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Monensin, Protein Supplementation and Tylosin for Feedlot Cattle

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MONENSIN, PROTEIN SUPPLEMENTATION AND

TYLOSIN FOR FEEDLOT CATTLE

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TYLOSIN FOR FEEDLOT CATTLE

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

Scientific research has made substantial contributions to the efficiency of American agriculture. Livestock producers in particular have benefited from the extensive study of animal nutrition. Nutrient requirements of animals and the nutrient composition of feeds are essential to efficient and economical feeding of farm animals. Research over many years has provided considerable information on animal requirements and feed composition. While there are still many gaps of knowledge in these areas, available information allows wise choice in selecting feedstuffs and using them in various combinations to meet animal requirements for various productive purposes.

Feed costs represent the single largest expenditure in a livestock feeding enterprise. Extensive research has therefore been devoted to investigation of methods to improve the efficiency with which animals utilize feed. Awareness of food shortages in developing nations has placed additional importance on techniques which improve the feed efficiency of domestic livestock. Cattle feeders have benefited from the availability of growth stimulants and antibiotics which can improve growth rate and feed efficiency.

Monensin is a feed additive which was made available to cattle feeders in 1975. While its action is distinct from antibiotics, the product has been shown to improve the efficiency of energy conversion in growing and finishing cattle. The effects of monensin on protein utilization are not well established. A primary objective of the feeding experiments reported was to determine the influence of monensin on the dietary protein needs of cattle fed corn silage growing rations and high-concentrate finishing rations. Of additional interest was the response to different sources of supplemental protein, either soybean meal or urea, when fed with monensin in a growing ration. Another objective was to determine the usefulness of feeding an antibiotic, tylosin, in combination with monensin in a high-corn grain finishing ration.

REVIEW OF LITERATURE

The anatomy of the ruminant digestive tract is unique in the animal kingdom. The reticulo-rumen or forestomach, peculiar to ruminants, provides these species with an exceptional capacity for the utilization of fibrous feeds. This large organ precedes the abomasum, comparable to the stomach of monogastric species, and is populated with microorganisms capable of digesting the structural carbohydrates of plants as well as other degradation and synthetic activities important to the host animal. A large portion of the nutrients available to the host are, therefore, synthetic and end-products resulting from microbial activity. Man has benefited from the domestication of certain ruminants by using them to consume plant material which might not otherwise be used. Forages produced on land not suitable for cultivation, crop residues and products from food processing can be converted into meat and milk for human consumption as well as fiber, hides and other useful products.

The study of the nutrition of ruminants has had to explore the relationship between the rumen microbes and the host in addition to the impact of the diet on animal performance. While the symbiotic microorganisms are beneficial they also tend to limit the efficiency with which ruminants produce meat or milk from feed. Efforts have been made to manipulate the rumen environment in order to reduce the losses of dietary nutrients resulting from microbial action and to improve the efficiency with which the resulting products are utilized. Monensin is a recently developed feed additive which has been shown to have a potential in improving the efficiency of feed utilization by ruminants.

This review will first examine those aspects of energy metabolism which are peculiar to ruminants. The influence of monensin on energy utilization and animal performance will then be discussed. Finally, it will remain to evaluate the potential for the use of antibiotics in combination with monensin and to explore the effects of monensin on protein utilization.

Energy Metabolism in Ruminants

Extensive exposure of ingested feedstuffs to microbial fermentation in the rumen has a significant impact on energy metabolism. Carbohydrates constitute the primary dietary energy source for ruminants. These include structural polysaccharides, principally cellulose, starches and small amounts of sugars. Under most feeding conditions, proteins and lipids are not commonly used for major sources of energy in diets of ruminants. In monogastric species, glucose and other simple sugars are the important products of carbohydrate digestion made available for absorption. While small amounts of carbohydrate may escape microbial degradation in ruminants and yield some glucose, the important energy containing compounds available to the host animal are the end-products resulting from the metabolic activities of the rumen microorganisms. The volatile fatty acids (VFA) are the compounds most significant in absorption and energy metabolism. Carbon dioxide and methane are also produced during fermentation and influence the energy available from feedstuffs. Of the VFA produced, acetate, propionate and butyrate are the most abundant. Valerate, isovalerate and higher acids are present, but in relatively inconsequential quantities. Small amounts of lactate, formate, succinate and hydrogen are frequently present in rumen fluid, but absorption of these is generally insignificant to the energy processes of the animal.

The fundamental substrates for microbial energy metabolism in the rumen are monosaccharides derived from the breakdown of plant carbohydrates. Microbes ferment simple sugars anaerobically producing VFA and energy. The anaerobic conditions in the rumen dictate that electron acceptors other than oxygen must be reduced to dispose of the metabolic hydrogen produced by fermentation. Two principal reactions which accomplish this are the reduction of carbon dioxide to methane and the reduction of pyruvate to propionate (Leng, 1970; Hungate, 1966). The production of methane which is lost largely during eructation represents an energy loss much greater than in nonruminants.

Stoichiometric calculations based on theoretical fermentation models which consider the three major VFA, methane and carbon dioxide have revealed that fermentations which result in greater evolution of propionate from a constant amount of hexose will be accompanied by lowered amounts of acetate and butyrate as well as decreased losses of methane and carbon dioxide (Wolin, 1960; Hungate, 1966). The efficiencies of fermenting hexose to acetate, propionate and butyrate are 62, 109 and 78%, respectively (Chalupa, 1977).

These considerations have led to attempts to alter rumen fermentation in order to enhance the generation of propionate and improve the efficiency of the fermentation process. A number of factors may influence the amount and proportion of VFA and methane resulting from fermentation. These include the chemical composition and physical form of the diet, the level and frequency of feeding, rumen pH and the use of chemical additives. The proportion of acetate produced is generally highest when long-stemmed roughages are fed (Thomas and Clapperton, 1972). Bath and Rook (1963) established that the molar proportion of propionate increased as the structural carbohydrate content of the diet decreased. It is well established that increasing levels of concentrates in the diet will result in a decrease in rumen pH accompanied by greater production of propionate and reduced acetate production (Theurer et al., 1974; Rumsey et al., 1970). Increasing levels of feed intake will increase total VFA production and also narrow the acetate:propionate ratio (Rumsey et al., 1970). Supplementing a ration with sucrose or starch has also increased propionate generation (Bath and Rook, 1963). Pelleting of mixed rations, and steam flaking of corn or cooking of starchy feeds has favored propionate production at the expense of acetate (Rhodes and Woods, 1962; Shaw et al., 1960). Woods and Luther (1962) found that when fed with concentrates, more finely ground roughages increased rumen propionate levels.

Other workers have used chemical additives to inhibit methane production in an effort to improve fermentation efficiency. In reviewing work on methane inhibitors, Church (1975) points out that products which reduce methane yields generally do increase propionate production and improve energy utilization. The limitation of such materials seems to be a reduction in feed intake when fed under feedlot conditions thus counteracting some of the potential for improvement in gain or feed efficiency.

Conditions which favor propionate formation apparently have the potential to improve energy efficiency by reducing the energy lost as methane. There is also some question about the efficiency with which the various VFA are utilized by the host animal. Blaxter (1962) infused acetate, propionate, butyrate or mixtures of the acids into the rumen of sheep. He detected an improved utilization of propionate or mixtures containing higher levels of propionate for maintenance and fat deposition when compared to acetate or butyrate. It is significant that these infusions were made while the sheep were consuming a roughage diet. Other workers have reported supplemental acetate utilization is inefficient compared to propionate when added to high-roughage rations. Such rations already have high levels of acetate resulting from the fermentation of the roughage. Acetate appears to be used more efficiently when added to diets higher in concentrates and therefore yielding lower acetate formation (Tyrrell et al., 1975; Poole and Allen, 1970; Ørskov and Allen, 1966). In reviewing the information on the heat increments of VFA, Smith (1971) has suggested that there is insufficient data to determine the efficiency with which the individual VFA are used, especially for growth. Ørskov (1977) reviewed the investigations dealing with the effects of levels of VFA absorbed on production efficiency and maintained that the critical factor is the ratio of glucogenic to nonglucogenic compounds; if this ratio is unusually high or low, it will reduce the efficiency of energy utilization.

Influence of Monensin on Rumen Fermentation

A group of four similar compounds with biological activity have been shown to be produced by the fermentation of a strain of *Streptomyces cinamonensis*. Of these four, the most abundant is monensin. It displays moderate growth-inhibiting activity against many gram positive bacteria and fungi (Havey and Hoehn, 1967). Monensin is a monocarboxylic acid with a molecular formula of $C_{36}H_{62}O_{11}$. Preparation of the commercial product results in the formation of the sodium salt (Agtarap and Chamberlin, 1967). Monensin has been demonstrated to be a useful coccidiostat for poultry (Shumard and Callender, 1967). Monensin has also proved to be effective in controlling coccidiosis in lambs, either artificially infected or with naturally occurring infestations (Bergstrom and Maki, 1976; Bergstrom and Maki, 1974). Fitzgerald and Mansfield (1973) demonstrated that coccidiosis in dairy calves could be controlled by including monensin in a pelleted feed.

It has been discovered that in addition to being a useful coccidiostat, monensin influences the end-products of rumen fermentation. The mode of action of the compound remains speculative, but its final effects on rumen fermentation are well substatiated. Richardson et al. (1976) examined the VFA profile in an in vitro fermentation system when monensin was added at levels ranging from .1 to 25 parts per million. The inocculum was obtained from cattle receiving a high-concentrate diet and the same diet was used as the substrate. Concentrations above 1 ppm reduced the molar percentage of acetate. Butyrate decreased above .5 ppm and propionate increased with increasing dosage levels. Total VFA production increased slightly with monensin levels below 1 ppm, while higher levels did not affect total volatile fatty acids. A similar response was obtained when an innoculum from sheep was used. Two levels of monensin (1 or 5 ppm) were tested in the fermentation of a high-roughage substrate. Acetate formation was reduced by the 5-ppm level. Propionate levels increased and butyrate levels decreased at both 1 and 5 parts per million. Total VFA generation was the same with or without monensin.

Investigations have also been conducted to determine the effects of monensin in vivo. Richardson et al. (1976) found that rumen samples taken from fistulated steers contained higher levels of propionate but lower concentrations of acetate and butyrate when monensin was fed. This trend was detected in both pasture-fed steers and those receiving high-grain rations. Similar patterns of VFA production were indicated by rumen samples taken in an additional feeding trial. Monensin has resulted in enhanced propionate production at the expense of acetate and butyrate while not significantly altering total VFA concentrations. These observations, substantiating the work done with in vitro fermentations, have been made with cattle fed high-concentrate rations (Perry et al., 1976; Raun et al., 1976), growing animals fed primarily forage (Boling et al., 1977; Riley et al., 1976), cattle on pasture (Potter et al., 1976a) and cows wintering on hay (Turner et al., 1977).

Dinius et al. (1976b) concluded that monensin had little influence on ration digestibility. Monensin did not alter cotton fiber digestibility in vitro. A similar response was observed when cotton strips were placed in the rumen of fistulated steers and recovered after 72 hours. Digestion trials indicated that levels of monensin up to 33 ppm had no effect on digestion of dry matter, crude protein and cellulose or hemicellulose when a forage diet was fed. Further, monensin did not change the numbers of protozoa, bacteria or cellulolytic bacteria in the rumen. The anticipated reduction in the acetate:propionate ratio was encountered. A decrease in cellulose digestion might have been expected since acetate is such a dominant product of cellulose fermentation, but none was observed. A later report by these workers (Simpson et al., 1976) indicated that monensin did inhibit cellulose digestion by rumen microbes unadapted to monensin in vitro. No explanation for the differences observed from the in vivo results was offered. Hanson and Klopfenstein (1977a) have reported data indicating a tendency for monensin to reduce the number of ruminal protozoa.

The shift in quantities of VFA produced when monensin is fed suggests that a decrease in methane losses would also occur. Thornton et al. (1976) verified this using indirect calorimetry. Monensin reduced methane production, energy lost as methane and the proportion of total heat loss due to methane. Carbon dioxide production increased, but oxygen consumption, respiratory quotient and total calculated heat production were not significantly altered by monensin. The response was similar over various levels of concentrate in the ration. There appeared to be some reduction in the effectiveness of monensin to inhibit methane formation with increasing time after feeding. In addition to the typical changes in VFA levels, steers fed a ration of alfalfa hay or meal had higher rumen pH when monensin was fed (Dinius et al., 1976a). Lemenager et al. (1977) found that monensin decreased the rate of turnover of solids and liquids in the rumen. Van Hellen et al. (1976) first reported that monensin decreased the activity of pancreatic amylase with two levels of energy intake. Subsequently, they found an increase in amylase activity due to monensin (Van Hellen et al., 1977). Monensin has also resulted in increased production of lactic acid in vitro (Beede and Farlin, 1977; Beede and Farlin, 1975). Increased lactic acid availability may be important as an intermediate in propionate synthesis through conversion to acrylate.

Monensin additions have resulted in consistent changes in the end-products of fermentation both in vitro and in vivo. Further, the pattern of increased propionate production accompanied by lowered generation of acetate and butyrate, without changing total VFA has been observed when rations of varying composition and energy density have been fed. The capacity of monensin to favor fermentations which release propionate and previous investigations which suggest more efficient utilization of feed when higher levels of propionate are produced have led to extensive investigation of the influence of monensin on the performance of growing and finishing cattle.

Monensin and the Performance of Growing and Finishing Cattle

High-Concentrate Rations

Richardson *et al.* (1976) suggested that a theoretical increase in the gross energy of the end-products of fermentation was possible when the VFA concentrations were shifted by monensin. They calculated that a change in the molar proportions of acetic, propionic and butyric acids from 60:30:10 without monensin to 52:40:8, typical of measured values with monensin, would theoretically increase the energy available from hexose fermentation by 5.6 percent. Such speculation has led to considerable investigation of the effects of monensin on feedlot performance. The objectives have been to evaluate the efficacy of the product and also to determine the optimum dosage level. Much of this work has been conducted with cattle fed high-concentrate rations.

Brown *et al.* (1974) compiled data from six feedlot trials where monensin was fed in high-grain rations at levels ranging from 0 to 44 parts per million. Increasing levels of monensin resulted in a nearly linear decline in feed intake. There was no appreciable effect on weight gain. All levels of monensin increased propionate concentrations in rumen fluid. The decrease in feed consumption with nearly equal weight gains resulted in an improvement in feed conversion when monensin was fed. The maximum improvement in feed efficiency (9.8%) occurred at a dosage of 33 parts per million. Raun et al. (1976) also examined the dosage response to monensin. Their results using levels from 0 to 88 ppm confirmed other data. Feed intake decreased progressively with higher dosages. There was a small improvement in growth rate with low levels of monensin (5.2% with 11 ppm). All treated animals had improved feed efficiency; the maximum response (17%) was again at 33 parts per million. Others have also shown that the most consistent response to monensin with high-grain diets is a decrease in feed intake without reducing average daily gain. The result is an improvement in feed conversion (Perry et al., 1976; Farlin et al., 1975; Wilson et al., 1975; Embry and Swan, 1974). A level of 33 ppm, comparable to 30 g/ton of air-dry feed, appears to produce the optimum improvement in feed utilization with high-concentrate rations (Sherrod et al., 1975; Wolfe and Matsushima, 1975).

Utley et al., (1977) determined that monensin was equally effective in promoting improved feed conversion when either dry corn or propionic acid treated high-moisture corn was fed as the major ration component. No difference was found in the response to monensin when whole and flaked corn were compared (Wolfe and Matsushima, 1975). Ralston and Davidson (1976) suggested that monensin was not as effective in promoting propionate production, and therefore in improving feed efficiency, when barley rather than corn was used in a finishing ration. On the other hand, in a direct comparison between barley or corn-based rations, the response to monensin was not different (Garrett, 1976).

Several workers have examined the influence of monensin on carcass composition, quality and yield indicators following finishing trials. Potter et al. (1976b) established that monensin did not alter the proportion of fat, lean or bone in the edible portion of the carcass. Furthermore, the amount of moisture, fat or protein in the rib-eye muscle was not changed. Dressing percent, quality and yield grades and internal and external fat measurements have revealed no differences attributable to the feeding of monensin (Farlin et al., 1975; Brown et al., 1974; Embry and Swan, 1974). Carcass fat and quality grades have been lowered when levels of monensin high enough to reduce growth rate were fed (Wilson et al., 1975).

Liver abscesses are frequently a problem when cattle are fed highly fermentable grain diets. In some instances, a higher incidence of abscessed livers has been encountered when cattle were fed monensin (Gill et al., 1977; Perry et al., 1976). While monensin appears to offer no protection from liver abscesses, most workers have not detected an increase in incidence when the product is fed (Potter et al., 1976b; Wilson et al., 1975; Wolfe and Matsushima, 1975).

High-Roughage Rations

Feedlot rations for growing cattle frequently contain larger amounts of roughages such as silages, corn cobs or hays than do finishing rations. Monensin appears to benefit the energy utilization of growing rations. Gill et al. (1976) determined that monensin decreased feed intake and improved feed utilization with rations containing 14, 30 or 75% corn silage with the remainder comprised of high-moisture corn grain and supplement. Others have also reported that the response to monensin with high-silage rations is similar to that with higher grain levels (Boling et al., 1977; Byers, 1977; Linn et al., 1976).

Several workers have reported some improvement in weight gain as well as feed efficiency with monensin fed in high-roughage growing rations. Steen et al. (1977) fed a corn silage-ground corn diet and reported that monensin improved gain as well as feed efficiency. In two trials with corn silage rations, Newmann et al., (1976) found that monensin decreased feed intake in one instance and improved average daily gain in the other; both resulting in improved feed conversion. Monensin additions to forage sorghum or milo stover silage rations have improved feed efficiency and also produced small increases in gain (Riley et al., 1976; Bolsen et al., 1975).

Grazing Cattle

In general, grazing cattle receiving monensin have gained faster than control animals. This effect has been observed on bluegrass-clover (Boling et al., 1977), coastal bermudagrass (Anthony et al., 1975; Oliver, 1975), native range (Corah et al., 1977; Brethour, 1976), wheat-ryegrass (De Moth et al., 1976) and wheat

(Horn et al., 1977) pastures. In two trials monensin did not improve pasture gains (Harris et al., 1976; Harvey et al., 1975).

Potter et al. (1976a) conducted three pasture experiments and one experiment in which green-chop forage was fed to cattle in drylot so that feed consumption could be monitored. Five levels of monensin ranging from 0 to 400 mg/per head daily were fed. Monensin increased pasture gain; the maximum response occurring at the 200-mg level. The green-chop trial indicated that monensin did not decrease forage intake except for a slight depression at 300-mg and 400-mg levels. Horn et al. (1977) used a chromic oxide indicator and hand clipped samples to determine intake from digestibility data for steers grazing wheat pasture. They calculated that monensin did result in decreased forage consumption.

It is significant that the most frequent change in animal performance when monensin is fed in rations with a high energy content is an improvement in feed efficiency with little alteration in gain. The response with cattle fed lower energy rations is more often a significant improvement in growth rate. This difference in the influence of monensin with high-concentrate or high-fiber diets is probably related to the mechanisms which control feed intake.

The major factors limiting the consumption of roughages are the capacity of the reticulo-rumen and the rate of disappearance from the digestive tract, including the absorption of digestion end-products and passage of undigested material. Ruminants will apparently graze or feed on roughages until distension of the reticulo-rumen halts the process (Campling, 1970). The nature of the roughage may also influence patterns of consumption. Lush pasture or high-quality harvested forages will have a faster rate of disappearance from the digestive tract because of better digestibility. This will promote more frequent feeding. Roughages of lower quality will not have as high a rate of turnover and total consumption will be somewhat reduced in comparison to more highly digestible forages. This reduces the energy available to the animal.

In contrast, animals feeding on concentrates will not fill the forestomach to capacity. Instead, intake appears to be regulated by the activation of receptors sensitive to products of digestion and energy metabolism. There may be a thermostatic level which is generally not exceeded. There is evidence for such receptors in the rumen, portal system and the hypothalmus (Baile and Mayer, 1970). Theurer et al. (1974) suggest that plasma propionate level or the acetate:propionate ratio is involved in the feedback satiety mechanism.

Since monensin increases the energy available from a given ration, the intake of cattle fed high-concentrate rations is reduced in order not to exceed the thermostatic ceiling. The increase in available energy allows comparable gains with less feed. On the other hand, when cattle are consuming roughages, feed intake is limited by gut capacity. Monensin makes more energy available from the same quantity of feed and therefore promotes faster growth. The response to monensin has been more variable with high-roughage rations, probably because of variations in the quality and digestibility of feedstuffs used. Campling (1970) indicated that voluntary feed intake is limited by rumen capacity when the digestibility of the feeds is below 60 to 70 percent. This is approximately the digestibility of corn silage and the higher quality forages. Those of lower quality and digestibility might then be expected to respond differently to monensin.

The large number of feeding trials conducted with monensin substantiate that the product does improve feed utilization and can be expected to be effective under a wide range of feeding conditions. When high-energy diets are fed, monensin has consistently reduced the feed requirement without altering daily gain. With pasture-fed cattle or those fed forage in drylot, the most frequent observation has been improved growth rate with nearly equal feed consumption. When rations of intermediate energy content, such as corn silage, have been fed, monensin has generally improved feed utilization; but improvement in feed efficiency with about equal gains and also with increases in daily gain have been reported in various experiments. Finally, monensin apparently has no influence on tissue or carcass composition.

Methods of Monensin Administration

Monensin is frequently provided to feedlot cattle in a complete mixed ration. This may not be convenient or appropriate under all circumstances. Summers and Sherrod (1976) compared the acceptability of either pelleted or meal protein supplements containing different levels of monensin when top-dressed on a finishing ration. All forms proved to be adequate methods to supply monensin with no detectable differences in acceptability. Corah et al. (1977) indicated that monensin could be successfully administered to grazing cattle in range blocks, a grain supplement or a liquid protein supplement. McCartor *et al.* (1976) found that grazing heifers refused a pelleted 20% protein supplement supplying 200 mg of monensin. Others have found no evidence of unacceptable palatability when monensin was supplied to cattle on pasture in a molasses-mineral block (Neumann *et al.*, 1976), cottonseed meal (Anthony *et al.*, 1975) or a grain supplement (Boling *et al.*, 1977; Harris *et al.*, 1976; Harvey *et al.*, 1975; Oliver, 1975).

Because monensin reduces feed intake, some investigators have first fed the product at a low level for periods of 1 to 3 weeks before increasing to the commonly recommended levels. Sherrod (1976) found there was no advantage in gain or feed efficiency with a high-concentrate ration from feeding monensin at 11 ppm for 7 or 21 days before increasing it to 33 ppm compared to the higher level from the start. These findings are supported by Perry *et al.* (1976) who also found no improvement from feeding a lower level of monensin for the first 21 days. Similar results occurred with a high-roughage ration. There was no benefit from feeding 100 or 200 mg of monensin per head per day compared to 300 mg per head daily from the initiation of the trial (Riley *et al.*, 1976).

Monensin for Other Classes of Livestock

While monensin has been studied most extensively for use with cattle intended for slaughter, it may be useful with other classes of livestock. Turner *et al.* (1977) found that feeding monensin to cows improved weight gains during gestation and reduced the hay required during wintering. In one trial, cows fed monensin had a shorter interval from calving to first subsequent estrus probably because of the improvement in available energy. Stauffer and Ward (1977) also attributed increased weight gains for heifers or cows wintered on corn stalks, grain sorghum stubble or cool-season grasses to monensin. Other workers found no difference in winter weight change due to monensin (Lemenager et al., 1976).

De Muth et al. (1976) reported that cows consumed less molasses block when it contained monensin with no difference in weight gain or calf weaning weight. Moseley et al. (1976) found that heifers in drylot reached puberty, determined by first standing estrus and a palpable corpus luteum, earlier when receiving monensin. However, there was no difference in weight gain or conception rate. Randel and Rouquette (1976) reported that monensin improved feed efficiency of cows during lactation. Decreases in butter fat content and total milk solids appeared to be offset by small increases in milk production so that early calf performance was not affected.

Monensin included in creep feed of calves has allowed comparable gains while reducing feed consumption (Walker et al., 1977a). Monensin has also been tested in feedlot receiving rations. Priggs et al. (1977) reported that in one trial monensin included at 33 ppm depressed feed intake during the first week when fed to stressed calves. After 56 days, these animals had outperformed control calves or those introduced to monensin at lower levels. In a second trial, no differences in performance were observed.

Monensin did not improve feed efficiency or gain with feedlot lambs when fed at dosages ranging from 0 to 2.2 parts per million (Glenn *et al.*, 1977). Another trial with lambs fed a corn silage-husklage ration indicated that monensin provided at 30 mg per head daily allowed small improvements in weight gain and feed efficiency in rations supplemented with a natural protein source. This was not observed with urea supplementation (Hanson and Klopfenstein, 1977b). Feedlot observations indicate that monensin may be used successfully with growing lambs, but that optimum results occur at lower dosage levels than with cattle. However, the product does not have Food and Drug Administration (FDA) clearance for feeding to sheep at the present time.

Use of Monensin in Combination with Other Products

Monensin and Growth Stimulants

Several hormone or hormone-like preparations (diethylstilbestrol, zeranol, Synovex-S, Synovex-H, melengesterol acetate) have been used successfully to improve growth rate and feed conversion of growing and finishing cattle. Experimentation with the combined use of growth stimulants and monensin has been conducted at several locations. These products do not presently have FDA clearance for use in combination with monensin. Those cleared for use as implants have frequently been administered with monensin provided in the feed.

The response to combined monensin and implant treatments for finishing steers has been rather consistent. Monensin has not improved gain, but has resulted in an improvement in feed utilization additive to that resulting from the implant. This has been observed using diethylstilbestrol (DES) (Burroughs et al., 1976; Davis and Erhart, 1975) and DES followed by a Synovex-S reimplant (Gill, 1976). A similar response has been observed when DES, Synovex-S and zeranol were compared in combination with monensin (Sherrod et al., 1976; Weichenthal et al., 1976). Perry et al. (1976) examined the VFA profile when monensin was fed and a DES implant was used. DES alone had no effect on VFA concentrations but appeared to further enhance the production of propionate when administered with monensin.

Experiments have also been conducted to examine the effects of monensin when used in combination with growth stimulants available for use with heifers. Utley et al. (1976) tested implant treatments with and without monensin for heifers grazing coastal bermudagrass. Monensin improved rate of gain and zeranol or Synovex-H implants produced a further additive growth response. In a finishing trial these workers found an additive response to monensin and implants for improving feed efficiency, but monensin had no effect on gain. Bruin et al. (1977) fed heifers corn silage and high-moisture corn grain. They reported that the maximum improvement in feed efficiency resulted from the combined use of monensin and melengesterol acetate (MGA) or with monensin and Synovex-H implants.

It appears that growth stimulants and monensin improve feed conversion or growth rate through different metabolic effects. In most feeding situations, the use of these materials in combination will produce a response nearly equal to the sum of the benefits of using each product alone with no synergistic effects.

Monensin and Antibiotics

A number of antibiotics have been used in feedlot rations for the past 25 years. While the mode of action is not certain, continuous feeding of antibiotics at sub-therapeutic levels often results in small advantages in growth and feed efficiency. Recent research has confirmed that oxytetracycline (O'Kelly *et al.*, 1972), chlortetracycline and tylosin (Brown *et al.*, 1975) can improve the performance of feedlot cattle. It is well documented that abscessed livers represent a loss to the producer not only because of the loss in sale value of the liver, but also because of the depressed performance of cattle with affected livers. Abscesses most frequently become a problem when cattle are fed a ration with very low levels of roughage or when roughage is absent (Foster and Woods, 1970). Tylosin has been observed to be effective in reducing liver damage (Brown *et al.*, 1975; Brown *et al.*, 1973).

Since it has been shown that monensin offers no protection from liver abscesses, several investigators have fed high-concentrate rations supplemented with both monensin and the antibiotic tylosin in an effort to control liver abscesses and to determine if the antibiotic might improve gain or reduce the feed required for gain in comparison to monensin alone. The addition of tylosin to a high-grain ration including monensin has proved to be effective in controlling liver abscesses (Heinemann *et al.*, 1977; Farlin, 1976; Sherrod and Burnett, 1976; Matsushima and Haaland, 1975). Farlin (1976) has reported that tylosin provided a small additional improvement in feed efficiency when fed with monensin and Ali *et al.* (1975) found that tylosin increased daily gain to a small extent compared to a treatment receiving monensin only. In contrast, other workers have found no benefit in feedlot performance by including tylosin in addition to monensin (Heinemann et al., 1977; Sherrod and Burnett, 1976; Matsushima and Haaland, 1975).

The major advantage in the use of tylosin with monensin appears to be a reduction in the number and severity of liver abscesses. Investigations with other antibiotics used in combination with monensin have not been reported. It might be expected that results would be similar to those observed with tylosin. There may be a potential for further small improvements in performance since monensin affects changes primarily in the rumen allowing for more efficient feed utilization while antibiotics may exert their influence through improvement in nutrient absorption from the intestine and by control of various diseases, often at subclinical levels.

Monensin Used with Other Feed Additives

Several other feed additives have been used in combination with monensin. When fed with a high-roughage ration of forage sorghum silage and rolled milo, amicloral, a methane inhibitor, and monensin both improved gain and feed efficiency. The greatest response in feed efficiency resulted from using the products together, their complementary effects approaching significance at the 5% level (Brethour and Chalupa, 1977). Two trials have tested a feed intake stimulant, elfazepam, in combination with monensin. From the limited data available, this combination does not seem to be beneficial

(Farlin and Baile, 1977; Isichei et al., 1977). Sodium bicarbonate and dolomite are sometimes used as rumen buffers when high-concentrate rations are fed. The combined use of either of these materials with monensin has not been shown to offer further improvement in feedlot performance compared to the use of monensin alone (Hale and Theurer, 1976; Hale et al., 1976; Lofgreen, 1976).

Influence of Monensin on Protein Utilization

Monensin and Protein Metabolism

Microbial fermentation modifies dietary protein in a manner similar to its effect on ingested carbohydrates. The amino acids available for absorption in the intestine may be the constituents of feed proteins and those which have been incorporated into microbial protein from feed protein and nonprotein nitrogen. Thus, the microbes have an impact on both the quantity and quality of protein available to the host animal.

Protein metabolism is closely related to the needs for energy and the available energy releasing materials in all animals. The use of amino acids for energy by either the host or by rumen microbes may alter protein utilization. Furthermore, the modification of the energy yielding substrates made available to the host could also have an effect on protein metabolism.

All mammals have a metabolic requirement for glucose. Adaptations which allow ruminants to use alternate energy sources, especially the VFA, to satisfy a substantial portion of their energy requirements results in lower needs for glucose. This is reflected in lower plasma glucose levels in ruminants than are found for the monogastric species. There are some body processes which must be supplied with glucose. Small amounts of readily digested carbohydrates may not be fermented to VFA in the rumen. Digestion in the small intestine may then make some glucose available for absorption. The remainder of the glucose need must be met through de novo synthesis. Large amounts of glucose are synthesized from propionate (Lindsay, 1970; Leng et al., 1967) and from the carbon skeletons of catabolized amino acids (Reilly and Ford, 1971). No capacity for ruminants to convert acetate to glucose has been established (Smith, 1971).

The use of amino acids for gluconeogenesis is expensive nutritionally. It represents a loss of precursors needed for synthesis of tissue protein. Further, catabolism of amino acids for carbohydrate synthesis increases heat losses because of the energy expended in the disposal of the amino nitrogen. Since monensin makes a larger percentage of the carbohydrate energy available in the form of propionate, it could favor the synthesis of glucose from this three carbon VFA, sparing the use of amino acids. Eskeland et al. (1974) disclosed that intravenous infusions of propionate or glucose were more effective in promoting nitrogen retension than isocaloric additions of acetate or butyrate. Potter et al. (1968) demonstrated that the infusion of propionate or glucose resulted in a greater reduction of the plasma essential amino acids than occured with acetate or butyrate. In addition, the pattern of amino acids removed was more highly correlated with meat tissue composition when glucose or propionate supplementation was used. Indirect evidence, therefore, suggests that propionate may spare amino acids from catabolism. Increased propionate levels may also enhance tissue protein synthesis by increasing cellular uptake of amino acids or by providing carbon skeletons for non-essential amino acid synthesis (Eskeland et al., 1974).

Recent studies have examined the influence of monensin on a number of parameters which reflect the nature of protein metabolism either in the rumen or in the tissues of the host animal. Several workers have found that animals fed monensin have higher blood glucose levels than control animals (Glenn et al., 1977; Potter et al., 1976a; Raun et al., 1976). These results support the contention that higher propionate levels enhance glucose synthesis. Trends for higher insulin levels for cattle fed monensin have also been presented (Potter et al., 1976a; Raun et al., 1976). Higher levels of insulin may be important in improving glucose and amino acid uptake by the tissues. In contrast, Steen et al. (1977) reported that monensin did not influence plasma glucose levels.

While all dietary protein is not degraded by the activity of microorganisms, most protein is subjected to some microbial conversion. Microbes utilize protein for their own synthetic processes. The result is that a large portion of the amino acids made available for absorption in the small intestine are those derived from the protein contained in microbial cells. Protein quality is therefore affected both by the quality of dietary protein and the nature of microbial action.

Microbes may also influence the amount of dietary nitrogen which the host recovers and can use for tissue growth. Two important reactions in microbial protein metabolism are the deamination of amino acids which produces ammonia and the combination of rumen ammonia with carbon skeletons in the synthesis of new amino acids. Losses of dietary nitrogen may result if deamination generates ammonia at a rate faster than the synthetic processes can accommodate. Ammonia is absorbed through the rumen epithelium and may be used to some extent as a nonspecific nitrogen source by the host. Some amino nitrogen may be reintroduced into the rumen when urea is returned in the saliva. Blood ammonia levels which exceed the capacities for these processes must be excreted in the urine. This represents a loss of nitrogen and of energy required in the excretion processes.

Trends for small increases in protein or nitrogen digestibility due to monensin have been reported (Glenn et al., 1977; Dinius et al., 1976b). Others have found no differences in digestibility attributable to monensin (Hanson and Klopfenstein, 1977a; Linn et al., 1976). Ammonia concentration has been depressed during in vitro fermentation by monensin additions (Tolbert et al., 1977). The same trend for decreased ammonia has been substantiated in vivo (Hanson and Klopfenstein, 1977a; 1977b; Dinius et al., 1976a; 1976b). Monensin has also increased the amount of free amino acids during in vitro fermentations. The concommitant decrease in the release of ammonia and increased levels of amino acids indicate that monensin may inhibit the extent of microbial deamination or it may enhance proteolysis (Tolbert et al., 1977). These changes were observed to be more dramatic at earlier stages of fermentation, suggesting that monensin may act by altering metabolic pathways rather than changing the microbial population (Tolbert, personal communication).

The addition of monensin has also produced an increase in blood urea levels (Glenn et al., 1977; Hanson and Klopfenstein, 1977a; Potter et al., 1976a; Raun et al., 1976). Steen et al. (1977) reported no difference in blood urea nitrogen due to feeding monensin. Raun et al. (1976) commented that if monensin increases energy availability without affecting amino acid availability, a decrease in blood urea nitrogen would be anticipated. The opposite observation may suggest that monensin increased the amino acids available in relation to energy or that propionic acid enhances cellular nitrogen metabolism. Eskeland et al. (1974) reported increased nitrogen retention and increased blood urea nitrogen in animals infused with propionate compared to those receiving acetate. While Potter et al. (1968) found that propionate infusion depressed the ratio of essential to nonessential plasma amino acids, Steen et al. (1977) indicated that monensin feeding did not change total plasma essential or nonessential amino acids. Isichei et al. (1977) reported that monensin did not depress plasma levels of branched-chain amino acids.

A trend for increased nitrogen retention due to monensin was detected by Dinius et al. (1976b). The same trend was not evident in data reported by Hanson and Klopfenstein (1977a). Byers (1977) found that protein deposition was higher in limit-fed steers receiving monensin. However, there was no difference in protein deposition in full-fed steers fed monensin in comparison to controls.

Urea is commonly used in rations for ruminants. The limited data available have not revealed any distinct differences in the effects of monensin on the utilization of this nonprotein nitrogen source compared to preformed protein either in *in vitro* fermentations (Tolbert *et al.*, 1977) or in the rumen (Hanson and Klopfenstein, 1977a). Van Hellen *et al.* (1977) found no differences in pancreatic protease activity due to monensin feeding.

Although the information available is somewhat inconclusive, monensin may exert some improvement in protein metabolism. It appears that the most plausible explanations for such a response would be due to higher levels of propionate sparing amino acids from catabolism, thus making them available for tissue protein synthesis. An additional possibility is that monensin reduces the loss of amino nitrogen by inhibiting the deamination activity of rumen microorganisms resulting in more efficient protein utilization.

Effects of Monensin on Dietary Protein Needs

Indirect evidence for improvement in protein assimilation is available from the large number of feeding trials which have been conducted with monensin. Cattle fed monensin in high-concentrate rations typically gain at the same rate and yield a carcass of comparable composition while consuming less feed than control animals. Reduced total feed intake results in a decrease in protein consumption to the same extent where protein has been provided at a constant percentage of the ration. Unless rations fed have contained excess protein, it can be inferred that better use of protein is made by cattle fed monensin. Conversly, cattle fed forage diets including monensin have often produced greater tissue growth on the same level of feed intake and therefore equal protein consumption. This again implies an improvement in the efficiency of protein utilization unless the protein content of the feed consumed has been higher than that required for optimum growth.

Several investigations have attempted to determine the effects of monensin on feedlot performance with diets containing different sources or levels of protein. Another technique used has been a periodic reduction in protein level, most often accomplished by withdrawing a high-protein ingredient from the ration.

Gill et al. (1977) fed a high-grain ration supplemented with soybean meal to provide four protein levels ranging from 9.5 to 12.3% for finishing steers. They found that the higher protein levels were beneficial only for cattle weighing less than 386 kilograms. Monensin was most effective in improving feed efficiency and gain at the lower protein levels,suggesting that the product may spare protein if protein intake is below the optimum amount. Hanson and Klopfenstein (1977b) also reported a greater response to monensin at a protein level of 11.1% than was observed at 13.1 percent. Walker et al. (1977b) conducted a trial in which the protein supplement was withdrawn after 56 days of the 78-day experiment. Cattle fed the lower protein level gained as well as the positive control so that protein utilization, expressed as the ratio of gain to protein intake, was improved. Monensin had no influence on protein utilization. Darit et al. (1976) fed corn grain and corn silage supplemented with soybean meal during a 168-day trial. Removal of the supplemental protein after 84 days resulted in decreased gain and poorer feed conversion for steers fed monensin as well as controls, although the reduction in performance was less dramatic for cattle receiving monensin.

Davis and Erhart (1976a) supplemented a corn grain-corn silage ration with urea to increase crude protein content from 9.5 to 11.5 percent. The urea was withdrawn at 0, 42 or 84 days in the 120-day feeding trial. When monensin was not fed, urea additions provided no improvement in performance. Monensin with urea improved rate of gain and tended to improve feed conversion. The investigators concluded that monensin promoted the utilization of the nitrogen provided by urea. Harvey et al. (1976) compared the response to monensin when fed with corn silage or silage ensiled with .5% urea. Monensin improved feed efficiency, but the effect was substantially more at the lower protein level.

In comparing the response to monensin when supplemental protein was provided by soybean meal or urea, Martin et al. (1977) reported no differences in either daily gain or feed efficiency between the two protein sources. When monensin was fed in finishing rations supplemented with either soybean meal or biuret, monensin improved feed efficiency to about the same extent with either protein source. There were no differences in daily gain (Thomas, 1976). Hanson and Klopfenstein (1977b) compared rations supplemented to either 10.5 or 12.5% crude protein with brewers dried grains or with urea. With the preformed protein, monensin resulted in faster gains and lower feed requirements at both protein levels. In contrast, the addition of monensin to the urea supplemented rations did not benefit growth or feed conversion. Davis and Erhart (1976b) fed a basal ration containing 10.5% protein or the basal ration supplemented to 13% protein with cottonseed meal or urea. There was little benefit in gain or feed efficiency for the additional protein. Monensin improved feed efficiency at either protein level with no difference between protein sources. The magnitude of the response was nearly the same with all three protein treatments.

From the information currently available it is difficult to draw precise conclusions about how the addition of monensin will affect dietary protein needs of cattle. In general, the response to monensin has been more substantial when protein levels have been below those considered optimum. In direct comparisons between different sources of protein, the response to monensin has often been similar with various protein sources. The influence of monensin on urea utilization has been inconsistent, with evidence for both increases and decreases in utilization. It is clear that a need exists for further investigation of how monensin may alter the microbial metabolism of protein and nonprotein nitrogen and to establish optimum protein levels when monensin is fed in growing and finishing rations.

MATERIALS AND METHODS

The investigation reported consisted of two feeding trials. The first, dealing with growing cattle, was conducted between January 29 and May 25, 1976. The subsequent finishing trial ran from June 23 through October 8, 1976. The two study phases were separated by an interim period and the same animals were used in both experiments.

The objectives of the first trial were to determine the response to monensin when different levels and sources of supplemental protein were fed in a corn silage ration and to examine a possible protein sparing effect of monensin and its influence on urea utilization. In the second trial, the response of finishing cattle fed a high-concentrate ration to an antibiotic (tylosin), monensin and a combination of the two products was measured by feedlot performance and the incidence of abscessed livers. Two protein levels were used to determine how each of the additives or the combination affected the need for supplemental protein in finishing rations comprised of corn grain and corn silage.

Growing Trial

One hundred ninety-two Hereford steer calves were selected from a group purchased at a local auction for use in this experiment. They were fed corn silage to appetite top-dressed with a ground corn supplement containing added vitamin A, trace mineral salt and supplemental calcium and phosphorus for 7 days prior to the beginning of the trial. No supplemental protein was fed during this first week.

All steers were treated with a pour-on grubicide and implanted with Synovex-S (200 mg progesterone and 20 mg estradiol benzoate) near the beginning of the experiment. The animals were confined to outside concrete-paved pens with water available from automatic waterers. Feeding was once daily in concrete fenceline feedbunks.

The corn silage fed during the trial was stored in upright concrete-stave silos. Samples were taken from each forage wagon load as the silos were filled. The samples were oven-dried and hand separated into grain and chopped forage portions and the resulting components weighed. Grain yield was determined to be 24.3% of the dry weight.

To begin the trial, a filled weight was taken in the morning before feeding. Animals were fed in the usual manner and unconsumed feed was removed from the feedbunks in late afternoon. After an overnight stand of about 16 hr without access to feed and water, a shrunk weight was taken the following morning. The steers were then randomly assigned within weight strata to 24 pens of 8 head each using the shrunk weight. Average initial shrunk weight was 225 kilograms.

The design of the experiment provided for three supplement treatments each fed with or without monensin. Each treatment was offered to four pens giving a 3x2 factorial arrangement with four replications. Since the drought conditions during the growing season resulted in a silage with a low grain content, additional corn grain was included in the supplements to provide a ration equivalent to a silage with a 50% grain content on a dry basis. This was expected to be more typical of silage from well-eared corn. This resulted in a ration containing 34% of the grain-supplement mixture and 66% silage on a dry basis. As fed, the grain-supplement mixture amounted to 18% of the ration and the corn silage 82 percent.

Three supplements were fed, each with and without monensin. These were: corn control providing no supplemental protein, one providing supplemental protein from soybean meal and the third providing supplemental protein from urea. Supplements were mixed with rolled corn grain to form the grain-supplement mixtures. The mixtures were fortified with appropriate ingredients to furnish rations with similar levels of calcium, phosphorus and trace minerals. Trace mineral salt and vitamin A were added to all supplements. Micro-ingredients were premixed with finely ground corn and then mixed with remaining ingredients to prepare the grain-supplement mixtures. Monensin was added to the treated supplements to provide about 11 ppm of dry ration for the first 21 days and 33 ppm for the remainder of the trial. Ingredient composition of the grain-supplement mixtures is shown in table 1.

Samples were taken after each mixing of the supplements and retained for chemical analysis to determine protein and moisture content. Corn silage samples were taken at intervals of about 1 week. One sample was oven dried to a constant weight to determine moisture content. This sample was kept for later determination of protein. A second sample was frozen for subsequent analysis to determine the water soluble nonprotein nitrogen content of the silage. Silage samples

TABLE 1. INGREDIENT COMPOSITION OF GRAIN-SUPPLEMENT MIXTURES (DRY BASIS) - GROWING TRIAL

Ingredient	Corn Suppl.	SBOM Suppl.	Urea Suppl.
Corn, dent yellow, gr 2 US, rolled (4-02-931)[a], %	95.69	75.71	92.82
Soybean seeds, solv-extd, grnd (5-04-604), %	----	20.41	----
Urea, 45% N, %	----	----	2.53
Limestone, grnd (6-02-632), %	1.70	1.73	1.30
Ca-P supplement 18-21.5% Ca, 18.5% P, %	1.66	1.26	1.72
Calcium sulfate, comm (6-01-087), %	----	----	.68
Trace mineral salt, %	.89	.89	.89
Trace mineral premix, %	.06	----	.06
Vitamin A, IU/kg	6468	6468	6468
Monensin, mg/kg[b]			
First 21 days	32.4	32.4	32.4
After 21 days	97.2	97.2	97.2

[a]Numbers given in parentheses are N.R.C. reference codes.

[b]Added only to treated supplements.

were composited by weigh periods for analysis. Crude protein contents of the silage and supplements were calculated from Kjeldahl nitrogen (A.O.A.C., 1970). Nonprotein nitrogen determinations of corn silage samples were made by M. Prokop, University of Nebraska, according to the procedure of Bergen et al. (1974). Protein and moisture contents of the silage and grain-supplement mixtures are shown in table 2.

Steers were fed once daily. Total feed offered was adjusted at each feeding to be available at all times yet to avoid accumulation in the feedbunks. Silage and the grain-supplement mixtures were fed in amounts to maintain constant ration composition of 18% grain-supplement and 82% silage, as fed. The grain-supplement mixtures were top-dressed on the silage.

Animals were weighed after 21 days and at intervals of 4 weeks thereafter, giving five weigh periods in the 116-day trial. Final filled and shrunk weights were obtained in the same manner as initially. Weight gain data were obtained for each animal. Feed intake and feed efficiency data were on a pen basis. Data presented for dry matter consumption and conversion efficiency of dry matter were calculated from the average dry matter composition of the complete rations.

The experiment was analyzed as a 2x3 factorial with four replications using analysis of variance (Steel and Torrie, 1960). The main effects were protein supplement treatment and monensin treatment. Five orthogonal comparisons shown in table 3 were also made.

TABLE 2. AVERAGE CHEMICAL COMPOSITION OF FEEDS
GROWING TRIAL

Feed	No. samples	Dry matter (%)	Crude protein (%)	Water soluble nonprotein nitrogen (%)
Corn dent yellow aerial	23	32.8	---	---
part, ensiled, drouth	5[b]	---	10.6	---
striken (3-08-403)[a]	4	---	---	.98
Corn suppl.	3	90.7	10.4	---
Corn-Monensin suppl.	3	90.4	10.3	---
SBOM suppl.	3	90.8	18.2	---
SBOM-Monensin suppl.	3	90.5	18.1	---
Urea suppl.	3	90.5	16.3	---
Urea-Monensin suppl.	3	89.7	16.9	---

[a]N.R.C. reference code.

[b]Samples analyzed were composites of several samples taken during each weigh period.

TABLE 3. SINGLE DEGREE OF FREEDOM COMPARISONS MADE FOR PERFORMANCE DATA - GROWING TRIAL

Comparison	Treatments Involved
1	Corn, Corn-Monensin vs. SBOM, SBOM-Monensin, Urea, Urea-Monensin
2	SBOM, SBOM-Monensin vs. Urea, Urea-Monensin
3	Corn vs. Corn Monensin
4	SBOM vs. SBOM-Monensin
5	Urea vs. Urea-Monensin

Interim Period

The growing trial was followed immediately by an interim period of 26 days during which all animals were fed identical rations. Steers were fed 4.54 kg/head/day of a corn grain-supplement mixture comparable to the corn supplement fed during the growing trial. It contained added minerals, vitamin A and trace mineral salt, but no high protein ingredients or monensin. In addition, steers were fed 4.54 kg of alfalfa-bromegrass hay each day for 11 days and then 18.2 kg of corn silage for the duration of the interim period.

Finishing Trial

The same group of Hereford steers was used in the finishing trial. Filled and shrunk weights were measured as they were in the growing phase. All cattle were reimplanted with Synovex-S for the second trial. Shrunk weights were employed to allot animals randomly within weight strata to 24 pens of 8 head without regard to previous treatment. Average initial shrunk weight was 372 kilograms.

All rations contained 66.5% whole corn grain, 8.5% supplement and 25% corn silage on an as fed basis. On a dry basis these percentages were 77.9, 11.7 and 10.4, respectively. Two types of rations were fed. One included no supplemental protein and the other contained soybean meal. Each ration then included a control, monensin, tylosin and monensin-tylosin treatment. Each of the eight ration treatments was fed to three pens resulting in a 2x2x2 factorial arrangement with three replications.

Supplements were prepared in the same manner as for the growing trial. Ingredients were included in the supplements to provide rations with similar levels of calcium, phosphorus, potassium and trace minerals. Trace mineral salt, vitamin A and vitamin E were added to all rations. Tylosin was included in the appropriate rations to provide approximately 75 mg/head/day. Monensin was added to designated rations to supply about 11 ppm of dry ration for the first 3 weeks and 33 ppm thereafter. Tylosin or monensin premixes, when added, replaced an equal weight of corn grain in the supplements. Ingredient composition of the supplements for the finishing trial is shown in table 4.

Samples of corn grain and corn silage were obtained at about weekly intervals and oven dried to a constant weight to determine moisture content. Dried samples were retained for chemical determination of crude protein after being composited by weigh period (A.O.A.C., 1970). Supplements were sampled at each mixing and later analyzed for protein in the same manner. Composition of the ration components is shown in table 5. Feed consumption and feed efficiency data were converted to a dry basis by adjusting as fed values according to the average dry matter content of the rations.

Feeding was once daily. Rations were offered at 4.54 kg/head the first day of the trial and increased .85 kg/head each day until steers were on full feed. Total daily feed was adjusted so that feed was continuously available, but in amounts to be nearly consumed by the next feeding. Rations were fed as complete mixes. Corn grain,

TABLE 4. INGREDIENT COMPOSITION OF SUPPLEMENTS (DRY BASIS) - FINISHING TRIAL

Ingredient	Corn Suppl.	SBOM Suppl.
Corn, dent yellow, gr 2 US, grnd (4-02-931)[a], %	75.66	12.13
Soybean seeds, solv-extd, grnd (5-04-604), %	---	67.63
Limestone, grnd (6-02-632), %	12.67	12.71
Potassium chloride, comm (6-03-756), %	4.32	1.74
Ca-P supplement 18-21.5% Ca, 18.5% P, %	1.65	.11
Trace mineral salt, %	5.68	5.68
Trace mineral premix, %	.02	---
Vitamin A, IU/kg	25,000	25,000
Vitamin E, IU/kg	341	341
Monensin, mg/kg[b]		
First 21 days	139	139
After 21 days	417	417
Tylosin, mg/kg[b]	85	85

[a]Numbers given in parentheses are N.R.C. reference codes.

[b]Added only to treated supplements.

TABLE 5. AVERAGE CHEMICAL COMPOSITION OF FEEDS FINISHING TRIAL

Feed	No. samples	Dry matter (%)	Crude protein (%)
Corn grain (6-02-632)[a]	12 4[b]	87.7 ---	--- 10.7
Corn silage (3-08-403)[a]	12 4[b]	34.8 ---	--- 9.6
Corn Control suppl.	3		8.8
Corn-Monensin suppl.	3		8.7
Corn-Tylosin suppl.	3		8.5
Corn-Monensin-Tylosin suppl.	3		8.8
SBOM Control suppl.	3		30.7
SBOM-Monensin suppl.	3		31.1
SBOM-Monensin suppl.	3		31.4
SBOM-Tylosin suppl.	3		31.4
SBOM-Monensin-Tylosin suppl.	3		30.5

[a]N.R.C. reference codes.

[b]Samples analyzed for protein were composites of several samples taken during each weigh period.

corn silage and supplements were weighed into a horizontal, scale-mounted mixer in amounts to maintain constant ration composition and mixed on an individual pen basis.

Steers were weighed at the end of 3 weeks and every 28 days thereafter for the duration of the experiment, giving four weigh periods in the 106-day trial. Final filled and shrunk weights were obtained in the same manner as initially.

During the second weigh period, four animals in each treatment were randomly selected to provide rumen samples. The samples of rumen fluid were obtained by stomach tube. Samples were analyzed for acetate, propionate, butyrate and total VFA levels at the Lilly Research Laboratories, Greenfield, Indiana.

Cattle were slaughtered in three groups made up of one pen from each treatment on three consecutive mornings at a nearby packing plant. Hot carcass weights were recorded and marbling score, quality grade and percent kidney, pelvic and heart fat were determined by a U.S.D.A. meat grader. Tracings of the rib-eye muscle and fat cover were made on one side of each carcass where it was separated between the 12th and 13th ribs. Fat thickness was measured on the tracings at a point three-fourths of the distance from the end of the muscle nearest the chine bone. Rib-eye muscle area was determined using a planimeter. Dressing percent was calculated from hot carcass weight and shrunk weight. Yield grade was determined from carcass weight, fat thickness, rib-eye area and percent kidney, pelvic and heart fat. Livers were examined at the time of slaughter to record the incidence of abscesses.

Feedlot performance data were analyzed as a 2x2x2x3 factorial using least-squares analysis of variance (Steel and Torrie, 1960). Protein level, monensin treatment and tylosin treatment were the main effects tested.

RESULTS AND DISCUSSION

Growing Trial

Protein contents of the complete rations fed during the growing trial are shown in table 6. Rations without supplemental protein contained 10.4% protein on a dry basis. Additions of soybean meal or urea increased the levels approximately 2.6 and 2.1 percentage units.

Average starting and finishing weights are shown in table 7. The control ration was deficient in protein for steers weighing less than 300 kg according to requirements of the National Research Council (1976). Protein-supplemented rations contained adequate protein for growing steers heavier than 200 kilograms.

Feed Consumption

Treatment means for daily dry matter consumption are shown in table 8. Data are cumulative to date for each weigh period. Feed consumption increased with increasing weights and time on experiment for all treatments. An orthogonal comparison indicated a tendency for higher ($P<.10$) dry matter intake by steers fed soybean meal-supplemented rations than by those fed rations with urea over the 116-day experiment. There was essentially no difference in consumption between corn or urea-supplemented rations. In other work at the South Dakota Agricultural Experiment Station, little difference in feed consumed has been observed where urea and soybean meal were compared as supplements to corn silage (Gates and Embry, 1976; Embry

TABLE 6. PROTEIN LEVEL OF COMPLETE RATIONS
GROWING TRIAL

Ration	Crude protein, dry basis (%)
Corn	10.4
Corn-Monensin	10.4
SBOM	13.1
SBOM-Monensin	13.0
Urea	12.4
Urea-Monensin	12.6

TABLE 7. AVERAGE INITIAL AND FINAL SHRUNK WEIGHTS
GROWING TRIAL

	Corn Suppl.		SBOM Suppl.		Urea Suppl.	
	Control	Monensin	Control	Monensin	Control	Monensin
No. animals	32	32	32	32	32	32
Init. wt., kg	225	225	225	226	225	225
Final wt., kg	352	358	367	369	360	364

TABLE 8. AVERAGE DAILY DRY MATTER INTAKE (kg) GROWING TRIAL

Days	Corn Suppl. Control	Corn Suppl. Monensin[a]	SBOM Suppl. Control	SBOM Suppl. Monensin[a]	Urea Suppl. Control	Urea Suppl. Monensin[a]
21	6.01	5.42	6.04	5.52	6.18	5.49
49	6.44	5.61	6.43	5.74	6.40	5.50
77	6.67	5.75	6.72	6.06	6.63	5.76
105	7.32	6.24	7.35	6.63	7.32	6.20
116	7.54	6.43	7.48	6.81	7.52	6.44

Daily Dry Matter Intake (kg)--116 days

Corn Suppl.	SBOM Suppl.	Urea Suppl.
6.99	7.15[+]	6.98

Control	Monensin
7.51	6.56**

[a]Monensin resulted in lower ($P<.01$) feed intake in all comparisons within supplement treatments.

[+]Feed consumption was higher ($P<.10$) for SBOM than for Urea.

**Monensin fed steers had lower ($P<.01$) dry matter intake.

and Swan, 1976; Burkhardt et al., 1973). Chalupa (1968) has reviewed research on feeding urea to ruminants and indicates that high levels of urea may depress feed intake.

When averaged across all treatments, monensin resulted in lower (P<.01) feed consumption. The reduction amounted to 12.7% over the entire experiment. Such a reduction in ration consumption is typical of that reported by other investigators where cattle were fed growing rations containing high levels of roughage (Boling et al., 1977; Riley et al., 1976; Embry and Swan, 1974). Variation in the magnitude of this effect has been encountered and reductions in feed consumption from 7.7% (Gill et al., 1976) to 18.5% (Linn et al., 1976) have been reported when monensin was fed in high corn silage rations.

Monensin addition resulted in reduced (P<.01) feed intake in all comparisons within each supplement treatment throughout the experiment. During the first 21 days when monensin was fed at 11 ppm, the product reduced feed consumption 9.8, 8.6 and 11.2% with the corn, soybean meal and urea supplements, respectively. After 21 days the dosage of monensin was increased to 33 parts per million. With the soybean meal supplement, the degree of depression in dry matter consumption remained consistent throughout the experiment resulting in an overall reduction of 9.0 percent. Feed consumption declined further after 21 days when monensin was fed with the corn or urea supplements. Upon termination of the experiment at 116 days, feed intake was reduced 14.7 and 14.3% respectively, with the corn and urea supplements.

Other researchers have examined the response to monensin as affected by levels and sources of protein. In a trial comparing urea and brewers dried grains supplementation of a ration composed of 60% corn silage and 40% alkali treated husklage, Hanson and Klopfenstein (1977b) reported no differences in feed consumption due to protein level or source. Monensin did not alter dry matter consumption by cattle during the experiment. The low energy content in the type of rations fed may account for the lack of any reduction in feed intake. Davis and Erhart (1976b) fed a 60% roughage ration with no supplemental protein or with added protein provided by urea or cottonseed meal. Feed intake tended to be higher with the natural protein source than with urea. Reduction in feed consumption due to monensin also appeared to be greater with the urea-supplemented ration than with cottonseed meal. The major difference in these results and those reported in this thesis was that monensin resulted in the least reduction in feed intake with the unsupplemented ration.

Weight Gain

Means for average daily gain are presented in table 9. The data are cumulative for each weigh period. Weight gains show good performance for all treatment groups. This level of performance can be attributed, at least in part, to the supplemental grain which was added to provide rations with about one-half of the dry matter as corn grain. In comparisons between cattle fed supplemental protein and controls, the additional protein resulted in higher ($P<.01$) daily gains at all weigh periods. It is apparent from this response that

TABLE 9. AVERAGE DAILY GAIN (kg)
GROWING TRIAL

Days	Corn Suppl. Control	Corn Suppl. Monensin	SBOM Suppl. Control	SBOM Suppl. Monensin	Urea Suppl. Control	Urea Suppl. Monensin
21	1.49	1.01	1.59	1.68	1.25	1.06
49	1.24	1.22	1.47	1.46	1.43	1.19
77	1.12	1.14	1.31	1.35	1.12	1.18
105	1.15	1.16	1.27	1.37	1.20	1.21
116[a]	1.15	1.22	1.29	1.34	1.25	1.26
116[b]	1.09	1.15	1.22	1.24	1.16	1.20

Average Daily Gain (kg)--116 days (shrunk)

SBOM Suppl.	Urea Suppl.
1.23+	1.18

No Protein Suppl.	Protein Suppl.
1.12	1.21**

Control	Monensin
1.16	1.20

[a]Based on filled weights.

[b]Based on shrunk weights.

+Cattle receiving SBOM supplements gained faster than those fed urea.

**Cattle fed protein supplemented-rations gained faster ($P<.01$) than those not receiving supplemental protein.

the control ration (10.4% protein) was deficient in protein required for optimum performance. Single degree of freedom contrasts indicated that steers fed rations supplemented with soybean meal grew faster ($P<.01$) than those fed urea through 105 days. This trend for greater ($P<.10$) daily gain from soybean meal than from urea was evident at the completion of the experiment, but was due to the poorer early performance from rations with urea. Such a depression in growth rate has been noted in other feeding trials where urea was the only source of supplemental protein fed with high-roughage corn cob rations (Freitag *et al*., 1968), high-concentrate rations (Lowrey and McCormick, 1969) or rations composed largely of corn silage or grass hay (Robertson and Miller, 1971). A number of studies have established that the utilization of nitrogen from urea improves as animals adapt to this nonprotein nitrogen source. Chalupa (1968) reviewed the research on adaptation to urea by ruminants and stated that the nature and site of this response could not be precisely determined. He concluded that it is more likely a change in tissue metabolism rather than alterations in microbial activity.

In overall comparisons at the completion of the study, monensin had little influence on growth rate. This has been corroborated in several other experiments where monensin has resulted in very little difference in average daily gain when fed in high-corn silage rations (Byers, 1977; Boling *et al*., 1977; Linn *et al*., 1976; Harvey *et al*., 1976). With lower energy rations, such as those provided by forage sorghum or milo stover silages, the addition of monensin has been reported to improve daily gains (Riley et al., 1976; Bolsen et al., 1975).

Monensin addition at a level of 11 ppm during the first 21 days resulted in lower ($P<.01$) gains with the corn and urea supplements. Except for the 49-day weight with the urea supplement, monensin allowed equal or slightly higher daily gains during the remainder of the experiment. After 116 days, all groups receiving monensin had grown faster than cattle fed the supplement without monensin. These differences were small and statistically nonsignificant ($P>.05$).

Hanson and Klopfenstein (1977b) reported that supplementation of a silage-husklage ration with brewers dried grains to increase the protein level from 10.5 to 12.5% tended to increase growth rate. When supplemental protein was provided by urea, there was no difference in daily gain between the two protein levels. Monensin addition tended to improve growth rate with the natural protein source but not with urea. A second study where soybean meal was used to increase the protein content of a corn silage ration to 11.1 or 13.1% was conducted by these investigators. In both experiments, the improvement in gain due to monensin was of greater magnitude at the lower level of protein. Results obtained in the experiment reported herein, however, are in agreement with those reported by Davis and Erhart (1976b). In a comparison of a basal growing ration (10.5% protein) and rations supplemented to 13% protein with urea or cottonseed meal, these workers reported an improvement in gain from additional protein. Preformed protein from cottonseed meal was slightly superior to urea,

TABLE 10. FEED EFFICIENCY (kg Dry Matter/kg Gain)
GROWING TRIAL

Days	Corn Suppl.		SBOM Suppl.		Urea Suppl.	
	Control	Monensin	Control	Monensin	Control	Monensin
21	4.05	5.37	3.80	3.29[c]	4.99	5.24
49	5.22	4.61[c]	4.37	3.93[c]	4.48	4.62
77	5.94	5.05[c]	5.14	4.52[c]	5.91	4.87[c]
105	6.34	5.39[c]	5.80	4.85[c]	6.11	5.12[c]
116[a]	6.55	5.27[c]	5.79	5.07[c]	6.01	5.11[c]
116[b]	6.91	5.62[c]	6.12	5.52[c]	6.45	5.36[c]

DM/Gain--116 days (shrunk)

SBOM Suppl.	Urea Suppl.
5.82	5.91

No Protein Suppl.	Protein Suppl.
6.27	5.87**

Control	Monensin
6.49	5.50**

[a]Based on filled weight.

[b]Based on shrunk weight.

[c]Feed efficiency improved ($P<.01$) by Monensin within supplement treatment.

**Feed efficiency was improved ($P<.01$) by supplemental protein or by Monensin compared to Control.

but monensin had essentially no effect on daily gain.

Feed Efficiency

Treatment means for feed efficiency are presented in table 10. Data are cumulative for each interval shown.

Cattle receiving supplemental protein were more efficient ($P<.01$) in utilization of feed throughout the experiment. Supplemental protein would have been expected to improve feed conversion, especially when steers were at lighter weights, since the control ration was deficient in protein (N.R.C., 1976) and weight gain was improved by protein supplementation.

Orthogonal comparisons between soybean meal and urea supplements showed that the preformed protein source resulted in improved ($P<.01$) feed efficiency through 105 days. This difference was most evident at early stages of the experiment, apparently resulting from a reduced growth rate with urea but with about equal feed consumption as for soybean meal. The difference was overcome during the course of the experiment resulting in essentially no difference in feed conversion between the two supplemental protein sources at termination of the experiment. Poorer early performance of urea-fed cattle has been observed previously (Embry and Swan, 1976; Gates and Embry, 1976). This effect becomes less evident with lengthening periods of feeding urea.

Monensin resulted in an improvement ($P<.01$) in feed efficiency when compared to controls at the termination of the experiment. Feed requirements were 15.3% lower for steers fed monensin. Improvement in feed efficiency has been demonstrated consistently with cattle fed high-roughage growing rations (Byers, 1977; Boling et al., 1977; Harvey et al., 1976; Linn et al., 1976; Gill et al., 1976; Riley et al., 1976; Bolsen et al., 1975; Embry and Swan, 1974).

While monensin did not improve feed efficiency during the first weigh period with the corn supplement and through 49 days with the urea supplement, in all other comparisons within supplement treatments feed conversion was improved (P<.01) by the addition of monensin. Improvement in feed efficiency with monensin appeared to be greater with the corn (18.7%) and urea (17.0%) supplements than with soybean meal (9.9%). Hanson and Klopfenstein (1977b) also reported a greater response to monensin at lower protein levels in rations where preformed protein was the supplemental source. With urea supplements, there was little improvement in feed conversion with monensin. Harvey et al. (1976) compared corn silage with urea added at ensiling to corn silage without urea. There was a greater improvement in feed efficiency from monensin in the lower protein ration. In a comparison between urea or cottonseed meal-supplemented rations and a lower protein basal ration, Davis and Erhart (1976b) found that monensin additions resulted in nearly identical improvement in feed conversion with each of the three rations.

A significant (P<.05) interaction between protein supplement and monensin was detected for final feed efficiency data. It resulted from somewhat different responses to protein supplementation with or without monensin. Soybean meal rations were used most efficiently when no monensin was included. Among rations with monensin, however, urea supplementation resulted in the most efficient feed conversion.

The response to monensin when level or source of protein has been varied has not been sufficiently consistent in the few studies conducted with growing rations to indicate reliable patterns. However, a number of studies, including the one reported herein, have demonstrated a greater response to monensin in feed efficiency and sometimes daily gain when protein level was suboptimal. Additionally, in this study there was a greater response to supplemental protein when it was fed without monensin. Both observations lend support to the suggestion that monensin spares protein.

Other workers have not confirmed the improvement in urea utilization when fed with monensin in growing rations. Davis and Erhart (1976a) have suggested that urea was more efficiently utilized when fed with monensin in high-grain rations. One factor limiting the efficiency with which urea can be used is its high solubility which promotes rapid deamination. If, as Tolbert et al. (1977) suggest, monensin reduces the rate of microbial deamination, then it might logically follow that monensin could enhance the utilization of the amino nitrogen provided by urea and also protein from the more soluble sources.

Finishing Trial

Nine steers died or were removed because of illness during the course of the experiment. One died of bloat and another of internal hemorrhage. The remaining cattle removed either displayed symptoms typical of polioencephalomalacia (PEM) or were necropsied at the South Dakota State Veterinary Diagnostic Laboratory and PEM was reported as the cause of death. Three steers with symptoms of PEM were treated with thiamine injections and later recovered, but they were not returned to the experiment. Two steers treated with thiamine injections showed prompt apparent recovery and were allowed to remain on test. The losses occurred in six of the eight treatment groups and did not appear to be related to dietary treatment. Feed consumption was adjusted for each pen from which steers were removed. An average value for individual feed intake was subtracted from the feed offered to that pen. Corrections were made to the beginning of the experiment.

Because of the unequal numbers resulting from removal of the steers, treatment means for weight gain were calculated using least-squares analysis of variance (Steel and Torrie, 1960). Feed consumption and feed efficiency were measured on a pen basis and the data reported are observed values.

Protein contents of the complete mixed rations are shown in table 11. The rations without supplemental protein contained about 10.4% protein on a dry basis. The addition of soybean meal raised the protein content to about 12.7 percent. Initial and final shrunk weights are presented in table 12. The protein level provided by the

TABLE 11. PROTEIN LEVELS OF COMPLETE RATIONS
FINISHING TRIAL

Ration	Crude protein, dry basis (%)
Corn Control	10.4
Corn-Monensin	10.4
Corn-Tylosin	10.3
Corn-Monensin-Tylosin	10.4
SBOM Control	12.6
SBOM-Monensin	12.7
SBOM-Tylosin	12.7
SBOM-Monensin-Tylosin	12.6

TABLE 12. AVERAGE INITIAL AND FINAL SHRUNK WEIGHTS
FINISHING TRIAL

	Control		Monensin		Tylosin		Monensin-Tylosin	
	Corn	SBOM	Corn	SBOM	Corn	SBOM	Corn	SBOM
No. animals	23	24	22	23	22	24	23	22
Init. wt., kg	393	393	388	392	395	393	390	392
Final wt., kg	534	535	523	540	539	540	536	544

unsupplemented rations was the same as that recommended by the N.R.C. (1976) for steers of the weight used in this experiment.

Feed Consumption

Daily dry matter consumption is shown by treatment groups in table 13. Values are cumulative to date for each weigh period. Protein supplementation had essentially no effect on feed consumption. Monensin additions did not lower feed consumption during the first weigh period at a level of 11 ppm in the ration. During the remainder of the study, monensin at 33 ppm resulted in lower feed consumption. From overall data at the completion of the experiment, monensin lowered ($P<.10$) feed intake compared to controls by 9.8 percent. This compares to a reduction of 12.7% in feed consumption observed during the growing phase when the ration was primarily corn silage. A reduction in feed intake of about 10% is rather typical for cattle fed high-concentrate rations with monensin at 33 ppm (Perry *et al.*, 1976; Raun *et al.*, 1976; Brown *et al.*, 1974).

While cattle fed tylosin had higher daily feed intake at the end of the experiment, the difference was nonsignificant ($P>.05$). Tylosin has been reported to have no effect on feed consumption when fed alone or when used in combination with monensin (Farlin, 1976; Sherrod and Burnett, 1976; Brown *et al.*, 1975; 1973).

Weight Gain

Least-squares means for daily gain, cumulative for each interval shown, are in table 14. During the first weigh period,

TABLE 13. DAILY DRY MATTER INTAKE (kg)
FINISHING TRIAL

Days	Control Corn	Control SBOM	Monensin Corn	Monensin SBOM	Tylosin Corn	Tylosin SBOM	Monensin-Tylosin Corn	Monensin-Tylosin SBOM
22	6.75	6.64	6.90	6.75	6.86	6.75	6.90	6.92
50	8.02	7.97	7.46	7.41	8.10	7.97	7.56	7.52
78	8.30	8.43	7.43	7.55	8.34	8.49	7.80	7.74
106	8.64	8.89	7.81	7.80	8.80	8.82	8.06	8.06

Average Daily Dry Matter (kg)--106 days

Corn	SBOM	No Monensin	Monensin	No Tylosin	Tylosin
8.33	8.39	8.79	7.93+	8.28	8.44

+Monensin reduced dry matter intake (P<.10).

TABLE 14. LEAST SQUARE MEANS OF DAILY GAIN (kg) FINISHING TRIAL

Days	Control		Monensin		Tylosin		Monensin-Tylosin	
	Corn	SBOM	Corn	SBOM	Corn	SBOM	Corn	SBOM
22	1.05	.89	1.25	1.13	.99	1.05	1.33	1.35
50	1.45	1.34	1.27	1.44	1.22	1.49	1.41	1.50
78	1.27	1.40	1.23	1.36	1.37	1.41	1.34	1.38
106[a]	1.32	1.29	1.26	1.36	1.31	1.32	1.35	1.38
106[b]	1.33	1.34	1.27	1.39	1.36	1.38	1.37	1.43

Average Daily Gain (kg)--106 days[b]

Corn	SBOM	No Monensin	Monensin	No Tylosin	Tylosin
1.33	1.39	1.35	1.37	1.33	1.39

[a]Based on filled weight.

[b]Based on shrunk weight.

soybean meal additions appeared to depress growth rate for steers not receiving tylosin. Previous research would indicate that supplemental protein at this level should not be anticipated to reduce daily gains. In other comparisons, protein supplementation had only small effects on weight gain and indicates that the control ration contained adequate protein (10.4%) for steers of the weights used in the experiment and for the growth rates observed. According to these results, N.R.C. (1976) requirements are adequate for weights and gain as in the experiment, but lower levels of protein were not tested.

Monensin resulted in higher (P<.05) daily gains during the first 3 weeks when it was included in the rations at 11 parts per million. From examination of final weight gain data, it is evident that monensin fed at a level of 33 ppm had essentially no influence on daily gain. This is supported by previous research (Perry et al., 1976; Raun et al., 1976; Sherrod et al., 1975; Brown et al., 1974).

Tylosin addition resulted in slightly higher weight gains, but the difference was nonsignificant (P>.05). Small improvements in growth rate have been attributed to tylosin (Brown et al., 1975; 1973). Other investigators have not found any increase in daily gains due to tylosin (Heinemann et al., 1977; Farlin, 1976; Sherrod and Burnett, 1976; Matsushima and Haaland, 1975).

The small advantages for tylosin and soybean meal additions resulted in the SBOM-Monensin-Tylosin treatment having the highest weight gains (7.5% higher than corn control). There also appeared to be a greater response to protein supplementation with the rations containing monensin. This observation suggests that protein levels in high-energy finishing rations may be more critical when monensin is fed because of the overall reduction in feed intake. A somewhat similar response was observed by Davis and Erhart (1976a). They reported that additions of urea to a high-concentrate ration did not improve gain with the control treatment. With rations containing monensin, however, there was a slight improvement in gain with urea supplementation. These investigations do not seem to provide clear evidence for a protein sparing action of monensin, but might indicate that supplemental protein was used more efficiently when monensin was included in the ration. In contrast, Gill et al. (1977) compared four high-grain rations supplemented with soybean meal to provide protein levels ranging from 9.5 to 12.3 percent. They found that monensin increased gain to a greater extent at lower protein levels and concluded that the additive might spare protein.

Feed Efficiency

Means for feed efficiency, cumulative by weigh periods, are shown in table 15. Soybean meal allowed small increases in daily gain while not affecting feed consumption. This resulted in a small but non-significant ($P>.05$) improvement in feed efficiency.

Addition of monensin consistently reduced ($P<.01$) the feed required for gain. The reduction in feed intake with about equal rates of gain resulted in an overall improvement in feed efficiency of 11.1% for monensin. The response is a typical one for monensin additions to high-concentrate rations according to other reported

TABLE 15. FEED EFFICIENCY (kg Dry Matter/kg Gain)
FINISHING TRIAL

Days	Control		Monensin		Tylosin		Monensin-Tylosin	
	Corn	SBOM	Corn	SBOM	Corn	SBOM	Corn	SBOM
22	6.49	7.57	5.53	5.96	7.74	6.52	5.21	5.11
50	5.55	5.97	5.98	5.17	6.80	5.37	5.39	5.05
78	6.64	6.04	6.06	5.58	6.17	6.01	5.81	5.61
106[a]	6.52	6.89	6.22	5.70	6.72	6.63	5.98	5.87
106[b]	6.51	6.65	6.18	5.62	6.50	6.38	5.89	5.65

Dry Matter/Gain--106 days[b]

Corn	SBOM	No Monensin	Monensin	No Tylosin	Tylosin
6.27	6.07	6.51	5.83**	6.24	6.11

**Monensin improved feed efficiency (P<.01).

[a]Based on filled weight.

[b]Based on shrunk weight.

research (Perry et al., 1976; Raun et al., 1976; Sherrod et al., 1975; Brown et al., 1974).

Tylosin also produced a slight but nonsignificant (P>.05) improvement in feed efficiency, corresponding to the effects of the additive on weight gain. Improvements in feed efficiency from about 1.5 to 4.5% have been reported when tylosin was fed alone or in combination with monensin (Heinemann et al., 1977; Farlin, 1976; Brown et al., 1973).

Improvement in feed efficiency due to monensin was more pronounced with soybean meal supplemented rations (13.5%) than with the control ration (7.1%). Davis and Erhart (1976a) have also reported slightly more improvement in feed conversion from monensin in rations supplemented with urea than from rations without urea. Other investigators have found that the magnitude of the improvement in feed efficiency is greater with rations containing lower levels of protein (Gill et al., 1977; Dartt et al., 1976).

VFA Production

Means for total VFA concentration and for acetic, propionic and butyric acids as a percentage of total VFA are shown by treatment in table 16. Means were averaged across treatment effects and were not analyzed statistically. Protein level had essentially no influence on the pattern of VFA production. Monensin tended to increase the percentage of propionate produced while reducing acetate and butyrate levels. This pattern is consistent with previous findings (Perry et al., 1976; Raun et al., 1976). Tylosin appeared to have an effect

TABLE 16. VOLATILE FATTY ACID PRODUCTION
FINISHING TRIAL

Treatment	No. samples	Acetic (%)	Propionic (%)	Butyric (%)	Total VFA (mMoles/liter)
Corn	16	54.39	40.13	5.24	54.63
SBOM	16	53.21	40.86	5.92	57.29
No Monensin	16	54.87	38.73	6.40	55.12
Monensin	16	52.73	42.26	5.01	56.80
No Tylosin	16	53.34	42.01	4.65	55.40
Tylosin	16	54.26	38.98	6.75	56.52

opposing the changes resulting from monensin addition. Samples from steers fed tylosin had higher levels of acetate and butyrate but lower levels of propionate than steers not receiving tylosin. Such an influence of antibiotics on VFA production is not substantiated by previous research (Haskins et al., 1967).

Carcass Data

Average values for carcass parameters measured are shown in table 17. Carcass data were rather uniform between treatment groups and revealed no differences which could be attributed to dietary treatments. Carcasses graded between high Good and low Choice for all treatments and average yield grades ranged from 3.6 to 3.8. Previous investigators support the conclusion that monensin and tylosin have essentially no influence on carcass composition or acceptability (Heinemann et al., 1977; Potter et al., 1976b; Brown et al., 1974).

Liver Abscesses

The number of carcasses in each treatment group which had abscessed livers is also shown in table 17. The incidence of liver abscesses was low for all rations, each of which included some roughage provided by corn silage. Liver abscesses were encountered in 7 of 92 steers not receiving tylosin and 5 of 91 fed rations containing tylosin. In other research where the incidence of liver abscesses has ranged from 24 to 59% in control groups, tylosin has been demonstrated to be effective in reducing the number and severity of liver abscesses (Heinemann et al., 1977; Farlin, 1976; Matsushima and Haaland, 1975; Brown et al., 1975; 1973).

TABLE 17. CARCASS DATA
FINISHING TRIAL

	Control		Monensin		Tylosin		Monensin-Tylosin	
	Corn	SBOM	Corn	SBOM	Corn	SBOM	Corn	SBOM
Hot carcass wt. (kg)	334	334	328	338	338	339	332	342
Dressing percent	62.47	62.47	63.02	62.29	62.69	62.85	61.94	62.80
Marbling[a]	4.8	4.8	5.1	4.6	4.7	4.8	4.6	4.9
Carcass grade[b]	18.3	18.3	18.7	18.1	18.3	18.5	18.2	18.6
K.P.H. fat, %	2.9	2.9	2.7	2.8	3.0	2.9	2.7	2.9
Fat thickness (cm)	1.75	1.73	1.60	1.68	1.80	1.88	1.65	1.68
Rib-eye area (cm^2)	75.94	75.55	75.35	77.35	77.68	78.52	76.00	78.97
Yield grade	3.7	3.8	3.6	3.6	3.8	3.8	3.6	3.6
No. steers with abscessed livers	1	2	2	2	2	0	3	0

[a]slight = 4; small = 5

[b]high Good = 18; low Choice = 19

SUMMARY

Two feeding experiments were conducted with a primary objective of examining the response of feedlot cattle to supplemental protein when monensin is included in the ration. The growing ration fed in the first experiment provided about 50% of the dry matter as forage from corn silage with the remainder of the ration concentrates, primarily corn-grain. In addition to the control ration (10.4% protein), soybean meal and urea were used as supplemental protein sources. Each ration was then fed with and without monensin.

In the growing experiment, monensin resulted in an overall reduction in feed consumption of 12.7 percent. The effect was less pronounced with the soybean meal supplement (9.0%) than with the corn (14.7%) and urea (14.3%) supplements. There was a tendency for steers fed soybean meal to consume more feed than steers fed the other supplements. This trend was more pronounced with supplements including monensin.

There was essentially no difference in average daily gain due to monensin. Supplemental protein, either from soybean meal or urea did improve growth rate, indicating that the control ration was deficient in protein. Soybean meal appeared to produce somewhat superior gains at the completion of the experiment, but this resulted from the poor response to urea during the early phases of the experiment.

Monensin additions produced an overall improvement in feed efficiency of 15.3 percent. This effect resulted from decreased feed

consumption with about equal daily gains. Supplemental protein also improved feed efficiency. Soybean meal was substantially more beneficial at early stages of the experiment, but this difference was less evident by the end of the experiment. Without monensin, the steers fed soybean meal supplemented rations had the best feed conversion. When monensin was included in the ration, however, urea supplemented rations were utilized most efficiently.

The results of the growing experiment confirm that monensin is effective in improving the energy utilization of a high-roughage growing ration. Furthermore, there was evidence that monensin had a protein sparing effect in rations slightly deficient in protein and also tended to improve the utilization of dietary nitrogen provided by urea.

In the finishing experiment, the high-concentrate rations included a low level of roughage supplied by corn silage. A control ration (10.4% protein) and a ration supplemented with soybean meal (12.7% protein) were fed. In addition to investigating the relationship between monensin and supplemental protein, another objective of the finishing experiment was to examine the response to monensin when used in combination with an antibiotic, tylosin. The two rations were fed without either additive, with monensin, with tylosin and with the two products in combination.

Monensin addition resulted in an overall reduction in feed intake of 9.3 percent. This was similar to the 12.7% reduction encountered in the growing trial. Neither protein supplementation nor tylosin addition altered feed consumption.

Monensin had no influence on average daily gain. Soybean meal or tylosin supplemented cattle had slightly higher growth rates, but the differences were nonsignificant.

Monensin improved feed efficiency by 11.1% corresponding to its reduction of feed consumption. There was a slight advantage in feed efficiency for rations including tylosin, but again the difference was not statistically significant. The improvement in feed conversion due to monensin was more pronounced with soybean meal supplemented rations (13.5%) than with the control ration (7.1%). This response differed from that observed in the growing trial in which monensin appeared to spare protein. It may be that the reduction in feed consumption which occurs when monensin is fed is more critical in high-concentrate rations and may explain the small apparent response to supplemental protein.

Dietary treatments had no influence on carcass parameters measured. The incidence of liver abscesses was low in all treatment groups. This experiment, therefore, provides no evidence that tylosin was effective in reducing the occurrance of abscessed livers.

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