1CTL, no feed additive; MON, sodium monensin (Rumensin®, 26 mg/kg DM, Elanco Animal Health, Indianapolis, IN, USA); XT, Xtract Ruminant® 7065 (120 mg of commercial product/kg DM, Pancosma SA, Geneva, Switzerland).  
2Pooled standard error of the mean, n = 11 pens for CTL, 10 pens for MON, 12 pens for XT and 11 pens for MON + XT.  
3Orthogonal contrast: 1, CTL vs. others; 2, MON vs. XT; 3, average of MON and XT vs. MON + XT.  
4Average of two consecutive days.  
5Marbling score: 30, slight; 40, small; 50, modest; 60, moderate; 70, slightly abundant.

(West Texas A&M University, Canyon, TX, USA). The dressing percentage was calculated by dividing the average HCW of the steers in the pen by the final BW of the pen.

2.3 Laboratory analysis

Samples of diets were collected every two weeks and analysed for DM at 105 °C (method 934.01; AOAC 2005), ether extract (method 920.39; AOAC 2005), crude fibre (method 978.10, AOAC 2005), crude protein (method 976.05, AOAC 2005), Ca and P (method 985.01; AOAC 2005) at a commercial laboratory (SDK laboratories, Hutchinson, KS, USA). Rumensin® and Xtract Ruminant® 7065 levels were analysed by Elanco and Pancosma, respectively, every two weeks.

2.4 Statistical analysis

Data were analysed using the MIXED procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC, USA) as a completely randomized design experiment. Pen was considered the experimental unit. The model used for the analysis of growth performance included the fixed effect of treatment and the random effect of pen (treatment). The model used for the analysis of carcass characteristics included the fixed effect of treatment and the random effect of animal(pen) and pen(treatment). The Kenward–Roger approximation method was used to determine the denominator degrees of freedom for testing fixed effects. Marbling score, quality grade and liver score, and health data (morbidity and mortality) were analysed using a binomial distribution by the GLIMMIX procedure of SAS. The link function was logit and the degree of freedom was adjusted using the Kenward–Roger method. Orthogonal contrasts were used to evaluate: (1) effects of feed additives (CTL vs. average of MON, XT and MON + XT); (2) type of feed additive (MON vs. XT) and (3) interaction between feed additives (average of MON and XT vs. MON + XT). Results were reported as LS means. Differences were declared significant when P < 0.05; trends were discussed when 0.05 < P ≤ 0.10.
Table 4. Effects of supplemental phytomolecules (a blend of cinnamaldehyde, eugenol, and capsicum) on liver abnormality assessment of finishing beef steers.

| Liver score4 | Treatments1 | Orthogonal contrast, P-value3 |
|--------------|-------------|-------------------------------|
|              | CTL         | MON                          | XT                           | MON + XT | SEM2 | 1 | 2 | 3 |
| Normal       | 0.95        | 0.48                        | 0.65                        | 0.67      | 0.28 | 0.86 | 0.05 | 0.17 | 0.27 |
| A           | 0.94        | 0.66                        | 0.72                        | 0.65      | 0.18 | 0.20 | 0.17 | 0.20 | 0.17 |
| A+          | 0.67        | 0.72                        | 0.81                        | 0.65      | 0.18 | 0.20 | 0.17 | 0.20 | 0.17 |
| A + AD      | 0.67        | 0.72                        | 0.81                        | 0.65      | 0.18 | 0.20 | 0.17 | 0.20 | 0.17 |
| A + OP      | 0.67        | 0.72                        | 0.81                        | 0.65      | 0.18 | 0.20 | 0.17 | 0.20 | 0.17 |
| Other5       | 0.67        | 0.72                        | 0.81                        | 0.65      | 0.18 | 0.20 | 0.17 | 0.20 | 0.17 |

1CTL, no feed additive; MON, sodium monensin (Rumensin®, 26 mg/kg DM, Elanco Animal Health, Indianapolis, IN, USA); XT, Xtract Ruminant® 7065 (120 mg of commercial product/kg DM, Pancosma SA, Geneva, Switzerland); MON + XT, combination of sodium monensin (Rumensin®, 26 mg/kg DM, Elanco Animal Health, Indianapolis, IN, USA) and Xtract Ruminant® 7065 (120 mg of commercial product/kg DM, Pancosma SA, Geneva, Switzerland).
2Pooled standard error of the mean, \( n = 11 \) pens for CTL, 10 pens for MON, 12 pens for XT and 11 pens for MON + XT.
3Orthogonal contrast: 1 = CTL vs. others; 2 = MON vs. XT; 3 = average of MON and XT vs. MON + XT.
4According to Brown and Lawrence (2010). Normal, edible liver; A, –, 1 or 2 small abscesses or inactive scars; A, 1–2 large abscesses or multiple small abscesses; A+, multiple large abscesses; A + AD, liver adhered to part of the gastrointestinal tract or diaphragm or both; A + OP, ruptured abscesses.
5Included A + Cirrho, A + Flukes, A + OpenFl, Contamin, Flukes, Telangie (Brown and Lawrence, 2010).

3. Results

Treatments did not affect growth performance (final BW, DMI, ADG and G:F) of finishing steers \((P \geq 0.12; Table 2)\).

The dressing percentage was lower for steers fed the combination of MON + XT than MON and XT \((P = 0.01; Table 3)\). There were no treatment effects on the marbling score \((P \geq 0.21; Table 3)\). Feeding XT tended to increase the percentage of the carcass with a small marbling score compared to MON \((P = 0.09; Table 3)\). Also, feeding the combination of MON + XT increased the percentage of the carcass with a small marbling score compared to MON and XT \((P = 0.02; Table 3)\).

The proportion of carcass grading premium choice tended to be greater for steers fed MON compared to XT \((P = 0.07; Table 3)\). This result was reversed for the proportion of carcass grading choice, that tended to be greater for steers fed XT compared to MON \((P = 0.08; Table 3)\). No other effects of treatments on carcass characteristics were noted \((P \geq 0.14; Table 3)\).

Treatments also did not affect liver score \((P \geq 0.14; Table 4)\) and morbidity \((P \geq 0.12; Table 5)\). Death loss tended to be greater for animals fed CTL compared to other treatments \((P = 0.08; Table 5)\). Feeding XT tended to increase death loss compared to MON \((P = 0.09; Table 5)\).

4. Discussion

In a meta-analysis conducted by Duffield et al. (2012) using a total of 40 peer-reviewed articles and 24 additional trial reports, feeding monensin for growing and finishing beef cattle at the average concentration of 28.1 mg/kg DM improved feed efficiency in ~6.4%, as a result of 3% decrease in DMI and 2.5% increase in ADG. Monensin can change the ratio of VFA in the rumen by increasing propionic acid production and reducing the molar proportion of acetic and butyric acids (Ellis et al. 2012), thus increasing the glucose supply to the animal. Contrarily, the lack of response to monensin supplementation in studies involving feedlot cattle was also reported. Differences in the efficacy of monensin, specially effects on DMI, are not well understood (Depenbusch et al. 2008). According to Montano et al. (2015), supplementing monensin at 26 mg/kg DM did not affect the DMI and tended to increase ADG of finishing steers fed diets containing 12% roughage and 88% concentrate (15% dried distillers grains plus solubles; DM basis). Felix et al. (2012) also did not report differences in DMI, ruminal pH and VFA concentration for steers fed monensin (22–44 mg/kg DM) in diets containing 10% corn silage and 90% concentrate (60% dried distillers grains plus solubles; DM basis). A significant interaction between tallow and monensin was observed by Clarly et al. (1993). Supplementing monensin in finishing diets containing tallow (4% DM) did not affect feed efficiency, but did increase the feed efficiency by 4% in diets with no tallow. According to Depenbusch et al. (2008), monensin may not be as effective when used in steam-flaked corn diets with 25% wet distillers grains with solubles. In the current trial, animals were fed a basal diet containing 22.5% wet distillers grains with solubles and 3% tallow, and these might be associate with the lack of response to monensin supplementation.

Plant-derived extracts, such as thymol, limonene, eugenol, vanillin, cinnamaldehyde and capsicum, have antimicrobial, anti-inflammatory and antioxidant effects and can enhance rumen fermentation of cattle consuming high-concentrate diets (Bakkali et al. 2008; Benchaa et al. 2020; Cardozo et al. 2006). Some specific phytomolecules or blends of phytomolecules may be used as alternatives to ionophores such as...
monensin (Fandiño et al. 2008). However, due to the great number of different phytomolecules and doses included in the finishing diets, the effects on cattle growth performance and feed efficiency are quite variable (Khiaosa-ard and Zebeli 2013; Meyer et al. 2009). Cinnamaldehyde can inhibit gram-positive (Ottara et al. 1997) and gram-negative bacteria (Helander et al. 1998), and decrease the ruminal proportion of acetate (Busquet et al. 2005). Eugenol can decrease the proteolytic activity in the rumen (Castillejos et al. 2006; Yang et al. 2010) and capsicum supplementation resulted in increased in vitro propionate production (Cardozo et al. 2006). According to Rodriguez-Prado et al. (2012), capsicum extract stimulated DMI and modified the pattern of DMI in beef cattle fed high-concentrate diets. However, supplementing the same blend of cinnamaldehyde, eugenol and capsicum used herein did not affect DMI compared to animals fed monensin, but improved ADG during the last 39 days of feeding period compared to monensin (Geraci et al. 2012). Also, supplementing cinnamaldehyde, eugenol and capsicum did not increase the growth performance of newly weaned feedlot calves compared to the control diet, without feed additives (de Souza et al. 2018).

Similar to our finding, no advantages or positive effects on growth performance and carcass characteristics were observed from the combination of monensin and phytomolecules compared with feeding monensin or phymolecules separately (Benchaar et al. 2006; Meschiatti et al. 2019). Ionophores usually have little or no effects on marbling score and yield grade (Goodrich et al. 1984). Differences in dressing percentage observed herein for animals fed the combination of MON + XT compared to MON and XT can also be related to the numerical difference in final BW.

Information regarding the effects of phytomolecules on liver abnormality is scare, and feeding monensin is not expected to reduce liver abesses (Nagaraja and Chengkappa 1998), so no differences between treatments were expected for the prevalence of liver abscesses.

According to Bartely et al. (1983), monensin is effective in controlling bloatting, that is often reported as an important cause of death in feedlot cattle. Bloat usually occurs when the animal is prevented from expelling ruminal gas, which places pressure on the diaphragm and lungs, thereby affecting breathing and potentially resulting in death (Galyean and Rivera 2003). Monensin can inhibit Gram-positive bacteria, specially the lactic acid and mucopolysaccharide-producing species (e.g. Streptococcus bovis and Lactobacillus sp.) (Cheng et al. 1998) and reduce feed intake variation (Stock et al. 1995), and meal size and frequency of meals (González et al. 2012), therefore reducing the risks of bloat. Limited research exists describing the bacterial activity or management effects (e.g. feed intake fluctuation) of natural compounds, such as phytomolecules, on bloat inhibition in feedlot cattle, but this might explain the tendency to decrease death loss for animals fed MON compared to XT in the current study.

5. Conclusion

Supplementing a blend of phytomolecules containing cinnamaldehyde, eugenol, and capsicum resulted in similar growth performance as steers fed monensin or not supplemented with any feed additive.

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ORCID

Vinicius N. Gouveia http://orcid.org/0000-0002-8317-4908

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