EFFECT OF PROTEIN LEVEL, MONENSIN AND CALCIUM:PHOSPHORUS RATIO ON FINISHING STEERS

by

SUSAN K. DURHAM

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LITERATURE REVIEW

Steer Performance

Monensin for Finishing Steers

Monensin is a polyether antibiotic produced by a strain of *Streptomyces cinnamonensis* (Haney & Hoehn, 1967). It is an effective anticoccidial agent in poultry (Shumard & Callendar, 1967) and for severe cases in ruminants (Fitzgerald & Mansfield, 1973). Goodrich *et al*. (1976) summarized data from twenty-nine experiments involving 3,042 cattle. Monensin was fed at 0, 5, 10, 20, 25, 30 or 40 grams per ton. This resulted in 7.89, 7.38, 7.41, 7.31, 7.08, 7.23 and 7.22 kg ration dry matter per kg gain, respectively. Each monensin treatment required less feed per kg gain than the control cattle. Feed efficiency improvements were: 5 g/ton, 6.5%; 10 g/ton, 6.1%; 20 g/ton, 7.4%; 25 g/ton, 10.3%; 30 g/ton, 8.4%; and 40 g/ton, 8.5%. Average daily gains for the cattle fed 10, 20, 25, or 30 grams per ton were equal to or greater than cattle not consuming monensin. However, monensin at 40 grams per ton of ration reduced gain.

Greuter *et al*. (1976) reported on six growing and finishing trials utilizing 846 cattle. Feeding 10 grams per ton monensin improved daily gain by 4% and feed efficiency by 6% during the finishing phase but 30 grams per ton resulted in a 1% daily gain increase and 11% feed efficiency improvement. Thus, even though monensin decreased consumption, gains were equal to or greater than control groups. Brown et al. (1974) summarized the results of seven field trials using 0, 5, 10, 20, 30 or 40 grams per ton and observed feed intake (kg) and average daily gain (kg) to be 9.64, 1.06; 9.30, 1.09; 9.24, 1.06; 9.09, 1.06; 8.66, 1.06; and 8.61, 1.10; respectively. The trials varied in length from 112 to 179 days. These studies show optimum feed efficiency is achieved when monensin is fed at 30 grams per ton with no significant change in rate of gain. In feedlot trials involving 350 head, feeding 0, 5, 10, 20, 30 or 40 grams per ton resulted in feed to gain values of 11.06, 10.33, 10.17, 9.35 and 9.54, respectively. In all trials, feed intake decreased with increased monensin level (Raun et al., 1974a). Feed efficiency was improved 6% when steers were fed 300 mg per head per day (Gill et al., 1976) monensin with diets containing 14, 30 or 75% corn silage (dry matter basis). Utley et al. (1976) fed heifers in an 84 day finishing trial and observed 33 grams monensin per ton of ration resulted in a feed intake of 6.8 kg per day and an efficiency of 5.8. The control heifers consumed 7.8 kg per day and required 6.9 kg feed per kg gain. Boling et al. (1977) reported feed intake decreased as level of monensin increased. All treatments fed monensin were more efficient than the controls. Other researchers have shown similar findings (Embry & Swan, 1974; Farlin et al., 1975; Raun et al., 1974b; Riley et al., 1976; Bartley et al., 1979; Byers, 1979).

Maximum feed efficiency occurred at 33 ppm of air dry feed (Brown et al., 1974; Raun et al., 1974c). Some workers reported decreased gains at this level (Davis & Erhart, 1975; Farlin et al., 1975; Wilson et al., 1975). Yet, other researchers did not observe a decrease or increase in gain (Brown et al., 1974; Embry & Swan, 1974; Raun et al., 1974a; Sherrod et al., 1975; Davis & Erhart, 1976; Utley et al., 1976; Bartley et al., 1979; Byers, 1979). Hale et al. (1975) reported an increase in average daily gain as monensin increased from 0 to 40 grams per ton for finishing steers. In a trial with green chop and 0, 50, 100, 200, 300 or 400 mg monensin per head per day; optimal response occurred at 200 mg. This level gave an 18% increase in average daily gain (Potter et al., 1976). Monensin fed at 11 ppm (Raun et al., 1976) increased daily gain by 5.2%. According to Boling et al. (1977), feeding 0. 100, 200 or 300 mg per steer per day resulted in gains of 1.14, 1.26, 1.23 and 1.18 kg per day, respectively. Monensin, as a top dressing, increased gain in 328 kg steers by 2% in a 112 day study (Riley et al., 1976).

Protein for Finishing Steers

According to Goodrich et al. (1961), yearling cattle fed 9.5, 10.6, 12 or 12.7 percent crude protein in a brome hay and rolled shelled corn diet had varying responses. Gains (kg) and feed efficiencies were: 1.1, 9.25; 1.16, 8.78; 1.12, 8.85; 1.09, 9.03; respectively. Thus, it was concluded that cattle of this age do not require more than 11% crude protein. Fontenot and Kelly (1963), used weanling calves, and found that rate of gain increased linearly when crude protein was adjusted from 9.9 to 14.3% (dry matter basis). Feed efficiency was also generally improved. The study was continued for two additional years with protein ranging from 10.9 to 19.3%. Average daily gain increased up to the 14.7% level. Similarly, Haskins et al. (1967) reported steer calves averaging 242 kg initially, needed protein exceeding 11% for maximum gains on all concentrate diets. Fontenot and Kelly (1967) in a three year study, fed 9.2, 12.9 and 17.0% crude protein to weanling calves. Daily gains were highest for steers receiving 12.9% crude protein. Weichental et al. (1963), used larger steers (averaging 352 kg) fed 80% ground shelled corn and 20% alfalfa hay. Comparing the two levels, 10.6 or 11.8% protein, the higher crude protien did not improve weight gain. No significant performance differences were noted in 347 kg steers receiving 11 or 12.4% crude protein for 117 days (Martin et al., 1976). Smith et al. (1967) reported similar performance in 336 kg steers fed 9.6 or 11% crude protein for 109 days. Putnam et al. (1969) reported 8 to 9% crude protein to be adequate for 370 kg steers during the terminal sixty days. However, Morrison (1956) observed lowered gains and poorer efficiency may be a problem at lowered levels of crude protein. Braman et al. (1973)

reported increased protein levels gave the greatest response in the first sixty days of the feeding period with little response observed during the final finishing stages. Bowers et al. (1965) suggested 16% crude protein is necessary for barley fed cattle, weighing 150 to 240 kg initially. However, Kay et al. (1968) found that 11, 14 or 17% crude protein resulted in no difference in growth rate for Friesian steers weighing 250 kg. Borger et al. (1973) observed no significant difference in daily gains for 269 kg steers getting 9.5, 11 or 12.5% crude protein. But, steers receiving 9.5% crude protein were the most efficient. Cattle weighing over 409 kg do not need supplemental protein when the diet is 40 to 60% corn and 40 to 60% corn silage (dry matter basis) suggested Geasler (1972). Klett (1973) also used heavier steers (386 kg) and found little difference in animal performance comparing 8 and 11.5% crude protein. Supplemental protein throughout the entire finishing period did not increase gain significantly when compared to steers fed the supplemental protein only during the first 56 to 112 days (Preston & Cahill, 1972; Preston & Parrett, 1972; Preston & Cahill, 1973; Preston et al., 1973; Harvey et al., 1974; Sherrod et al., 1976) and then reduced to 8.2 to 8.6% for the last part of the finishing period. Results by other workers support the concept of supplemental protein withdrawal (Putnam et al., 1969; Young et al., 1973). Riley et al. (1973) observed withdrawal of supplemental protein the last 28 days improved gain 6.9% and feed efficiency 8.4%.

Light weight steers receiving 9.5% crude protein gained .2 kg (P .05) less than steers fed 11.8% crude protein and were less efficient. However, in a second trial with heavier steers, 8.4 or 10.8% crude protein caused no difference in gain or feed efficiency (Greathouse et al., 1974). Results from a 181 day finishing period indicated British breeds of cattle above 430 kg did not require supplemental protein exceeding 8.7 to 9.3% crude protein. Minimal effects were detected when protein was removed at 340 kg (Riley & Harrison, 1975). According to Thomas et al. (1976), steers fed a diet with no supplemental protein (7.4% dry matter basis) during the first part of the feeding period had reduced performance ($P<.01$). When supplemental protein was withdrawn at 386 kg, those steers had reduced performance and withdrawing supplemental protein at 430 kg decreased performance. However, in a second trial, feeding no supplemental protein the final 88 days did not affect animal performance for steers weighing 409 kg.

Hill et al. (1979) observed steers (343 kg initially) receiving 0, .34 or .68 kg cottonseed meal supplement per head per day. Corn silage was fed ad libitum with whole shelled corn at 1% body weight, oyster shell flour and trace mineral salt. Steers gained faster as cottonseed meal was increased. Average daily gain (kg) and efficiency for 0, .34 and .68 kg cottonseed meal treatments were, respectively: .80, 11.5; 1.0, 10.0; and 1.18, 8.9. Total crude protein consumption was 79, 100 and 117% of the National Research Council (1976) recommendations.

Perry and Peterson (1979), in a preliminary report, observed heifers fed (initially 227 kg) 14.9% protein diets (dry matter basis) gained 10% faster during the first 56 days of the finishing period than heifers getting 11.9%. Increasing protein from 11.9% to 13.9% for the next 36 days increased gain 13%. Whereas, decreasing from 14.9 to 11.5% reduced gain by 22%. The final report (Perry & Peterson, 1980) compared the following treatments: (1) 11.4% - 11.9% crude protein throughout the 190 day trial; (2) 11.9% the first 56 days and 13.5% the last 133 days; (3) 14.9% the first 56 days and 11.4% the last 133 days; (4) 14.9% initially and 13.5% the final 133 days. The 407 kg heifers from day 57 to day 190 had average daily gains (kg) and efficiencies, as follows: (1) .88, 7.82; (2) 1.04, 7.06; (3) .91, 7.55; and (4) 1.14, 6.42. For the entire 190 day trial, average daily gains (kg) and efficiencies were: (1) .85, 7.45; (2) .94, 7.05; (3) .89, 7.15; and (4) 1.05, 6.35. Similarly, Beeson <u>et al</u>. (1975) reported a 34% reduction in gain and 53% poorer efficiency when supplemental protein was removed at day 56 from steers which weighed 268 kg initially. Removing supplemental protein at 112 days, also, caused decreased performance.

Monensin and Protein for Finishing Steers

Research has shown that cattle eat less feed when monensin is included in the diet. This raises the question of protein adequacy, suggesting that a greater percentage of protein is needed in the diet to meet the animal's requirements. However, other research has shown monensin to have a protein-sparing effect. That is, less protein is required with the addition of monensin in the diet (Byers, 1979). Davis and Erhart (1976) added urea to increase crude protein from 9.5 to 11.5% (dry matter basis) in a corn, corn silage, supplement diet with urea withdrawn at 0, 42, 84 or 120 days. Monensin decreased daily feed intake as expected and higher protein (11.5%) increased rate of gain. Gill et al. (1976) fed 9.5, 10.3, 11.2 and 12.3% crude protein with and without monensin to steers. Monensin improved animal performance the most at the lower protein levels. Dart et al. (1978) used 96 steers (averaging 278.6 kg initially) in a 168 day finishing trial to study the effect of monensin and supplemental protein withdrawal on performance. Diets used were: (1) corn, corn silage and soybean meal (control); (2) control with soybean meal removed at 84 days; (3) control with 200 mg monensin; and (4) control with monensin but soybean meal was removed at 84 days. Daily gains (kg) and efficiencies for the four treatments were: (1) .98, 7.02; (2) .78, 8.28; (3) 1.07, 5.83; and (4) .92, 6.14. Monensin fed steers had improved feed efficiency and a protein-sparing effect seemed to exist. In contrast, Walker et al. (1977) did not find monensin to significantly affect protein utilization. Another researcher compared 9, 11 and 13% protein diets with and without monensin (M) and reported gains (kg) and efficiencies: 9%, 1.30, 5.52; 9% + M, 1.25, 5.57; 11%, 1.23, 5.67; 11% + M, 1.26, 5.44; 13%, 1.35, 5.46; and 13% + M, 1.27, 5.25 (Byers, 1979). McCarthy et al. (1979) reported feeding monensin (30 g per ton) to finishing steers receiving an 11% crude protein diet (85% high moisture corn, 15% corn silage on an as fed basis) and found monensin created a protein-sparing effect. However, the greatest sparing effect was observed when 9% dietary protein was apparently not meeting the animal requirements in the growing phase. Mies et al. (1979) reported feeding 156 steers in a 167 day trial. Diets were 9, 11, 13, 13-11-9% with crude protein reduced every 56 days and each dietary treatment with and without monensin (30 g per ton). Steers fed monensin and 13% crude protein gained the fastest and were most efficient. This study indicated monensin may have a protein-sparing effect for steers fed 9 - 13% crude protein. Thompson and Riley (1980) observed monensin did not significantly affect animal performance. Steers fed 200 mg monensin and 11% crude protein had the highest average daily gain and were most efficient.

Calcium and Phosphorus for Finishing Steers

Conflicting data exists on the effect of calcium and phosphorus levels on cattle performance. Dowe et al. (1957) reported 216 kg calves receiving 1.3:1 and 4.3:1 calcium to phosphorus ratio (Ca:P) did not gain significantly different. Those calves receiving 9.1:1 and 13.7:1 also had similar gains. There were significant differences between the two groups with rate of gain decreasing as calcium level increased. This suggests a critical ratio may exist between 4.3 and 9.1 parts calcium to one part phosphorus. Russell et al. (1980) reported that adding 1.8% limestone to a control diet reduced dry matter intakes and lowered average daily gains.

Nicholson et al. (1960) observed the opposite effect. Feeding two month old calves similar protein (14.7%) with (1) .4% Ca, .4% P; (2) .9% Ca, .5% P; or (3) .5% Ca, .4% P resulted in the following feed consumptions (kg) and gains (kg): (1) 2.36, .54; (2) 2.95, .65; and (3) 2.82, .62; respectively. The addition of calcium carbonate improved feed consumption and growth.

Varner and Woods (1972b) found average daily gain was increased by increasing calcium from .20 to .31% in the diet for steers (336-344 kg). Another increase was seen when the level was raised to .41%. Feed required per unit of gain was less ($P<.05$) for cattle fed .31 or .41% calcium as compared to the .20% level. Phosphorus was kept at a constant level. In a heifer study (234 kg), Perry et al. (1980) reported 1.06% calcium resulted in 13.5% faster gain in a 28 day period as compared to .46%. The heifers were approximately 90 days away from finished weight. Wheeler and Noller (1976) reported increased limestone decreased feed consumption in one trial. In two other trials, increased limestone had no affect on feed intake but feed efficiency and weight gain were improved. Dunn et al. (1977) used lambs with limestone being fed at dietary levels 1 to 4% above calcium requirements. Feed intake and average daily gain were increased during the initial 21 days. However, no difference existed for the rest of the 121 day finishing period. Trenkle and Arnold (1979) fed limestone at 30 or 72 grams per day. The higher level tended to increase consumption and average daily gain.

Other workers have found no differenece due to additional calcium. Krause and Britton (1979) compared finishing diets for 318 kg steers containing (11.5% protein, .35% Ca, .3% P) high moisture corn, corn silage and urea with the same diet plus limestone added at the rate of 2% dry matter. Average daily gain (kg) and efficiency values were: 1.16, 7.26 and 1.15, 7.08, respectively. Thus, no benefit from the additional calcium. Kertz et al. (1977) reported adding 2% dolomite to a control grain based diet did not affect feed intake or milk production in dairy cows.

Wise et al. (1965) observed that extra calcium carbonate increased feed intake and performance when mixed thoroughly into the diet. Adding the same amount of limestone as a top dressing resulted in decreased intake and gain.

Ferriera et al. (1979) postulated that limestone particle size would influence animal production. This difference would be caused by the differenece in buffering ability measured in time required to neutralize 50% of acid (T_{50}). However, feeding 40 lactating cows different particle size limestone did not affect production. Wheeler et al. (1979) reported the opposite. Daily gain was related to particle size and rate of reactivity. Steers were fed three limestones of varying particle size and T_{50} values. Limestone with the smallest particle size and fastest T_{50} produced the most gain.

Fecal starch was also affected by limestone source. Steers fed the limestone resulting in the highest average daily gain, had the lowest fecal starch content and the highest fecal pH (Wheeler et al., 1979). Steers fed 1.8% limestone had increased fecal pH but starch concentration was not changed (Russell et al., 1980). Perry et al. (1980) reported no difference in fecal pH when calcium was fed at .46 or 1.06% of the diet. Other workers observed no effect on fecal pH or starch content when the diet was buffered (Kertz et al., 1977; Ferriera et al., 1979; Zinn & Owens, 1980).

Daily gain was significantly ($P<.01$) reduced in lambs when dietary phosphorus level was raised from .22 to .47 (Hoar et al., 1970a). Calcium was fed at a level of .31%. Increasing the calcium level overcame the depressing effect of phosphorus on weight gain. Further increases in calcium to 1.06% did not cause additional increase in gain. Feed consumption was not different. Other work has also shown calcium can partially overcome weight gain depression associated with .5 to .6% phosphorus in the diet (Bushman et al., 1965; Hoar et al., 1969). In another trial with lambs (Hoar et al., 1970b), this time fed .24% and .57% phosphorus, .28% and 1.20% calcium with .41% or 1.01% potassium, the higher level of phosphorus reduced weight gains at the .28% calcium level. The lambs fed 1.20% calcium had significantly ($P<.05$) higher gains and feed consumption, apparently eliminating the depressing effect of phosphorus. Wilson et al. (1975) found no difference in weight gain or feed intake for yearling steers receiving calcium to phosphorus ratios ranging between 2.9 and 1.7 parts calcium to one part phosphorus.

Rumen Constituents

Volatile Fatty Acids

Monensin affects rumen volatile fatty acids by increasing the molar percentage of propionic acid (Potter et al., 1974; Richardson et al., 1974; Dinius et al., 1976; Riley & Fink, 1976: Martin et al., 1976; Lemenger et al., 1978; Bartley et al., 1979) and decreasing acetic and butyric acids. Total ruminal volatile fatty acid concentration is not changed. Richardson et al. (1976) reported decreased acetic, butyric, isovaleric and valeric acids. Feeding monensin at 150 mg per day increased propionate pool size from 37 to 66 g and increased propionate production from 510 to 899 g per day for high grain fed steers (Van Maanen et al., 1978).

In vitro studies showed 33 ppm monensin in the diet decreased molar percentages of acetic, butyric and isobutyric acids with increased propionic and valeric acids (Slyter, 1979). Van Nevel and Demeyer (1977) had similar results.

Results of research on the effect of protein levels on ruminal volatile fatty acids have been variable. Davis et al. (1956) found that protein level did not significantly change the amount of rumen acetic acid for the dairy cow. As protein level increased, the proportion of total volatile fatty acids represented by acetic acid decreased. Propionic acid increased, but proportion of propionic acid was similar for low, medium and high protein levels. Butyric acid levels were significantly ($P<.01$) increased in medium and high protein diets. There was a definite increase in total volatile fatty acids as protein increased. This data indicates that as protein level increases the amounts and proportion of volatile fatty acids in the rumen is altered. Cross et al. (1974) observed a trend toward a decrease in molar percent of acetic acid in steers fed higher nitrogen levels. Similar findings were reported by Shaw et al. (1959). Burris et al. (1974) found no difference ($P<.05$) in molar percent of volatile fatty acids for steers averaging 290 kg receiving 13.64 kg corn silage and 3.64 kg protein supplement. Using four yearling steers in two successive balanced, non-repetitive 4x4 latin square designs, Lyle et al. (1979) studied the effect of protein supplement and monensin on volatile fatty acid (VFA) production. Diets consisted of *ad libitum* whole corn and .5 kg per day soybean meal, or *ad libitum* corn and .5 kg commercial supplement. The two treatments were fed with and without 300 mg per head per day monensin. Treatments resulted in no affect upon VFA concentration. Steers fed a sorghum grain based diet (11.7% crude protein) and no monensin resulted in the following VFA amounts: total VFA, 78.2 μmole/ml; 47.1% acetic (C_2); 40.3% propionic (C_3); 8.3% butyric (C_4) compared to 11.7% and 33 ppm monensin: total VFA, 81.6 μmole/ml; 45.6% C_2; 41.9% C_3; and 12.4% C_4. Steers fed a 10.5% crude protein whole shelled corn based diet had ruminal VFA values of: 70.2 μmole/ml; 53.6% C_2; 25.3% C_3; and 12.4% C_4. Steers fed 10.5% crude protein and 33 ppm monensin gave the following levels: 72.1 μmole/ml; 50.2% C_2; 31.9% C_3; and 11.6% C_4 (Muntifering *et al.*, 1980). Thompson and Riley (1980) reported a significant monensin by protein interaction for acetic and propionic acids and the acetate to propionate ratio. Steers fed 200 mg monensin per head per day, had decreased acetic and increased propionic acid and a lowered acetate to propionate ratio at the 9%, 11%, 12% reduced to 10.5%, 13% decreased to 11% and lowered to 9% treatments. However, steers fed 15% crude protein had increased acetic acid and decreased propionic with an increased acetate to propionate ratio. Total VFA concentration and butyric acid were not affected by monensin or protein level.

Calcium may affect volatile fatty acid levels. Emery *et al.*, (1964) reported increased volatile fatty acids resulted from the addition of .27 kg per day calcium carbonate to dairy diets. Varner and Woods (1972a) compared .41% and .70% calcium with phosphorus level of .35% in the diet of 177 kg steers. The individual volatile fatty acid amounts were not affected by treatment. Molar concentration (moles per 100 g) of acetic acid was significantly increased ($P<.01$), by the higher calcium level while propionic acid decreased ($P<.01$), butyric and isovaleric were increased. Nicholson *et al*. (1963) found that mixed buffer, containing 33% limestone, lowered rumen acetate in cattle fed all concentrate diets. Anaya *et al*. (1979) used two diets: (1) 20% ground alfalfa hay, 74.1% steam flaked wheat, 5% molasses, .5% salt and .4% limestone; (2) 20% ground alfalfa hay, 72.9% steam flaked wheat, 5% molasses, .5% salt and 1.6% dolomite. Steers receiving dolomite had a wider acetate to propionate ratio than the control animals.

Rumen Gases

Methane production was depressed due to monensin (Dinius *et al*., 1976; Tolbert *et al*., 1977). Van Nevel and Demeyer (1977) reported 17 of 25 individuals had reduced methane production. But, most observations were not statistically significant. Hydrogen recovery was also lowered, but not significantly. Chalúpa *et al*. (1980), using *in vitro* fermentation, reported monensin decreased methanogenesis 15 to 40% with no accumulation of hydrogen gas, and 10% decreased carbon dioxide production. Other researchers reported decreased methane production and increased carbon dioxide and hydrogen. Furthermore, a significant increase in lactic acid production existed (Thornton et al., 1976; Bartley et al., 1979).

Rumen Lactate and Ammonia

Calcium may also affect lactic acid. Emery et al. (1964) reported increased lactic acid resulted from the addition of .27 kg calcium carbonate to dairy diets. In cantrast, Varner & Woods (1972a) did not observe significantly different lactic acid levels due to added calcium. Nevertheless, animals consuming the higher calcium levels had the lower lactic acid values.

Rumen ammonia depression resulted from monensin (Dinius et al., 1976; Tolbert et al., 1977). Short et al. (1978) used in vitro studies to show monensin decreased ammonia nitrogen concentration and raised non-ammonia, non-microbial nitrogen. Martin et al. (1976) also observed decreased ammonia concentration in monensin fed cattle.

Rumen ammonia levels are influenced by protein source and level of protein (Burris et al., 1974). Steers, averaging 290 kg, receiving corn alone at day 69 and day 140 had rumen ammonia concentrations of 2.5±.9, 2.3±.6, Soybean meal supplemented steers had levels of 5.0±.7, 6.3±.9; fishmeal 3.7±.4, 6.7±.2; and linseed meal 4.9±.7, 5.6±1.4. Cross et al. (1974) reported a trend toward higher rumen ammonia values in steers fed higher nitrogen levels.

Steers fed a 15.9% crude protein corn and soybean meal diet had a concentration of 18.7±2.1 mg/100 ml ammonia nitrogen. An 11.5% crude protein diet resulted in 11.1±1.2 mg/100 ml ammonia nitrogen. Haaland et al. (1979) observed rumen ammonia (mg/100 ml) increased as dietary protein increased: 11%, 10.9; 14%, 18.1; 17%, 29.6. Slyter et al. (1973) suggested 4.5 mg/100 ml ammonia nitrogen is adequate for maximum microbial growth. Thus, most of the above levels would be considered adequate.

Rumen samples were taken four hours post-feeding at 21 day intervals from 12 steers fed cracked corn, cottonseed hulls and soybean meal to make 8%, 12%, or 16% crude protein diets (as fed basis). Monensin (M) was fed at 0 or 33 ppm. Rumen ammonia levels (mg/100 ml) were: 8%, 2.04; 8% + M, 2.60; 12%, 7.84; 12% + M, 8.21, 16%, 15.21; and 16% + M, 13.93. Rumen ammonia was decreased at the 16% level with monensin, but not at the 8 or 12% levels (Schlagheck, et al., 1979). Thompson and Riley (1980) observed a positive correlation between protein intake and rumen ammonia concentration. Steers fed monensin had lower rumen ammonia levels and those receiving low protein and no monensin had the lowest rumen ammonia amounts. Monensin fed at 33 ppm resulted in rumen ammonia nitrogen levels of 2.5 mg/100 ml as compared to 6.5 mg/100 ml for steers not receiving monensin. The corn based diet contained 10.5% crude protein (Muntifering et al., 1980).

INTRODUCTION

Monensin, produced by Streptomyces cinnamonensis (Haney & Hoehn, 1967), has been shown to increase feed efficiency and lower feed intake (Gill *et al.*, 1976; Perry *et al.*, 1976; Potter *et al.*, 1976; Raun *et al.*, 1976). However, gain is not affected by the addition of monensin in finishing diets (Brown *et al.*, 1974; Gill *et al.*, 1976; Perry *et al.*, 1976; Utley *et al.*, 1976; Bartley *et al.*, 1979; Byers, 1979).

Feeding high concentrate diets to finishing animals is very popular and determining the requirements of these animals continues to be extensively studied. Some research has indicated animals need a crude protein level exceeding 11% in the finishing diet (Fontenot & Kelly, 1963; Bowers *et al.*, 1965; Fontenot & Kelly, 1967; Haskins *et al.*, 1976; Thomas *et al.*, 1976; Hill *et al.*, 1979). Other work has found no benefit in feeding diets containing greater than 11% crude protein (Goodrich *et al.*, 1961; Weichental *et al.*, 1963). Heavier steers apparently have a lower requirement than 11% crude protein (Putnam *et al.*, 1969; Geasler, 1972; Braman *et al.*, 1973; Klett, 1973; Riley *et al.*, 1973).

Since monensin reduces total feed intake, the question of protein adequacy has arisen when monensin is added to the diet, because the amount of protein consumed by the animals has been reduced. However, research has shown monensin may have a protein sparing effect (Gates & Embry, 1976; Dartt *et al.*, 1978; McCarthy *et al.*, 1979; Mies *et al.*, 1979). Other workers have not observed this same protein sparing response (Walker *et al.*, 1979; Thompson & Riley, 1979).

Renewed interest has been created concerning the level and ratio of calcium to phosphorus in finishing diets. Research has indicated a buffering effect from increased limestone, which may improve animal performance (Wheeler & Noller, 1976; Emerick, 1979; Trenkle & Arnold, 1979). Increased limestone will alter the calcium to phosphorus ratio and, as a result, the optimum ratio of calcium to phosphorus needs to be determined for finishing animals.

The purpose of this study was to obtain additional information regarding monensin, protein and calcium:phosphorus effects on finishing steers.

EXPERIMENTAL PROCEDURE

Sixty Hereford steers (averaging 346 kg) were fed twice daily to *ad libitum* consumption. Steers were randomly allotted to twelve pens of five animals. Experimental design was a 2x2x3 factorial containing two monensin, two protein and three calcium to phosphorus levels. The two monensin levels were 0 or 200 mg raised to 300 mg per head per day after 37 days on feed. The crude protein levels were either 10.4% or 12% (dry matter basis). Three calcium to phosphorus ratios of 1.1:1, 1:2.25 or 1.7:1 were evaluated. The calcium:phosphorus ratios were calculated to be 1:1, 1:2 or 2:1. However, actual laboratory analysis of rations are shown in Table 1.

Composition of rations and supplements are shown in Table 1. Soybean meal was used at the supplemental protein source for the corn based diets. Ground corn was the carrier for monensin and replaced 1.70 kg corn per feeding in the monensin diets. Corn silage was included at a level of 15% of the diet (dry matter basis). Dicalcium phosphate, monosodium phosphate and limestone were used to adjust the calcium and phosphorus levels.

Rumen samples were collected via stomach tube from two animals in each treatment group, four hours post-feeding on days 37, 65 and 84. Rumen fluid was preserved with hydrochloric acid for ammonia determination using the Conway (1963) method. Volatile fatty acid concentration was determined by gas chromatography. Sample preparation was done by acidifying rumen fluid with a 1:9 dilution of 6N hydrochloric acid. Samples were spun for twenty minutes in an International Refrigerated Centrifuge at 10,000 g. The column was six feet by one quarter inch glass, packed with Supelco Chromosorb 101 packing. The carrier gas was nitrogen and a flame ionization detector was used. Injection size was 1.5 liter.

Rumen vault gas samples were collected at the same time as rumen fluid using vacutainers. Rumen gas was analyzed by gas chromatography, by directly injecting .3 ml sample into a Carbosieve S column (80/100 mesh), seven feet long by one-eighth inch. The carrier gas was argon.

Individual initial and final weights were taken following a fifteen hour period without feed or water. Interim individual weights were taken four hours post-feeding on day 37 and 65.

Fecal samples were collected at approximately one week intervals following an adaptation period to the treatments. A composite fecal sample for each pen was taken for a total of nine collection times. Fecal pH readings were taken immediately and samples were frozen for later starch analysis (Macrae & Armstrong, 1968).

Steer performance, rumen data, fecal starch and fecal

TABLE 1. COMPOSITION OF DIETS

Treatments:							
Protein, %		12	12	12	10.4	10.4	10.4
Calcium, %		.43	.41	.74	.50	.38	.74
Phosphorus, %		.41	.95	.44	.42	.84	.44
Ca:P Ratio		1:1	1:2.3	1.7:1	1.2:1	1:2.2	1.7:1
Ingredient[1]:	I.R.N.						
Corn Silage,%	3-08-153	15	15	15	15	15	15
Rolled Corn[2],%	4-02-931	77	76	75	81	79	80
Supplement, %		8	9	10	4	6	5
Dicalcium phosphate, %	6-01-080	-	13.2	-	3.3	25.6	-
Monosodium phosphate,%	6-04-288	.6	8.1	.5	-	15.3	2.2
Limestone, %	6-02-232	10.5	-	20.4	21.7	-	38.5
Salt, %		2.9	2.5	2.5	6.4	4.5	4.6
Trace mineral, %		1.0	1.0	1.0	1.0	1.0	1.0
Vitamin A premix[3], %		.1	.1	.1	.2	.1	.1
Soybean meal, %	5-04-604	84.9	75.1	75.5	67.4	53.5	53.6

[1]The amount of the ingredient in the ration is given as a percent of ration dry matter.

[2]One replicate received 1.70 kg/feeding of corn with monensin and other replicate received the same amount of non-medicated corn.

[3]Vitamin A premix contained 30,000 I.U. per gram.

TABLE 1A. CHEMICAL ANALYSIS OF DIET COMPONENTS

	Crude Protein (%)	Calcium (%)	Phosphorus (%)	Starch (%)
Corn	10.16	.09	.36	62.68
Corn Silage	7.40	.29	.31	13.79
Supplement 1	33.69	2.94	5.82	3.61
Supplement 2	37.01	6.78	1.41	3.87
Supplement 3	40.05	5.11	1.25	2.33
Supplement 4	23.67	5.08	10.96	2.57
Supplement 5	22.65	12.46	2.30	2.16
Supplement 6	29.82	8.72	1.84	1.68

pH data were statistically analyzed using a 2 x 2 x 3 factorial design. The analysis included monensin with one degree of freedom, protein with one degree of freedom and calcium:phosphorus ratio with two degrees of freedom. The possible interactions between treatments were also included. Rumen data included sample day (two degrees of freedom) and the above treatments interacted with time. All data was tested using analysis of variance: general linear model, least square means, predicted difference and standard error procedures (Barr *et al.*, 1976).

Sieve test on the limestone was done using the method of Pfost and Headley (1976).

RESULTS AND DISCUSSION

Steer Performance

Monensin Effect

The effects of monensin on steer performance are shown in Table 2. Monensin did not significantly affect gain (P=.0987) during the 84 day finishing period which agrees with results from other studies (Brown et al., 1974; Raun et al., 1974a; Gill et al., 1976; Perry et al., 1976; Utley et al., 1976). Feed intake was depressed due to monensin and feed efficiency was improved (P .05). Similar findings have been reported by numerous researchers (Embry & Swan, 1974; Raun et al., 1974b; Farlin et al., 1975; Gill et al., 1976; Goodrich et al., 1976; Riley et al., 1976; Boling et al., 1977).

Protein Effect

The effects of protein are summarized in Table 3. For the finishing period, protein did not significantly influence gain, efficiency or intake. Steers fed 12% (1.08 kg/head/day) did not perform better than those fed 10.4% (.89 kg/head per day) on a dry matter basis. The higher protein intake depressed consumption and efficiency, but not significantly. Other researchers (Preston & Cahill, 1972; Preston & Parrett, 1972; Klett, 1973; Preston & Cahill, 1973; Preston et al., 1973; Sherrod et al., 1975; Thompson & Riley, 1980) indicated

TABLE 2. EFFECT OF MONENSIN ON STEER PERFORMANCE

	Monensin	No Monensin
Number of steers	30	30
Number of days on feed	84	84
Initial weight, kg	351	353
Final weight, kg	444	437
Average daily gain, kg	1.12	1.00
Daily feed intake, kg	8.70	8.94
Kg feed/kg gain	7.78[a]	9.00[b]

[a,b]Values in the same row with different superscripts differ significantly ($P<.05$).

Effect of monensin by weigh period is not shown because there were no significant differences.

TABLE 3. EFFECT OF CRUDE PROTEIN

Crude protein, %	10.4	12
Daily protein intake, kg	.89	1.08
Number of steers	30	30
Initial weight, kg	349	355
Final weight, kg	444	438
Average daily gain, kg	1.05	1.07
Daily feed intake, kg	8.59	9.04
Kg feed/kg gain	8.15	8.46

No significant differences existed at the ($P<.05$) level. Effect of protein on performance by weigh period is not shown for this reason.

that protein level could be reduced during the latter portion of the finishing period without decreasing performance.

Monensin and Protein Effect

Monensin and protein treatments did not interact significantly (Table 4). This may have been because the protein level was not deficient enough to cause protein stress. This finding agrees with others (Walker et al., 1977; Byers, 1979). Nevertheless, other workers (McCarthy et al., 1979; Mies et al., 1979; Thompson & Riley, 1980) have observed a protein sparing effect to be induced by monensin when diets were marginal in protein content.

Calcium:Phosphorus Effect

The effects of calcium:phosphorus (Ca:P) ratio are shown in Table 5. Average daily gain (P=.1110), feed efficiency (P=.0778) and feed intake were not significantly altered by the three ratios. The additional calcium in the 1.7:1 diet did not increase rate of gain. The animals receiving 1.1:1 Ca:P had the highest gain and were the most efficient. Steers fed the 1:2.25 Ca:P gained the least, consumed the least and required the most feed per kg of gain. Hoar et al. (1970a) reported decreased gain when dietary phosphorus level was .47%. Increasing the calcium to 1.06%, overcame this weight gain depression. Other workers have observed a gain reduction with increased phosphorus (Bushman et al., 1965; Hoar et al., 1969).

There were no significant interactions ($P<.05$) observed

TABLE 4. EFFECT OF MONENSIN AND PROTEIN LEVEL ON STEER PERFORMANCE.

	Monensin		No Monensin	
Protein Level, %	10.4	12	10.4	12
Number of steers	15	15	15	15
Initial weight, kg	354	348	356	349
Final weight, kg	445	444	442	433
Average daily gain, kg	1.09	1.14	1.02	.99
Average daily feed, kg	8.37	9.03	8.82	9.05
Kg feed/kg gain	7.78	7.93	8.84	9.15

No significant differences ($P<.05$) occurred due to protein and monensin interaction.

TABLE 5. EFFECT OF CALCIUM:PHOSPHOROUS RATIO ON STEER PERFORMANCE.

Ca:P	1.1:1	1.7:1	1:2.25
Number of steers	20	20	20
Initial weight, kg	353	351	351
Final weight, kg	450	440	432
Average daily gain, kg	1.15	1.06	.97
Average daily feed, kg	8.89	8.95	8.62
Kg feed/kg gain	7.75[a]	8.53[a,b]	8.99[b]

[a,b]Values in the same row with different superscripts differ significantly ($P<.05$).

between protein and calcium:phosphorus ratios or monensin and calcium:phosphorus ratios for gain, intake or efficiency.

Rumen Constituents

Volatile Fatty Acids

Table 6 shows the effects of monensin on volatile fatty acids. Monensin decreased the molar percent of acetic, isobutyric and valeric acids while molar percent of propionic was increased. No effect on butyric or isovaleric was observed. This concurs with other researchers (Potter et al., 1974; Richardson et al., 1974; Dinius et al., 1976; Richardson et al., 1976; Riley & Fink, 1976). As the trial progressed, an increase in molar percent of isobutyric was seen both with and without monensin. Total concentration of volatile fatty acids (μmole/ml) was not changed by monensin addition except for a reduction in valeric acid.

Protein treatment did not significantly (Table 7) affect molar percent of volatile fatty acids. Burris et al. (1974) found no difference in molar percent of volatile fatty acids due to protein source. The total concentration of isobutyric was reduced at the 10.4% crude protein level. There was an interaction between protein and time with percent valeric acid decreasing for both protein levels, as the trial progressed.

Calcium:phosphorus ratio did not affect (See Table 8) the molar percent of acetic, propionic, butyric, isovaleric or valeric acids. Steers fed the 1:2.25 Ca:P had the lowest

TABLE 6. EFFECT OF MONENSIN ON VOLATILE FATTY ACIDS

	Monensin	No Monensin	SE
Acetic acid			
molar percent	45.40[a]	49.20[b]	.67
µmole/ml	36.82	37.82	1.30
Propionic acid			
molar percent	38.46[a]	34.00[b]	1.10
µmole/ml	31.08	26.99	1.47
Isobutyric acid			
molar percent	1.09[a]	1.27[b]	.06
µmole/ml	.86	.97	.04
Butyric acid			
molar percent	11.56	11.32	.71
µmole/ml	9.24	8.91	.67
Isovaleric acid			
molar percent	1.81	1.82	.17
µmole/ml	1.43	1.36	.14
Valeric acid			
molar percent	1.70[a]	2.30[b]	.12
µmole/ml	1.39[a]	1.82[b]	.14

[a,b]Means in the same row with different superscripts differ significantly ($P<.05$).

TABLE 7. EFFECT OF PROTEIN ON VOLATILE FATTY ACIDS

Crude Protein, %	10.4	12	SE
Acetic acid			
molar percent	47.65	46.95	.67
μmole/ml	35.94	38.01	1.30
Propionic acid			
molar percent	35.61	36.84	1.10
μmole/ml	27.76	30.30	1.47
Isobutyric acid			
molar percent	1.14	1.21	.06
μmole/ml	.84[a]	.98[b]	.04
Butyric acid			
molar percent	11.86	11.02	.71
μmole/ml	9.18	9.07	.67
Isovaleric acid			
molar percent	1.84	1.78	.17
μmole/ml	1.33	1.46	.14
Valeric acid			
molar percent	1.91	2.08	.12
μmole/ml	1.48	1.73	.14

[a,b]Means in the same row with different superscripts differ significantly ($P<.05$).

TABLE 8. EFFECT OF CALCIUM:PHOSPHOROUS RATIO ON VOLATILE FATTY ACIDS

Ca:P	1.1:1	1:2.25	1.7:1	SE
Acetic acid				
molar percent	47.68	46.73	47.49	.82
µmole/ml	36.16	34.69	40.07	1.56
Propionic acid				
molar percent	35.06	37.42	36.21	1.34
µmole/ml	27.38	28.75	30.97	1.80
Isobutyric acid				
molar percent	1.32[a]	1.06[b]	1.15[a,b]	.07
µmole/ml	.97[a]	.80[b]	.96[a]	.05
Butyric acid				
molar percent	11.72	11.16	11.44	.87
µmole/ml	9.29	8.22	9.87	.82
Isovaleric acid				
molar percent	1.99	1.69	1.75	.21
µmole/ml	1.51	1.19	1.48	.17
Valeric acid				
molar percent	2.01	1.90	2.08	.15
µmole/ml	1.60	1.41	1.80	.17

[a,b]Means in the same row with different superscripts differ significantly ($P<.05$).

molar percent of isobutyric acid and the total concentration of isobutyric acid was reduced. Varner and Woods (1972a) observed no alteration in volatile fatty acid level because of additional dietary calcium.

An interaction was observed for molar percent of valeric acid between monensin and protein level. Feeding no monensin and 12% crude protein gave the highest percent of valeric acid.

Rumen Vault Gases

Percentages of hydrogen, methane and carbon dioxide (See Table 9) were not altered by monensin, protein or calcium:phosphorus ratio. A monensin by protein interaction was noted on the hydrogen gas percent. Steers receiving 12% crude protein and monensin had the most hydrogen and methane with the lowest carbon dioxide. A protein by month interaction was seen on methane and carbon dioxide gas production. As the trial progressed, both protein treatments had increasing levels of methane. The 10.4% crude protein fed cattle had decreasing carbon dioxide levels. A significant monensin by sample day interaction was also seen. There was a decrease in hydrogen as the trial progressed for both monensin and non-monensin fed cattle.

Rumen Lactate and Ammonia

Table 10 summarizes the lactate and ammonia values. Rumen lactates were measured using a modified Barker &

TABLE 9. EFFECTS OF DIETARY TREATMENTS ON RUMEN VAULT GAS VALUES

Gases, %	H_2	SE	CH_4	SE	CO_2	SE
Treatment:						
Monensin	1.83	.23	22.10	1.35	76.07	1.28
No monensin	1.41		22.33		76.26	
Protein 10.4%	1.52	.23	22.07	1.38	76.41	1.31
12%	1.71		22.36		75.92	
Ca:P						
1.1:1	1.77	.27	19.99	1.62	78.24	1.54
1:2.25	1.80		23.13		75.07	
1.7:1	1.28		23.54		75.18	
Significant Interactions:						
10.4 x no monensin	1.74[a,b]	.31	23.53	1.87	74.73	1.78
10.4% x monensin	1.30[a]	.31	20.61	1.87	78.08	1.77
12% x no monensin	1.08[a]	.32	21.14	1.94	77.78	1.85
12% x monensin	2.35[b]	.32	23.59	1.94	74.06	1.85

[a,b]Means in the same column with different superscripts differ significantly ($P<.05$).

TABLE 9A. EFFECTS OF TREATMENT AND SAMPLE DAY ON RUMEN VAULT GASES

Gas, %	H_2	SE	CH_4	SE	CO_2	SE
Protein x Sample Day						
10.4% x 37	3.25	.38	13.74[a]	2.29	83.00[a]	2.18
10.4% x 65	.95		21.53[b]		77.51[a,b]	
10.4% x 84	.35		30.94[c]		68.71[c]	
12% x 37	4.19		20.51[a,b]		75.29[b,c]	
12% x 65	.57		22.27[b]		77.16[a,b]	
12% x 84	.38		24.30[b]		75.32[b]	
Monensin x 37	4.57[a]	.40	16.34	2.42	79.08	2.30
Monensin x 65	.55[b]	.38	24.11	2.29	75.34	2.18
Monensin x 84	.36[b]	.38	25.84	2.29	73.80	2.18
No Monensin x 37	2.88[c]	.40	17.91	2.42	79.20	2.30
No Monensin x 65	.98[b]	.38	19.69	2.29	79.33	2.18
No Monensin x 84	.37[b]	.38	29.40	2.29	70.23	2.18

[a,b,c]Means in the same column with different superscripts differ significantly ($P<.05$).

Summerson (1941) method. Rumen lactate (mg/ml) production was not altered by monensin, protein or calcium:phosphorus ratio. A monensin by protein interaction was detected with steers fed 12% crude protein with and without monensin having similar lactate levels while steers fed 10.4% crude protein and monensin had significantly higher (P .05) lactate levels. Other researchers have observed an increase in lactate level due to monensin (Thornton et al., 1976; Bartley et al., 1979).

Rumen ammonia-nitrogen (mg/100 ml) was not altered by monensin or calcium:phosphorus treatments. However, the 12% protein diet produced an increase in rumen ammonia-nitrogen ($P<.05$). Haaland et al., (1979) reported steers fed 11%, 14%, and 17% crude protein had rumen ammonia levels of 10.9, 18.1 and 29.6 mg/100 ml, respectively, when sampled three hours post-feeding. Thus, increased rumen ammonia was attributed to increased dietary protein. Cross et al., (1974) reported similar findings. Rumen ammonia-nitrogen levels increased as the trial progressed for steers receiving 12% crude protein. But, values for steers fed 10.4% crude protein did not change significantly. A protein by calcium:phosphorus interaction was observed. Steers fed 12% protein diets had higher rumen ammonia levels which would agree with Haaland et al. (1979), that extra protein can overcome the decrease in ammonia production caused by increased limestone. Limestone can increase the rumen pH

TABLE 10. EFFECTS OF DIETARY TREATMENTS ON RUMEN LACTATE AND AMMONIA-NITROGEN LEVELS

	Lactate (mg/ml)	Ammonia Nitrogen (mg/100 ml)
Treatment:		
No Monensin	.91	2.04
Monensin	.94	1.72
10.4% Crude Protein	.97	1.09[a]
12% Crude Protein	.88	2.67[b]
1.1:1 Ca:P	.83	1.56
1:2.25 Ca:P	1.00	2.08
1.7:1 Ca:P	.95	2.01
Significant Interactions:		
10.4 x No Monensin	.84[a]	
10.4 x Monensin	1.09[a]	
12 x No Monensin	.98[a]	
12 x Monensin	.79[b]	
10.4 x 1.1:1		1.32[a,b]
10.4 x 1:2.25		1.07[a,b]
10.4 x 1.7:1		.89[a]
12 x 1.1:1		1.80[b]
12 x 1:2.25		3.10[c]
12 x 1.7:1		3.12[c]
1.1:1 x No Monensin		1.88[a,b]
1.1:1 x Monensin		1.24[c]
1:2.25 x No Monensin		1.78[a,b]
1:2,25 x Monensin		2.38[a,b]

[a,b,c]Means in the same column with different superscripts differ significantly ($P<.05$).

TABLE 10A. EFFECTS OF PROTEIN LEVEL AND SAMPLE DAY ON RUMEN AMMONIA-NITROGEN

	Rumen Ammonia-Nitrogen (mg/100 ml)	
Sample Day	10.4%	12%
37	1.11[a,c]	1.38[a,c]
65	1.05[a,c]	3.48[b,d]
84	1.13[a,c]	3.16[b,d]

[a,b]Means in the same column with different superscripts differ significantly (P .05).

[c,d]Means in the same row with different superscripts differ significantly (P .05).

which can enhance the absorption of volatile fatty acids from the rumen. This increased absorption of volatile fatty acids results in increased absorption of ammonia (Hogan, 1961). Thus, at the 10.4% crude protein level, ammonia production is lower than the amount needed to overcome the increased absorption associated with the higher pH.

A significant interaction also resulted from monensin and calcium:phosphorus on rumen ammonia. Monensin decreased rumen ammonia at the 1.1:1 level, showed no influence at the 1:2.25 and lowered rumen ammonia at the 1.7:1 level. A decrease in rumen ammonia concentration has been observed in cattle fed monensin (Martin *et al.*, 1976) and, as indicated previously, limestone can decrease rumen ammonia level (Haaland *et al.*, 1979). The additional phosphorus may partially counteract the ability of monensin to depress rumen ammonia.

Fecal Starch and Fecal pH

Effects of monensin, protein and calcium:phosphorus ratio on fecal starch content and fecal pH are shown in Table 11. No significant effect by week of sample was observed, so average values for the finishing period are reported. Monensin, protein, calcium:phosphorus or their interactions did not significantly affect fecal starch values. Fecal starch was higher for steers not receiving monensin, those getting the higher protein level and those fed 1.7:1 calcium:phosphorus. The 1:2.25 fed animals had the lowest fecal

TABLE 11. EFFECT OF MONENSIN, PROTEIN LEVEL AND CALCIUM:PHOSPHORUS RATIO ON FECAL STARCH AND FECAL PH

	Fecal Starch (%)	SE	Fecal pH	SE
Protein, %				
10.4	19.38	1.23	6.19	.09
12	21.46	.87	6.28	.09
Monensin	19.44	1.23	6.16	.09
No Monensin	21.41	.87	6.32	.09
Calcium:Phosphorus				
1.1:1	18.97	1.69	6.17	.11
1:2.25	18.22	1.07	6.11	.11
1.7:1	24.08	1.07	6.43	.11

starch content. Rust (1978) observed starch increased with decreasing protein and no monensin, while Thompson & Riley (1980) noted a small increase in fecal starch when monensin was fed.

Fecal pH was not altered by monensin, protein, calcium: phosphorus ratio or by interactions of these. Fecal pH was increased in steers not given monensin and those fed 12% protein, but those of the 1.7:1 ratio had the highest. A ratio of 1:2.25 gave the lowest fecal pH. Rust (1978) and Thompson & Riley (1980) noted monensin gave a small increase in fecal pH. Krause and Britton (1978) reported that additional limestone increased fecal pH.

The correlation coefficient between fecal starch and fecal pH was -.08. This low correlation indicates a lack of relationship between fecal starch and fecal pH. Wheeler and Noller (1977) reported -.82 and -.94 correlations between fecal starch and fecal pH for two cattle trials. Owens et al. (1979) reported a correltation of -.69 between fecal starch and fecal pH. Zinn and Owens (1980) observed a correlation of -.74 for fecal starch and fecal pH when unbuffered diets were fed. However, using buffered diets, the correlation coefficient decreased to -.14. Other low correlations also have bee reported. Thompson and Riley (1980) found a correlation of -.23. Thornton et al., (1978) observed a -.24 correlation between fecal starch and fecal pH.

Wheeler *et al*. (1979) suggested that animal response to limestone varies depending on particle size. The limestone with the smallest particle size resulted in the highest average daily gain, fecal pH and lowest percent fecal starch. A sieve test for particle size was completed on a 100 gram sample of limestone (Pfost & Headley, 1976). One hundred percent of the limestone passed through a 2,380 micron sieve, 9.62% passed through a 210 micron screen and 1.01% passed through a 53 micron sieve. Mean particle size was 333.96 microns with a surface area (sq. cms/g) of 103.82. Wheeler *et al*. (1981) observed steers fed limestone at levels of .35%, .65% or .95% calcium. Limestone with 1.27-1.31% passing through a 53 micron sieve resulted in lowered gain and efficiency for steers as compared to steers fed a limestone having 1.53-1.77% passing through a 53 micron screen. Williams *et al*. (1981) observed particle size did not significantly affect performance using limestones with mean diameters of 420, 20, 3.2 and 2.5 microns for 288 kg steers receiving .5 to .6% calcium in the diets.

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EFFECT OF PROTEIN LEVEL, MONENSIN AND CALCIUM:PHOSPHORUS RATIO ON FINISHING STEERS

by

SUSAN K. DURHAM

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Sixty Hereford steers (averaging 346 kg) were randomly allotted to twelve pens of five animals. Utilizing a 2x2x3 factorial design, the following treatments were fed: monensin or no monensin; 10.4% or 12% crude protein; 1.1:1, 1:2.25 or 1.7:1 calcium to phosphorus ratio. Six pens were assigned to each protein level, with two of the pens receiving each calcium:phosphorus ratio and three were fed monensin. Complete mixed diets were 75-81% corn, 15% corn silage and 4-10% supplement on a dry matter basis. Protein and calcium:phosphorus were adjusted by changing the supplement. Feed intake was *ad libitum* for the eighty-four day finishing period.

There were no significant differences in gain or feed efficiency for the 10.4% and 12% crude protein diets: 1.05 kg per day, 8.15 and 1.07 kg per day, 8.46, respectively. Feeding a 1.1:1, 1:2.25 or 1.7:1 calcium:phosphorus ratio resulted in daily gains (kg) and feed efficiencies of: 1.15, 7.75; .97, 8.99; and 1.06, 8.53, respectively. Monensin improved feed efficiency but not gain ($P<.05$). Monensin fed steers gained 1.12 kg per day with an efficiency of 7.78 compared to steers not fed monensin with gains of 1.00 kg per day and an 8.90 feed conversion. The protein level by monensin interaction was not significant. Steers receiving 10.4% crude protein with a 1.1:1 calcium:phosphorus ratio had the best gain and efficiency.

Monensin lowered the molar percent of acetic, Monensin lowered the molar percent of acetic, isobutyric and valeric fatty acids while increasing the percent propionic. Protein or calcium:phosphorus treatments did not alter the molar percent of volatile fatty acids.

Rumen vault gases were unaffected by protein, monensin or calcium:phosphorus treatments. Some significant interactions were noted between monensin and protein on percent hydrogen and a sample day interaction with protein or monensin on hydrogen, methane and carbon dioxide percents.

Rumen lactate level was not altered by any of the treatments. A monensin by protein interaction was observed. Steers fed 10.4% crude protein and monensin had significantly higher lactate levels.

Rumen ammonia-nitrogen lelvel was unchanged by monensin or calcium:phosphorus treatments. Steers fed the 12% crude protein level had significantly higher levels. Some significant interactions were also noted.

Fecal starch and fecal pH were unaltered by protein, monensin or calcium:phosphorus treatment. Fecal starch and fecal pH were higher for steers not fed monensin, steers fed 12% crude protein and steers receiving the 1.7:1 calcium:phosphorus treatment. The correlation between fecal starch and fecal pH was low, -.08.