Interaction of early metabolizable protein supplementation and virginiamycin on feedlot growth performance and carcass characteristics of calf-fed Holstein steers

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ABSTRACT
One hundred sixty-eight Holstein steer calves (133.4 ± 7.9 kg) were used to evaluate the influence of virginiamycin (VM) supplementation on cattle growth performance and liver abscess incidence, and the effect of feeding 100% vs. 87% of metabolizable protein (MP) requirements during the initial 112 d on growth performance, efficiency of energy utilization, and carcass characteristics. Steers were balanced by weight and assigned to 28 pens (6 steers/pen). During the initial 112-d feeding period, dietary treatments consisted of two levels of MP (100% vs. 87% of expected requirements) supplemented with or without 22.5 mg/kg VM in a 2 × 2 factorial arrangement. There were no VM × MP supplementation interactions (P ≥ 0.14) on any of the parameters measured in both experiments. Calf-fed Holstein steers supplemented with VM increased (P ≤ 0.03) overall average daily gain (ADG), feed efficiency (G:F), observed/expected net energy (NE) values for maintenance and gain, and final body weight (BW). Calf-fed VM also increased (P ≤ 0.04) carcass weight, dressing percent, and longissimus muscle area. However, there was no effect (P ≥ 0.22) of VM supplementation on any other carcass characteristics. Calf-fed Holstein steers fed 100% MP requirements during the initial 112-d feeding period had greater (P ≤ 0.02) ADG, G:F, observed/expected NE values for maintenance and gain, and live BW compared with steers fed 87% of the expected MP requirements. However, there was no effect (P ≥ 0.17) of MP supply during the initial 112-d period on overall (342 d) growth performance measurements. The incidence of liver abscesses was low (averaging 7.7%) and not affected by dietary treatments. We conclude that, independent of MP supplies, supplemental VM enhances overall growth performance and efficiency of energy utilization of calf-fed Holstein steers.

Key words: feedlot, Holstein, performance, protein, virginiamycin

INTRODUCTION
Calf-fed Holstein steers in the southwestern United States are usually fed diets containing 12% to 13% of crude protein (Zinn et al., 2005; Vasconcelos and Galyean, 2007), with urea as the primary or sole source of supplemental N. Although these diets meet average metabolizable protein (MP) and amino acid requirements for the overall feedlot period (300 to 350 d; NASEM, 2000), they do not meet the amino acid requirements of calf-fed Holstein steers during the first 112 to 168 d of the early growing phase of those animals (Zinn and Shen, 1998; Zinn et al., 2007). Recently, Torrentera et al. (2017) and Montaño et al. (2019) concluded that the addition of rumen-protected amino acids (methionine and lysine) to the diet of growing Holstein calves might enhance gain efficiency and dietary energetics during the early growing phase. According to Loerch et al. (1983) and Stock et al. (1981), blood meal (BM) has above 82% of ruminal undegradable protein. Moreover, Titgemeyer et al. (1989) stated that among four different protein sources in the diet, BM had the greatest amount of lysine reaching the duodenum of beef steers.

Virginiamycin (VM) is an antimicrobial additive that inhibits the growth of Gram-positive bacteria (Cocito, 1979; De Araújo et al., 2016) and the growth of ruminal lactic acid-producing bacteria, thereby reducing the risk of lactic acidosis and associated digestive dysfunctions (Owens et al., 1998). Previous research has also demonstrated that VM is an effective tool to control liver abscess incidence in feedlot cattle (Rogers et al., 1995; Nagaraja and Chengappa, 1998; Nagaraja and Lechtenberg, 2007, Tedeschi and Gorocica-Buenfil, 2018). In an earlier study (Salinas-Chavira et al., 2016), enhancements in gain efficiency and estimated dietary NE were augmented in diets formulated to meet metabolizable amino acid requirements during the initial 112 d on feed. Therefore, the objective of the present study was to further evaluate the influence of VM supplementation on cattle growth performance and liver abscess incidence, and the effect of feeding 100% vs. 87% of MP requirements during the initial 112 d on growth performance, efficiency of energy utilization, and carcass characteristics of calf-fed Holstein steers.

MATERIALS AND METHODS
Animal care and handling techniques were approved by the University of California Animal Care and Use Committee (#20548).
Table 1. Composition of experimental diets (DM basis)

| Item                                  | 0 VM† | 22.5 mg VM   | Conventional | MP‡ | Conventional | MP |
|---------------------------------------|-------|--------------|--------------|-----|--------------|----|
| Ingredient composition, % DM          |       |              |              |     |              |    |
| Sorghum Sudan                         | 8.00  | 8.00         | 8.00         | 8.00|              |    |
| Alfalfa hay                           | 4.00  | 4.00         | 4.00         | 4.00|              |    |
| Tallow                                | 2.50  | 2.50         | 2.50         | 2.50|              |    |
| Molasses, cane                        | 4.00  | 4.00         | 4.00         | 4.00|              |    |
| Dry distillers grains plus solubles   | 10.00 | 7.00         | 10.00        | 7.00|              |    |
| Porcine blood meal                    | 0.00  | 3.00         | 0.00         | 3.00|              |    |
| Steam-flaked corn                     | 68.09 | 68.09        | 68.06        | 68.06|             |    |
| Urea                                 | 1.15  | 1.15         | 1.15         | 1.15|              |    |
| Limestone                            | 1.68  | 1.68         | 1.68         | 1.68|              |    |
| Dicalcium phosphate                  | 0.10  | 0.10         | 0.10         | 0.10|              |    |
| Magnesium                            | 0.15  | 0.15         | 0.15         | 0.15|              |    |
| Vmax                                 | 0.00  | 0.00         | 0.03         | 0.03|              |    |
| TM salt                              | 0.30  | 0.30         | 0.30         | 0.30|              |    |
| Nutrient composition, % DM basis      |       |              |              |     |              |    |
| Dry matter                           | 87.90 | 87.90        | 87.90        | 87.90|             |    |
| NE 0.90 Mcal/kg                      | 2.21  | 2.19         | 2.21         | 2.19|              |    |
| NEg 0.90 Mcal/kg                     | 1.54  | 1.52         | 1.54         | 1.52|              |    |
| Crude protein, %                      | 14.30 | 16.20        | 16.20        | 16.20|             |    |
| Rumen DIP, %                          | 63.80 | 57.30        | 63.80        | 57.30|             |    |
| Rumen UIP, %                          | 36.20 | 42.70        | 36.20        | 42.70|             |    |
| Ether extract, %                      | 6.70  | 6.40         | 6.70         | 6.40|              |    |
| Ash, %                                | 5.78  | 5.71         | 5.78         | 5.71|              |    |
| Nonstructural CHO, %                  | 58.00 | 57.50        | 58.00        | 57.50|             |    |
| NDF, %                                | 17.70 | 16.30        | 17.70        | 16.30|             |    |
| Calcium, %                            | 0.80  | 0.81         | 0.80         | 0.81|              |    |
| Phosphorus, %                         | 0.35  | 0.34         | 0.35         | 0.34|              |    |
| Potassium, %                          | 0.77  | 0.75         | 0.77         | 0.75|              |    |
| Magnesium, %                          | 0.28  | 0.27         | 0.28         | 0.27|              |    |

CHO: carbohydrates; DIP: degradable intake protein; NDF: neutral detergent fiber; UIP: undegradable intake protein.

†Trace mineral salt contained: CaSO4, 0.068%; CuSO4·5H2O, 0.068%; FeSO4·7H2O, 1.04%; ZnO, 0.75%; MnSO4·H2O, 1.07%; KI, 0.052%; and NaCl, 93.4%.

‡Based on tabular values for individual feed ingredients (NASEM, 2000).

CHO: carbohydrates; DIP: degradable intake protein; NDF: neutral detergent fiber; UIP: undegradable intake protein.

Energy gain (EG, Mcal/d) was calculated by the equation: $EG = 0.0557W^{0.75} \times ADG^{1.997}$, where EG is the daily deposited energy, and W is the body weight (BW; NASEM, 1984).

The determination of ADG, interim and final weights were reduced by 4% to account for digestive tract fill. The final shrunk weight was carcass adjusted by dividing HCW by the decimal fraction of the average dressing percentage of all steers in the study (0.621).

Statistical Design and Analysis

Data for growth performance variables were analyzed in a randomized complete block design, with a 2 × 2 factorial arrangement of treatments, considering initial shrunk weight groupings for blocks, and pen as an experimental unit, according to the following statistical model:

$Y_{ij} = \mu + B_i + T_j + e_{ij}$, where $\mu$ is the common experimental effect, $B_i$ represents initial weight block effect, $T_j$ represents dietary treatment effect, and $e_{ij}$ represents the residual error.
Protein and virginiamycin for Holsteins steers

Treatment effects on cattle growth performance and dietary NE values are presented in Table 2. Supplementation with 22.5 mg/kg VM increased \( P \leq 0.03 \) the overall ADG, G:F, observed/expected NE values for maintenance and gain, and final BW. Overall, ADG (1.44 kg/d) was in close agreement with the projected value (1.43 kg/d; Torrentera et al., 2016). Similarly, overall dietary NE estimated from growth performance measures agreed (98%) with expected NE values estimated based on tabular feed values from NASEM (2000).

Similar to the current study, Salinas-Chavira et al. (2016) observed that VM supplementation increased gain efficiency (G:F) and dietary NE when calf-fed Holstein steers were supplemented with 22.5 mg/kg of VM for 308 d. However, Latack et al. (2021) reported no effect of VM supplementation on calf-fed Holstein steers feedlot growth performance when VM was fed at 16 mg/kg of dry matter (DM) for 321 d. In a summary review study by Rogers et al. (1995), the authors reported that maximal growth performance response to VM in traditional beef breeds was observed at levels of supplementation of 19.3 to 27.3 mg/kg of diet DM. Therefore, based on the current study and previous research from our group (Salinas-Chavira et al., 2009, 2016; Latack et al., 2021), supplementation of growing-finishing diet to calf-fed Holstein steers with VM enhances cattle growth performance in the feedlot when supplemented at 22.5 mg/kg of DM.

Compared with non-supplemented calves, supplementation with 22.5 mg/kg of DM of VM increased \( P \leq 0.04 \) carcass weight, dressing percentage, and LM area (Table 3). These enhancements were consistent with the increase in final BW (Table 2). Consistent with previous studies involving calf-fed Holstein steers (Salinas-Chavira et al., 2009, 2016; Latack et al., 2021), the influence of supplemental VM on kidney, pelvic, and heart (KPH), fat thickness, and marbling score was not appreciable \( P \geq 0.22 \).

Although VM supplementation has been reported as an effective method to control the incidence of liver abscesses in feedlot cattle (Rogers et al., 1995; Nagaraja and Lechtenberg, 2007, Tedeschi and Gorocica-Buenfil, 2018), there was no effect \( P = 0.14 \) of VM supplementation on the percentage of abscessed livers (Table 3). However, the incidence of liver abscesses was low (averaging 7.7%) compared with values of 30% or greater previously reported in the literature (Rogers et al., 1995; Tedeschi and Gorocica-Buenfil, 2018). Rogers et al. (1995) and Tedeschi and Gorocica-Buenfil (2018) noted that feedlot cattle management practices influence the relative effectiveness of VM. Supplemental VM did not affect \( P = 0.29 \) calf morbidity, which was likewise low, averaging 3%.

Metabolizable Protein

Calf-fed Holstein steers fed 100% of the expected MP requirements during the initial 112-d feeding period (NASEM, 2000) had greater \( P \leq 0.02 \) ADG, G:F, observed/expected NE values for maintenance and gain, and live BW at 112 d compared with steers fed 87% of the expected MP requirements (Table 2). Previous research has reported that as MP supply increased, cattle feedlot growth performance also increased, reaching a plateau when supplies of limiting amino acids are met (Zinn and Owens, 1993; Zinn et al., 2007). Similar to the current study, Zinn et al. (2007) and Salinas-Chavira et al. (2016) observed that meeting MP requirements enhanced cattle growth performance during the initial growing phase of calf-fed Holstein steers compared with conventional steam-flaked corn-based diet with urea as the sole source of supplemental N. Although cattle in the 100% MP group had greater growth performance during the first 112 d compared with the control group, observed NE values for cattle fed a diet meeting MP requirement were still less than expected based on NASEM (2000; 86.5% for maintenance and 83.5% for gain) during the initial 112-d period.

Zinn et al. (2007) and Salinas-Chavira et al. (2016) observed that when calf-fed Holstein steers were supplemented with 100% MP requirements during the growing phase, the enhancement in growth performance during that period remained appreciable at the time of harvest (more than 300 d on feed). In contrast, in the present study, there was no effect \( P \geq 0.17 \) of early supply of MP on the overall (342 d) cattle growth performance (Table 2). The basis for this effect is not certain but may reflect the somewhat less-than-expected enhancement in gain efficiency as well as diluting effect of the protracted overall days on feed.

Moreover, in order to meet 100% of MP requirements of growing calf-fed Holstein steers during the initial 112 d on feed, porcine BM was supplemented at 3% of the diet (DM basis), replacing dry distillers’ grains plus solubles. Previous research has reported that BM supplementation enhances the amount of ruminal undegradable protein compared with other protein sources, such as soybean meal and canola meal (Loerch et al., 1983; Tigemeyer et al., 1989; Piepenbrink and Schingoethe, 1998). However, in its drying process, BM undergoes varying degrees of nonenzymatic browning (e.g., Maillard reactions), thereby decreasing the amount of amino acids (particularly lysine) available for absorption in the small intestine. According to Tigemeyer et al. (1989), BM had the largest amount of nonavailable nitrogen for either ruminal degradation or small intestine absorption when compared with other protein sources. With NASEM (2000), it is assumed that 80% of dietary protein that escapes ruminal degradation is digested in the small intestine. Consistent with Tigemeyer et al. (1989), it appears that this may not have been the case in the present study and may explain the less-than-expected enhancement in growth performance and observed/expected dietary energy during the initial 112-d period.

Supplemental MP requirements during the initial 112-d period did not affect \( P \geq 0.33 \) dressing percentage, KPH, fat thickness, marbling score, or incidence of liver abscess. However, there was a trend \( P = 0.08 \) for greater (5.6%) LM area of cattle supplemented to meet 100% of the expected MP requirements during the initial 112-d feeding period (Table 3). Likewise, Zinn et al. (2000) and Zinn et al. (2007) observed that enhancing the growth performance of calf-fed Holstein steers during the initial growing phase increased carcass LM area. In contrast, Salinas-Chavira et al. (2016) observed that although supplementation to meet MP requirements enhanced initial 112-d and overall 308-d...
Table 2. Treatment effects on growth performance and dietary NE energetics of feedlot steers

| Item                          | 0 VMylation1 | VMylation1 | 22.5 mg VM | SEM | P-value |
|-------------------------------|--------------|------------|------------|-----|---------|
|                               | Conventional | MP¶ | Conventional | MP | MP | VM |
| Days on test                  | 342          | 342        | 342        | 342 |    |    |
| Pen replicated                | 7            | 7          | 7          | 7   |    |    |
| Live weight, kg†              |              |            |            |     |       |
| Initial                       | 131.3        | 131.2      | 131.9      | 131.4 | 0.37 | 0.43 | 0.23 |
| 112 d                         | 275.7        | 284.2      | 279.4      | 284.7 | 2.3 | <0.01 | 0.36 |
| 224 d                         | 453.3        | 456.2      | 458.3      | 459.7 | 3.7 | 0.57 | 0.27 |
| Final                         | 616.5        | 613.3      | 629.9      | 631.4 | 6.9 | 0.90 | 0.03 |
| ADG, kg                       |              |            |            |     |       |
| 1 to 112 d                    | 1.29         | 1.37       | 1.32       | 1.37 | 0.02 | <0.01 | 0.46 |
| 112 to 224 d                  | 1.59         | 1.54       | 1.59       | 1.56 | 0.03 | 0.17 | 0.51 |
| 224 to 342 d                  | 1.38         | 1.33       | 1.45       | 1.45 | 0.03 | 0.46 | 0.01 |
| 1 to 342 d                    | 1.42         | 1.41       | 1.46       | 1.46 | 0.02 | 0.94 | 0.04 |
| DMI, kg/d                     |              |            |            |     |       |
| 1 to 112 d                    | 5.80         | 5.93       | 5.78       | 5.88 | 0.06 | 0.08 | 0.58 |
| 112 to 224 d                  | 8.42         | 8.34       | 8.25       | 8.35 | 0.11 | 0.96 | 0.48 |
| 224 to 342 d                  | 10.40        | 10.30      | 10.40      | 10.20 | 0.11 | 0.17 | 0.5  |
| 1 to 342 d                    | 8.26         | 8.23       | 8.18       | 8.18 | 0.08 | 0.85 | 0.41 |
| G:F                           |              |            |            |     |       |
| 1 to 112 d                    | 0.22         | 0.23       | 0.23       | 0.23 | 0.002 | 0.02 | 0.13 |
| 112 to 224 d                  | 0.19         | 0.18       | 0.19       | 0.19 | 0.003 | 0.13 | 0.23 |
| 224 to 342 d                  | 0.13         | 0.13       | 0.14       | 0.14 | 0.003 | 0.89 | <0.01 |
| 1 to 342 d                    | 0.17         | 0.17       | 0.18       | 0.18 | 0.002 | 0.97 | <0.01 |
| Dietary ME, Mcal/kg§          |              |            |            |     |       |
| Maintenance                   |              |            |            |     |       |
| 1 to 112 d                    | 1.84         | 1.89       | 1.88       | 1.91 | 0.02 | 0.05 | 0.10 |
| 112 to 224 d                  | 2.18         | 2.18       | 2.25       | 2.21 | 0.03 | 0.53 | 0.11 |
| 224 to 342 d                  | 2.15         | 2.13       | 2.24       | 2.28 | 0.03 | 0.77 | <0.01 |
| 1 to 342 d                    | 2.12         | 2.11       | 2.19       | 2.19 | 0.02 | 0.98 | <0.01 |
| Gain                          |              |            |            |     |       |
| 1 to 112 d                    | 1.21         | 1.25       | 1.24       | 1.26 | 0.01 | 0.05 | 0.10 |
| 112 to 224 d                  | 1.50         | 1.50       | 1.56       | 1.53 | 0.02 | 0.53 | 0.11 |
| 224 to 342 d                  | 1.48         | 1.46       | 1.56       | 1.59 | 0.03 | 0.77 | <0.01 |
| 1 to 342 d                    | 1.45         | 1.44       | 1.51       | 1.52 | 0.02 | 0.98 | <0.01 |
| Observed/expected dietary NE  |              |            |            |     |       |
| Maintenance                   |              |            |            |     |       |
| 1 to 112 d                    | 0.84         | 0.86       | 0.85       | 0.87 | 0.01 | <0.01 | 0.10 |
| 112 to 224 d                  | 0.99         | 0.99       | 1.02       | 1.00 | 0.01 | 0.53 | 0.11 |
| 224 to 342 d                  | 0.98         | 0.97       | 1.02       | 1.04 | 0.01 | 0.77 | <0.01 |
| 1 to 342 d                    | 0.96         | 0.96       | 0.99       | 1.00 | 0.01 | 0.86 | <0.01 |
| Gain                          |              |            |            |     |       |
| 1 to 112 d                    | 0.79         | 0.83       | 0.81       | 0.84 | 0.01 | <0.01 | 0.10 |
| 112 to 224 d                  | 0.99         | 0.99       | 1.02       | 1.00 | 0.02 | 0.53 | 0.11 |
| 224 to 342 d                  | 0.97         | 0.96       | 1.02       | 1.05 | 0.02 | 0.77 | <0.01 |
| 1 to 342 d                    | 0.95         | 0.95       | 0.99       | 1.00 | 0.01 | 0.86 | <0.01 |

DMI, dry matter intake.
†Live weight reduced by 4% to account for gut fill.
‡Calculated based on the cattle performance according to Zinn and Shen (1998).
‖VM: V-Max, Phibro Animal Health, Ridgefield Park, NJ.
§Conventional: Diet not supplemented with BM providing 87% of expected MP requirements during the initial 112-d feeding period (NASEM, 2000).
¶MP: Diet supplemented with 3% BM providing 100% of expected MP requirements during the initial 112-d feeding period (NASEM, 2000).
growth performance, it did not appreciably affect carcass characteristics.

**CONCLUSIONS**

Supplementation of a steam-flaked corn-based growing-finishing diet with 22.5 mg/kg VM enhanced the overall growth performance and efficiency of energy utilization of calf-fed Holstein steers during a 342-d feeding period. Supplementing to meet MP requirements during the initial 112 d on feed enhanced cattle growth performance and efficiency of energy utilization during that initial period. However, the long-term benefit of that response was not appreciable.

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**Conflict of interest statement**

The authors declare no conflict of interest.

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