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Title: MONENSIN AND ZERANOL ALONE AND IN COMBINATION FOR GROWING-FINISHING STEERS AND GROWING HEIFERS

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Ninety-two spring-born and 76 fall-born steer and heifer calves (Hereford and Angus x Hereford) averaging 188 and 255 kg, respectively, were utilized in a 2x2 factorial arrangement of treatments to study the effects of zeranol and monensin, alone and in combination, on growth rate, feed efficiency and carcass characteristics. After weaning, calves were stratified by weight for random allotment to four treatments: 1) control (no monensin, no zeranol); 2) zeranol alone; 3) monensin alone; and 4) zeranol-monensin combination. Zeranol (36 mg) was implanted subcutaneously in the ear every 90 days and monensin (200 mg) was fed daily. The diet for both growing periods consisted of hay free choice and a barley-biuret supplement. The diet of both finishing periods (steers only) consisted of a full feed of barley with limited hay intake and biuret for additional protein. Results for the spring-born calves indicated treatments 3 and 4 increased ADG ($P<.05$) during the winter (196 days) while feed efficiency for steers and heifers was improved by 8, 5; 24, 21; and 27, 27% on treatments 2, 3 and 4, respectively, as compared to 1. Average daily gain for the summer grazing period (98 days)

was increased (P<.05) by treatments 2 and 4. During the finishing period (97 days), treatment 4 increased ADG (P<.05), while monensin improved feed efficiency by 12%. Overall ADG (391 days) for steers was increased 3, 7 and 16% on treatments 2, 3 and 4, respectively, as compared to 1. During the growing period (111 days), fall-born steers and heifers gained .68, .61; .86, .70; .82, .71; and .88, .86 kg, respectively, on treatments 1, 2, 3 and 4. All treatments increased gains (P<.05) over 1 with treatment 4 producing increased gains (P<.05) with the heifers. During the 153-day finishing period for treatments 1, 2, 3 and 4, gains were .85, .95, .92 and 1.01 kg, respectively, with treatments 2 and 3 different (P<.05) from 1 and treatment 4 different (P<.05) from 1 and 3. Again, monensin improved feed efficiency by 12%. Overall ADG (264 days) for steers was increased 13, 9 and 18% on treatments 2, 3 and 4, respectively, over 1. Carcass data for all steers indicated a one-third older maturity score (P<.05) for steers receiving zeranol. Zeranol-implanted steers also exhibited a tendency for a slight reduction in quality grade but improved (2.1 vs. 2.3) yield grade. Either zeranol or monensin produced an acceptable increase in gains, but the additive effect exhibited by their combination provided additional and more consistent gains during the growing and finishing periods.

# Monensin and Zeranol Alone and in Combination for Growing-Finishing Steers and Growing Heifers

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## REVIEW OF LITERATURE

### Monensin

#### Introduction

Monensin sodium, a feed additive for use in both growing and finishing cattle diets, is produced by the bacteria, Streptomyces cinamonensis. First used as an anticoccidiostat for poultry, monensin has been found to alter the volatile fatty acid (VFA) concentration in the rumen (Raun et al., 1976; Richardson et al., 1976) and improve feed efficiency (Brown et al., 1974). Several different levels of monensin have been tested (Brown et al., 1974; Raun et al. 1974) with a daily intake of 200 mg attaining the best results (Shell et al., 1979; Turner et al., 1980). Monensin is currently marketed under the trade name, Rumensin $^{R}$, by the Eli Lily Company for use as a feed supplement for cattle.

#### Alterations in Volatile Fatty Acid Production

Monensin has been found to improve feed efficiency (Brown et al., 1974) and increase the efficiency of converting dietary energy into carcass energy (Raun et al., 1974). Although the mechanism of this action is not completely understood, it is partially related to the shift in ruminal VFA toward more proprionic acid, thereby altering the quality and form of energy available for metabolism. Therefore, part

of the feed efficiency due to monensin may be attributed to the increased quantity of net energy available from the feed. This shift in VFA concentration toward proprionic acid may be seen with either grazing or feedlot animals.

Richardson et al. (1976) observed that monensin increased the molar percentage of proprionate, while reducing the relative amounts of acetate and butyrate, when fed to grazing cattle. In 1979, Shell et al. reported significant increases in proprionate and the reduction of butyrate along with a slight decrease in the formation of acetate in fistulated steers.

In the feedlot, Raun et al. (1976) observed an increase in the molar percentage of proprionate of 5 to 10%. This would indicate a 3 to 6% increase in metabolizable energy. Gill et al. (1976) observed a 6% improvement in feed efficiency across three corn silage rations (14, 30 and 75%) by feedlot steers. These data are in accord with Davis and Erhart (1976) in their finding that rumen fluid extracted from steers on a finishing ration, contained significantly more proprionate and less butyrate than the controls.

This shift in the VFA production may be associated with a change in the rumen microflora. Chen and Wolin (1978) implied that the elevation in proprionate formation may result from selection for succinate forming organisms and for a proprionate producer that decarboxylates succinate to proprionate. Selection for proprionate may result in reduced cellulose digestion by reducing cellulolytic bacteria numbers (Simpson, 1978). Inasmuch as proprionate is more efficiently produced by the rumen microflora (Hungate, 1966) as opposed to acetate

or butyrate, part of the reduced feed consumption apparently results from a greater recovery of energy from the ration. The increase in available energy is mediated through the glucongenic properties of proprionate. According to McDonald et al. (1973), 17 moles of adenosine triphosphate (ATP) are produced by one mole of proprionate upon conversion to glucose succeeded by oxidation to carbon dioxide and water. This conversion takes place in the liver where the glucose may join the liver glucose pool, form glycogen, be utilized as an energy source by various body tissues or as a source of reduced coenzymes for fatty acid synthesis.

Increases in proprionic acid production have separate metabolic ramifications beyond increases in available energy. Bryce et al. (1975) established that proprionic acid given intraveniously (.5mg/kg body weight) resulted in a significant rise is plasma insulin and growth hormone (GH). Li (1956), along with Turner and Bragnara (1971), have proposed that GH may be involved in biological activities creating an environment in endocrine organ tissues necessary for other hormones to maximize their potential. This increase in proprionic acid due to monensin may have a significant effect on the endocrine system, expecially with prepuberal heifers.

It is obvious that the complete role of VFA's, proprionate in particular, are not entirely understood. However, the increases in energy related to the rise in proprionate production are well documented. Other possibilities regarding this increase will require additional research.

## Growth Performance

### Life Body Weight Gains

Previous studies, exercising numerous management schemes, have indicated that monensin will increase the average daily gain (ADG) of growing steers and heifers. Mowatt et al. (1977) demonstrated that feeding alfalfa silage supplemented with monensin would increase live weight gains by 12%. This is in agreement with McCarthy et al. (1979), who found a significant increase in gains by Hereford x Angus steers fed corn silage supplemented with soybean meal (SBM) and monensin. Increases in ADG have also been reported for Angus steers grazed on Kentucky bluegrass-clover pastures for 140 days (Boling et al., 1977). Increases in ADG have been documented when cattle were fed various levels of monensin and grazed on coastal bermuda grass (Oliver, 1975) or grass-clover pastures (Campbell, et al., 1973). Males et al. (1979) found Angus feeder calves fed monensin daily at 200 mg per head while grazing winter pasture gained significantly faster than steers not receiving monensin. Potter et al. (1976) observed a 17% increase in gains for forage-fed steers receiving 200 mg of monensin daily.

No increases in live weight gains were exhibited when steers were fed monensin and cottonseed hulls (Oltjen et al., 1977; Vijchulata et al., 1980), grass straw (Turner and Raleigh, 1975) or pelleted wheatstraw (Coombe et al., 1979). The lack of response to monensin on poor quality roughages may be related to the reduction of cellulolytic bacteria (Simpson, 1978).

When ruminants are consuming roughage, as with grazing animals, intake is limited by rumen capacity. Since many roughage sources are

of low energy value, this automatically limits the amount of energy available for metabolism. The additional energy related to monensin supplementation is partially responsible for the increased gains observed in growing ruminants.

Feed Efficiency

Mowatt et al. (1977) reported an 11% increase in feed efficiency with monensin for growing cattle fed alfalfa silage. This coincides with McCarthy et al. (1979) who noted a significant decrease in the feed to gain ratio for growing steers fed corn silage supplemented with soybean meal (SBM) and monensin. Turner et al. (1980) supplied evidence that beef cows fed meadow hay supplemented with monensin in a barley carrier, would consume 7 to 10% less hay per day. This is augmented by the work of Walker et al. (1979) whose data indicated a decrease in dry matter intake without reducing performance. Boling et al. (1977) concluded that monensin will reduce the consumption of Kentucky bluegrass-clover pastures by Angus steers, which is in agreement with the reduced intakes observed by Campbell et al. (1973) for steers grazed on grass-clover pastures. This reduction in feed required per unit of body weight gain has likewise been observed by Males et al. (1979) in Angus feeder calves grazing fescue pastures.

Monensin has produced increases in live weight gains during the growing period which are beneficial to producers. The added bonus during this period, in addition to greater gains, are reductions in feed intake. The reduced consumption is partially due to the reminal energy savings mediated through the glucogenic properties of proprionic

acid (Leng et al., 1967). Raun et al. (1976) proposed other possible benefits from monensin such as changes in the composition in the ingesta reaching the small intestines and increases in the extent of digestion. To date, the overall benefits realized by monensin have not been elucidated.

## Finishing Performance

### Life Body Weight Gains

Studies utilizing monensin along with corn silage, ground corn and a protein supplement (Davis and Erhart, 1976; Gill et al., 1976; Perry et al., 1976; Boling et al., 1977; Darrt et al., 1978; Steen et al., 1978; McCarthy et al., 1979; Perry et al., 1979) show that high concentrate diets, supplemented with monensin, would not elevate live weight gains over control animals. Mowatt et al. (1977) reported no increase in gains by feedlot cattle fed high moisture corn along with alfalfa silage and monensin. This agrees with the results of Johnson et al. (1978) who showed the lack of additional gains from monensin for steers fed a 50-50 mixture of alfalfa pellets and steam-rolled barley. Along these lines, Horton et al. (1980) executed a study feeding different barley levels (30, 50, 70 and 90%) with monensin and found no net rise in gains at any of the barley levels.

When cattle are fed a high energy ration, intake may not be limited by gut fill or distension exhibited by cattle on roughage, but by net energy intake (Potter et al., 1976). Monensin will increase the net energy per unit of feed, but high energy diets are not limited by intake, therefore, increased gains are negligible. These studies

leave little doubt regarding the inability of monensin to increase body weights for finishing cattle.

Feed Efficiency

In feedlot studies concerned with corn silage, ground corn and a protein supplement in conjunction with monensin, cattle exhibited significant reductions in dry matter intake (Davis and Erhart, 1976; Gill et al., 1976; Perry et al., 1976; Boling et al., 1977; Darrt et al., 1978; Steen et al., 1978; McCarthy et al., 1979; Perry et al., 1979). A study performed by Baile et al. (1979) with finishing steers fed an 85% corn ration, showed that steers responded with a significantly lowered feed intake. This is in harmony with Raun et al. (1976), who attained a 17% increase in feed efficiency for cattle fed a 70% corn finishing ration. In the experiment reported by Horton et al. (1980) with a variety of barley levels (30, 50, 70 and 90%), it was demonstrated that barley influenced dry matter intake in a quadratic manner, while monensin reduced intake. In feedlot cattle fed high moisture corn and alfalfa silage, monensin significantly reduced feed consumption (Mowatt et al., 1977) which agrees with a reduced intake by cattle fed a 50-50 mixture of alfalfa pellets and steam-rolled barley (Johnson et al., 1979). Johnson also stated that for barley rations, 33 ppm may be too high since best results were recorded at 22 ppm.

These increases in feed efficiency reported by these authors result from, at least in part, the rise in ruminal energy production for which proprionic acid is responsible. Cattle consume to a certain energy level and monensin increases the energy per unit of feed, resulting in the reduced feed consumption.

## Protein Sparing

It has been suggested (Raun et al., 1976) that protein sparing from gluconeogenisis is a possible property pertaining to the feeding of monensin. Hanson and Klopfenstein (1979) staged an experiment with growing steers (Angus, Charolais, Hereford and Angus x Hereford breeding) exercising two protein levels (10.5 and 12.5%) from two protein sources, brewer's dried grain (BDG) and urea. Monensin-fed steers responded with a more efficient feed to gain ratio on the 10.5% BDG ration as opposed to the 12.5% level. Concerning the urea-fed steers, monensin did not alter in results for the two protein levels and there was a tendency for reduced gains and feed efficiency. This lack of a response by urea suggests microbial protein synthesis was not limited by ammonia nitrogen. Poos et al. (1978) observed a significant reduction in the microbial nitrogen entering the abomassum for monensin-urea diets. Simpson (1978) proposed that monensin suppresses cellulose digestion in vitro, insinuating that monensin may reduce the cellulolytic bacteria population. This is at odds with Dinius et al. (1976), who found no decrease in cellulolytic bacteria numbers in vitro and no significant shifts in protozoa populations. The greatest response seen by Hanson and Klopfenstein (1979) was recorded when monensin was fed with natural protein sources. Monensin may spare proteins from deamination while the rise in proprionic acid may reduce the number of glucogenic amino acids degraded in the liver. Perry et al. (1979) found that a lower protein level (478 g total protein per day) resulted in significant increases in blood plasma urea N and rumen fluid ammonia, indicating a protein sparing effect at the

deficient to borderline protein levels. In addition, the works of Rust et al. (1979) and Mies et al. (1979) demonstrated a possible protein sparing effect between the 9 and 13% crude protein levels.

Pendlum et al. (1980), while conducting an amino acid profile for monensin-fed steers, discovered that on day 106 the essential (EAA) amino acide profile was similar or higher for monensin treatments, with significant increases in threonine and methionine. Plasma serine, glutamic acid, glutamine, alanine and ornithine were significantly higher with a trend for the steers receiving monensin to have an elevated non-essential (NEAA) amino acid concentrations. The steers exhibited significant elevations in the EAA to NEAA amino acid concentrations. At this time feed intakes were comparable, but ADG were significantly higher for monensin treatments. Plasma free amino acids represent a balance between gastrointestinal absorption and cellular utilization in the fed state. Therefore, the amino acid profile is compatible with performance, to a certain extent, if the rise in essential amino acid concentrations are available at the cellular level for protein synthesis.

This increase in live weight gains demonstrated by monensin-fed steers while exhibiting an elevated plasma amino acid profile, corresponds with previous works that monensin reduces ruminal protein synthesis. Also, this supports the hypothesis that monensin may have a protein sparing effect, providing dietary energy intake is not limiting.

## Methane Inhibition

Reducing the production of methane would improve rumen fermentation efficiency and support the theory of Raun et al. (1974) and Chalupa et al. (1980) that the increase in proprionic acid is not entirely responsible for the improvements from monensin.

Chalupa et al. (1980) reported that monensin partially reduced methanogenesis without the accumulation of hydrogen gas. Chen and Wolin (1978) stated that decreases in methane production were related to reductions in hydrogen producing bacteria (i.e., ruminococcus albus). This would explain the lack of hydrogen accumulation observed by Chalupa and co-workers.

The basic reaction by which methane is produced involves the reduction of carbon dioxide by hydrogen, some of which may be derived from formate. However, methanogenesis is a complicated process which utilizes vitamin $B_{12}$ and folic acid. Approximately 4.5 g of methane are formed for every 100 g of carbohydrates consumed. This may result in a 7% energy loss in food energy as methane (McDonald et al., 1973).

## Carcass Characteristics

Monensin has been shown to improve the efficiency of converting dietary energy into carcass energy (Raun et al., 1974). Research conducted by Embry and Swan (1974) and Farlin et al. (1975) indicated that this increase in energy did not alter the carcass characteristics. Mowatt et al. (1977) found that finishing steers fed high moisture corn and monensin exhibited no difference in carcass parameters when compared with controls. Brown et al. (1974) performed a field evaluation using various levels of monensin (0, 5.5, 11, 22, 33 and 44 ppm).

They utilized seven field trials involving 1157 feedlot cattle and reported no difference in carcass quality. However, cutability was increased for the 44 ppm level. This coincides with the research of Raun et al. (1974), who also fed different levels of monensin (0, 2.7, 5.5, 11, 22, 44 and 88 ppm). They found that carcass fat was decreased at the 44 ppm level but this level did not exhibit a dose response relationship and cutability did not differ from the controls.

These carcass data indicate that the increase in feed efficiency, realized from monensin supplementation, is not related to an energy change in the carcass. This further supports the hypothesis that monensin increases the available net energy from most rations.

## Zeranol

### Introduction

It has been shown that moldy corn may result in estrogen-like symptoms when consumed by swine (Mirocha and Christensen, 1974). In 1962, Stob et al. isolated a compound from moldy corn infected by Fusarium roseum, that exhibited both uterotropic and anabolic tendencies. This compound was termed zearalenone. Zearalenone, a resorcylic acid lactone, and its derivatives are mycotoxins (also referred to as fermentation estrogenic substance or F-2 toxin). This mold may infect corn, wheat, barley, sorghum or hay (Mirocha et al., 1971; Mirocha and Christensen, 1974; Shipchandler, 1975; Hidy et al., 1977). In U.S. surveys of corn and wheat, zearalenone infections of marketable corn was 10 to 20% with wheat containing 10 ppm (Stoloff et al., 1976; Hesseltine et al., 1978). The zearalenone derivative, zeranol (a tetrahydro derivative), is currently marketed as an

anabolic agent for cattle and sheep under the trade name Ralgro $^{R}$. Subcutaneously implanted in the ear, at 36 or 12 mg for cattle and sheep, respectively (every 84 to 112 days), zeranol has been approved by the Food and Drug Administration (Perry et al., 1970; Sharp and Dyer, 1972; Borger et al., 1973a).

## Estrogen Receptor Association

In 1979, Greenman et al. revealed information that zearalonol (at $4 \times 10^{-7}$M) would inhibit almost the entire number of estradiol binding sites in the cytosol of mouse uteri. Incubation of uteri with either zearalanol or zearalenone increased the quantity of exchangeable nuclear sites above the endogenous level, suggesting that both mycotoxins are capable of translocating specific estrogen binding sites into the nuclei from the cytosol. Of the two mycotoxins, zearalanol was the most effective and resulted in a maximum accumulation of exchangeable sites. This is supported by the work of Boyd and Wittliff (1978), who indicated, despite the fact that zeranol is a non-steroidal moeity, it would inhibit the binding of estradiol-17 beta in a competitive fashion. Zeranol possesses phenolic and alcoholic hydroxyl functions which may act in binding site recognition similar to steroidal estrogens.

A strong possibility exists that the mechanism(s) by which zeranol produces an estrogen-like response is related to an association with the estrogen receptors of target cells. There is a relationship between estrogen administration and uterine RNA synthesis mediated through increased RNA polymerase II activity, followed by an elevation in RNA polymerase I and a second rise in polymerase II (Glasser et al., 1972; Borthwick and Smellie, 1975; Hardin et al., 1976). Therefore,

if zeranol is an estrogen agonist, RNA and protein synthesis should increase. This hypothesis is supported by Ueno and Yagasaki (1975) in their findings of an acceleration in RNA and protein synthesis in the uteri of laboratory animals. In addition to these results, zeranol has been shown to increase RNA values of intercostal muscle, indicating more RNA present in the sarcoplasm for protein synthesis (Borger et al., 1973b). This elevation in RNA values may be related to increased RNA polymerase activity.

Zeranol has been found to have a relatively low binding affinity for serum proteins (Martin et al., 1978). Steroid hormones, upon release, are bound to a specific plasma binding protein. Steroids must be in the unbound state in order to diffuse through the cell wall to the receptor sites. This inability of zeranol to bind with serum proteins may enhance its activity by increasing the concentration in the free form at the cellular level. This could make zeranol very effective even at low blood levels.

These data suggest the uterotropic effect of zeranol is mediated through an association with cellular uterine estrogen receptors. The anabolic effect may also be directly or indirectly related to an association with estrogen receptors elsewhere in the body.

## Growth Hormone

According to R. D. Frandson (1974), growth hormone (GH) stimulates growth of all body cells that can grow, particularly bone and muscle tissue. Growth hormone also increases the amino acid uptake by muscle cells, along with the utilization of amino acids for protein synthesis which increases muscle growth and N retention at the expense

of fatty acids and glycerol from adipose tissue for metabolism. In addition, elevated levels of GH result in decreased glucose oxidation which increases blood glucose and insuline levels.

Administration of exogenous estrogens results in faster gains, greater retention of N, Ca and P, and changes body composition with an increase in protein at the expense of fat deposition. Also, exogenous estrogens result in an enlarged pituitary and elevated secretions of GH (Beverly, 1980). This increase in GH may account for the anabolic effect of estrogens seen in cattle and sheep.

Zeranol appears to be an estrogen agonist and several studies have indicated a rise in GH related to zeranol implantation (Borger et al., 1973a; Olsen et al., 1977; Galbraith, 1979). Galbraith (1979) stated that the trend towards elevated blood concentrations of GH are similar to that seen in castrated males following estrogen treatment. This suggests that estrogen or zeranol may cause an increase in the synthesis of GH from the anterior pituitary. Since zeranol binds with the estrogen receptors in the uteri, it may also have the ability to effect the estrogen receptors located in the pituitary. The research of Riesen et al. (1977) lends supportive evidence that zeranol can effect pituitary performance. Riesen and co-workers reported the reduction of testicle weights, resulting from zeranol implantation, were mediated through the inhibition of gonadotropin synthesis. Exogenous testosterone or estradiol will suppress the release of follicle stimulation hormone (FSH) and leuinizing hormone (LH) from the pituitary in prepuberal bulls (Hafez, 1974). In conjunction with this is the data compiled by Kwan and Ellington (1978) which was concerned with zeranol utilization. It indicated that subcutaneous

injections of zeranol into rats resulted on total inhibition of ovarion follicular and luteal development at the 5 and 500 mcg levels. Also, significant increases were noted on the adjusted pituitary weights for the 500 mcg level. It would seem that zeranol has the capability of altering pituitary secretion in the same manner as natural estrogens.

Overall, the effects of zeranol appear to be closely related to natural or synthetic estrogens, especially receptor site affinity, inhibition of gonadatropin secretion and GH production.

## Growth Performance

### Gain Performance of Preweaned Calves

Brown (1970) initiated a study concerned with the effects of zeranol for feedlot steers and heifers, suckling beef calves, veal calves and growing calves. The suckling calves were not creep fed and ran with their dams on pasture. In four of the tests, range conditions were very dry and resulted in poor gains for all calves and no response from zeranol. Once pasture conditions returned to normal and gains improved, zeranol improved gains by 9.8% over controls. In agreement with these results is an experiment performed by Moran (1972). Moran observed live weight changes of shorthorn weaner heifers and steers implanted with zeranol versus a control group over an eleven-month period. Between August and the following February the implanted group exhibited an 11% increase in body weight gains. From February until July they responded with a 19% increase in gains. It is interesting to note that during the nutritional stressful period of the year (data not reported), zeranol had a small, non-significant effect on live weight gains. Trenkle (1974)

stated that with undernutrition, either energy or protein, muscle fails to develop. In young animals there is a loss of RNA with a reduction in nuclear division and a normal ratio of protein per nucleus. Therefore, if zeranol accelerates RNA and protein synthesis, the absence of energy and/or protein would result in decreased performance.

Ambruster (1975) implanted suckling steers and heifers between two and four months of age. Weaning weights indicated zeranol increased gains by 6.4 and 9.8 kg for steers and heifers, respectively. This is not entirely in unison with Ward et al. (1978). They found that for calves implanted at birth, only the steers responded significantly in gains. Lewis et al. (1979) utilized 335 calves from ten different herds averaging 60 days of age and 74 kg. The experiment was for two periods and four possible implant combinations. The calves were either implanted (I) or not implanted (NI) in each period. Treatments consisted of NI-NI, I-NI, NI-I and I-I. Calves and their dams were pastured through both periods. All three implant treatments significantly elevated gains with the dual implant resulting in greater overall gains. The above studies were concerned with either steer or heifer calves. However, today's market is opening up for greater numbers of intact males. Therefore, the effects of zeranol is important during this preweaning period for bull calves. VanderWal et al. (1975) utilized ten feeding trials with 593 Freisen bull calves from 40 to 170 kg. Results indicated that no increase in live weight gains were seen with zeranol. This agrees with the finding of Utley and McCormick (1976), who found zeranol implants had no effect on the ADG of intact males.

The results of these studies indicate it is economically beneficial to implant calves, excluding bulls, prior to weaning. However, it should be stated that if replacement heifers are to be chosen from those calves, none of the heifers should be implanted. This is because of the detrimental reproductive effects of zeranol and the fact that replacement heifers are not decided upon prior to weaning but at a more mature age.

Gain Performance for Growing Calves

Thomas and Armitage (1970) implanted steers (averaging 181 kg) with either 36 or 72 mg of zeranol for a 140 day growing trial. During the period, control steers gained .59 kg per day while the implanted steers gained .63 kg per day. This was 6.7% faster rate of gain for the zeranol steers. Ilg et al. (1976) utilized 72 crossbred steers separated into light (170 kg) and heavy (223 kg) groups. The steers were then stratified by weight within their respective groups. They were fed alfalfa with grain substituting for 20% of the ration once the animals reached 341 kg. Zeranol significantly increased ADG while reducing feed per kilogram of gain and number of days on feed. Two other studies (Hathaway, 1972; Nicholson, 1974) concerned with the feeding of high roughage diets, in conjunction with zeranol implantation, yielded similar results related to faster gains, improved feed efficiency and fewer days on feed. This agrees with the work of Ward et al. (1978) in their study using 119 crossbred (3/4 Hereford and 1/4 Angus) steers and heifers. Their results also indicated that during the growing period zeranol implants significantly increased ADG for both sexes.

Sharp and Dyer (1971) observed a contrast between the performance of steers and heifers during the growing period. Results showed that heavier steers at implantation tended to gain faster than their lighter counterparts. Contrary to these results, the lighter heifers demonstrated a greater response as opposed to the heavier heifers within the zeranol treatment group. They attempted to explain this by considering the different phases of the bovine growth curve. In the self-accelerating phase, somatotrophin (GH) and thyroxine predominate in controlling the rate of growth. Once the animals begin to mature, their respective sex hormones begin to restrain the normal decline in growth. The response to exogenous sex hormones is related to the rate of production of GH, thyroxine and sex hormones at the time of administration. The increase in gains seen with lighter heifers may be associated with their maturation at lighter weights.

During a protein utilization study (Borger et al., 1973a) zeranol animals receiving low protein (9.5%) consumed 21.3% more feed than controls. In contrast, high protein (11 and 12.5%) controls consumed 13.7 and 16.7%, respectively, more than the zeranol steers at these protein levels. Elevated consumption for low protein zeranol steers agrees with the hypothesis that zeranol increases RNA and protein synthesis. These steers would have to overeat in order to compensate for the extra amino acids necessary to satiate increased muscle protein synthesis at the molecular level.

Zeranol has also been compared to various growth promotants. In a 112-day growing study, Wilson and Wiggins (1974) treated 60 heifers averaging 227 kg and 276 steers averaging 275 kg, with several different implants. The calves were implanted with either DES (36 mg

for steers, 24 mg for heifers), Synovex-H (200 mg testosterone, 20 mg estradiol benzoate), Synovex-S (200 mg progesterone, 20 mg estradiol benzoate) or Ralgro (36 mg zeranol). The ration consisted of corn silage and ground ear corn to raise the total protein level. All treatments significantly accelerated the rate of gain compared to controls, with no significant difference between implants or combinations thereof. The lack of a significant difference between DES and zeranol has also been reported by Perry et al., 1970; Thomas et al., 1970; Mount et al., 1973; and Ralston, 1978.

In summary, either steers or heifers will respond to zeranol implantation during the growing period. Proper nutrition is vital with protein levels being paramount.

Gain Performance for Finishing Calves

Sharp and Dyer (1968) implanted 60 heifers one time during a 112-day finishing trial to measure the effects of zeranol at various concentrate and roughage levels. Implants significantly increased gains for the 70:30 concentrate-roughage diet, but not the 80:20 or 60:40 diets. The 70:30 diet may have been the proper balance between energy and protein intake to fully realize the beneficial gains from zeranol. The 80:20 ration had sufficient energy, but may have been somewhat dificient in protein with the reverse true for the 60:40 diet. During a finishing trial conducted by Ward et al. (1978), results indicated zeranol significantly increased steer gains. In contrast with Sharp and Dyer (1968), the heifers utilized by Ward et al. (1978) did not exhibit elevated gains. Sharp and Dyer (1968) implanted their heifers only once while Ward and co-workers implanted their heifers five times. Multiple implants also increased gains for

fattening steers in a study conducted by Lesperance et al. (1978). The lack of a response with multiple implants for heifers has not been elucidated, but may be related to zeranol heifers being heavier at the initiation of the feedlot trial with the controls compensating for lighter body weights.

In 1970, Perry et al. fed 87 Hereford steers, averaging 350 kg, a fattening ration consisting of ground ear corn and a protein supplement for 141 days. Zeranol steers were implanted initially or on day 56. Both groups significantly increased gains over the controls. The delayed implant increased gains during the last 100 days, while the initial implant indicated a reduced effect as the trial progressed. Perry and co-workers also determined the effects of delayed implants compared to implanting twice during a 156-day finishing trial. The diet was similar to the previous diet. Steers were divided into two lots of 52 animals each with one lot implanted on day one and half of both lots receiving implants at the end of day 56. The dual implant resulted in significantly greater gains as compared to the single implants or controls. This coincides with Thomas and Armitage (1970) in their experiment using 36 or 72 mg implants for finishing steers. Both levels significantly increased gain performance with no significance observed between implantation levels.

Overall, zeranol implants elevated ADG of feedlot animals with either single, double or delayed implants. If multiple implants are necessary or desired, the producer should observe the 65 day withdrawal period. This is required to eliminate any possibility of residues in the edible tissues. Sharp and Dyer (1972) reported

that zeranol was slowly released from the pellet and was cleared rapidly from the plasma. No evidence of residual label was observed in the main edible tissues. Zeranol appears to be a safe, effective mechanism for accelerating body weight gains.

## Carcass Characteristics

In two different studies, one conducted by Hathaway (1972), the other by Utley and McCormick (1976), no difference was seen between control and zeranol implanted steers in quality grade, marbling score, fat thickness over the 12th rib, yield grade or percent cutability. In contrast, Nicholson (1974) reported that zeranol implantation resulted in an increase in carcass water along with an improved yield grade and cutability. Supporting this, Sharp and Dyer (1971) noted significant increases in both water content and protein at the expense of fat. This is concurrent with the rise in GH which should reduce fat deposition, thereby improving yield grade and cutability.

The results of the previous studies suggest that zeranol has no detrimental effects on carcass characteristics. The increase in water retention may have an effect on customer satisfaction, but further studies are required.

## Reproductive Disorders

Numerous effects of zearalenone have been observed in experimental animals. Swine, which are extremely sensitive to zearalenone infected feeds, exhibit severe reproductive disorders when fed diets containing this mycotoxin. Mirocha and Christensen (1974) stated that approximately 1-5 ppm zearalenone (4 mg cumulative dose) is

adequate to produce vulvovaginitis in gilts. Miller et al. (1973) have demonstrated that pregnant sows and gilts treated with 5 mg of purified zearalenone daily during the last month of pregnancy produce stillborn pigs or pigs with ataxic hindquarters. Upon subcutaneous administration, zearalenone is less potent in mouse uterine enlargement assay as opposed to administration by gavage (Mirocha et al., 1968). Both Zearalenone and zeranol have been shown to bind to estradiol binding sites from various mamalian tissues (Greenman et al., 1977; Boyd and Wittliff, 1978; Martin et al., 1978). Hobson et al. (1977) examined the effects of zearalenone on serum gonadatropins of ovariectomized rhesus monkeys and determined that zearalenone is slightly less potent than DES upon subcutaneous implantation.

Staigmiller et al. (1978) divided 98 crossbred heifers into two groups, above (H) 298 kg and below (L). Half of each group received implants (I) and half did not (C). The proportion of those heifers not reaching puberty by August 1st for HI, HC, LI and LC were 1/25, 0/23, 6/24 and 0/26, respectively. These data tend to indicate that the lighter, less mature heifers are more suseptible to a negative puberty response via zeranol implantation. This agrees with Utley and McCormick (1974) in their study concerned with yearling heifers implanted one time during a 112-day feedlot trial. The reproductive organs from implanted heifers were similar to literature values for normal reproductive tracts. Once the heifers develop mature reproductive organs, zeranol may not have a detrimental effect.

Zeranol has been demonstrated to significantly reduce testicle weights in domestic animals (Ralston, 1978). Zeranol inhibits

gonadotropin synthesis, thereby reducing testicle weights (Riesen et al., 1978). Kwan and Ellington (1978) reported the 5 and 500 mcg levels of zeranol injected subcutaneously for 52 days, totally inhibited ovarian follicular and luteal development.

These data suggest the uterotropic effects of zeranol are related to an estogen-like activity. The adverse effect zeranol has on fertility traits indicates that zeranol should not be used in replacement heifers or bulls until more precise work is done.

## Zeranol and Monensin in Combination

Few studies have been conducted using zeranol and monensin in unison. Utley et al. (1976) found that monensin would increase feed efficiency while zeranol improved ADG for growing and finishing heifers. Sherrod et al. (1976) reported further increases in feed efficiency from the zeranol-monensin combination over either alone. Hoffman et al. (1977) performed a study using 96 crossbred steers with 24 pens and four head per pen in a 2 x 3 factorial. The improvement (%) in ADG and feed efficiency for zeranol alone, zeranol and low monensin (50 mg daily) and zeranol plus high monensin (330 mg daily) were 21.4, 10.9; 28.2, 15.1; and 23.9, 15.6, respectively.

Due to the lack of a significant interaction in the literature cited above when using zeranol and monensin in combination, it may be concluded that producers will achieve an additive effect by using the two in combination.

# MONENSIN AND ZERANOL ALONE AND IN COMBINATION FOR GROWING-FINISHING STEERS AND GROWING HEIFERS

## Summary

Ninety-two spring-born and 76 fall-born steer and heifer calves (Hereford and Angus x Hereford) averaging 188 and 255 kg, respectively, were utilized in a 2x2 factorial arrangement of treatments to study the effects of zeranol and monensin, alone and in combination, on growth rate, feed efficiency and carcass characteristics. After weaning, calves were stratified by weight for random allotment to four treatments: 1) control (no monensin, no zeranol); 2) zeranol alone; 3) monensin alone; and 4) zeranol-monensin combination. Zeranol (36 mg) was implanted subcutaneously in the ear every 90 days and monensin (200 mg) was fed daily. The diet for both growing periods consisted of hay free choice and a barley-biuret supplement. The diet of both finishing periods (steers only) consisted of a full feed of barley with limited hay intake and biuret for additional protein. Results for the spring-born calves indicated treatments 3 and 4 increased ADG ($P<.05$) during the winter (196 days), while feed efficiency for steers and heifers was improved by 8, 5; 24, 21; and 27, 27% on treatments 2, 3 and 4, respectively, as compared to 1. Average daily gain for the summer grazing period (98 days) was increased ($P<.05$) by treatments 2 and 4. During the finishing period (97 days), treatment 4 increased ADG ($P<.05$), while monensin improved feed efficiency by 12%. Overall ADG (391 days) for steers was increased 3, 7 and 16% on treatments 2, 3 and 4, respectively, as compared to 1. During the growing period (111 days), fall-born steers and heifers gained .68,

.61; .86, .70; .82, .71; and .88, .86 kg, respectively, on treatments 1, 2, 3 and 4. All treatments increased gains ($P<.05$) over 1 with treatment 4 producing increased gains ($P<.05$) with the heifers. During the 153-day finishing period for treatments 1, 2, 3 and 4, gains were .85, .95, .92 and 1.01 kg, respectively, with treatments 2 and 3 different ($P<.05$) from 1 and treatment 4 different ($P<.05$) from 1 and 3. Again, monensin improved feed efficiency by 12%. Overall ADG (264 days) for steers was increased 13, 9 and 18% on treatments 2, 3 and 4, respectively, over 1. Carcass data for all steers indicated a one-third older maturity score ($P<.05$) for steers receiving zeranol. Zeranol-implanted steers also exhibited a tendency for a slight reduction in quality grade but improved (2.1 vs. 2.3) yield grade. Either zeranol or monensin produced an acceptable increase in gains, but the additive effect exhibited by their combination provided additional and more consistent gains during the growing and finishing periods.

## Introduction

Feed additives and subcutaneous implants have been used in the cattle industry for over two decades to increase average daily gains (ADG) and improve feed utilization. Rapid weight gains and efficient feed utilization are two important factors in maximizing the efficiency of red meat production. Zeranol, a subcutaneously implanted anabolic agent, promotes weight gains in the pasture and in the feedlot (Perry et al., 1970; Ward et al., 1978). Monensin, a biologically active feed additive, has improved the feed to gain ratio in grazing animals

(Boling et al., 1977; Turner et al., 1980) and in the feedlot (Davis and Erhart, 1976; Raun et al., 1976). The few studies concerned with utilizing zeranol and monensin in unison (Sherrod et al., 1976; Utley et al., 1976; Hoffman et al., 1978), indicated no significant interaction, suggesting that their effect may be additive.

This study was designed to evaluate the effects of monensin and zeranol, alone and in combination, on ADG, feed efficiency and carcass characteristics for growing-finishing steers and growing heifers. The heifers will become part of a five-year study to evaluate the effect of these treatments on developing replacement heifers.

## Experimental Procedure

Spring calves (Hereford and Angus x Hereford breeding), born in March and April, were weaned on September 11 and started on a barley (IFN-4-07-939) and biuret supplement along with rake-bunched meadow hay (IFN-1-03-181). On October 24, 56 steers and 36 heifers were weighed and stratified by weight for random allotment to four treatments; control (no zeranol, no monensin), zeranol alone, monensin alone and a zeranol-monensin combination. All weights for these trials were taken after an overnight (14 hr) shrink without feed or water. The steers formed two replications of the four treatments with 14 head per treatment while the heifers formed a separate replication consisting of nine head per treatment. Zeranol implants were 36 mg, and daily intake of monensin was 200 mg.

From October 24 to May 7, a period of 196 days, all animals were kept in identical side by side pens and received a full feed of meadow

hay plus a daily supplement. The supplement consisted of .06 kg of biuret mixed with 1.13 kg of ground barley. Monensin was mixed with .23 kg of finely ground barley to act as a carrier for those animals receiving monensin. Both the hay and supplement were hand fed daily with the hay fed in covered bunks and the supplement in open feeders located in the center of the pens. All animals had free access to water, salt and a 50-50 mixture of salt and bonemeal during all trials conducted in this experiment. Hay intake was measured, on a replication basis, with hay weighted in daily and orts weighed back weekly. Calves on zeranol treatments were reimplanted on January 23, 91 days after the first implant. Upon termination of the winter phase, all animals were weighed with the steers continuing on the summer pasture phase.

During the summer grazing period, steers were combined into two groups, animals receiving monensin formed one group and those not receiving monensin another. The two groups were kept in similar fields consisting of early vegetative crested wheatgrass (IFN-2-05-420). Both groups received a daily hand fed supplement, beginning at .5 kg of barley and no biuret, increasing to 1.4 kg of barley and .06 kg of biuret by August 13, the termination date for the summer grazing period. Monensin was added to the supplement as previously described. This increasing supplementation program was necessary to compensate for the decline in the nutritive quality of the range as the plants matured. On August 13, all steers were weighed with those on zeranol treatments being reimplanted.

In the finishing period, steers remained in the combined groups and were put on an accelerated supplement program by increasing the

barley by .5 kg every other day until they reached full feed. Steers attained full feed when they no longer consumed the entire amount of barley fed. Steers remained on range receiving barley ad libitum, .06 kg of biuret and .06 kg of limestone hand fed in open bunks. Monensin was fed as previously described. Hay was fed on the ground daily and was held at 1.4 kg per head. On November 18, the finishing period was terminated and final weights were taken. Steers were slaughtered at a commercial packing plant and carcass data were collected by a USDA inspector. Carcass parameters included maturity; marbling; quality grade; warm carcass weight; adjusted fat thickness; ribeye area; kidney, heart and pelvic fat; and yield grade.

Fall calves (Hereford and Angus x Hereford breading), born in October and November, were weaned on July 25 and started on a barley-biuret supplement along with meadow hay aftermath and (or) rake-bunched meadow hay ad libitum. On August 22, 36 steers and 40 heifers were weighed and assigned to treatments as previously described, except these steers were not replicated. At the initiation of the growing trial, steers and heifers remained on pasture and were mixed and combined by treatments as described previously. Initially, all animals were hand fed 1.6 kg of supplement and were increased to 3 kg by the termination date of December 11. The supplement consisted of increasing levels of barley with biuret remaining at .06 kg mixed in .23 kg of finely ground barley. Monensin was fed as described earlier. These supplement levels were used to background the steers for the feedlot. Normally, the recommended supplement would not exceed 1.4 kg, particularly for growing heifers.

Calves were weighed on December 11, with steers on the zeranol treatments being reimplanted and moved into the feedlot. Hay and barley were fed separately in open feeders on a daily basis with orts weighed back monthly. The steers were put on the accelerated supplement program as described earlier. The finishing ration was the same as before, except for an additional .23 kg of beet pulp pellets (IFN-4-00-669). On May 13, final weights were taken, steers were slaughtered and carcass data collected as described previously. Statistical analysis for all gain data were conducted by the least-square mean procedure of Harvey (1975).

## Results and Discussion

Performance of the spring-born steers over the winter are summarized in table 1. Average daily gains for the control, zeranol alone, monensin alone and the combination were .56, .51, .61 and .62 kg, respectively. Monensin alone and the combination increased ADG ($P<.05$) over the control and zeranol alone treatments. Zeranol alone, monensin alone and the combination reduced the feed required per unit of gain by 9, 24 and 27%, respectively, over the controls. Zeranol alone did not improve gains. Also, no additional gains were observed with the combination compared to monensin alone. Hay consuption for the zeranol alone steers was reduced by 15% compared to controls. This study utilized crossbred calves, and pen conditions during this period were extremely muddy. The data reported here seems to indicate zeranol implantation, under these conditions, may have reduced the number of times the steers consumed hay during the day resulting in a lower plane of nutrition. Previous studies have

Table 1. Gain, feed intake and feed efficiency of spring-born steers over the winter (196 days)

| Treatment[1/] | Initial weight | ADG | Daily feed intake[2/] | Feed per kg of gain | Improvement in feed efficiency over the controls |
|---|---|---|---|---|---|
| | kg | | | | % |
| Control | 190 | .56[a] | 7.2 | 5.9 | - |
| Zeranol | 190 | .51[a] | 6.1 | 5.4 | 8 |
| Monensin | 190 | .61[b] | 6.0 | 4.5 | 24 |
| Zeranol-Monensin | 190 | .62[b] | 5.9 | 4.3 | 27 |

1/ Each treatment group consisted of 14 steers.

2/ Includes 1.5 kg of supplement with the remainder being meadow hay.

a,b Means within the same column without a common superscript differ ($P<.05$).

Table 2. Gain, feed intake and feed efficiency of spring-born heifers over the winter (196 days)

| Treatment[1/] | Initial weight | ADG | Daily feed intake[2/] | Feed per kg of gain | Improvement in feed efficiency over the controls |
|---|---|---|---|---|---|
| | kg | | | | % |
| Control | 185 | .45[a] | 5.8 | 5.9 | - |
| Zeranol | 186 | .46[a] | 5.6 | 5.5 | 5 |
| Monensin | 186 | .53[b] | 5.5 | 4.6 | 21 |
| Zeranol-Monensin | 186 | .59[b] | 5.1 | 4.3 | 27 |

1/ Each treatment group consisted of 9 heifers.

2/ Includes 1.5 kg of supplement with the remainder being meadow hay.

a,b Means within the same column without a common superscript differ ($P<.05$).

also reported a reduced response to zeranol during nutritionally stressful periods (Brown, 1970; Moran, 1972). Furthermore, zeranol appears to be an estrogen agonist and has been demonstrated to be associated with estrogen receptors (Greenman et al., 1979) and to accelerate RNA and protein synthesis in laboratory animals (Ueno and Yagasaki, 1975). This estrogen-like activity may elevate growth hormone (GH) levels (Borger et al., 1973, Olson et al., 1977; Galbraith, 1979). Borger et al. (1973) reported that zeranol animals fed low protein (9.5%) consumed 21.3% more feed than controls. This lends supportive evidence to the increase in RNA and protein synthesis previously mentioned. These animals would have to overeat in order to obtain the additional amino acids necessary to satiate accelerated muscle protein syntheses at the molecular level. Animals utilized in this study received more than 9.5% total protein but did not consume enough to fully realize the accelerated anabolism due to zeranol.

Spring-born heifer performance, summarized in table 2, shows relatively the same trend as the spring-born steers. Heifers receiving monensin exhibited greater gains ($P<.05$) as opposed to those not receiving monensin. This evaluation in ADG for the monensin-fed heifers may have been mediated through an increase in available energy per unit of feed (Raun et al., 1974). As with the steers, zeranol did not improve heifer gains. The trend for the combination to have the best overall feed conversion was the same as for the steers, resulting in a 27% improvement compared to 5 and 21% for zeranol alone and monensin alone, respectively, over controls. During the summer grazing period (table 3), zeranol alone and the

Table 3. Gains for the summer period (98 days) and gain, feed intake and feed efficiency data for the finishing period (97 days) and overall gains (391 days) for the spring-born steers

| Treatment | Summer ADG | Finishing ADG | Daily feed intake[1/] | Feed per kg of gain[1/] | Improvement in feed efficiency | Overall ADG | Final weight | Improvement over control |
|---|---|---|---|---|---|---|---|---|
| | kg | | | | % | kg | kg | % |
| Control | .63[a] | 1.21[a] | 10.1 | 3.7 | - | .74[a] | 478 | - |
| Zeranol | .78[b] | 1.26[a] | | | | .76[a] | 488 | 3 |
| Monensin | .67[a] | 1.28[a] | 9.7 | 3.2 | 12 | .79[a] | 498 | 7 |
| Zeranol-Monensin | .73[b] | 1.46[b] | | | | .86[b] | 525 | 16 |

[1/] Steers were fed by monensin groups so data on zeranol are not available.

[a,b] Means within the same column without a common superscript differ (P<.05).

combination increased ADG ($P<.05$) over the control and monensin alone treatments. Steers on the zeranol alone treatments appeared to compensate for reduced gains during the preceding growing trial. Steers on the monensin alone treatment responded early, but gains tailed off towards the end. This was a high precipitation year with quantity of grass substantially increased over average years, but quality was exceptionally low. This reduced response by monensin may have been because of this poor quality forage (Turner and Raleigh, 1975; Coombe et al., 1979).

The performance data for the finishing period are also presented in table 3. The combination treatment resulted in greater gains ($P<.05$) compared to all other treatments. The increases in gains by the combination were 21, 16 and 14% greater than the control, zeranol alone and monensin alone treatments, respectively. Even though the zeranol alone animals did not exhibit faster gains, the increase exhibited by the combination must have resulted, at least in part, from zeranol implantation. Zeranol performance may have been improved due to monensin increasing the availability of energy (Raun et al., 1974) and amino acids (Pendlum et al., 1980) necessary for the anabolic effect of zeranol. Trenkle (1974) stated that with undernutrition, either energy or protein, muscle fails to develop. Also, in young animals, there is a loss of RNA with a reduction in nuclear division and a normal ratio of protein per nucleus. Therefore, if zeranol accelerates protein synthesis, the absence of energy or protein would result in poor gain performance. Monensin also resulted in a 12% reduction in feed consumption.

The overall ADG for the entire 391 days (table 3) was .74, .76, .79 and .86 kg for the control, zeranol alone, monensin alone and the combination, respectively. The combination significantly increased ADG ($P<.05$) over all other treatments. Throughout this entire trial the combination has shown consistent significant positive results, while some inconsistency has been demonstrated by either monensin or zeranol when utilized alone. The possible increase in available energy and protein related to monensin, may compliment the increased dietary requirements resulting from zeranol implantation. Final weights for steers on the combination treatment were 47 kg heavier than the controls, with the steers on the zeranol and monensin alone treatments having 10 and 20 kg heavier weights, respectively, compared to the control.

Gain performance for the fall-born heifers is presented in table 4. Zeranol alone and monensin alone increased ADG ($P<.05$) over the controls, while the combination produced greater gains

Table 4. Gain performance of fall-born heifers during the growing period (111 days)

| Treatment[1/] | Initial weight | ADG | Increases in gains over the controls |
|---|---|---|---|
| | kg | kg | % |
| Control | 231 | .61[a] | - |
| Zeranol | 231 | .70[b] | 14 |
| Monensin | 234 | .71[b] | 16 |
| Zeranol-Monensin | 229 | .86[c] | 41 |

1/ Each treatment consisted of 10 heifers.

a,b,c Means within the same column without a common superscript differ ($P<.05$).

($P<.05$) compared to all treatments. Performance for the fall-born steers during their growing and finishing trials are presented in table 5. All three treatments increased ADG ($P<.05$) over the control during the growing trial. Gains for the combination group were not significantly greater than the zeranol alone or monensin alone treatments as was seen in the fall-born heifers.

Sharp and Dyer (1971) suggested that the response to exogenous six hormones depends on the relative rate of production of GH, thyroxine and sex hormones at the time of administration. Since zeranol seems to be an estrogen agonist and heifers mature at a lighter weight, as opposed to steers, this may have contributed to these differences in gain responses.

During the finishing trial, the combination group increased ADG ($P<.05$) over the control and monensin alone treatments. Zeranol did not significantly increase ADG over the controls. Again, zeranol performance may have been inhibited by the lack of protein due to the high concentrate diet they consumed. Monensin may have made available the amino acids necessary for zeranol to improve gains within the combination treatment. Monensin also improved the feed to gain ratio by 12% as was seen with the spring-born steers.

Overall ADG for the 264 day period was .81, .91, .88 and .95 kg for the control, zeranol alone, monensin alone and combination treatments, respectively. The zeranol alone and monensin alone treatments increased ADG ($P<.05$) over the controls, while the combination increased ADG ($P<.05$) over all treatments except zeranol alone. Zeranol displayed a more consistent response with the fall-born calves as

Table 5. Gains for the growing period (111 days) and gain, feed intake and feed efficiency for the feedlot period (153 days) and overall gains (264 days) for the fall-born steers

| Treatment[1] | Initial weight | Growing ADG | Feedlot ADG | Daily feed intake[2] | Feed per kg of gain | Improvement in feed efficiency over control | Overall ADG | Final weight | Improvement over control |
|---|---|---|---|---|---|---|---|---|---|
| | kg | | | | | % | kg | kg | % |
| Control | 243 | .68[a] | .89[a] | 12.5 | 6.2 | - | .81[a] | 455 | - |
| Zeranol | 247 | .86[b] | .95[ab] | | | | .91[bc] | 487 | 13 |
| Monensin | 249 | .82[b] | .92[a] | 11.6 | 5.5 | 12 | .88[b] | 481 | 9 |
| Zeranol-Monensin | 248 | .88[b] | 1.01[b] | | | | .95[c] | 499 | 18 |

[1] Each treatment consisted of 9 steers.

[2] Steers were fed by monensin group so data on zeranol are not available.

[a,b,c] Means within the same column without a common superscript differ ($P<.05$).

opposed to those born in the spring. The fall calves were heavier and more mature at the initiation of their trial, which may have improved their response to zeranol.

Carcass data for both spring and fall-born steers are presented in table 6. Spring-born steers implanted with zeranol exhibited a one-third older ($P<.05$) maturity score as opposed to non-implanted steers. Since zeranol appears to function as an estrogen agonist these maturity scores are not unexpected. Zeranol alone resulted in a reduced marbling score ($P<.05$) compared to steers not receiving zeranol. This agrees with Sharp and Dyer (1971) who observed an increase in water content and protein, at the expense of fat, for animals fed to similar weights. The combination treatment exhibited tendencies for lower marbling and quality scores while increases were observed for carcass weight, adjusted fat thickness and ribeye area when compared to control steers. The combination treatment appeared to reduce the effect of zeranol on fat deposition while amplifying the effect of zeranol on increasing skeletal and muscle maturity. These altercations in carcass characteristics by the combination treatment, may be attributed to monensin increasing available energy necessary for the accelerated protein anabolism. Therefore, monensin supplementation may allow for less fat utilized as energy for protein synthesis.

The fall-born steers implanted with zeranol had a tendency for older maturity scores but did not significantly differ from non-zeranol treated steers. Also, marbling and quality grades appeared to be unaffected by zeranol implantation. This does not coincide with the spring-born steer data and may have resulted from the

Table 6. Carcass data for both spring and fall-born steers

| Treatment | Spring Steers[1/] | | | | Fall Steers[2/] | | | |
|---|---|---|---|---|---|---|---|---|
| | Control | Zeranol | Monensin | Zeranol-Monensin | Control | Zeranol | Monensin | Zeranol-Monensin |
| Maturity[3/] (1/3) | 1.0[a] | 1.71[b] | 1.0[a] | 2.0[b] | 1.0 | 1.4 | 1.0 | 1.6 |
| Marbling[4/] (1/3) | 9.0[a] | 7.0[b] | 8.9[a] | 8.0[ab] | 9.2 | 9.6 | 9.1 | 9.9 |
| Quality[5/] grade (1/3) | 13.4 | 12.4 | 14.1 | 13.0 | 14.2 | 14.6 | 13.9 | 14.3 |
| Carcass weight (kg) | 276 | 286 | 292 | 311 | 268 | 286 | 285 | 297 |
| Adjusted fat thickness (cm) | .97 | .99 | .91 | 1.1 | .74 | .74 | .89 | .71 |
| Ribeye area ($cm^2$) | 78.7 | 81.9 | 81.3 | 84.5 | 72.3 | 76.8 | 75.5 | 79.4 |
| Kidney, pelvic and heart fat (%) | 1.6 | 1.5 | 1.9 | 1.8 | 1.9 | 1.8 | 2.3 | 1.9 |
| Yield grade (tenths) | 2.2 | 2.0 | 2.0 | 2.2 | 2.1 | 2.1 | 2.4 | 2.1 |

1/ All treatments consisted of 14 steers.

2/ All treatments consisted of 9 steers except zeranol which had 7 steers due to lack of returned carcass data and monensin which had 8 steers due to the death of one steer during the finishing period.

3/ A=1, $A^{-}$=2.

4/ Values for PD, T-, T, T+, SL-, SL, SL+, SM-, SM and SM+ were 3, 5, 6, 7, 8, 9, 10, 11, 12 and 13, respectively.

5/ Values for S-, S, S+, G-, G, G+ and C- were 10, 11, 12, 13, 14, 15 and 16, respectively.

a,b,c Means within the same row and calving group without a common superscript differ ($P<.05$).

older, more mature fall steers receiving only two implants while the younger spring steers were implanted four times. However, the combination treatment did exhibit a tendency for a heavier carcass weight and greater loineye area compared to all other treatments.

No adverse effects were observed for any of the treatments, although zeranol implantation did exhibit less fat deposition resulting in a lower quality grade. This requires either a longer feeding period or the acceptance of greater muscle content at the expense of quality grades. However, data reported here seems to demonstrate that utilizing zeranol and monensin in unison will result in slightly higher quality grades over zeranol alone.

In summary, either monensin or zeranol alone stimulated gains, but the additive effect exhibited by their combination, provided additional and more consistent gains throughout the growing and finishing periods. The increase in available energy and possible protein sparing effect of monensin seem to compliment the accelerated anabolic effect of zeranol. Monensin improved feed efficiency in all of the trials except during the summer grazing period of the spring-born steers when a poor quality forage was consumed.

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# APPENDICES

Table A. Gain performance, onset of puberty, conception rates and calving age for spring-born heifers (196 days)

| Treatment[1/] | Initial weight | ADG | Age at first estrus | Conception rates | Calving age |
|---|---|---|---|---|---|
| | kg | kg | days | % | days |
| Control | 185 | .45[a] | 385 | 100 | 720 |
| Zeranol | 186 | .46[a] | 397 | 67 | 719 |
| Monensin | 186 | .53[b] | 383 | 100 | 717 |
| Zeranol-Monensin | 186 | .59[b] | 397 | 78 | 742 |

1/ Each treatment consisted of 9 heifers.

a,b Means within the same column without a common superscript differ ($P<.05$).

Table B. Gain performance, onset of puberty, conception rates and calving age for fall-born heifers (111 days)

| Treatment[1/] | Initial weight | ADG | Age at first estrus | Conception rates | Calving age |
|---|---|---|---|---|---|
| | kg | kg | days | % | days |
| Control | 245 | .65[a] | 327 | 83 | 715 |
| Zeranol | 241 | .74[b] | 317 | 100 | 719 |
| Monensin | 240 | .72[b] | 319 | 100 | 714 |
| Zeranol-Monensin | 239 | .90[c] | 310 | 100 | 712 |

1/ Each treatment consisted of 6 heifers except the control in which one heifer died prior to calving. Her data included in all measures except calving age.

a,b,c Means within the same column without a common superscript differ ($P<.05$).

It has been demonstrated that heifers with an elevated ruminal proprionate content will reach puberty significantly faster and at a lighter weight as opposed to control animals (McCartor et al., 1979). Mosley et al. (1977) reported that heifers fed monensin reached puberty at an earlier age compared to controls. Bushmich et al. (1980) observed a definite, fast action, positive relationship between increased ruminal proprionate levels and ovarian response to exogenous and endogenous gonadotropins. This enhanced ovarian sensitivity of heifers with elevated ruminal proprionate levels due to monensin is supported by the research of Mosley et al. (1977), Turner et al. (1977) and McCartor et al. (1979). Turner et al. (1977) observed the interval from calving to the first signs of estrus were 12 days sooner for cows receiving monensin. McCartor and Randell (1977) reported that twice as many monensin-fed cows reached puberty after 122 days compared to controls. Although no definite mode of action has been elucidated, the increase in proprionate may cause a significant rise in GH and insulin levels (Bryce et al., 1975). This elevation of GH may produce an environment in endocrine organ tissues necessary for other hormones to express themselves (Li, 1956; Turner and Bragnara, 1971).

The reproductive disorders and uterotropic effect resulting from zeranol implantation have been cited earlier in this thesis. They seem to be related to an association between zeranol and endogenous estrogen receptors in the uterus.

The following discussion of the reproductive data is from the spring and fall-born heifers in which gain data was previously

reported. Reproductive traits reported here are tentative at best, so that only possible trends shall be discussed.

The spring-born heifers were kept in identical side by side pens with heat detection conducted by injecting the lightest heifer in each treatment group with testosterone and equiping her with a chin-ball marker. This marker system was used in conjunction with visual observation. Heifers were injected with 25 mg of prostaglandin $F_2\alpha$ on May 4, initiating the artifical insemination (AI) program. The second prostaglandin injection was on May 15. At this time, any animals that exhibited signs of heat were bred and all other animals were bred 80 hours after the second injection. The cover bull was then kept with the spring herd from May 23 until June 2 whereupon the AI program was resumed. The cover bull was utilized from June 12 until June 23, an eleven day period. The AI program resumed from June 23 until July 11. The cover bull then remained with the herd from July 11 until July 20, the termination date for the AI program.

Spring-born heifers (table A) on the monensin alone and combination treatments exhibited greater live body weight gains ($P<.05$) over the controls and zeranol alone animals. Of the heifers receiving monensin, only the monensin alone heifers reduced the days to puberty. Monensin alone heifers reached puberty 14 days before the zeranol alone or combination but was only two days ahead of the controls. In this case, monensin may not have altered puberty with the difference being attributed to the detrimental effects of zeranol. Although, monensin may offset the effects of zeranol on the reproductive tract by increasing progesterone (Chew et al., 1978) necessary for initiating the estrus cycle (Gonzalez-Padilla et al., 1975). The

delayed puberty age demonstrated by the zeranol calves may be mediated through a delayed physiological maturity (Sharp and Dyer, 1971). The grain supplement that was fed to all heifers may account for some of the similarities seen in puberty ages between the control and monensin alone heifers, since fermentable carbohydrates may alter the production of insulin, glucagon, somatostatin and GH (Bassett, 1976).

Conception rates were 67 and 78% for zeranol alone and the combination treatments. In contrast, the non-implanted heifers demonstrated a 100% conception rate. These heifers averaged 185 kg at the initiation of the growing trial and those in the zeranol groups received two implants. The data presented here suggests, the younger, more immature heifers may be suseptible to the detrimental reproductive traits attributed to zeranol. This reproductive failure may be regulated through the estrogen-like association of zeranol with the estrogen receptors in the uterus (Greenman et al., 1979).

The average calving age for the control, zeranol alone, monensin alone and combination treatments were 720, 719, 739 and 742 days, respectively. Monensin alone heifers, while attaining puberty 14 days sooner than the zeranol alone heifers, did not calve (average) until 20 days after the zeranol alone heifers. There is no solid explanation for this although, variation in the A.I. program may have influenced these results.

Results for the fall-born heifers are presented in table B. Zeranol alone and monensin alone increased ADG ($P<.05$) over the controls while the combination accelerated ADG ($P<.05$) over all treatments. Results for age at first estrus indicate that heifers on the zeranol alone, monensin alone and combination treatments exhibited signs of

estrus 10, 8 and 17 days, respectively, earlier than the controls. All three treatments increased body weight and skeletal size which have been shown to decrease the number of days to puberty (Short and Bellows, 1971). In addition, the fall heifers received twice the barley supplement (3 vs 1.3 kg) as did the spring heifers. This may increase the endogenous hormone levels previously discussed. The interesting observation here is that zeranol, either alone or with monensin, demonstrated a positive effect. The fall-born heifers only received one implant while the spring heifers received two but the fall heifers were heavier and more mature at the initiation of their trial. This advanced maturity may play a role in offsetting the reproductive disorders related to zeranol.

Conception rates were 100% for all three treatments with the control exhibiting an 83% conception rate. These heifers were combined by monensin groups and run on pasture as previously described within this text. Heat detection was conducted by yearling male calves, recently castrated, and equipped with a chin-ball marker. Visual observations were also utilized. All animals in heat were bred on December 17 with the first prostaglandin injection on December 21. The cover bull was utilized from December 28 until January 3. AI resumed on January 4 with the cover bull utilized from January 18 until January 26. On January 27, AI was resumed and the cover bull was combined with the fall cow herd from February 8 until February 10, marking the termination of the AI program.

The average age at calving was 715, 719, 714 and 712 days, respectively, for the control, zeranol alone, monensin alone and

combination treatments. The data for the fall calves seem to indicate that the combination treatment will increase gains while reducing the number of days to estrus and calving age. Although the combination did not reduce these two parameters for the spring-born heifers, it must be remembered that the spring heifers were under stressful pen and climatic conditions, while the fall heifers were not. Also, the spring heifers received two implants and were younger as opposed to only one implant for the older, more mature fall heifers.

The reproductive data presented here are the first of a five-year study and the number of heifers are too few to establish definite results.