DEVELOPMENT OF A SELF-LIMITED MONENSIN-CONTAINING ENERGY SUPPLEMENT FOR GROWING CATTLE ON WHEAT PASTURE

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Chapter 1
Introduction

Wheat and other small grains are important cash crops in Oklahoma. A valuable by-product of the small grain industry is the highly productive and high quality forage grown in the late fall and early spring. Over four million stocker cattle graze wheat pasture in the southern great plains (Horn et al., 1977). Wheat forage supplies high protein, is low in fiber and dry matter and is readily and rapidly fermented in the rumen. The high quality of the forage can produce gains in excess of 1 kg per day. Bloat of cattle grazing wheat pasture causes a large number of losses of cattle and reduces gains. Bloat may be caused or intensified by the high quality and rapid fermentation of the forage.

Wheat forage commonly contains 75% digestible dry matter and 25 to 30% crude protein with much of the nitrogen present as non-protein nitrogen (Horn, 1984). Hogan and Weston (1970) and Hogan (1982) discussed the necessity of providing balanced levels of nitrogen and digestible organic matter for efficient microbial protein synthesis. Owens and Zinn (1988) stated that the quantity of microbial crude protein that can be synthesized in the rumen is limited by the amount of energy available for the microbes and the efficiency with which microbes use available energy. In forage with TDN:CP ratios less than 8 and greater than 4, crude protein and energy are thought to be in balance. Forages with TDN:CP ratios that are greater than 8 are considered to be protein deficient (Moore, 1992). Forage containing

TDN:CP ratios less than 4:1 have been associated with losses of ruminal nitrogen and forages with TDN:CP ratios less than 3:1 rumen, rumen ammonia-N concentrations were increased (Hogan, 1982). Digestible organic matter levels of wheat forage are often in excess of 75% and crude protein levels are often greater than 25%. The DOM:CP ratio for wheat forage is about 3 to 1 and therefore supplemental energy could improve the balance between energy and protein.

Rate of weight gain and predictability of performance are key figures in the determination of the profitability of a stocker cattle enterprise. Gains on high quality wheat forage are potentially quite high, but variability in forage yield, and imbalances in nutrients may keep performance below the potential. Wagner et al. (1984) suggested that supplements can be supplied to cattle on wheat pasture to increase daily gains or carrying capacity, carry feed additives, supply deficient nutrients, or correct nutrient imbalances. Seemingly small improvements in rate of gain can increase profitability by $25 to $35 per head. High energy grain-based supplements improve weight gains by approximately .1 to .15 kg per day (Oliver, 1975; Smith et al. 1989; Vogel et al. 1989). Supplement conversion is traditionally considered quite poor at 7 to 10 kg supplement/kg increased gain (Elder, 1967; Utely and McCormick, 1975). However, when low levels of supplement are fed (< 30 g/kg metabolic body weight; Horn and McCollum, 1987) efficiency may be improved, possibly due to lower substitutive effects. Grigsby et al. (1991) increased gains by .57 kg/day by feeding a corn-based energy supplement at a rate of 1.33 kg/day to calves grazing rye-ryegrass mixed pastures, resulting in a supplement conversion of 2.33.

Feed additives, which can be supplied in the supplement, have increased performance. The ionophores monensin (Horn et al., 1981) and lasalocid (Anderson and Horn, 1987) have been shown to increase rate of gain of wheat pasture stocker cattle by approximately .07 to .09 kg/day and .11 kg/day, respectively. Monensin has also been shown to decrease the incidence and severity of bloat in grazing cattle (Grigsby, 1984; Bagely and Feazel, 1989; Branine and Galyean, 1990). Other bloat preventative compounds can be supplied in a supplement during periods of bloat outbreaks. Thus, the first objective of this research was to develop a self-fed monensin-containing energy supplement and characterize intake of the supplement and effect the supplement has on performance. The supplement was designed to have a targeted level of intake of .91 to 1.36 kg/day and supply 165 mg monesin/kg of supplement.

There has been increased interest in the effect of the supply of supplemental trace minerals to high producing cattle. The requirements for copper is 8 ppm of diet with an acceptable range of 4 to 10 ppm and maximum tolerable levels to be 115 ppm (NRC, 1984). Selenium is adequate at a range of .05 to .3 ppm with a suggested value of .20 ppm of the diet and maximum tolerable levels are 2 ppm (NRC, 1984). It has been suggested that required levels may be greater than those reported with the presence of interfering factors present in the diet. The second objective of the research was to evaluate the effect of a supplemental copper injection or a long lasting intraruminal selenium bolus on performance of growing cattle grazing winter wheat pasture.

Chapter 2

REVIEW OF LITERATURE

Composition and Quality of Wheat Forage

Crude Protein Content

The crude protein content of wheat forage in the late fall and early spring commonly exceeds 20% and is usually between 25 and 30% of dry matter (DM) (Johnson et al. 1974; Horn, 1984). Large proportions of the crude protein fraction may be in the form of non-protein nitrogen. Horn et al. (1977) reported that up to 1.94% of dry matter or 37.18% of total N in wheat forage collected from bloat provocative pastures was in the form of NPN. Pastures where bloat was not observed contained 1.06% of DM or 25.84% of total N in the form of NPN. Johnson et al. (1974) reported that NPN concentrations in wheat forage ranged between .4 and 1.2% of DM or 16 to 33% of total N. Horn et al. (1977) also reported that from 44 to 62% of total N in wheat forage was in the form of soluble N. Branine and Galyean (1990) reported that total N of winter wheat pasture in early April was 4.9% of DM, with 40.8% of total N as soluble N and 30.6% of total N as soluble NPN. Vogel (1988) reported that up to 75% of wheat forage N was in a pool with rapid disappearance rates of 16 to 19%/hour. Beever (1984) reported that some N in high quality forages is so rapidly degraded in the rumen that it is not incorporated into microbial protein and is lost as ammonia-nitrogen. Thus, performance of cattle grazing wheat may be limited by the amount of protein flow to the small intestine.

Carbohydrate and Energy Levels

The digestibility of wheat pasture is high, usually ranging from 70% to over 80%. Soluble carbohydrate levels have been reported as 9 to 13% of DM (Horn et al., 1977) and 20 to 30% of DM (Johnson et al., 1974). Beever et al. (1986) reported that soluble carbohydrate concentrations of perennial ryegrass ranged from 15 to 18% of DM. The water soluble carbohydrates are the more rapidly and completely fermented carbohydrate fractions found in forages, where the extent of digestion of the fiber fractions depend on the level of lignification (Van Soest, 1982). Horn et al. (1977) reported levels of NDF to be 35 to 44%. Branine and Galyean (1990) reported that NDF concentration of wheat forage collected in early April, late April and mid May increased from 43 to 50%, while ADF increased from 21 to 22% and ADL increased from 3.0 to 3.5% as maturity increased.

Energy:CP Ratio

For forage protein to be used efficiently in the production of microbial protein, rumen microorganisms must have readily available sources of energy for protein synthesis (McDonald et al., 1988). Owens and Zinn (1988) stated the quantity of microbial protein which can be synthesized within the rumen is limited by the amount of energy available for the microbes and the efficiency with which microbes use available energy. With the high CP and NPN content of wheat forage, the availability of energy in relation to the release of soluble forage NPN sources (or synchrony of energy and NPN release) comes into question. Moore et al. (1991) calculated ratios of TDN:CP from requirements of 364 kg heifers at maintenence, 364 kg heifers pregnant and gaining .45 kg per day, 273 kg heifers gaining .57 kg per day and lactating cows with 6.8 kg milk produced per day and found required ratios range from 5.6:1 to 7.7:1. The authors felt that ratios of TDN:CP which are less than 8:1 are adequately balanced with TDN and CP and ratios greater than 8:1 are deficient in protein relative to energy. Hogan and Weston (1970) and Hogan (1982) also discussed the necessity of providing balanced levels of nitrogen and digestible organic matter for efficient microbial protein synthesis. But, Hogan (1982) stated that forage DOM:CP ratios less than 4:1 resulted in losses of nitrogen and with ratios less than 3:1 rumen ammonia concentrations were increased. For perspective, wheat forage with a crude protein content of 25% and DOM content of 75% would have a DOM:CP ratio of 3:1. This would suggest that the energy levels are too low for optimal microbial incorporation of the high N levels in wheat forage into microbial protein and causes losses of N to occur. Beever and Siddons (1986) concluded that, with the rapid degradation of the N supply from temperate forages, imbalances between energy supply and degraded N exist and these imbalances cause rumen N losses. A ratio of 25 to 35 g degraded N per kg of digestible organic matter was suggested to meet microbial requirements for optimal growth. A possible protein deficiency at the small intestine is likely caused by a ruminal or microbial energy deficiency. Therefore, added energy in diets of cattle grazing wheat pasture or other small grain forages may be beneficial.

Energy Supplementation of Grazing Ruminants

Supplementation Effects on Forage Intake and Digestibility

Additional nutrients are often required by ruminants grazing pastures. It is well known that low amounts of a high rumen-degradable protein supplement will increase both intake and digestibility of low quality roughages (McCollum and Galyean, 1985). Beever (1984) suggested that nondegradable protein (or high bypass protein) sources may improve animal performance on high quality forages that tend to have negative ruminal N digestibilities. Research on supplementation of bypass protein feeds (ie. corn gluten meal, fishmeal, meatmeal or meat and bone meal) to ruminants grazing high quality pastures has had inconsistent effect on performance (Smith et al., 1989; Horn, 1990; Worrell et al., 1990; Grigsby et al., 1991). Energy supplementation has been shown to increase performance of cattle grazing high quality forages. Although large substitutions of grain for forage have been noted with moderate to high levels of grain supplementation (Elder, 1967; Gulbransen,1976; Utley and McCormick, 1976; Lowery et al. 1976a; Lowery et al. 1976b). Mieres and McCollum (1992) reported that feeding increasing levels (from 0 to .8 % of BW) of a high corn supplement to growing cattle grazing native range in June and August had no effect on forage OM intake until supplement intake was increased to .55% BW. Horn and McCollum (1987) summarized the results of several studies on the effect of increased amounts of high-starch supplements on voluntary forage intake and digestibility by ruminants. It was shown as forage quality increased, the substitution ratio also increased. It was concluded that concentrate supplementation at rates less than 30 g•kg $BW^{.75}$ may not cause significant decreases in the intake of high-quality forages. In a summary of 40 studies, Moore (1992) reported that concentrate supplementation had a variable effect on voluntary intake of forage depending on type and amount of supplement fed. Voluntary forage intake was increased by as much as .21% of BW by small amounts of a protein supplement and decreased by as much as 1.48 % of BW by supplementation with high levels of barley. In a New Mexico study, Pordimingo et al. (1991) reported .2% BW of corn fed to steers grazing native range, had a tendency to increase forage OM intake where providing the supplement at .4 or .6% of BW decreased forage OM intake. Cravey (1993) studied the effects of four levels (0, .4, .8 and 1.0% BW) of two types of energy supplements (high-fiber or high-starch) on intake of wheat forage by grazing cattle. He reported that for every kg of supplement intake, forage intake was decreased by .91 kg. Goetsch et al. (1991) reported DM intake of bermudagrass hay was decreased by .46 kg for every kg added corn supplementation up to 1.0% of BW. Hannah et al. (1989) reported that forage OM intake by cattle grazing tall fescue was not affected by supplemental corn fed at 1.0% of BW. Branine and Galyean (1990) reported that .5 kg energy supplement fed to cannulated steers weighing 393 kg (.13% of BW) grazing wheat pasture decreased ruminal NH_3 and had no effect on forage intake.

Effect of Energy Supplementation on Performance

Classically, the efficiency of supplement conversion (kg of supplement per kg of added gain) has been poor with energy supplementation. Elder (1967) reported increased gains and stocking rates of cattle grazing a wheat-rye mixture with a supplement conversion of 9.4 kg feed•kg added gain^{-1}•ha^{-1}. Gulbransen (1976) reported ad libitum grain sorghum increased daily gains of steers grazing oat pasture by .18 to .38 kg. Stocking rates ranged from .40 to

.08 ha/ head and ad libitum grain consumption ranged from 2.90 to 6.52 kg/ head. Supplement conversions averaged 10.3 kg feed•kg added gain^{-1}•ha^{-1}. Utley and McCormick (1976) showed daily gains of finishing steers grazing rye pasture were increased by .3 kg and stocking rates of the pastures were increased by 100% by feeding corn or grain sorghum ad libitum. The average consumption of the two supplements was over 5.85 kg/ day. Supplement conversion was 7.2 kg feed • kg added gain^{-1} • ha^{-1}. Lowery et al. (1976a) doubled stocking rate of steers by ad libitum feeding steers on a wheat, rye and ryegrass mixture and reported daily gains tended to be increased by .05 kg. Cravey (1993) reported that feeding either a high-starch or high-fiber energy supplement (containing monensin at a concentration of 88 mg/kg) at levels of .65% BW (across 3 years), enabled stocking rate to be increased by 33% and increased daily gains by .15 kg. The supplement conversion was 5.0 for both supplements and are lower than those reported earlier, possibly due to the lower level of feeding (.65% BW vs. 1.0 to 1.5% BW) and the presence of monensin.

Feeding lower levels (<.4% BW) of energy supplements have the potential to increase gains of growing cattle grazing high-quality pastures by balancing the energy:CP ratio, and improving the efficiency of microbial protein production. Also, energy supplements can be used as carriers for ionophores which will also increase gains and improve efficiency of supplementation. Lake et al. (1974) reported that feeding increasing amounts of corn (0 to 2.7 kg/d) to steers grazing irrigated mixed pastures increased gains linearly. Steers consuming 1.82 kg supplement were found to have the highest gains in two trials, increasing daily gain by .2 kg over controls, for a supplemental conversion of 9.1. In the first 63 d of both trials gains were higher indicating the higher quality or quantity of available forage. During the early part of the trials, gains were still highest for the steers receiving 1.82 kg supplement, increasing daily gains by .30 kg. The supplemental conversion was 6.1 for this treatment during this part of the trial. The authors suggested the grain supplementation improved N utilization by increasing the energy:CP ratio.

Oliver (1975) fed .91 kg of corn either alone or as a carrier for 25, 50, 100, or 200 mg monensin•hd^{-1}• d^{-1} to steers grazing Coastal bermudagrass. The author reported that corn alone increased average daily gain by .1 kg and monensin increased gains by an average of .17 kg. Monensin fed at a rate of 100 mg increased daily gains the largest extent by .22 kg. The supplement conversion for corn alone was 9.1. For the average of monensin treatments, the supplement conversion was 3.4 and the supplement conversion for monensin supplied at 100 mg daily was 2.8. These results indicate that adding monensin to energy supplements improves the economics of supplementation programs dramatically. Horn et al. (1981) reported the results of two trials where heifers grazing wheat pasture were fed .91 kg•hd^{-1} of a pelleted grain-based energy supplement daily containing 0 or 100 mg monensin. In the first trial, daily gains were increased over unsupplemented cattle by .09 kg for cattle receiving supplement only and .18 kg for cattle receiving supplement and monensin together. Actual daily supplement consumption across both trials was .88 kg/ head for the cattle fed supplement only and .82 kg/ head for cattle fed supplement with monensin. Daily gains of cattle receiving supplement only were not increased in Trial 2, but the supplement and monensin increased daily gains by .08 kg. Supplement conversion across both trials was 17.6 kg supplement/ kg added gain without monensin and 6.3 with monensin.

Grigsby (1984) decreased bloat and increased daily gains of steers grazing wheat pasture by feeding .5 kg•hd^{-1}•d^{-1} three times per week, a grain-based energy supplement containing 160 mg monensin•hd^{-1}•d^{-1}. Cattle fed supplement only had no advantage in performance over cattle receiving no supplement. Daily gains of cattle receiving supplement with monensin were increased by .28 kg. Supplement conversion with monensin was therefore 1.79. Grigsby (1984) also reported that feeding 1 kg of the above supplement in another trial, without monensin increased daily gains by 17.3% over controls and feeding the supplement containing monensin increased performance by 9.1% over cattle receiving supplement only.

Smith et al. (1989) and Vogel et al. (1989) studied the effects of energy supplement versus bypass-protein supplements on performance of cattle grazing wheat pasture. Performance was increased by .14 and .10 kg respectively by supplementation, and type of supplement had no effect performance.

Grigsby et al. (1991) used self-limiting supplements containing fishmeal, corn or corn plus rumen stable lysine and methionine, to test the effects of bypass-protein supplements or energy supplements on gains of calves grazing rye-ryegrass pastures. The daily intake of the supplements was to be limited to under .91 kg•hd^{-1} by a combination of salt, minerals and monensin. Actual consumption of the supplements was .35, .76 and .73 kg/d for the fishmeal, corn and corn plus amino acids supplements, respectively. Daily gains of calves in the first trial were reported to be increased over non-supplemented cattle by .19 kg for fishmeal, .57 kg for corn and by .47 kg for corn plus amino acids. In the second trial, only the effects of the fishmeal supplement and corn supplements were studied. In the second trial daily consumption of the supplements was again limited to less than the targeted maximum of .91 kg with actual intakes of .15 and .51 kg•hd^{-1} for fishmeal and corn supplements respectively. Compared to the non-supplemented cattle, daily gains were increased .17 kg by the corn supplement and tended to be increased ($P<.06$) by the fishmeal supplement. For both trials, supplement conversions were about 2.2 kg feed/kg added gain.

Horn et al. (1990 and 1992) and Beck et al. (1993) reported the effects of a self-limited monensin-containing energy supplement fed to steers grazing wheat pasture. The daily consumption of the supplement was to be limited to .91 to 1.36 kg and contained 165 mg monensin/kg. Mean daily consumption of the supplement was high in one pasture in each of the two trials reported by Horn et al. (1990) and Horn et al. (1992), but within the targeted range in all other pastures and trials. Daily gain was improved consistently by about .23 kg and supplement conversion (kg supplement/ kg added gain) ranged from 4.6 to 5.0 for cattle that consumed the desired amount of supplement to 8.0 to 8.5 for cattle that consumed excessive amounts of supplements. This agrees with work conducted by Rouquette et al. (1990) that showed self-regulated corn-based energy supplements (containing monensin) limited to a rate of either .91 or 1.82 kg•head^{-1}•d^{-1} increased gains of calves grazing rye-ryegrass pastures. Performance was not increased with increased supplement intake. Daily gains were increased by .15 kg in the .91 kg supplement group and the supplement conversion was 7.03. Daily gains were increased .11 kg in the 1.82 kg supplement group and the supplement conversion was 16.82.

It appears from the literature that the effects of low levels of energy supplements on performance can be quite variable but are more consistent and efficient when used in conjunction with an ionophore. Higher levels of supplementation are less efficient due to larger substition ratios. This may be useful in situations where the stocking rates are increased or forage levels are low. Low levels of energy supplementation are more efficient because they have little or no substituition of supplement for forage.

Effect of Timing or Method of Supplementation

Timing of Supplementation. The effect of time of day of supplementation has been considered an important issue that may affect performance and grazing time of ruminants. Wagnon (1963; as cited by Adams, 1985) reported that cattle have been observed to have a major grazing period starting at sunrise and lasting 3 to 6 hours and another major grazing period in the late afternoon. Adams (1985) reported that unsupplemented steers grazing Russian wild ryegrass consumed more forage than steers supplemented with .3% BW either in the morning or afternoon. Forage intake and digestible energy intake were greater for steers supplemented in the afternoon than for steers supplemented in the morning. Daily gains were greater for steers supplemented in the afternoon than for steers supplemented in the morning or control steers. Steers receiving supplement did not graze for 2 to 4 hours after supplementation and grazing time tended to be longer for steers supplemented in the morning, possibly because the major morning grazing period was interrupted.

Frequency of Supplementation. The labor and other costs associated with supplementation are great if the supplement has to be provided daily. Significant savings are possible if supplements can be fed less frequently and if performance of the supplementation program is not adversely affected. Chase and Hibberd (1985) fed two levels of grain supplement (.82 vs. 1.73 kg corn) either daily or on alternate days (at twice the daily amount) to beef cows fed chopped prairie hay. The feeding frequency had no effect on either hay or dry matter intake, while alternate day feeding decreased digestible dry matter intake. Kartchner and Adams (1982) reported that feeding grain supplements on alternate days to cows grazing fall and winter range decreased gains and body condition and consistently lowered ruminal pH compared to daily supplementation. Ruminal VFA concentrations were higher for cattle supplemented daily. Del Curto et al. (1986) compared performance of steers supplemented with corn daily, three times per week, daily with lasalocid or three times per week with lasalocid. Steers fed lasalocid daily had 10% greater daily gains, while performance of steers fed lasalocid three times weekly were not improved. Muller et al. (1986) reported that a series of 5 trials showed monensin supplements fed on an alternate day basis increased performance of cattle to the same extent as feeding the supplements daily. Performance was increased .077 and .082 kg/d for calves supplemented daily or on alternate days, respectively. Self-feeding monensin containing supplements resulted in equal performance as hand-feeding monensin supplements.

Hunt et al. (1989) conducted a ruminal fermentation trial and a steer growth trial to determine the effects of the time interval of cottonseed meal supplementation on nutrient digestion and performance of steers fed grass hay. The supplemented steers were fed a low level of CSM at 12, 24 or 48 h intervals, in both trials. The authors reported dry matter and NDF intake, NDF and ADF disappearance and ruminal VFA concentrations were greater when CSM was fed, with no effect of frequency of feeding. In the growth trial, supplement increased steer gains, but timing of supplementation had no effect on performance. McIlvain and Shoop (1962) found no differences in winter performance or subsequent summer performance when comparing daily, every third day and weekly feedings of cottonseed meal to steers grazing winter range.

Method of Supplementation. Self-limited rations have been used as a labor saving management scheme beginning in Texas in the 1930's. Labor shortages during World War II increased the popularity of the practice (Riggs et al., 1953). Self feeding supplements have other advantages such as allowing timid livestock a better chance to consume supplement (Rich et al., 1976).

Pickett and Smith (1949; as reported by Riggs et al., 1953) compared hand-feeding and self-feeding cottonseed meal to steers on bluestem pasture. Steers hand-fed cottonseed meal had gains that were .20 kg higher on .25 kg less cottonseed meal than steers fed the salt-limited cottonseed meal ration. Riggs et al. (1953) reported that cows grazing range performed similarly whether hand-fed or fed salt-limited cottonseed meal mixtures. Daily consumption of the cottonseed meal ration was .09 kg/hd greater for cows fed the self-limited ration, and five cows exhibited signs of salt toxicity, causing death in one cow. Weir and Miller (1953) used salt to limit the intake of a protein supplement by sheep and found no difference in performance between ewes that were hand-fed a protein ration and ewes fed a salt-limited ration.

Brandyberry et al. (1991) conducted two trials to determine the effects method of supplementation on grazing behavior and forage utilization by cattle grazing native range in two seasons (late summer and early winter). Three treatments were used: self-fed salt-limited ration, daily hand-fed supplement with high salt level and daily hand-fed supplement without salt. Grazing behavior, measured by distance traveled and time spent grazing, was not influenced by supplement treatment. The steers grazed heaviest during mid morning hours (0600 to 0900) and late afternoon (1500 to 1800). A series of 72-h visual observation periods showed that self-fed steers visited the feeders once or twice a day, primarily during mid-day which coincides with a less active grazing period. While steers were observed feeding during mid-morning this was reported to be minor and usually only involved more aggressive steers. Conversion of self-fed supplements may be poorer than hand-fed supplements (Pickett and Smith 1949; as reported by Riggs et al. 1953). In instances where cattle over consume or fail to consume the supplement, or have variable supplement intake patterns.

Limiters of Feed Intake

A feed intake limiter is usually considered a material added to a ration in small amounts to reduce consumption of the ration. Almost any feedstuff that causes a decreased consumption of feed can be considered a feed intake limiter. Most limiters fed in small amounts have their effect through physiological changes (ie. taste, pH, osmolality etc.), thus it is important to avoid excessive consumption of these substances (Ruffin and McGuire, 1991). The combination of several intake limiters can allow the concentration of any one substance in the supplement to be lower which will decrease the likelihood of over consumption of a limiting compound. Also, the supplement may be more accurately limited to the desired level.

Salt

Limiting intake of livestock supplements with salt is a common practice, yet salt is not a precise regulator of intake due to differences in individual tolerances to salt (Rich et al., 1976), and the intake of salt-limited feed depends on the availability of forage or other feeds (Ruffin and McGuire, 1991). For example, Rich et al. (1976) reported that with cattle weighing 227 kg, intake of a self-fed supplement could be limited to .91 to 1.36 kg/d with salt levels between 16 and 35% depending on the salt consumption of the cattle. Care should be exercised in limiting rations with salt, Riggs et al. (1953) indicated that some cows fed cottonseed meal limited by salt exhibited scouring and one cow became weak and died after 60 days of feeding. They concluded that death losses can occur from salt toxicity when daily intake of salt is .45 to .68 kg/d. Savage and McIvain (1951; as reported by Riggs et al., 1953) showed salt can limit daily consumption of a cottonseed meal ration to .91 kg/hd with levels of salt at about .14 % of BW. Brandyberry et al. (1991) reported that daily self-fed supplement intake was restricted to.95 kg/hd with .23 kg salt/hd during the summer and .40 kg salt/hd during the winter.

The addition of salt to rations as an intake regulator may effect ration digestibility. Nelson et al. (1955) showed that the average digestibility of rations with high salt levels was lower than control rations for sheep with no significant difference found in rations fed to steers. Total urine output was increased and sodium retention was slightly higher in cattle and sheep fed rations with high salt levels. Riggs et al. (1953) showed that protein digestibility was increased by 8% and crude fiber and NFE digestibility was increased by 5% by feeding high salt rations. Brandyberry et al. (1991) observed that feeding supplements containing high salt levels increased total OM digestibility and fluid dilution rate during the summer. Feeding rations containing high salt concentrations decreased the acetate:propionate ratio, but no difference in total VFA's was found.

Other Minerals

Ruffin and McGuire (1991) listed gypsum, a by-product of the phosphate mining industry, as a feed intake regulator that can be used. Gypsum has available calcium as high as 27% and sulfur can be as high as 22%. The presence of these nutrients are advantageous as other calcium sources can be decreased in the ration and sulfur is needed in the utilization of feeds containing urea. The authors suggested several advantages of gypsum as a feed intake limiter: (1) it will not corrode equipment; (2) it will not cause ill effects to livestock when properly managed; (3) large amounts of water are not necessary, as is the case with salt; (4) a much smaller amount is required to regulate intake of feed compared to other types of material; (5) it is usually not as costly as other intake limiters. Levels of gypsum required to limit intake in cattle vary with type of livestock. For example, heifers weighing 227 kg fed hay will consume about .68 kg of cottonseed meal mixed with 12 to 13% gypsum. The high sulfur level in gypsum is a concern because high sulphur levels are toxic to livestock. Miller and Ramsey (1988) reported a high level of sulfate causes copper requirements to increase because they form cupric sulfide, which is reletively insoluble. Excessive sulfur intake can cause the formation of large amounts of H_2S in the rumen which can inhibit rumen motility. Other signs of sulfur toxicity include anorexia, weight loss, pulmonary emphysema, hepatic necrosis and possibly polioencephalomalacia, a disease causing degeneration and necrosis of the gray matter of the brain.

Grigsby et al. (1991) reported that a self-fed corn-based supplement was limited to less than .91 kg/d in cattle grazing rye-ryegrass pastures by a combination of ionophore and minerals. The supplement contained .5% Rumensin 60 premix, 3% salt, 2% ground limestone, .25% ammonium sulfate, 1% magnesium oxide, 7% dicalcium phosphate and .25% trace mineral premix. The supplements were limited, with the ionophore and 13.5% minerals (including 3% salt), to a low level of intake in cattle grazing high quality pastures. This is supported by Rouquette et al. (1990) who reported that a level of 3-4% salt with other minerals and monensin limits daily intake of a self-limiting corn-based supplement to a level of .91 kg/hd. A similar ration containing one-half of the non-energy constituents was successfully limited to a daily intake level around 1.82 kg/hd. Horn et al. (1990) reported that heifers grazing wheat pasture consumed 1.29 kg/hd of a self-fed monensin-containing energy supplement which was within the desired daily intake range of .91 to 1.36 kg/hd. The supplement contained mostly ground milo and wheat middlings, 4.00% salt, 4.99% calcium carbonate, 2.26% dicalcium phosphate, .60% magnesium oxide and .125% Rumensin 60 premix (to supply 165 mg monensin/kg feed). DeHaan et al. (1984) reported that a ration containing 2.25% limestone and .75% magnesium oxide decreased feed intake by steers. Rations containing other buffers and magnesium oxide or limestone alone had no affect on feed intake.

Natural Feedstuffs

Feeds that occasionally come into least cost ration formulations and feeds that have other special purposes in supplementation programs (i.e. fishmeal, fats etc.) may be unpalatable enough that in small quantities they can help limit intake of a supplement. Grigsby et al. (1991) reported that a self-fed supplement designed to supply bypass protein at a level of around .91 kg/d to cattle grazing rye-ryegrass pasture had very low intake compared to a corn-based supplement that contained 13.5% total minerals and Rumensin 60 premix as the limiting agents. The bypass protein supplement contained 50% fishmeal, 30% cottonseed hulls, 12.6% wheat mill run, 3% salt, .25% ammonium sulfate, .75% magnesium oxide and .25% trace mineral premix. The intake of this supplement was limited to .35 and .15 kg/d in the two trials, with a total mineral level of 4.25% which is considerably less than 13.5% contained in the corn supplement. Intake of the corn supplement was close to target levels at .76 kg/d and .51 kg/d in the two trials. The low intake of the fishmeal supplement indicates that fishmeal itself may be useful as a feed intake regulator.

Wise et al. (1967) compared salt and animal fat to control supplement intake of steers fattened on high quality pasture. Salt, included at 15%, in the ration effectively limited intake of the supplement to a level of .5% of BW/d. This low level of intake could not be matched in cattle fed fat. Ten percent animal fat did control intake to a level of .8 to 1 % of BW/d. Another study reported by Wise et al. (1967) compared the ability of 10% animal fat and 10% cottonseed foots, a byproduct of the filtering of mechanically processed cottonseed oil, to limit concentrate intake of grazing steers. The authors reported that cottonseed foots limited intake to about 1.15% of BW, and animal fats limited intake of concentrates to about 1.04% of BW.

Condensed molasses solubles (CMS), a liquid byproduct of lysine production that contains high quantities of sulfur and non protein nitrogen, has been shown to decrease feed intake to a level of 1.4% of BW at levels of around 6.6% of the ration. Performance of calves in drylot were decreased by feeding CMS compared to calves fed rations containing urea or soybean meal (Klopfenstein et al., 1989). It was suggested that the levels of sulfur were the factor attributed to decreased intake of the ration. Hannon and Trenkle (1990) showed that CMS reduced feed intake and rates of gain in cattle fed in drylot. These results indicate CMS has the potential to act as a feed intake regulator in self-fed supplements, but further research needs to be conducted to determine the effect self feeding supplements containing CMS has on supplement intake and performance of animals.

Monensin

Research has indicated that feed intake of cattle on high grain rations was reduced by 15% during the early part of the feeding period and by 10% during the entire finishing phase when monensin was fed at a level of 30 g/ton (Parrot, 1990). Goodrich (1984), in a review, reported significant reduction in feed intake in finishing cattle with inclusion of 20-30 g monensin/ton. This data indicates that the addition of monensin to a ration will limit intake of feeds, and may be used in combination with other feed intake limiters in self-fed supplements for grazing cattle.

Muller et al. (1986) reported monensin fed to grazing cattle in self-limited rations in 9 trials reduced supplement intake compared to self-limited rations without monensin, while daily gains were increased by 15.3%. The average minimum salt level was reported to be 50% lower in self-limited rations containing monensin as compared with self-limited rations without monensin, and salt levels were changed less often in treatments containing monensin. Berger and Clanton (1979) fed a self-limiting protein supplement containing salt or salt and monensin and found that less salt was needed to limit the ration containing monensin. Also, less of the feed containing monensin was consumed by the steers until the steers became familiarized with monensin. Monensin was tested as a regulator of the intake of a molasses/urea supplement by Gulbransen and Elliot (1990). Intake of the molasses/urea supplement was reduced when the monensin concentration was over 40 mg/kg.

Norris et al. (1986) studied the efficacy of monensin in controlling feed intake of merino wethers. Five levels of monensin were included in the study: 0, 33, 66, 132 and 264 mg/kg of feed and feed intake was 1304, 959, 793, 403 and 137g for each group, respectively. The authors reported that intake was negatively and linearly related to monensin levels in the feed. Signs of toxicity and death were observed in groups of sheep given diets containing monensin at 66, 132 and 264 mg monensin/kg of feed. This is supported by Huston et al. (1990) who reported that increasing the monensin concentration of supplemental feed reduced supplement intake greatly in sheep and slightly in goats.

Effect of Monensin on Intake Pattern of Feedlot Cattle

Parrot, (1990) stated that monensin has been observed to reduce the variability of feed intake by cattle. This is supported by the reduced incidence of digestive upsets in fattening cattle when fed monensin. It has been suggested that this reduction in digestive upsets and reduced variability in feed intake is brought about by changed intake patterns by cattle. The author stated the possible explanation is that cattle consume feed in smaller amounts in a larger numbers of meals throughout the day when monensin is fed. Burrin (1988) measured intake patterns with electronic gates and showed that monensin reduced the mean variance of daily feed intake. Monensin also decreased the variance of intake pattern during 'stepping-up' rations fed to finishing cattle. Britton et al. (1991, as reported by Parrot, 1990) made a comparison of cattle fed individually a high-concentrate ration containing 0 or 25 g monensin/ton. Monensin reduced variability of feed intake during days 8-12, 57-70 and 97-110 of the feeding period. Chirase et al. (1991) monitored feed intake patterns with a Pinpointer and found monensin had no effect on the number of visits to the feeder, yet reduced feed intake by reducing time spent eating, intake/visit, intake/time and time/visit. Monensin also reduced the variability of intake.

Monensin has been shown to decrease feed intake and the variability of feed intake by finishing cattle, as well as decrease the intake of self-fed supplements in grazing cattle. The study, reporting the effects of monensin in self-fed supplements, did not look at the effect of monensin on variability of supplement intake. However, it may be assumed that the variability of supplement intake can be changed with the addition of monensin as it has been shown in finishing cattle. Research needs to be conducted to verify the assumption that monensin decreases the variability of self-fed supplement intake.

Measurement of Supplement Intake by Individual Animals

Aside from individualized feeding of animals, which may cause changes in behavior of the animal, several ways to measure individual animal intake have been developed. These include electronic feeders and use of markers.

Electronic Feeding Equipment

Calan gates. Calan gates have been used by researchers in instances where individual animal intakes are required yet the simulation of the competitive nature of eating from feedbunks is desired (Stock and Klopfenstein, 1987). Byers et al. (1984) and Solis et al. (1988) used calan gates to set feed intake of cows at different levels in order to measure the maintenence requirements of different breeds of cows. Burrin et al. (1988) used calan gates to individually feed cattle and monitored daily intake during the initial 28-d feeding period to measure the effect of monensin on total intake and daily intake-patterns of cattle fed high-grain finishing rations. Stock and Klopfenstein (1987) stated that calan gates have been used to observe and measure the intake patterns and variability of cattle on high grain diets in acidosis studies and enabled researchers to relate changes in ruminal lactate concentrations to changes in feed intake. Calan gates also helped determine the need for supplemental protein by feeding of small quantities of protein to animals in increasing levels and to measure supplemental protein responces. The determination of the effects of energy, protein and feed additive supplementation of grazing cattle has been aided by calan gates.

Stock and Klopfenstein (1987) discussed the advantages and disadvatages as well as some uses of calan gates in research. Advantages of calan gates include: (1) individual intakes can be measured for specific kinds of data collection; (2) fewer animals are needed per treatment or larger numbers of treatments can be evaluated; (3) individual animals can be observed for sorting dietary ingredients, feeding patterns, variation in daily consumption and digestibility and metabolism data collection; (4) improved accuracy of weighing and delivery of feed. Some disadvantages that were discussed include: (1) increased labor and management; (2) increased observation of animals and electronics, checking for both bad electronics and animals taking feed from incorrect bunk; (3) variability of animals.

Stock and Klopfenstien (1987) suggested that animal variation can be measured with calan gates, yet calves that are used should be as similar as possible to reduce the variation. Animals which are accustomed to being handled by people and eating prepared feed from bunks are the easiest and quickest to train. Also, small groups are easier to handle and decrease training time.

General guidlines to training calves to use calan gates suggested by Stock and Klopfenstein (1987):

1. Need uniform set of calves.
2. Need 5 to 10% extra calves.
3. Train small groups of 15 head or less
4. Fix doors open for 4 to 7 days to train calves to eat from bunks.
5. Close doors and turn off solenoid for 4 to 7 days to train calves to push doors open.

6. Hang pipes around calves necks, turn solenoids on for 4 to 7 days to train calves to unlock doors.
7. Split pens into 7 to 8 head groups and hang keys around necks for 4 to 7 days to train calves to open one door only.
8. Calves trained and ready to start on experiment.

Pinpointer feeders. The Pinpointer 4000 is a automatic feeder system which employs a single stall to feed a group of up to 15 cattle. An animal can enter only from the rear of the stall and typically only one stall is provided per pen (Stricklin, 1987). Kautz-Scanavy and Stricklin (1983) reported that cattle fed in a pen via Pinpointer feeders gained less and were less efficient than bulls individually housed and fed. Stricklin and Nicholson (1978) found cattle fed by Pinpointer feeders gained less in the first three weeks of feeding than trough fed cattle. Yet after the third week, the Pinpointer fed cattle gained faster than trough fed cattle. Gonyou and Stricklin (1981) reported that cattle fed from a Pinpointer had different diurnal eating patterns and consumed feed faster than trough fed cattle, yet no difference in feed intake was found.

Chirase et al. (1991) used the Pinpointer to determine the intake pattern of cattle consuming high-grain finishing rations containing monensin. Saunders et al. (1991) used the Pinpointer measured the daily intake variation of a self-limiting supplement in calves grazing Coastal bermudagrass. Targeted intake of the supplement was .91 kg/d. Mean daily intake of the supplement was reported to be .75±.71 kg/d, with daily intake among animals ranging from 0 to 4.68 kg/d. Mean daily intake among individual animals ranged from .17±.29 to 1.86±.76 kg/d. The frequency which animals had 0 kg/d consumption averaged 19.2% for the group. The range of observed 0 kg/d consumption among animals was from 0 to 69%. Stroup et al. (1987) determined the feed intake cycles of cattle using a Pinpointer and drew conclusions on how feed intake behavior affects animal experiments. The authors suggested that standard analysis of varience in trials that include feed intake data using Latin square and cross-over designs in animal experiments can be use only if cyclic variation of intake is the same for all animals (i.e. no row by column interaction). If the interaction is significant time series analysis of covarience improves the accuracy of estimates of treatment effects.

Use of Markers

Little research has been conducted to determine the use of markers to estimate supplement consumption by individual animals. Markers have been used to determine the intake of feeds or determine the digestibility of a feed. There are two types of markers. Internal markers are constituents of the plant which are neither digested or absorbed in the animal. Examples of internal markers include: lignin, silica and acid-insoluble ash (Merchen, 1988). External markers are also neither digested nor absorbed in the animal, but are administered orally to the animal or added to the feedstuff (Merchen, 1988). Examples of external markers include stained feeds, chromic oxide, rare-earth elements (including lanthanum, samarium, cerium, ytterbium, and dysprosium) and chromium mordated fiber (Merchen, 1988). Kotb and Luckey (1972, as cited by Merchen, 1988) outlined several factors that are necessary to be regarded as a ideal marker: (1) it must be inert with no toxic effects; (2) it must be neither absorbed nor metabolized in the gastro-intestinal (GI) tract; (3) it must not have any appreciable bulk; (4) it must mix intimately and remain uniformly distributed in the digesta; (5) it must have no influence on GI secretions, digestion, absorption, or normal motility; (6) it must have no influence on the microflora of the GI tract; and (7) it must have physico-chemical properties readily discernible throughout the GI tract.

Merchen (1988) suggested several uses of markers in animal research. When feed intake is known but total fecal output cannot be measured and an estimate of digestibility is required, either an internal or external marker can be used. If neither feed intake nor fecal output is known and an estimate of digestibility is required, an internal marker must be used. Where neither feed intake nor fecal output is known and estimates of both digestibility and intake are required, digestibility can be measured by an internal marker and fecal output estimated by an external marker.

From the observations by Merchen (1988) we can conclude that to determine individual supplement intake by grazing livestock, digestibility of the forage and the supplement must be known, as well as intake of the forage. If these factors are known then fecal output can be estimated by a marker and fecal output can be partitioned into forage and supplement components. If forage intake is not known, a researcher must use a marker to estimate fecal output from forage and a different marker to estimate the fecal output from the supplement. There has been no research to determine the efficacy of this procedure and it may be a possible avenue for future research.

Effect of Physical Form of Feeds on Intake and Digestibility of Feeds

Little research has been conducted to test the effect of pelleting supplement on supplement intake. Researchers in the 1950's and 60's tested the effects of pelleting of feeds on intake, digestibility and performance of fattening cattle and sheep. Esplin et al. (1957) showed group fed lambs self-fed a pelleted ration consumed .23 kg /day more feed than lambs offered the same ration in meal form. McCroskey et al. (1961) increased consumption by pelleting a high roughage ration. Daily gains were increased with the increased consumption of the high roughage ration. No differences in intake or performance were found when a high concentrate ration was pelleted. Greenhalgh and Reid (1973) pelleted various rations (low quality grass hay, high quality grass hay or 60-40 grass and barley) to test the effect processing had on intake and digestibility of diets fed to cattle and sheep. Pelleting increased the intake of all diets by 45% in sheep and 11% in cattle. Digestibility of diets was decreased by pelleting from 67.2 to 58.6% in sheep and from 69.9 to 56.9% in cattle. Weir et al. (1959) compared pelleted rations to chopped or ground rations fed to steers and lambs. Lambs fed chopped alfalfa and chopped alfalfa plus barley gained less than lambs fed pelleted alfalfa or pelleted alfalfa and barley. Also, feed consumption and feed efficiency was lower for lambs consuming the chopped rations as compared to pelleted rations. Steers gained more when pelleted alfalfa versus long-stem alfalfa was offered along with a barley and oat hay ration. Intake of the pelleted alfalfa was greater than the long-stem alfalfa.

In another study Weir et al. (1959) fed pelleted rations of varying concentrate:roughage ratios to investigate the effects of pelleting in diets fed to finishing steers. Steers fed 100% alfalfa gained more when pelleted than ground. Steers fed 30% concentrate rations gained the same when pelleted or ground and steers fed a 60% concentrate ration gained less when pelleted than ground. Lindahl and Reynolds (1959) found that pelleting alfalfa meal had little effect on the digestion coefficients of dry matter, protein or gross energy in mature wethers fed 120% of maintenence in metabolism stalls.

Beever et al. (1981) reported that the digestibility of organic matter and structural carbohydrates as well as the production of VFA's in sheep was reduced by pelleting Italian ryegrass and Timothy. Overall, grinding and pelleting reduced total absorbed energy supply by 10% but increased absorbed protein supply by 15%. Cullison (1961) reported intake and gains were increased over long or ground hay by pelleting a bermudagrass hay and cottonseed meal ration and it was concluded that the pelleted hays were more palatable than the long or ground hays. In a second trial, steers were fed a complete ration to compare ground or pelleted rations to a long hay and grain ration. Gains and intake were lower for steers fed the pelleted ration compared to steers fed the ground or control rations. Greenhalgh and Reid (1974) reported that pelleted roughages were consumed much more readily that chopped roughages by sheep. Digestible dry matter intake was 58.2 g/kg metabolic BW for lambs fed the chopped roughage and 81.4 g/kg metabolic BW for lambs fed the pelleted roughage. Jordan et al. (1959) creep fed lambs either pelleted or meal rations and found that in self-fed rations lambs consumed more pelleted supplement than lambs that were offered the supplement in the meal form.

Hannah et al. (1989) compared the effects of whole corn supplement to ground-pelleted corn supplement on grazing time, forage intake and digestibility of fescue. Supplementation with whole corn decreased forage organic matter (OM) intake by 19% while the ground-pelleted decreased forage OM intake by 6%. Starch digestibility of the whole corn supplements was 66.6% and starch digestibility was 92.4 for the ground-pelleted supplement. Bensadoun et al. (1962) fed three different forms of rations at different levels in an attempt to determine how plasma glucose levels are affected. The rations were chopped hay, ground and pelleted hay and a pelleted mixture of corn and hay. At medium and high intake levels, the lambs fed pelleted rations had higher plasma glucose concentrations than lambs fed chopped rations. Theurer (1986) reported that processing of grain sorghum and corn improved the ruminal fermentation of starch as well as increased digestion in the small intestine. About 10 to 25% of the starch in steam-flaked corn or grain sorghum escapes the rumen where up to 45% of the starch from dry-rolled and ground grains escapes rumen fermentation.

In summary, these studies indicate pelleting improves the acceptability of feeds with lower palatability, and shifts the digestion of some feedstuffs from the rumen into to small intestine and lower gut. This can be important in instances where supplements are self-fed and intake is limited with salt or other intake limiter. Since acceptability of feeds is increased by pelleting, intake of self-fed supplements may be better controlled if they are fed in the meal form.

Comparison of Monensin and Lasalocid

Monensin and lasalocid have been used extensively in the feedlot industry to increase efficiency and decrease digestive upsets. The major effect of ionophores is an about 7.5% improvement in feed efficiency (Goodrich et al., 1984; Parrott, 1990; Bergen and Bates, 1984; Bartley et al., 1979). Average daily gain has been increased by about 1.6% on the average in cattle fed high-grain finishing rations (Goodrich et al., 1984). Ionophores also reduce the incidence and severity of common feedlot disorders such as bloat and lactic acidosis (Bergen and Bates, 1984). Boling et al. (1982) in a comparison of lasalocid and monensin in high-grain rations found no differences in rate of gain or feed efficiency. Ionopores have been shown to increase ruminal propionic acid concentrations and decrease acetic acid production in cattle consuming high-grain diets (Bergen and Bates, 1984; Parrott, 1990) and high-roughage diets (Anderson and Horn, 1987; Horn et al., 1981; Spears and Harvey, 1984;

Thonney et al., 1981). These changes in rumen metabolites in animals fed ionophores are thought to be brought about by a decrease in gram positive bacteria with a subsequent reduction in methane production (Bergen and Bates, 1984).

Effects of Ionophores on Ruminal Fermentation and Digestion

Studies examining the effects of monensin and lasalocid on digestion and ruminal characteristics of cattle consuming high quality roughages have shown few differences. Thonney et al. (1981) reported that cattle fed alfalfa cubes with supplements containing varying levels of either monensin or lasalocid had highest and most efficient gains with 175 mg lasalocid per day. Steers fed monensin at 183 mg/d had decreased intake and gains compared to lasalocid treatment, possibly due to aversion of the supplement. Monensin fed steers had lower ruminal and plasma acetate to propionate ratios than cattle receiving lasalocid, but found no correlation between metabolite concentrations and growth or feed efficiency. In vitro studies with monensin and lasalocid, Bartley et al. (1979) found increased propionic acid concentrations and decreased acetic acid concentrations. Total volatile fatty acid production was not affected and methane production was decreased with both monensin and lasalocid. In a study with sheep fed alfalfa-corn diets, Ricke et al. (1984) found lasalocid and monensin had no affect on dry matter or fiber digestibility, but found rumen ammonia-N was increased with lasalocid where monensin decreased rumen ammonia-N levels. Both ionophores increased propionate levels and decreased the acetate to propionate ratio. Ward et al. (1990) supplemented barley and/or monensin to steer grazing Northern Great Plains range during the summer at three times (June, July and August). Neither grain or monensin had any affect on particulate passage rate. Monensin reduced total tract fill and increased In vivo OM digestibility and had no effect on forage OM intake. Tanner et al. (1984) compared the effects of monensin and lasalocid fed at different levels to heifers grazing wheat-ryegrass pastures. They reported an increase of dry matter and organic matter digestibilities with 100 mg monensin and 200 mg lasalocid at day 47 of the trial. Monensin at the 100 mg per day level also increased fiber digestibility by 5.1 % over control. On day 97 of the trial, fiber digestibility was increased and fill was decreased by the lasalocid treatments, with monensin treatments being similar to controls.

Effects of Ionophores on Performance of Grazing Ruminants

Gains of cattle grazing mixed orchard grass, alfalfa, brome grass, and ladino clover were increased by 17% when monensin was fed at levels of 100 to 300 mg per day in .9 kg of supplement (Potter et al.,1976). This is supported by Horn et al. (1981) who found daily gains of heifers fed a supplement with monensin were increased by .08 kg over carrier supplement alone. Oliver (1975) also reported steers grazing coastal bermudagrass and supplemented with 100 mg monensin/d in a pelleted corn carrier gained .32 kg greater than non-supplemented steers and .215 kg greater than steers supplemented corn alone. Worrell et al. (1990) improved weight gains of steers grazing ryegrass pastures by 22% by feeding supplemental cottonseed meal and 150 mg lasalocid per day. The weight gain response occurred only in the spring grazing period with no response in the fall grazing period. Andersen and Horn (1987) reported improvements of .11 kg in heifers grazing wheat pasture and fed 200 mg lasalocid over heifers fed 0 or 100 mg lasalocid per day. Spears and Harvey (1984) in a 126 day trial determined the influence of varying levels of lasalocid on performance of cattle grazing mixed tall fescue, orchard grass and ladino clover. Ionophore was fed in .91 kg ground corn per head per day. Performance was improved by .10 and .07 kg for 200 and 300 mg lasalocid, respectively, over controls.

Effect of Ionophores on Pasture Bloat

Bloat is an important problem with cattle fed high concentrate rations and grazing legumes or small grain pastures. Annual death losses from wheat pasture frothy bloat average about 2 to 3% but can be as high as 20% (Branine and Galyean, 1990). Majak et al. (1983) indicated a set of conditions that predispose cattle to pasture bloat. The flotation and accumulation of feed particles and the increased capacity for gas production interact to create a precondition that promotes the occurance of bloat. Also, the microbial colonization and retention of particulate matter provide inocula for promoting rapid digestion which inhances gas production, the fermentation gases are trapped by buoyant frothy ingesta resulting in pasture bloat. McArthur and Miltmore (1969) showed that bloat occured only when the pH of rumen contents was in the range 5.2 to 6.0. Once bloat was present, severity of bloat was not related to the rumen pH. It was noted that with pH above 6 the foam had very little resistance to flow, while at pH below 6 foam viscosity increased. It was concluded that four important conditions were necesarry to create bloat: (1) vigorous gas production to produce the foam gas phase and rumen pressure, (2) adequate protein to produce and maintain foam, (3) sufficient acid to reduce the rumen pH below 6 and (4) cations to bind the protein molecules in the surface film. Buckingham (1970) indicated that the strength of cytoplasmic protein foams of red clover are affected by pH, protein concentration and temperature. Maximum foam strength was found at a pH of about 5.5, at temperatures under 40°C and increased with increasing protein concentration.

Bartley et al. (1975) showed that poloxalene prevented ruminal foam formation and decreased the incidence and severity of bloat. Bartley et al. (1983) indicated that doses of .66 to .99 mg monensin•kg BW reduced legume bloat by 66% compared to pretreatment bloat scores, while similar doses of lasalocid reduced bloat by about 26%. For comparison, a dose of 44 mg poloxalene/ kg BW reduced legume bloat by 100%. Katz et al. (1986) measured microbial and fermentation changes in the rumen in monensin- and lasalocid-fed cattle grazing bloat provacative alfalfa pasture. Monensin fed at a rate of .66 and .99 mg•kg BW^{-1} reduced the severity of legume bloat by 41 and 73%, respectively; while the same doses of lasalocid reduced bloat by 25 and 12%. The monensin treatment decreased protozoal numbers and microbial activity as shown by lower gas production in vitro, while lasalocid had no effect on protozoal counts and in vitro gas production.

Other research has shown that monensin reduces bloat in cattle grazing small grain pastures. Grigsby (1984) decreased the incidence of bloat and increased daily gain of stocker cattle by supplementing 160 mg•$head^{-1}$•d^{-1} of monensin in a grain supplement. Death losses due to bloat were 15.2% for control steers, 2.8% for grain supplemented steers and 0% steers supplemented both grain and monensin. Branine and Galyean (1990) reported that the incidence and severity of bloat was decreased by the daily supplementation of .5 kg grain containing 170 mg monensin. The supplementation of grain only had no effect on bloat. Fluid passage rate was increased by the supplementation of monensin in early April when most bloat problems were observed, yet there were no differences in particlulate passage rate or forage intake at anytime during the trial. Ruminal pH was higher for monensin supplemented steers during the early April period (6.3 versus 6.0 for grain supplemented and control steers). The authors suggested that monensin reduces ruminal foaming, thus preventing bloat by decreasing ruminal entrapment and accumulation of fermentation gasses and the effect of monensin on fluid passage rate might have decreased the incidence of bloat.

Toxicity of Ionophores

Potter et al. (1984) reported the levels of monensin necessary to cause toxicity in cattle. The level of monensin necassary to cause acute toxicity in cattle was found by giving a single oral dose of 0, 12.6, 22.4, or 39.8 mg of monensin activity/kg BW. The cattle were observed for 14 d post-dosing and 5 of 10 cattle given the 22.4 and 39.8 mg/kg BW treatments died between d 6 and 12. No deaths were observed before d 3 after dosing. Other studies were combined to estimate the LD 50, 10 and 1% doses. The LD 50, 10, and 1% were estimated at 26.4, 11.2 and 5.5 mg/kg BW, respectively. The LD1 corresponds to a dose of about 1250 mg monensin for a 227 kg steer. A study to determine the lethal level of monensin in a multiple dose used 30 steers dosed daily with 0, 400, 600, 1000, 2000, or 4000 mg monensin/head for 7 d. Feed intake was reduced by 400 and 600 mg/d treatments, while steers on the 1000 mg or higher treatments showed signs of anorexia by d 2. Cattle receiving 1000 mg monensin or less showed signs of mild depression and diarrhea. Cattle receiving the 2000 and 4000 mg treatments exhibited signs of anorexia, diarrhea, depression, rapid breathing and ataxia. Death loss for the 2000 and 4000 mg treatments were 60% and occurred on d 5-7 in the 2000 mg treatment and d 4-6 in the 4000 mg treatment. The safety of monensin in pasture supplements was studied by daily feeding .23 kg supplement/head containing 0, 200, 600 or 1000 mg of monensin to groups of 16 cattle in pasture. Seven deaths were observed in the two highest monensin treatments and monensin consumption was low after d 3. Conclusions were that death can occur when supplements contain monensin at 1200 mg (2640 ppm) or higher. In other studies 200, 500 and 1000 mg monensin was fed in .45 kg of supplement, again supplement was consumed until d 3 and then consumption was reduced to low levels. No deaths or signs of toxicity was observed, so it was concluded that monensin should be fed to cattle on pasture in a minimum of .45 kg of supplement. It was also further suggested that the .45 kg of supplement should contain not less than 100 mg (220 ppm) for the first 5 d and not more than 200 mg (440 ppm) after d 5.

Galitzer et al. (1986) compared acute toxicity of lasalocid and monensin in cattle. Steers were given a single oral dose of rice hulls or 1, 10, 50 or 100 mg/ kg BW lasalocid or 25 mg/ kg monensin. In the groups given rice hulls or 1 and 10 mg/ kg BW lasalocid no deaths occurred. The steers were observed for 30d and killed for necropsy. In the group administered 50 mg lasalocid/ kg BW, 1 steer survived to d 30 and the other steers in the group died between d 2 and 22.5. In the group administered 100 mg lasalocid•kg BW^{-1}, 1 steer survived to d 30 and 5 steers died between d 1 and 2 after dosing. One steer of the monensin group survived to d 30 and 5 steers died between d 2.5 and 8.5 post dosing.

These studies have shown that both monensin and lasalocid are toxic to cattle. Monensin is toxic with a high percent death loss at much lower levels than lasalocid. Acute toxicity was found with monensin at level of around 25 mg monensin/kg BW. Lasalocid was found to be toxic at a level of 50 mg lasalocid/ kg BW

Micromineral Nutrition of Cattle Grazing Forages

Copper

Dietary Requirements and Deficiency Symptoms. Copper (Cu) is a constituent of several enzymes in the body and is involved in a broad range of biochemical functions (Miller et al., 1988). The level of dietary copper required for health is species dependant and is usually positively correlated with dietary levels of molybdenum (Mo) and inorganic sulfur, but ruminant rations are considered adequate at 8 to 10 ppm Cu (NRC, 1980). Forage containing <3 ppm of Cu in the DM during the growing period is generally deficient, between 3 and 6 ppm is marginal and with >6 ppm Cu defeciency diseases are rarely a problem (Miller et al., 1988). Levels of copper in the liver of ruminants are usually the highest and are usually between 100 and 600 ppm in normal adults. Blood copper levels are typically near 100 μg/dl but may increase to 165 μg/dl (Miller et al., 1988). Cu deficiency symptoms, in order of appearance, include: hypocupremia (<20 μg/dl), decreased growth, poor feed conversion, rough hair coat, diarrhea and leg abnormalities.

Effect of Supplementation of Copper to Growing Cattle. Miltmore et al. (1973) reported that the injection of copper improved daily gains while selenium and vitamin E injections had no effect on performance. Injections of copper given to cattle on two ranches on two years increased overall daily gains by 22%. The forage grown on these soils contained 10.4 ppm Cu, 10.0 ppm Mo, 211 ppm Fe, 45 ppm Mn, 28 ppm Zn, 8.9 ppm boron and 2.16 ppm Se for ranch A; and 5.0 ppm Cu, 4.7 ppm Mo, 261 ppm Fe, 50 ppm Mn, 20 ppm Zn, 4.1 ppm boron and .74 ppm Se for ranch B. The levels of these nutrients were within tolerable ranges except for copper in ranch B may be considered low. The

Cu:Mo ratio may be of some concern in the areas studied with high levels of Mo decreasing Cu uptake. Herd et al. (1992a) studied the effects of Cu injections on performance, serum levels and hair coat of limousin calves. The calves were injected with 200 mg of cupric glycinate (Molycu® , Schering Corporation, Kennilworth, NJ) on day 0 and 300 mg on day 60. Serum Cu levels and weight gains were not affected by the Cu injections, while hair characteristics did not decrease as much in Cu injected cattle as in non-injected cattle. Ward et al. (1992) showed gains, feed intake and feed efficiency of cattle fed Cu in the form of copper sulfate or copper lysine were not higher than unsupplemented cattle. Herd et al. (1992b) indicated that orally dosing suckling calves with copper oxide increased gains even though initial serum copper levels were .6 ppm. Hutcheson et al. (1991) showed that stressed calves injected with Cu (as copper glycinate) had lower feed intake and body weight. Spears et al. (1991) reported that cattle given an injection of copper 11 days prior to being shipped had higher serum Cu levels but performance was decreased and morbidity was increased in injected calves.

Selenium

Dietary Requirement and Deficiency Symptoms. Selenium (Se) is an integral part of the enzyme glutathione peroxidase, which destroys lipid peroxides and thus protects cell membranes against peroxidative damage. In addition, Se has been shown to be a part of other enzymatic systems in microorganisms (NRC, 1980). Miller et al. (1988) suggested that the dietary Se level of .10 ppm is recommended for domestic ruminants and is generally adequate under many situations. For cattle, the beef cattle NRC (1984) suggests that a level of .2 ppm is best, with a range of .05 to .3 ppm. In the

United States, forages from several regions have been found to have inadequate Se concentrations to meet the requirement of the animals. The regions noted with the lowest soil and forage Se concentrations are the Northwest, Northeast, Southeast and regions of the Midwest that adjoin the Great Lakes (Campbell et al., 1990) and California (Dunbar et al. 1984). Selenium deficiency results in nutritional muscular dystrophy (NMD) in young and growing animals as well as problems with reproduction in sheep and cattle. These problems are more prevalent in areas with volcanic soil types. NMD primarily occurs in calves from 4-6 weeks of age, but can occur in animals several months of age (Miller et al. 1988). Heinz bodies and anemia have been identified with low serum levels of selenium in catttle grazing selenium deficient forage growing on peaty muck soils in the Everglades. Supplementing cattle with Se has been shown to decrease anemia, prevent Heinz body formation, increase body weight and elevate blood Se levels (Morris et al., 1984).

Effect of Selenium Supplementation. Researchers have used Se and vitamin E injections (Miltmore et al., 1973), Se fortified salt and mineral mixtures, intraruminal pellets containing 90% iron and 10% Se (Dunbar et al.,1984) and long-lasting Se boluses which make use of an osmotic pump (Campbell et al., 1990) to provide supplemental selenium to sheep and cattle. The response of supplementing cattle with Se has been very inconsistent. There have been reports of increased levels of Se in test animals and increased performance, but many studies show little effect of supplemental selenium. Miltmore et al. (1973) found that injections of Se and vitamin E had no effect on performance in grazing cattle on two ranches in a two year study. Hill et al. (1993) reported that although steers grazing native range during the summer had marginal blood Se concentrations and performance of supplemented cattle was not affected, blood

Se concentrations were increased by supplementation with the Dura Se-120® bolus. Thus it was concluded that even though blood Se concentrations were marginal, Se intake was adequate to maintain performance. Greene et al. (1991) reported that administering Dura Se-120® bolus to calves grazing oat pasture did not increased weight gains, but blood Se concentrations and body condition were increased and hair coat quality was improved. This agrees with research reported by Herd et al. (1992b) that showed no improvement in performance due to Se supplementation with the Dura Se-120® bolus. Phillips et al. (1989) found that overall growth of suckling calves was not increased by supplementation with long-lasting Se bolus, even though blood Se levels were higher with supplementation and an increase in gains was seen in the last 30 days of the trial.

Swecker et al. (1989) used calves with marginal blood Se concentrations fed a Se deficient diet to determine the effects of increasing levels of Se (20, 80, 120, 160 or 200 mg Se/kg mineral) in a mineral mixture or feeding the 20 mg of Se/kg mineral with an additional Se and vitamin E injection. Calves fed the low Se mineral had lower antibody responses than either calves fed low Se mineral with Se injection or calves fed mineral with 80, 120, 160 or 200 mg Se/ kg. Calves fed the mineral with 80, 120, 160 or 200 mg Se/ kg had higher blood Se concentrations on day 70 compared with calves fed low Se mineral and injected with Se and vitamin E.

Hidiroglou et al. (1985) reported that nutritional muscular dystrophy of calves was decreased by supplementation of cows with ruminal pellets during the last 3 months of pregnancy, and plasma Se concentrations and glutathione peroxidase in whole blood were increased in cows supplemented with selenium. Campbell et al. (1990) reported that Se supplemented (via long lasting bolus) to cows grazing Se deficient pastures increased blood Se concentrations and Se levels in the colostrum over non-supplemented controls while weight differences were not detected. Calves suckling Se supplemented cows had higher blood Se concentrations than calves suckling unsupplemented cows. Dunbar et al. (1984) compared the ability of rumen pellets containing Se or a Se injection to unsupplemented controls. Blood Se concentrations were higher in cows receiving intraruminal pellets than control cows or cows given Se injections

Copper and Selenium Interactions. It has been reported that the absorption of Se is not affected by increasing the Cu concentration of a ration (Codwallander, 1980). Copper has also been shown to reduce the toxicity of Se in chicks (NRC, 1980). Wilson (1964) studied the effects of oral Cu supplementation, as copper sulfate, and Se supplementation, as sodium selenite, to dairy calves and found that gains were increased with the supplementation. Buckley et al. (1987) reported that cattle given soluble glass boluses containing copper and selenium did not increase weight gains or serum copper levels, but serum selenium levels were increased. In 5 experiments with calves and yearlings fed low Se and low Cu forage, Hidiroglou and Jenkins (1975) showed no increases in performance from Se containing mineral mixes or Se and/or Cu injectioned subcutaneously.

Summary of Literature Reveiw

Wheat forage with CP levels commonly in excess of 25% and DOM levels commonly in excess of 80% has a very narrow DOM:CP ratio. A large percentage of the protein in wheat forage is in the form of NPN and is rapidly fermented in the rumen. It has been suggested that the microbes in the rumen cannot produce microbial protein as efficiently in diets with DOM:CP ratios less than 4:1. The addition of low levels of a high energy supplement has the potential to increase efficiency of microbial protein production and carry feed additives such as ionophores. These energy supplements can be self-fed or possibly fed on alternate days in order to save labor and money associated with daily feeding.

The supplementation of copper and selenium has shown very inconsistent performance responses in the literature. Supplementation of cattle with copper has shown increased gains in some studies with deficient conditions, but supplying additional copper to cattle when it is not limiting has not affected performance. Supplementing cattle with selenium has been shown to increase blood Se levels and improve hair coat condition, but very little effect has been shown on performance unless the cattle are exhibiting signs of Se deficiency.

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Chapter 3

Development of a Self-Limited Monensin-Containing Energy-Supplement for Growing Cattle on Wheat Pasture.

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ABSTRACT

Four trials were conducted during the wheat grazing seasons 1989 - 1993, to determine the intake of a self-limited monensin/energy supplement and the effects of the supplement and a copper injection (Trial 1) or a slow release selenium bolus (Trials 2 and 3) on performance of steers grazing wheat pasture (variety 2157). Trials 1, 2 and 3 were designed as split-plot experiments, and had supplement treatment randomly assigned to each pasture. One half of the steers in each pasture received a copper injection (Trial 1) or a slow release selenium bolus (Trials 2 and 3). Trial 4, designed as a completely randomized experiment, had supplement treatment randomly assigned to pasture. Supplements were designed to contain monensin at 165 mg/kg and daily intake was targeted at a level of .91 to 1.36 kg/hd. The supplement was fed in the pelleted form in Trials 1 and 2. Supplement intake was 1.19 and 1.93 kg, respectively for groups 1 and 2, during Trial 1; supplement intake was 1.85 and 1.10 kg, respectively for groups 1 and 2 during Trial 2. During Trials 3 and 4 the supplement was fed in the meal form. Supplement intake was .91 kg for both groups during Trial 3 and 1.21 and 1.42 kg/hd for groups 1 and 2 during Trial 4. Across all trials, the monensin/energy supplement increased daily gains by about .22 kg with a supplemental conversion of 6.0. The addition of copper had no effect on performance in Trial 1. In Trial 2 selenium increased daily gains by .08 kg, but had no effect during Trial 3.

(Key words: Cattle, Pasture, Supplementation, Monensin, Copper, Selenium)

Introduction

Wheat forage commonly contains 75% digestible DM and 25 to 30% CP during the fall and early spring grazing periods. The energy:CP ratio of wheat forage is less than optimum for maximal microbial protein production as discussed by Hogan and Weston (1970) and Hogan (1982). Lake et al. (1974) suggested grain supplementation improved ruminal N utilization and performance of steers grazing irrigated pastures (containing mixtures of orchardgrass, smooth bromegrass and alfalfa) by increasing the dietary energy:CP ratio.

Daily gains of growing cattle grazing wheat pasture have been increased by the addition of monensin to supplements, and with the increase in gains there is an increase in the economic value of supplementation programs. Horn et al. (1981) reported that daily gains of cattle grazing wheat pasture were increased by about .08 kg with the addition of monensin. Grigsby (1984); Bagley and Feazel (1989); Branine and Galyean (1990) have indicated that monensin decreases the incidence and severity of bloat of grazing steers. The objective of this research was to develop a self-fed monensin/energy supplement with a targeted intake of .91 to 1.36 $kg \bullet head^{-1} \bullet day^{-1}$ and determine the effect of the supplement and supplemental copper or selenium on performance of wheat pasture stocker cattle.

Experimental Procedures

Study Site and Soils. Four performance trials were conducted in the fall/spring of 1989-90 through 1992-93 on 57 hectares of clean tilled wheat pasture (variety 2157) at the Perkins Wheat Pasture Unit, about 15 miles southwest of Stillwater. The soils are mapped as Teller loam (Fine-loamy, mixed, thermic Udic Argiustolls) and Konowa fine silty loam (Fine-loamy, mixed, thermic Ultic Haplustalfs). Soil test results on July 30, 1990 revealed high P and K with soil pH of 4.5, 4.8, 4.6 and 5.3 for pastures 1-4, respectively. One ton of lime per acre was applied to pastures 1, 2 and 3 during the summer of 1990. Soil pH values for pastures 1-4, respectively, were 4.7, 5.0, 4.7 and 4.5 in August, 1991.

Cattle. Ninety-four (94), 71, 76 and 82 steers in Trials 1-4, respectively, were randomly allotted to the four pastures according to breed and initial weight. The steers were purchased at auction in the summer and early fall of each year and were treated for internal and external parasites, vaccinated for respiratory diseases and implanted with Synovex-S. Breeds of the steers, their area of origin, mean initial weight, stocking density and length of the trials are summarized in Table 1. Mean inital weight of the steers was 252 kg and the trials were about 120 days in length. Average initial stocking densities (steers/ha) on wheat pasture were 1.65, 1.25, 1.33, and 1.44, respectively, for Trials 1-4. In Trial 1, 94 British and exotic crossbred steers from north central Arkansas were allocated to groups of 21, 23, 21 and 29 head and placed on wheat pasture for a trial beginning October 26, 1989 and ending February 24,

1990. In Trial 2, 71 exotic crossbred steers from north central Arkansas were allocated to groups of 16, 17, 17 and 21 and placed on wheat pasture for the trial beginning November 13, 1990 and ending March 14,1991. In Trial 3, seventy-six Brahman crossbred steers from Gonzales, Texas were allotted to four groups of 16, 22, 18 and 20 head per group and placed on wheat for a trial beginning November 7,1991 and ending March 6,1992. In Trial 4, 82 British and exotic crossbred steers purchased in central Oklahoma were allotted to groups of 22, 22, 18 and 20 head per group and placed on wheat from November 13, 1992 to March 14, 1993. Initial and final live weights of the steers were measured after an overnight shrink (16 to 18 hr) without feed and water.

Stocking of Pastures. Available wheat forage was measured before each trial and periodically throughout the trials, by hand-clipping to ground level 10 (.5 m^2) quadrats in each pasture. Cattle were allotted each pasture to equalize the amount of available forage per steer across pastures. Number of steers in the pastures was adjusted if needed during the trials in an effort to equalize amounts of available forage per steer. Forage availability throughout the four trials is shown in Appendix A.

Experimental Design. Trials 1, 2 and 3 were designed as split-plot experiments, where treatments, consisting of control (no energy supplement) or the self-fed supplement, were randomly assigned to pastures. In Trial 1, one-half of the steers in each pasture were given a copper injection (as Ethylenedinitrilo-Tetraacetic Acid Copper Disodium Salt; Bovi-Cu; Anthony Products Co., Arcadia, CA). In Trials 2 and 3, one-half of the steers in each pasture were administered a slow release selenium bolus designed to supply 3 mg selenium per day for 4 months (as sodium selenite; Dura Se-120; Schering

Corporation; Kenilworth,NJ). During Trials 2 and 3, blood was collected from 3 or 4 cattle in each pasture, at three times during the trial, and whole blood selenium was analyzed by Schering-Plough Animal Health, Technical Services. Ten wheat forage samples were collected from each pasture by hand-clipping to ground level in Trial 2 and hand-clipping at a level to mimic forage intake by steers in Trial 3. Forage sample were dried to constant weights in a forced-air oven at 55° and ground in a Wiley Mill through a 2 mm mesh screen. Forage samples were composited within pasture and sampling date. The forage samples were sent to a commercial forage testing lab where mineral content of the wheat forage was analyzed by induction coupled plasma atomic emission spectroscopy. In Trial 4, only the effect of the monensin/energy supplement on performance was studied using a completely randomized design with supplement treatment randomly assigned to pasture.

Supplement. The monensin/energy supplement, which was fed in the pelleted form in Trials 1 and 2 and in the meal form in Trials 3 and 4, contained mostly ground milo and wheat middlings, as well as 165 mg/ kg monensin (as shown in Table 2). Each new mix of supplement was sampled and analyzed for monensin concentration by colorimetric analysis (Golab et al., 1973) to assure monensin content was close to calculated level. Daily intake of the supplement was targeted at .91 to 1.36 kg/ head to supply 150 to 224 mg monensin/day. The supplement was fed in covered feeders with openings to one side that provided 6 meters of total bunk space in each pasture. Supplement intake was measured twice weekly (i.e. at 3 and 4-day intervals).

Control cattle had free-choice access to a commercial mineral mixture (CO OP Wheat Pasture Pro Mineral, Farmland Industries Inc.) throughout the trials in weather vane type mineral feeders located near the water source in each pasture. Guaranteed analysis of the mineral mixture was: calcium, 15 to 17%; phosphorus, not less than 4%; salt, 18.5 to 21.5%; and magnesium, not less than 5.5%. Intake of the commercial mineral mixture was measured weekly.

Large roll bales of medium quality grass hay (Bermudagrass or Old World Bluestem) were offered in all pastures during periods of ice and snow cover or periods of low forage availability. During Trial 1, hay was fed beginning October 26 and continuing at approximately weekly intervals to the end of the trial. During Trial 2, hay was put out in all pastures on December 1 and hay feeding was discontinued until December 19 when hay was fed as needed (at 3 to 7 day intervals) until the end of the trial. Due to the mild winter and excellent forage growth in Trial 3, hay was fed at four times over the entire trial (November 7, December 19 and February 15 and 25). The winter of 1992-93 was wetter than normal and regrowth of wheat forage was slow due to extended periods of cold temperatures, overcast skies and ice and snow cover, subsequently available forage was inadequate for a period of time and additional hay was fed 15 times beginning November 13 and continuing to the end of the trial as needed at approximately 4 to 10 day intervals.

Statistical Analysis. The data were analyzed by least squares ANOVA using the GLM procedure of SAS (1985). Performance of the steers in Trials 1, 2 and 3 was analyzed as a split-plot experimental design using pasture as the experimental unit and steers as the sampling unit. The main unit treatment was supplement and the subunit treatment was supplemental copper injection or selenium bolus. In the presence of a significant main unit x subunit interaction ($P<.10$) standard errors for the split plot design were calculated to find the LSD and proper t-values as described by Steel and Torrie (1980) for comparison of two subunit means at different main units. In Trial 4, the data were analyzed as a completely randomized design with pasture as the experimental unit and steers as the sampling unit. Due to extremely wet weather that occurred during the trial, sampling of forage availability showed uneven forage production in the pastures. On January 15 (day 63 of the trial) four steers were removed from pasture 2 and added to pasture 4 in order to equalize available forage. These steers were removed from performance data analysis.

Supplement and mineral intake were analyzed using the MEANS procedure of SAS (1985) to find the simple mean and standard deviation of intake for each group.

Statistical analysis of whole blood selenium concentrations in Trials 2 and 3 was completed as a split-split plot of a completely randomized design due to the repeated nature of blood sampling. Sources of variation included in the model were selenium treatment, supplement treatment, pasture, animal, sample dates and interactions of these terms. The effect of supplement treatment was tested by the pasture within supplement error term. The effect of selenium bolus and the supplement X selenium interaction and the selenium by pasture within supplement terms were tested by animal within supplement and selenium. Sample date and the sample date by monensin interaction were tested by sample date by pasture within supplement. The sample date by selenium interaction was tested by sample date by selenium by pasture within supplement.

Results and Discussion

Supplement Intake. Horn et al. (1990) in a preliminary trial using heifers grazing wheat pasture, reported that daily intake of the pelleted self-fed supplement was 1.25±.29 kg/hd. In this preliminary trial, daily supplement intake ranged from .54 to 1.92 kg/hd which was close to the targeted range of .91 to 1.36 kg/hd. Monensin consumption averaged 206±48 mg•hd^{-1}•d^{-1} with a range of 89 to 316 mg/hd/d. Mean daily intake of the energy supplement and monensin are shown for each trial and group in Table 3. In Trials 1 and 2, one group of steers had a mean supplement intake that was within the targeted range, while one group of steers in each trial had a mean intake that was greater than the desired level. In the pastures where intake was excessive during Trials 1 and 2, block salt was offered to the cattle (November 17 in Trial 1 and November 20 in Trial 2) to supress a possible salt craving. Intake of the salt blocks was low and had no effect on supplement intake so the salt blocks were removed in each trial. The salt content of the supplement was then increased from 4.00% to 6.00% at the expenses of milo (December 1 in Trial 1 and November 27 in Trial 2), for the duration of the trials in the pasture where excessive intake was observed. Monensin intakes averaged 197 and 318 mg• hd^{-1}•d^{-1} by groups one and two, respectively, during Trial 1; and 306 and 181 by groups one and two during Trial 2.

Due to the variability and high levels of intake when feeding the pelleted supplement, the supplement was fed in the meal form in Trials 3 and 4. Cullison et al. (1961) concluded that when unpalatable feeds are pelleted, acceptability to cattle and sheep is increased and intake is increased. Thus, feeding a self-limiting supplement in the meal form may allow for better intake regulation by decreasing mean intake and daily variation of intake. Mean supplement intake during Trial 3 was .91 ± .32 and .91 ± .35 for groups 1 and 2, respectively, which provided 150 mg monensin/d. The winter of 1991-92 was extremely mild and the wheat forage was lush and growing throughout the trial, which may have helped limit intake of the supplement compared to earlier studies. In Trial 4, daily supplement intake averaged 1.21 ± .58 and 1.42 ± .69 kg/hd with monensin intake of 200 and 235 mg/hd by groups 1 and 2, respectively. The supplement intakes were somewhat excessive during snow and ice cover during the trial. Salt levels were not increased and supplement intake returned to normal levels with melt off of snow cover. Feeding the supplement in the meal form limited the mean consumption to the desired range in both trials, yet the form of the supplement had no effect on the variability of supplement intake.

Intake of mineral supplements by control cattle varied greatly from year to year, as shown in Table 3. During Trial 1, mineral intakes were quite low. The average daily mineral consumption by cattle in group 3 was .05 kg. The average daily mineral consumption by cattle in group 4 was .06 kg. During Trial 2 mineral intakes by control steers were closer to the manufacturer's desired level of .11 kg per day. During Trial 3 the daily mineral intake by control cattle were again near desired levels. During Trial 4, daily mineral intakes were low.

Figure 1 shows the daily supplement intake variation found by groups 1 and 2 during Trial 1. Supplement intake by group 1 started low yet continued at an upward trend throughout the trial with the peak level of intake in February. While group 2 started the trial with an initial peak, supplement intake dipped to a low in December then started on an upward trend with a peak level of intake in February. Figure 2 shows that supplement intake patterns by groups 1 and 2 during Trial 2, were similar to supplement intake patterns by group 2 during Trial 1. Both groups in Trial 2 had early peaks in supplement intake just after the onset of the trial in November. This was followed by decreased intake in December. Supplement intake then increased to a peak in January followed by generally decreasing intakes going into the end of the trial. Figure 3 shows different supplement intake patterns by groups 1 and 2 during Trial 3. The supplement intake pattern shown by group 1 was similar to the pattern of intake exhibited in Trial 2. Figure 4 shows similar intake patterns to group 2 during

Trial 3. Both groups started with low intakes, increasing to a peak in early March and decreasing at the end of the trial.

Grigsby et al. (1991) reported that daily intake of a self-fed corn-based supplement in two trials was limited to .76 and .51 kg /head by a combination of monensin and minerals that comprised 13.5% of the supplement in two trials with cattle grazing rye-ryegrass pastures in the spring. The supplement contained .5% Rumensin 60 premix, 3% salt, 2% ground limestone, .25% ammonium sulfate, 1% magnesium oxide, 7% dicalcium phosphate and .25% trace mineral premix. Brandyberry et al. (1991) reported that daily self-fed supplement intake by steers grazing native range was restricted to .95 kg/head by .23 kg salt/hd (20% salt) during the summer and .40 kg salt/head (30% salt) during the winter. The salt content of the rations fed by Grigsby et al. (1991) and in the current studies are much lower than the levels reported by Brandyberry et al. (1991). The presence of monensin and minerals as well as higher quality pastures may explain these differences.

Muller et al. (1986) reported monensin fed to grazing cattle in self-limited supplements in 9 trials reduced supplement intake compared to self-limited rations without monensin, while daily gains were increased by 15.3%. The average minimum salt level was reported to be 50% lower in self-limited rations containing monensin as compared with self-limited rations without monensin, and salt levels were changed less often in treatments containing monensin.

Cattle Performance. Performance of the steers in Trial 1 is shown in Table 4. Weight gains of the steers was not influenced (P> .60) by the injection of copper and the copper by supplement interaction was not significant (P> .80). On day 53 of the trial, 15 steers (4 from Group 1 and 11 from Group 3) were removed from the trial in order to provide adequate amounts and to equalize forage availabilities among pastures. Seventy-nine cattle were used (39 control and 40 supplemented) in the data set to test the effect of the monensin/energy supplement and copper injection on performance. Daily gains of supplemented cattle were increased by .24 kg (1.03 vs. .79; $P<.03$) over control cattle.

In Trial 2, the monensin/energy supplement and the selenium bolus increased performance ($P<.003$ and $P<.03$, respectively), and the supplement by selenium interaction was not significant ($P> .80$). Therefore, performance is shown in Table 5 pooled across both selenium treatment and supplement treatment. Daily gains were increased by .08 kg (1.25 vs. 1.17; $P<.03$) by the Se bolus and were increased by .22 kg (1.32 vs. 1.10; $P<.003$) by the monensin/energy supplement.

Problems with bloat were encountered during Trial 3 and four steers that were frequently observed bloated were deleted from the data set because of poor performance. The supplement X selenium interaction was significant ($P<.08$) as shown in Table 5, so the simple effects of the monensin/energy supplement and the Se bolus are shown in Table 6. The Se bolus tended to increase gains of control steers while it tended to decrease gains of steers fed the monensin/energy supplement. We have no explanation for this interaction. Due to the nature of the interaction and the fact that supplement increased performance at both levels of selenium, performance of the steers pooled across supplement and selenium treatment is shown in Table 5. The monensin/energy supplement tended to increase daily gains by .20 kg over controls (1.25 vs. 1.05; $P=.15$). The selenium bolus had no overall effect on performance (1.15 vs. 1.15; $P=.80$).

Daily gains of the steers in Trial 4 are shown in Table 7. On January 15, 1993, four steers were removed from pasture 2 and added to pasture 4, in order to equalize forage availabilities expressed as kg DM/ head, among pastures.

Seventy-eight steers were used to test the effect of the monensin/energy supplement on performance. Daily gains of supplemented steers were increased by .21 kg over control steers (.96 vs. .75 ; P<.02).

The effect of the energy supplement was consistent from year to year, as shown in Table 8. Daily gains were increased by .20 to .24 kg, the average increase in performance was .22 kg. Mean daily supplement consumption across pastures ranged from .91 to 1.56 kg, and the overall average supplement consumption across trials was 1.32 kg. Supplement conversion ranged from .15 to .22 kg increased gain per kg supplement, with an average supplement conversion of .17. Potter et al. (1976) reported that monensin fed daily in doses of 100 to 300 mg/hd increased daily gains by .06 to .09 kg in four experiments using mixed breed cattle grazing high quality pastures containing orchard grass, alfalfa, brome grass and ladino clover or pen fed greenchop. On wheat pasture, Horn et al. (1981) increased daily gains of light weight heifers by .08 kg/d when feeding 100 mg monensin/hd.

The Se bolus had variable effects on performance and blood Se concentrations. As shown in Appendix C., overall blood Se concentrations were not increased in either Trial 2 or Trial 3. Performance of selenium supplemented steers was improved in Trial 2 (Table 5). In Trial 2 during the first period, blood Se concentrations were increased (.20 ppm vs. .24 ppm; P=.01). Also in Trial 2, overall daily gains were increased by .08 kg with the Se bolus (1.25 vs. 1.17; P<.03). Phillips et al. (1989) found that overall growth of suckling calves was not increased by supplementation with the Dura Se-120® bolus, even though blood Se levels were higher with supplementation, and gains were increased in the last 30 days of the trial. Hill et al. (1993) reported that blood Se concentrations of steers with marginal blood Se grazing native range were improved by the Dura Se-120® bolus, but no improvement in performance was found. In Trial 3, Se supplementation had no effect on performance or blood Se concentrations at any of the sampling times. Similar results were reported by Greene et al. (1991) who reported that administering Dura Se-120® bolus to calves grazing oat pasture did not increase weight gains, but blood Se concentration and body condition were increased and hair coat quality was improved by Se supplementation. Herd et al. (1992a and 1992b) also showed no improvement in performance of suckling calves due to Se supplementation with the Dura Se-120® bolus.

The mineral concentrations of wheat forage for Trials 2 and 3 are shown in Table 9. Forage samples were collected in Trial 2 by hand-clipping to ground level. Forage samples were collected in Trial 3 by hand-clipping at a height to mimic forage consumed by steers. Copper levels during both trials were within the requirement range of 4 to 10 ppm in all but one sampling date, but were lower than the suggested level of 8 ppm (NRC,1984). Forage selenium levels were within the requirement range of .05 to .30 ppm in both trials and met the suggested value of .20 ppm on three of the four periods sampled (NRC, 1984).

Implications

A self-limiting monensin-containing energy supplement economically increased daily gains by about .22 kg/hd with a supplement conversion of .17 kg gain per kg supplement. Feeding the supplement in the meal form allowed us to limit the range of supplement intake closer to the targeted range of .91 to 1.36 kg/ day. This supplementation program will improve the profitability of the wheat/stocker operation with increasing weight gains and decreased bloat.

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Table 1. Number, description of cattle and length of each grazing trial on wheat pasture.

		Steers			Length of Trials		Initial Stocking Density	
Trial	Year	Number	Mean initial wt., kg	Breed/Area of Orgin	Dates	Days	Head/ha	kg forage DM /head
1	1989-90	94	222	British and Exotic Crossbred/ north-central Arkansas	10/26 - 2/24	120	1.65	660
2	1990-91	71	242	Exotic Crossbred/ north-central Arkansas	11/13 - 3/14	120	1.25	770
3	1991-92	76	270	Brahman Crossbred/ Gonzales, Texas	11/7 - 3/6	120	1.33	900
4	1992-93	82	273	British and Exotic Crossbred/ central Oklahoma	11/13 - 3/14	122	1.44	770

Table 2. Composition of monensin-containing energy supplement fed to steers grazing wheat pasture (as-fed basis).

Ingredient	%
Ground milo	62.78
Wheat middlings	20.99
Sugarcane molasses	4.80
Calcium carbonate	4.00
Dicalcium phosphate	2.55
Magnesium oxide	.75
Salt[a]	4.00
Rumensin 60 Premix	.125
Calculated nutrient content	
NE gain, Mcal /kg	37.9
Crude Protein, %	9.2
Calcium, %	1.94
Phosphorus, %	1.17
Magnesium, %	.63
Monensin content, mg/kg	165

[a] Fine gradation of Rock Salt (95.6 to 96.8% NaCl). Carey Salt Co.

Table 3. Mean daily intake of the mineral mixture, energy supplement and monensin by cattle grazing wheat pasture[a,b].

	Supplement, kg/head		Monensin, mg/head	
	Mean	S. D.	Mean	S.D.
Trial 1				
Group 1 (3)	1.19 (.05)	.45 (.014)	197	75
Group 2 (4)	1.93 (.06)	.46 (.015)	318	77
Trial 2				
Group 1 (3)	1.85 (.09)	.58 (.036)	306	96
Group 2 (4)	1.10 (.10)	.54 (.045)	181	89
Trial 3				
Group 1 (3)	.91 (.11)	.32 (.025)	150	53
Group 2 (4)	.91 (.11)	.35 (.038)	150	58
Trial 4				
Group 1 (3)	1.21 (.05)	.58 (.031)	200	95
Group 2 (4)	1.42 (.04)	.69 (.027)	235	114

[a] Measured twice weekly at three and four day intervals. Fed as 5 mm (3/16-inch) pellet in Trials 1 and 2 and in the meal form in Trials 3 and 4.

[b] Group numbers in parentheses were control cattle and had free-choice access to a commercial mineral mixture throughout the trials Intake of the mineral mixture was measured weekly.

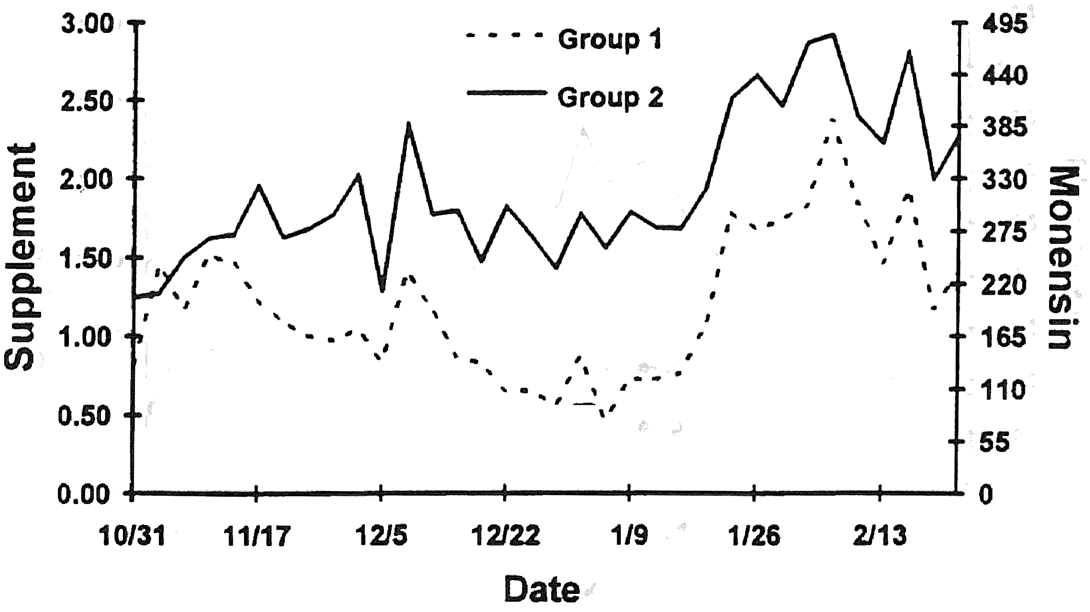

Figure 1. Daily supplement (kg/hd) and monensin (mg/hd) intake by steers during Trial 1. Standard error for supplement intake .08 and .08 for Groups 1 and 2, respectively. Standard error for monensin intake 76 and 121 for Groups 1 and 2, respectively.

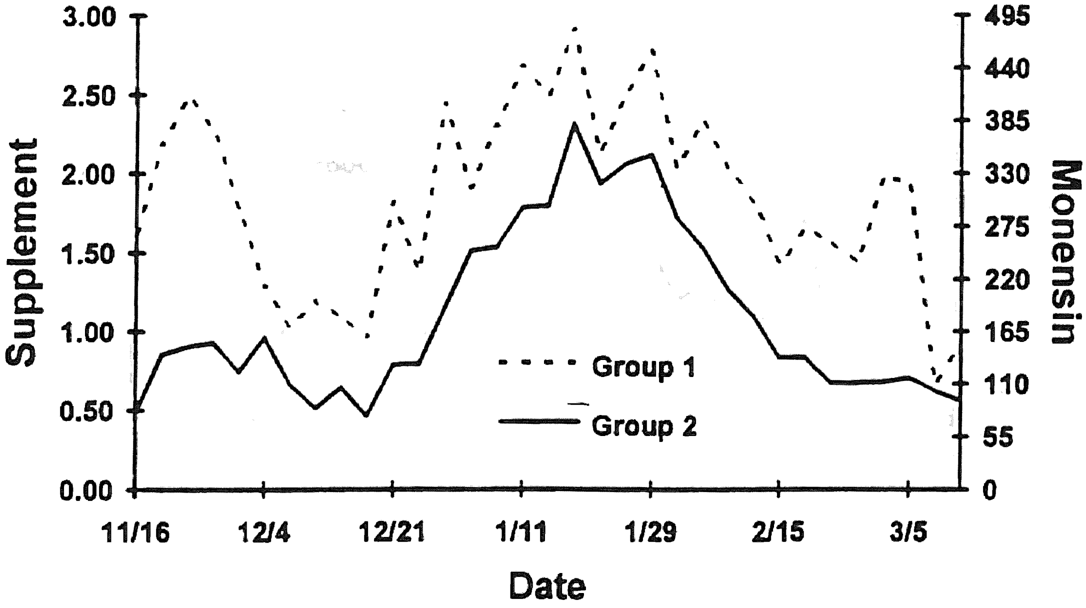

Figure 2. Daily supplement (kg/hd) and monensin (mg/hd) intake by steers during Trial 2. Standard error for supplement intake .59 and .10 for Groups 1 and 2, respectively. Standard error for monensin intake 17 and 16 for Groups 1 and 2, respectively.

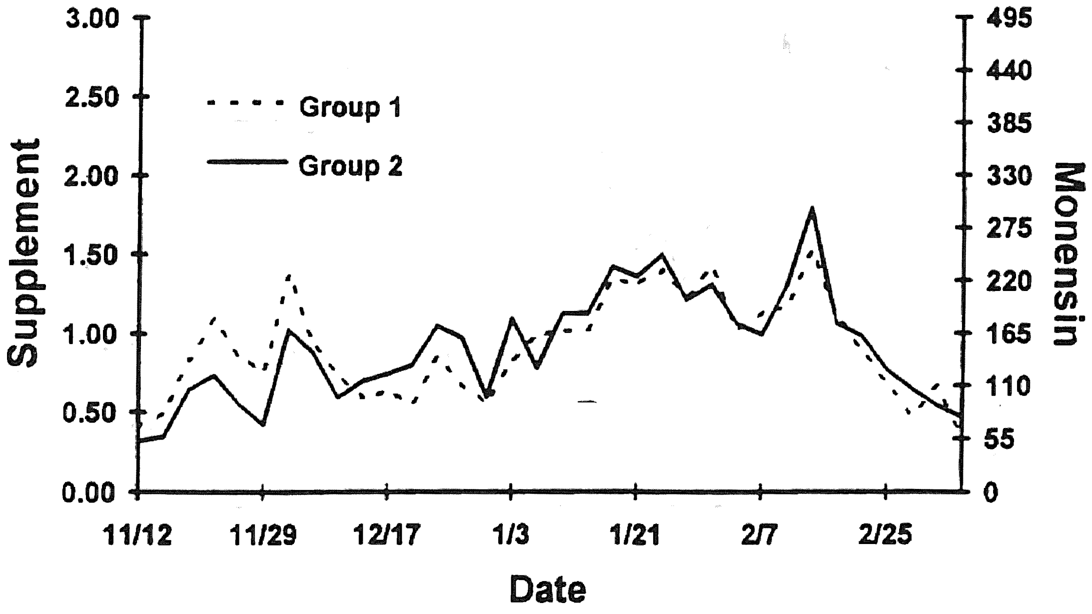

Figure 3. Daily supplement (kg/hd) and monensin (mg/hd) intake by steers during Trial 3. Standard error for supplement intake .05 and .06 for Groups 1 and 2, respectively. Standard error for monensin intake 9 and 10 for Groups 1 and 2, respectively.

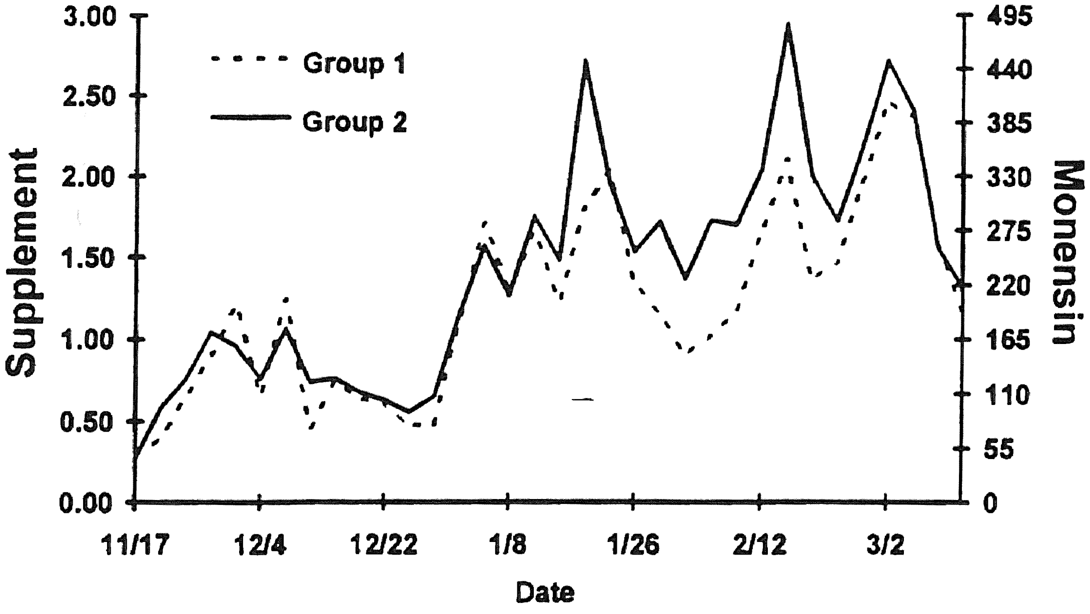

Figure 4. Daily supplement (kg/hd) and monensin (mg/hd) intake by steers during Trial 4. SE for Supplement intake .10 and .12 for Groups 1 and 2, respectively. SE for monensin intake 16 and 19 for Groups 1 and 2, respectively.

Table 4. Least square means showing the effect of monensin/energy supplement on performance of steers grazing wheat pasture in Trial 1.

	Treatment		Significance Level (P< .XX)		
	Control	Energy Supplement[a]	Energy Supplement	Copper[b]	Supplement x Copper
Number steers	39	40			
Initial weight, kg	225	221			
Final weight, kg	320	345			
Daily gain, kg	.79	1.03	.03	.63	.87

[a] Monensin/energy supplement fed as 5 mm (3/16-inch) pellets.

[b] Copper injection as Ethylenedinitrilo-tetraacetic Acid Copper Disodium Salt; Bovi-Cu; Anthony Products Co., Arcadia, CA.

Table 5. Least square means showing the effect of monensin/energy supplement or selenium bolus on performance of steers grazing wheat pasture in Trials 2 and 3.

	Treatment				Significance Level (P< .XX)		
	Control	Energy Supplement[a]	No Bolus	Se Bolus[b]	Energy Supplement	Selenium	Supplement x Selenium
Trial 2							
Number steers	38	33	37	34			
Initial weight, kg	239	246	242	243			
Final weight, kg	372	405	383	393			
Daily gain, kg	1.10	1.32	1.17	1.25	.003	.03	.84
Trial 3							
Number steers	36	36	36	36			
Initial weight, kg	270	269	265	274			
Final weight, kg	396	419	403	412			
Daily gain, kg	1.05	1.25	1.15	1.15	.15	.80	.08

[a] Monensin/Energy supplement fed as 5 mm (3/16-inch) pellets in Trial 2 and in the meal form in Trial 3.

[b] Dura Se-120; Schering Corporation; Kenilworth, NJ.

Table 6. Least square means showing the effect of monensin/energy supplement and selenium bolus on performance of steers grazing wheat pasture in Trial 3.

	Treatment							
	Control		Energy Supplement[a]		Comparison and Significance Level (P< .XX)			
	No Bolus (1)	Se Bolus[b] (2)	No Bolus (3)	Se Bolus (4)	1 vs. 2	3 vs. 4	1 vs. 3	2 vs. 4
Number steers	18	18	18	18				
Initial weight	267	273	263	275				
Final weight,	388	404	418	420				
Daily gain, kg	1.01	1.08	1.29	1.21	.16	.13	.10	.20

[a] Monensin/Energy supplement fed in the meal form.

[b] Dura Se-120; Schering Corporation; Kenilworth, NJ.

Table 7. Least squares means of the effect of monensin/energy supplement on performance of steers grazing wheat pasture in Trial 4[a].

	Treatment		
	Control	Energy Supplement	OSL[b]
Number steers	38	40	
Initial weight,	278	269	
Final weight,	370	386	
Daily gain, kg	.75	.96	.02

[a] Monensin/Energy supplement fed in the meal form.

[b] Observed Significance Level.

Table 8. Summary of individual trials showing the effect of monensin/energy supplement on daily gain, supplement consumption and supplement conversion of steers grazing wheat pasture.

	Daily Gain, kg				
Trial No.	Control	Energy Supplement[a]	Increased gain	Supplement Consumption, kg[b]	Supplement Conversion[c]
1	.79	1.03[d]	.24	1.56	.15
2	1.10	1.32[d]	.22	1.48	.15
3	1.05	1.25[e]	.20	.91	.22
4	.75	.96[d]	.21	1.32	.16
Mean:	.92	1.14	.22	1.32	.17

[a] Monensin/energy supplement fed as 5 mm (3/16-inch) pellets in Trials 1 and 2 and in the meal form in Trials 3 and 4.

[b] Average supplement consumption across pastures.

[c] Kg added gain•kg $supplement^{-1}$•$head^{-1}$.

[d] Supplement greater than control ($P<.03$).

[e] Supplement greater than control ($P<.15$).

Table 9. Mineral content[a] (% DM Basis) of wheat forage during Trials 2 and 3.

	Trial 2[b]		Trial 3[c]	
Date:	1/20/91	3/8/91	11/5/91	2/5/92
No. Pastures/samples:	4	4	4	4
Calcium, %	.33±.02	.42±.03	.68±.04	.35±.05
Phosphorus, %	.24±.01	.24±.02	.36±.02	.39±.06
Magnesium, %	.21±.01	.26±.01	.35±.03	.21±.02
Potassium, %	1.13±.17	1.71±.20	2.44±.36	2.37±.38
Sodium, %	.02±.007	.02±.009	.016±.003	.07±.090
Iron, ppm	1855±711	890±383	179±11.3	661±382
Zinc, ppm	23.5±2.52	23.5±.58	23.8±1.26	23.0±2.94
Copper, ppm	3.5±1.0	4.3±.96	5.6±.70	5.8±1.00
Manganese, ppm	193.8±27.3	207.3±58.7	172.3±60.5	130.3±52.8
Molybdenum, ppm	2.33±.94	1.50±.47	.50±.58	1.28±.62
Selenium, ppm	.10±.04	.29±.14	.21±.10	.21±.15

[a] Mean ± Standard Deviation

[b] Samples collected by hand-clipping to ground level.

[c] Samples collected by hand-clipping at a height to mimic forage consumed by steers.

APPENDIXES

Appendix A. Wheat forage availability and stocking density during Trials 1-4.

				Wheat Pasture Year and Date								
				1989 - 90				1990 - 1991				
Pasture	Acres	Hectares		10/25	12/10	1/30	3/19	11/11	12/15	1/20	2/18	3/08
1	32	12.95	lb/acre	943	881	922	883	561	1113	808	678	577
			kg/ha	1059	989	1036	992	630	1250	908	761	648
			No. Steers	21	21	17	17	16	16	16	16	16
			lb forage/ steer	1438	1343	1736	1662	1121	2225	1616	1356	1153
			kg forage/ steer	653	610	789	756	510	1012	735	616	525
2	33.4	13.5	lb/acre	1358	2205	1299	712	904	1725	1299	780	897
			kg/ha	1525	2477	1459	800	1015	1937	1459	876	1007
			No. Steers	23	23	23	23	17	17	17	17	17
			lb forage/ steer	1972	3203	1887	1034	1777	3389	2553	1532	1763
			kg forage/ steer	896	1455	857	470	807	1541	1160	697	801
3	33.4	13.5	lb/acre	554	562	1401	1556	1041	1474	1088	630	967
			kg/ha	622	631	1574	1748	1169	1656	1222	708	1086
			No. Steers	21	21	10	10	17	17	17	17	17
			lb forage/ steer	880	895	4679	5196	2046	2896	2137	1238	1899
			kg forage/ steer	401	406	2127	2362	930	1316	972	563	864
4	42	17.0	lb/acre	1070	1878	603	543	927	1518	1015	641	815
			kg/ha	1202	2109	677	610	1041	1705	1140	720	915
			No. Steers	29	29	29	29	21	21	21	21	21
			lb forage/ steer	1549	2720	874	786	1855	3037	2029	1282	1630
			kg forage/ steer	704	1236	394	357	843	1380	923	583	741

Appendix A. Continued.

				Wheat Pasture Year and Date									
				1991 - 1992					1992 - 1993				
Pasture	Acres	Hectares		11/5	12/5	1/8	2/5	3/6	11/5	12/17	1/7	1/28	3/8
1	32	12.95	lb/acre	972	889	854	952	2002	1194	1204	1290	983	744
			kg/ha	1092	999	959	1069	2249	1341	1352	1449	1104	836
			No. Steers	16	16	16	16	16	22	22	22	22	22
			lb forage/ steer	1944	1778	1707	1903	4005	1737	1751	1877	1430	1082
			kg forage/ steer	884	808	776	865	1820	789	796	853	650	492
2	33.4	13.5	lb/acre	1152	1514	1228	1114	1657	1066	849	988	1079	825
			kg/ha	1294	1700	1379	1251	1861	1197	954	1110	1212	927
			No. Steers	22	22	22	22	22	22	22	22	18	18
			lb forage/ steer	1748	2298	1864	1691	2516	1618	1289	1500	2003	1531
			kg forage/ steer	795	1045	847	769	1143	736	586	682	910	696
3	33.4	13.5	lb/acre	1041	1472	1253	1207	1871	940	907	988	916	633
			kg/ha	1169	1653	1407	1356	2101	1056	1019	1110	1029	711
			No. Steers	18	18	18	18	18	18	18	18	18	18
			lb forage/ steer	1932	2731	2325	2239	3471	1744	1683	1834	1700	1175
			kg forage/ steer	878	1242	1057	1018	1578	793	765	833	773	534
4	42	17.0	lb/acre	1077	1133	1125	1074	2147	806	1132	1089	969	830
			kg/ha	1210	1273	1264	1206	2411	905	1271	1223	1088	932
			No. Steers	20	20	20	20	20	20	20	20	24	24
			lb forage/ steer	2261	2379	2362	2256	4508	1693	2377	2287	1696	1452
			kg forage/ steer	1028	1082	1074	1025	2049	769	1080	1039	771	660

Appendix B. Daily intake of monensin/energy supplement by cattle grazing wheat pasture during Trials 1-4[a].

Table 1. Daily intake of monensin/energy supplement during Trial 1.

Trial	Date	Group 1		Group 2	
		No. Head	Supplement Intake, kg/hd	No. Head	Supplement Intake, kg/hd
1	10/31	20	1.10	23	1.24
1	11/3	21	1.45	23	1.27
1	11/7	21	1.18	23	1.50
1	11/10	21	1.52	23	1.62
1	11/14	21	1.47	23	1.65
1	11/17	21	1.24	23	1.96
1	11/21	21	1.10	23	1.63
1	11/24	21	1.01	23	1.69
1	11/28	21	.98	23	1.78
1	12/1	21	1.05	23	2.03
1	12/5	21	.85	23	1.29
1	12/8	21	1.41	23	2.35
1	12/12	21	1.17	23	1.78
1	12/15	21	.88	23	1.80
1	12/19	21	.82	23	1.47
1	12/22	17	.66	23	1.83
1	12/26	17	.65	23	1.64
1	12/29	17	.57	23	1.43
1	1/2	17	.87	23	1.78
1	1/5	17	.48	23	1.56
1	1/9	17	.73	23	1.79
1	1/12	17	.73	23	1.69
1	1/16	17	.77	23	1.68
1	1/19	17	1.05	23	1.94
1	1/23	17	1.79	23	2.51
1	1/26	17	1.68	23	2.66
1	1/30	17	1.74	23	2.46
1	2/2	17	1.83	23	2.86
1	2/6	17	2.37	23	2.92
1	2/9	17	1.85	23	2.40
1	2/13	17	1.46	23	2.22
1	2/16	17	1.93	23	2.82
1	2/20	17	1.18	23	1.99
1	2/23	17	1.40	23	2.28
1	2/27	17	.76	23	1.88
1	3/2	17	1.20	23	2.08
1	3/6	17	.61	23	1.78
1	3/9	17	.18	23	.79
1	3/13	17	.38	23	.95
1	3/16	17	.26	23	1.16

[a] Measured twice weekly (ie. at 3 and 4-day intervals). Fed as 5 mm (3/16-inch) pellets in Trials 1 and 2 and in the meal form in Trials 3 and 4.

Appendix B. Continued.

Table 2. Daily intake of monensin/energy supplement during Trial 2.

		Group 1		Group 2	
Trial	Date	No. Head	Supplement Intake, kg/hd	No. Head	Supplement Intake, kg/hd
2	11/16	16	1.63	17	.48
2	11/20	16	2.20	18	.85
2	11/23	16	2.49	18	.91
2	11/27	16	2.28	17	.94
2	11/30	16	1.78	17	.75
2	12/4	16	1.29	17	.97
2	12/7	16	1.03	17	.66
2	12/11	16	1.20	17	.51
2	12/14	16	1.10	17	.65
2	12/18	16	.97	17	.46
2	12/21	16	1.82	17	.79
2	12/28	16	1.38	17	.80
2	1/1	16	2.45	17	1.15
2	1/4	16	1.91	17	1.51
2	1/8	16	2.30	17	1.54
2	1/11	16	2.68	17	1.78
2	1/15	16	2.50	17	1.80
2	1/18	16	2.91	17	2.32
2	1/22	16	2.14	17	1.94
2	1/25	16	2.50	17	2.06
2	1/29	16	2.77	17	2.12
2	2/1	16	2.04	17	1.72
2	2/5	16	2.33	17	1.53
2	2/8	16	2.03	17	1.26
2	2/12	16	1.82	17	1.10
2	2/15	16	1.43	17	.84
2	2/19	16	1.65	17	.84
2	2/22	16	1.58	17	.67
2	2/26	16	1.44	17	.67
2	3/1	16	1.98	17	.68
2	3/5	16	1.94	17	.70
2	3/8	16	.67	17	.62
2	3/12	16	.93	17	.56

Appendix B. Continued.

Table 3. Daily intake of monensin/energy supplement during Trial 3.

		Group 1		Group 2	
Trial	Date	No. Head	Supplement Intake, kg/hd	No. Head	Supplement Intake, kg/hd
3	11/12	18	.40	20	.32
3	11/15	18	.49	20	.35
3	11/19	18	.83	20	.65
3	11/22	18	1.09	20	.74
3	11/26	18	.86	20	.55
3	11/29	18	.76	20	.42
3	12/3	18	1.38	20	1.03
3	12/6	18	.93	20	.88
3	12/10	18	.75	20	.60
3	12/13	18	.59	20	.70
3	12/17	18	.63	20	.74
3	12/20	18	.55	20	.80
3	12/24	18	.85	20	1.05
3	12/27	18	.68	20	.97
3	12/31	18	.55	20	.60
3	1/3	18	.83	20	1.10
3	1/7	18	.99	20	.78
3	1/10	18	1.01	20	1.13
3	1/14	18	1.88	20	1.13
3	1/17	18	1.34	20	1.42
3	1/21	18	1.31	20	1.36
3	1/24	18	1.40	20	1.50
3	1/28	18	1.23	20	1.21
3	1/31	18	1.42	20	1.31
3	2/4	18	1.02	20	1.06
3	2/7	18	1.13	20	.99
3	2/11	18	1.16	20	1.29
3	2/14	18	1.52	20	1.79
3	2/18	18	1.12	20	1.06
3	2/21	18	.89	20	.98
3	2/25	18	.69	20	.76
3	2/28	18	.48	20	.65
3	3/3	18	.66	20	.54

Appendix B. Continued.

Table 4. Daily intake of monensin/energy supplement during Trial 4.

Trial	Date	Group 1		Group 2	
		No. Head	Supplement Intake, kg/hd	No. Head	Supplement Intake, kg/hd
4	11/17	22	.28	22	.27
4	11/20	22	.40	22	.58
4	11/24	22	.65	22	.76
4	11/27	22	.91	22	1.05
4	12/1	22	1.21	22	.96
4	12/4	22	.66	22	.75
4	12/8	22	1.24	22	1.07
4	12/11	22	.46	22	.74
4	12/15	22	.74	22	.76
4	12/18	22	.64	22	.68
4	12/22	22	.61	22	.63
4	12/25	22	.47	22	.55
4	12/29	22	.48	22	.65
4	1/1	22	1.11	22	1.16
4	1/5	22	1.71	22	1.58
4	1/8	22	1.30	22	1.26
4	1/12	22	1.66	22	1.76
4	1/15	22	1.23	22	1.49
4	1/19	22	1.81	18	2.72
4	1/22	22	2.04	18	1.97
4	1/26	22	1.33	18	1.54
4	1/29	22	1.16	18	1.72
4	2/2	22	.90	18	1.37
4	2/5	22	1.02	18	1.73
4	2/9	22	1.16	18	1.70
4	2/12	22	1.66	18	2.04
4	2/16	22	2.10	18	2.95
4	2/19	22	1.36	18	2.00
4	2/23	22	1.47	18	1.72
4	2/26	22	1.96	18	2.17
4	3/2	22	2.46	18	2.71
4	3/5	22	2.36	18	2.41
4	3/9	22	1.57	18	1.55
4	3/12	22	1.17	18	1.31

Appendix C. Effect of Dura Se-120 Selenium Bolus on Whole Blood Selenium Concentrations (ppm) during Trials 2 and 3.

	Treatment		
Date	No Bolus	Se Bolus	OSL[a]
	Trial 2		
11/13/90	.20 (7)[b]	.18 (6)	.87
1/31/91	.20 (6)	.24 (7)	.01
3/14/91	.27 (6)	.27 (7)	.81
Overall	.22 (19)	.23 (20)	.58
	Trial 3		
11/6/91	.18 (12)	.16 (12)	.16
1/9/92	.18 (12)	.15 (12)	.63
3/6/92	.15 (12)	.16 (12)	.65
Overall	.17 (36)	.17 (36)	.53

[a] Observed Significance Level.

Sample date P=.08 and .57 for Trials 2 and 3, respectively; Sample date X selenium P=.46 and .58 for Trials 2 and 3, respectively.

[b] Number of observations are in parentheses.

VITA 2

Paul Arthur Beck

Candidate for the Degree of

Master of Science

Thesis: DEVELOPMENT OF A SELF-LIMITED MONENSIN-CONTAINING ENERGY SUPPLEMENT FOR GROWING CATTLE ON WHEAT PASTURE

Major Field: Animal Science

Biographical:

Personal Data: Born in Guthrie, Oklahoma, October 3, 1967, the son of Raymond A. and Mary M. Beck

Education: Graduated from Guthrie High School, Guthrie, Oklahoma, in May 1986; earned Bachelor of Science Degree from Oklahoma State University in May, 1990; completed requirements for the Master of Science degree at Oklahoma State University in December, 1993.

Professional Experience: Graduate Research and Teaching Assistant, Department of Animal Science, January, 1991 to December, 1993. Oklahoma State University. Partner in family farming and ranching operation 1984 to present. Owner Beck Feed and Livestock Supply, Guthrie, Ok, January 1993 to present

Professional Organizations: The American Society of Animal Science, Animal Science Graduate Student Association, Oklahoma State University, Texas Cattle Feeders Association, National Cattlemen's Association, Oklahoma Grain and Stocker Producer's Association.