



The effect of trace mineral supplements upon the performance of wintering and fattening heifers
by Jack L Clark

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
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Abstract:

Four experiments were conducted to determine the effect of minerals upon the performance of wintering and fattening cattle under drylot conditions.

Experiment I was conducted with 32 Hereford heifer calves fed for 144 days. The calves were fed a ration of 80 percent steam rolled barley and 20 percent beet pulp ad libitum, and three pounds of grass hay daily. In addition, two pounds of a twenty percent protein supplement was fed. This supplement was the carrier for the trace minerals. Lot 5 received trace mineral; Lot 6, no trace mineral; Lot 7, chelated trace mineral; and Lot 8, trace mineral with high zinc. There was no difference in weight gains among lots. The heifers fed trace minerals with high zinc required 6.5 percent less feed per pound of gain than the control heifers. There was little difference in carcass grades between lots of heifers.

In Experiment II, III, and IV, the amount of trace minerals furnished in the supplement was increased over that used in Experiment I. The amount of minerals supplied per pound was as follows: trace mineral, Mn, 200 mg.; Zn, 41 mg.; Fe, 300 mg.; Cu, 60 mg.; Co, 10.4 mg.; and I, 13.6 mg. The trace mineral with high zinc furnished the same as trace mineral, except the zinc level was 545 mg. per pound. The chelated trace mineral furnished the following: Mn, 15 mg.; Zn, 19.5 mg.; Fe, 14.5 mg.; Cu, 4.4 mg.; Go, 3.7 mg.; and I, 7.7 mg.

In Experiment II, 38 head of heifer calves were wintered for 84 days on grass hay and a barley:beet pulp ration. The trace minerals were added as above by feeding one pound of a protein supplement. There was no significant difference in gain among lots. There was an increase in feed efficiency of 5 and 12 percent for heifers fed the high zinc and chelated trace minerals, respectively.

In Experiment III, the calves in Experiment II were continued onto a fattening ration for 135 days, staying on their respective treatments. The fattening ration consisted of a mixture of 80 percent barley, 20 percent beet pulp fed ad libitum, and three pounds of grass hay. There was no significant difference in gain. However, heifers fed the high zinc were slightly more efficient than the control heifers. The daily feed intake of heifers was increased in all trace mineral supplemented lots.

Experiment IV was conducted with 32 yearling heifers fed a fattening ration for 125 days. The treatment and rations were the same as used in Experiment III. There was a significant increase in gain ($P < .05$) of the trace mineral supplemented heifers over the control lot. There was no difference in gain among the trace mineral lots. There was also an increase in daily feed intake and feed efficiency in favor of the trace mineral supplemented heifers. There was little difference in carcass grades between lots, however, heifers fed the trace mineral and the trace mineral with high zinc had higher dressing percents than the controls.

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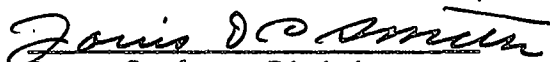
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ABSTRACT

Four experiments were conducted to determine the effect of minerals upon the performance of wintering and fattening cattle under drylot conditions.

Experiment I was conducted with 32 Hereford heifer calves fed for 144 days. The calves were fed a ration of 80 percent steam rolled barley and 20 percent beet pulp ad libitum, and three pounds of grass hay daily. In addition, two pounds of a twenty percent protein supplement was fed. This supplement was the carrier for the trace minerals. Lot 5 received trace mineral; Lot 6, no trace mineral; Lot 7, chelated trace mineral; and Lot 8, trace mineral with high zinc. There was no difference in weight gains among lots. The heifers fed trace minerals with high zinc required 6.5 percent less feed per pound of gain than the control heifers. There was little difference in carcass grades between lots of heifers.

In Experiment II, III, and IV, the amount of trace minerals furnished in the supplement was increased over that used in Experiment I. The amount of minerals supplied per pound was as follows: trace mineral, Mn, 200 mg.; Zn, 41 mg.; Fe, 300 mg.; Cu, 60 mg.; Co, 10.4 mg.; and I, 13.6 mg. The trace mineral with high zinc furnished the same as trace mineral, except the zinc level was 545 mg. per pound. The chelated trace mineral furnished the following: Mn, 15 mg.; Zn, 19.5 mg.; Fe, 14.5 mg.; Cu, 4.4 mg.; Co, 3.7 mg.; and I, 7.7 mg.

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Experiment IV was conducted with 32 yearling heifers fed a fattening ration for 125 days. The treatment and rations were the same as used in Experiment III. There was a significant increase in gain ($P < .05$) of the trace mineral supplemented heifers over the control lot. There was no difference in gain among the trace mineral lots. There was also an increase in daily feed intake and feed efficiency in favor of the trace mineral supplemented heifers. There was little difference in carcass grades between lots, however, heifers fed the trace mineral and the trace mineral with high zinc had higher dressing percents than the controls.

INTRODUCTION

Cattle feedlot operators are, at present, receiving lower net returns on their cattle. This lower return greatly emphasizes the importance of providing means for increasing gain and feed efficiency in cattle. Little is known about the need for trace minerals in feedlot rations in Montana. There has also been little work with trace minerals using barley as the chief basal component of the diet. Many experiment station tests have shown some need for trace minerals when corn was the main component of the diet.

The addition of trace mineral supplements to the ration is relatively inexpensive. Thus, if a response in terms of weight gain and feed efficiency could be obtained with the use of trace mineral supplements, they would be of importance in increasing the net returns of the feeders. Chelated trace minerals have been used in monogastric animals to obtain increases in gain and feed efficiency. These minerals are more expensive per pound than the common trace minerals, but smaller amounts are recommended to be added to the ration.

Because trace minerals may be of importance in beef cattle rations, there is a need to determine if a response will be obtained by adding these minerals. The objectives of the experiments reported in this manuscript were to evaluate the use of trace minerals for feedlot cattle in Montana.

The trace minerals used in these studies were commercial trace mineral mixtures commonly used in commercial feeds.

REVIEW OF LITERATURE

Many minerals have been found to occur in animal tissues. These minerals are generally regarded as either macro- or micro-nutrients. According to Lamb et al. (1957) in animal physiology, it is customary to regard any element which normally occurs in, or is required by, the higher forms of animal life in amounts greater than those of iron as a macro-nutrient and to include among the micro-nutrients all those elements which normally occur or are required in amounts no greater than those of iron. Morrison (1959) stated that as late as thirty years ago, little was known about the need for any of this micro-minerals. Of the micro-nutrient minerals, iron, copper, zinc, manganese, cobalt, and iodine are necessary for animal life (Gilbert 1948).

THE BIOLOGICAL FUNCTIONS OF MINERALS

The biological functions of minerals were classified by Mitchell (1947) as follows: (1) minerals contribute to the structure of the body, (2) minerals participate in the functional activities of the body, such as muscular activities, (3) they aid in maintaining the status quo of the tissues already formed against the constant erosion of the life processes, and (4) as integral parts of enzyme systems in the tissues, minerals aid materially in the metabolizing of organic food nutrients.

EXPERIMENTAL EVIDENCE OF THE NEED FOR TRACE ELEMENTS

Cobalt

Cobalt is needed for the production of vitamin B₁₂ by the rumen micro-organisms (Underwood 1962).

According to the NRC requirements (1963), the believed cobalt requirement of beef cattle falls between 0.07 and 0.10 mg, per 100 pounds body

weight. Lamb et al. (1957) stated that one mg, of cobalt per day for an adult cow will be satisfactory. Tillman (1964) reported that beef cattle require 0.07 parts per million (ppm) of cobalt daily.

Apparently all feedstuffs are not adequate in cobalt content. Hale et al. (1950), using chicks as an assay animal, determined the relative amount of vitamin B₁₂ in the rumen of a cobalt deficient sheep as compared to a cobalt treated animal. In the assays, there was an average difference of 42 grams of growth, favoring the cobalt supplemented sheep, when chicks were fed ingesta from the two sheep. These data tend to show that vitamin B₁₂ production was limited in the rumen of the cobalt deficient sheep when compared to the production of the vitamin in the rumen of the cobalt-fed sheep.

Keener and Percival (1950) reported that sheep supplemented with cobalt gained approximately seven times as much in weight, were eating five times as much concentrates, six times as much hay, and were drinking twice as much water as cobalt deficient animals. Klosterman et al. (1951) found that the addition of cobalt to a ration, containing wheat straw, cane molasses, field peas, and cerelese, significantly increased ($P < .05$) the value of protein for growing ewe lambs.

In a fattening ration composed of sorghum silage, ground corn, and soybean meal, Tsien et al. (1960) found that adding a 20 mg. bullet containing 90 percent cobalt oxide significantly increased ($P < .01$) the gains of cattle. Feeding cobalt in soybean meal at the rate of 0.75 mg. per day for the first 90 days and then 1.5 mg. for the last 80 days produced average daily gains of 2.00 pounds compared to 1.70 pounds for the control lot,

when cattle are fed a sorghum grain, alfalfa hay ration (Koch et al. 1961). This difference was significant ($P < .01$). In grazing trials, cattle fed 0.8 mg. of cobalt daily gained 189 pounds compared to 153 pounds for the control group (Chapman and Kidder 1963). However, this difference was non-significant ($P > .05$).

Not all workers have obtained an increase in production by supplementing cobalt. Smith et al. (1961) reported that when grazing steers consumed 0.38 mg. of cobalt daily, there was no increase in average daily gain. Embry and Dittman (1961) and Thomas et al. (1961) obtained no increase in gain when cobalt bullets were administered to grazing yearling steers.

Lamb et al. (1957) found that 100 mg. of cobalt may be fed per day to cows and not be toxic. Salsbury et al. (1956) reported that 12 ppm of cobalt caused some depression of cellulose digestion in vitro, and 100 ppm of cobalt caused a pronounced depression. McNaught et al. (1950), also working with in vitro studies, found that rumen bacteria were able to tolerate 10 ppm of cobalt but 1000 ppm inhibited bacterial growth.

It has been reported by Keener et al. (1951) that cobalt in the form of carbonate was absorbed in appreciable quantities as indicated by its presence in the blood and urine. Keener and Percival (1950) had reported that both cobalt carbonate or sulfate would relieve a cobalt deficiency in sheep. An intravenous injection of cobalt sulfate brought about a slow response, in deficient animals, if administered daily or in large quantities twice a week.

Copper

Copper is known to have many functions. According to Underwood (1962),

copper is important in the production of hemoglobin, the processes of pigmentation of hair and wool, and myelination of the spinal cord. Copper is also present in the oxidative enzymes at cellular level, needed for proper bone formation, keratinization of wool, and normal reproduction.

According to the NRC (1963) standards for beef cattle, the daily requirement of copper is between two and four mg. per pound of total air dry feed. Tillman (1961) noted that beef animals require five ppm of copper. Tillman (1964) stated that requirements of copper are 5 to 10 ppm.

Although the requirements of copper are small, feedstuffs are known to be deficient. The use of copper supplements for curing or preventing diseases such as "swayback" and "falling disease" in sheep has been practiced for some time (Gilbert 1948). Arthur et al. (1959) found that a conditioned copper deficiency in cattle in Eastern Ontario is alleviated by feeding two grams of copper sulfate per animal daily.

When copper, cobalt and manganese were fed free choice to calves, Dent et al. (1956) obtained an increased daily gain of 0.3 pound which was significant at the 10 percent level. There was also increased feed consumption as well as increased feed efficiency.

Considerable research has been carried out concerning the toxicity of copper. Chapman et al. (1962) administered to steers 0.5, 1.0, 2.0, 4.0, 8.0, grams of copper sulfate daily in a gelatin capsule. It was found that administering copper sulfate in this manner was not toxic. Increasing the level of copper sulfate to 12 grams daily did not create a toxic syndrome. However, when 12 grams of copper sulfate was administered in a water drench, the copper sulfate was toxic. Kidder (1949) reported that a 500 pound steer

developed chronic copper poisoning and died in 122 days when five grams of copper sulfate was given daily as a drench. It has also been reported (Anonymous 1957) that 0.25 grams of copper per day per 1000 pounds of body weight produces a toxicity in cattle.

Arthur et al. (1959) has reported that three to five grams of copper sulfate daily for three years showed no ill effects. According to McNaught et al. (1950) rumen bacteria will tolerate 10 ppm of copper but the bacteria are inhibited by 25 ppm of copper.

It appears that the form in which copper is administered to the animal is important. Lassiter and Bell (1960) reported that the concentration of copper in blood and plasma was significantly higher ($P < .05$) after oral administration of copper chloride than after copper sulfate, copper nitrate or cupric oxide needles. Lassiter also found that the copper concentration of blood and plasma was higher after use of the oral carbonate source compared to the copper oxide source. Chapman and Bell (1963) in a series of experiments determined the availability of copper from several sources using Cu-64 labeled compounds. Cupric oxide powder had a relatively low absorption rate and a high rate of fecal excretion. Cupric oxide needles and copper wire had a low absorption rate, but passed slowly through the body. Cuprous oxide had a moderate rate of absorption, but a high rate of urinary excretion. Cupric carbonate had the highest rate of absorption, but also the highest rate of excretion. Copper sulfate had a moderate rate of absorption and had a low excretion rate indicating a favorable retention. Cupric nitrate and copper chloride compared favorably with copper sulfate.

Iron

According to Underwood (1962), iron is concerned in the oxidative mechanism of all cells. Iron is also important in oxygen transport as part of the hemoglobin molecule, and it is present in iron containing flavo-proteins.

The iron requirements for cattle are unknown (NRC 1963). However, according to Tillman (1961 and 1964), the iron requirement of beef cattle is 80 to 150 ppm. Underwood (1957) stated that no true iron deficiency has ever been recorded except in pigs. This seems to be the case as Bentley et al. (1954), Smith et al. (1964), and Kolari and Harvey (1964) failed to get an added response when iron was added to rations for cattle. However, Hoefler et al. (1958) obtained an increased daily gain of 0.31 pounds when pigs were supplemented with 100 ppm of iron.

McNaught et al. (1950) found that rumen bacteria will tolerate 100 ppm of iron but 1000 ppm will inhibit the bacteria.

Manganese

Manganese is involved in the calcification of bone (Underwood 1962). Manganese is also important in reproduction and it has a lipotropic action. Manganese in the animal may also be concerned with the development of the pituitary gland and the regulation of the sex glands (Gilbert 1948).

Manganese requirements of beef cattle are uncertain but appear to be met with as little as 2.7 to 4.5 mg. per pound in the air-dry ration (NRC 1963). Tillman (1964) stated that the manganese requirement is 15 to 30 ppm. Since many roughages contain 22.5 to 67.5 mg. per pound of manganese on a dry basis, and grains other than corn contain 6.75 to 22.5 mg. per pound, it seems unlikely that most beef cattle rations require manganese

supplementation (NRC 1963). However, when Lassiter and Alligood (1963) fed either 3.4 or 7.5 mg. of manganese per pound of a corn, soybean meal and hay ration to cattle, there was a significant difference ($P < .01$) in digestibility between the two treatments in favor of the latter.

Rojas and Dyer (1964) observed that all calves born to manganese deficient dams were deformed. The ration of the deficient dams contained 15.8 ppm of manganese. Chamberlain and Burroughs (1962) found that when manganese was omitted from the rumen medium that cellulose digestion decreased. Chamberlain's data suggested that there were two possible pathways for cellulose degradation; one way is to make use of the manganese or magnesium ion, while the alternate pathway doesn't make use of either of these ions. However, Hubbert et al. (1958) obtained no increase in cellulose digestion when manganese was added to a manganese deficient medium.

Embry et al. (1958), working with cattle, obtained no added response when 30 ppm of manganese was added to a ration containing 15 ppm of manganese. There was also no response when up to 1000 ppm of manganese was added to a corn, cottonseed meal, molasses ration for cattle (Robinson et al. 1963). At the higher levels of manganese, iron absorption and fiber digestibility were reduced.

Cunningham et al. (1962) found that feeding up to 818 ppm of manganese to calves would not adversely affect weight gains, feed efficiency or feed intake. Hansard et al. (1960), studying the effects of high manganese on rats, reported that either 500 or 1000 ppm of manganese depresses growth and iron absorption. Hansard also stated that excess daily manganese added to a low phosphorus diet drastically reduces iron utilization by the red blood

cells.

Zinc

According to Underwood (1962) zinc is a constituent of the enzymes carbonic anhydrase, carboxy peptidase, alkaline phosphatase, and alcohol dehydrogenase. Zinc is also a cofactor of many other enzymes as well as being needed for proper keratinization of the skin. Gilbert (1948) stated that zinc is also a constituent of insulin crystals.

Zinc requirements have not been established for beef cattle (NRC 1963). Tillman (1961 and 1964) has reported, however, that the requirement of beef cattle is 30 ppm.

It has only been recently that research has shown a need for supplemental zinc in cattle. Zinc supplementation of beef cattle rations may also become increasingly more important with greater use of high-concentrate feeds (Anonymous 1964). Miller and Miller (1960) found that calves on a diet containing 2.7 ppm of zinc developed a zinc deficiency, while animals receiving 46 ppm zinc remained normal. The body weight gain per week was approximately 10.5 pounds for the calves receiving 46 ppm zinc and 8.0 for calves receiving 2.7 ppm zinc. Miller and Miller (1962) observed that calves receiving a purified basal diet developed parakeratosis, while calves receiving the basal plus 43 ppm of zinc remained normal. It was also found that adding 260 ppm zinc to zinc deficient animals brought about recovery.

Smith et al. (1962) obtained significant differences ($P < .01$) in gain with lambs when 100 ppm zinc was added to a basal ration containing 2.7 ppm zinc. The daily gains were 0.06 pounds for the basal ration and 0.54 pounds for the zinc supplemented ration. Ott et al. (1964) also obtained

significant increased ($P < .01$) daily gain and feed efficiency in lambs when zinc was added to the basal ration.

According to Legg and Spears (1960), cows that had body lesions similar to those produced on rats fed zinc deficient diets, were fully recovered in three weeks after zinc sulfate was administered. Green et al. (1962) has reported a significant increased ($P < .01$) gain and feed efficiency when zinc was added to the diets of pigs. Miller et al. (1962), working with calves, obtained no response when zinc was added to the diet. McElroy (1964) also failed to get a response in rate of gain or feed efficiency when zinc oxide was added to the ration of steers.

"High" Levels of Zinc

Ott et al. (1963) reported that when 100 ppm of zinc was added to a basal ration containing 2.7 ppm zinc, the daily gain of calves was increased from 0.54 pounds to 1.20 pounds, and the feed required per 100 pounds of gain was 993 and 392 pounds respectively. Hoaranen and Hyppola (1961) reported that feeding 100 mg. of zinc per day per 100 pounds of body weight, prevented itching and hair sticking in dairy cows. These symptoms were associated with reduced milk production.

Beeson et al. (1962) found that adding 100 ppm of zinc to a basal ration containing 24 ppm of zinc increased gain of steers by 17 percent, feed consumption by 5.1 percent and feed efficiency by 11 percent. The difference in gain was significant ($P < .05$).

Smith et al. (1964) reported a significant increase in gain ($P < .05$) when 1205 mg. or 2205 mg. of zinc per day was fed to steers compared to a level of 196 mg. per day. There was, however, no effect on carcass grades

or dressing percent. Results by Wise and Barrick (1963) and Oltjen and Davis (1963) showed no response when 100 ppm of zinc was added to the basal ration of cattle.

Cox and Hale (1962) found that neither 0.2 or 0.4 percent zinc in the diet of swine produced signs of marked toxicosis, nor had an adverse effect on growth or feed consumption. Brink et al. (1959) reported that up to 0.1 percent zinc in the diet of weanling pigs is not toxic. However, 0.2 percent zinc in the diet was toxic since it depressed daily gains and feed intake. When 0.8 percent of the diet was zinc, there was body weight loss and a severely depressed feed intake. According to Hansard et al. (1957), the addition of zinc at 0.5 or 1.0 percent of the diet caused a marked decrease in net retention and in the apparent and true digestibility of calcium in sheep.

TRACE MINERALS IN COMBINATION

Although an individual element will, in many cases, not give a response, as reported previously, a combination of more than one element may give a response. Underwood (1957) reported that the dietary level as well as the proportion of trace minerals are extremely important. In many experiments where alfalfa ash or molasses ash were used as a supplement, there was an increase in production which may be due to the trace minerals in the ash (Klosterman et al. 1953, Bentley et al. 1952, Bentley et al. 1954). Bentley et al. (1954) found that when either alfalfa ash or trace minerals were added to steer rations that the average daily gain was significantly increased ($P < .05$): 1.34 pounds for basal, 1.96 pounds for basal plus trace minerals, and 1.89 pounds for basal plus ash. There was also an increase in feed

efficiency and consumption.

Lassiter et al. (1958) working with dairy heifers, added alfalfa ash to a ration containing corn cobs plus 5.6 pounds of a soybean meal-grain mixture. The supplemented heifers gained 1.47 pounds daily compared to 1.26 pounds for the control group. The supplemented group also required less feed per pound of gain, 12.40 compared to 14.70 for the control group.

Nicholson et al. (1960) reported that alfalfa ash increased the rate of digestion and efficiency in calves. Swift et al. (1951) working with sheep, found that alfalfa ash increased the mean digestibility of every ration constituent; however, only the digestibility of crude fiber was found to be significant ($P < .01$). Chappel et al. (1955) also found that alfalfa ash significantly increased ($P < .01$) the digestibility of crude fiber as well as organic matter in sheep.

Bentley and Moxon (1952) added trace minerals to a basal ration of corn cob meal, and poor timothy hay and obtained a 43 percent increase in gain with calves. When trace minerals were added to a corn, prairie hay, soybean meal ration, for steers, the average daily gain was 3.52 pounds for the controls and 3.78 pounds for the trace mineral supplemented group (Koch et al. 1960). The carcass grades were about the same between groups. Smith et al. (1959) supplied trace minerals to a corn, prairie hay ration for fattening cattle in the following amounts per day: cobalt, 1.25 mg.; copper, 3.65 mg.; iodine, 1.97 mg.; iron, 46.13 mg.; manganese, 56.3 mg.; and zinc, 3.42 mg. There was an improvement of 0.33 pounds of gain per day with the addition of trace minerals. Oltjen et al. (1959) fed the same levels of trace minerals as above and obtained a significant increase

($P < .01$) in gain with fattening cattle. There was also an increase in consumption and efficiency of gain. Oltjen et al. (1958) obtained gains of 2.51 pounds per day for controls and 2.88 pounds per day for Hereford heifers when the rations were supplemented with trace minerals. The carcass data were similar between lots.

Carmack et al. (1960) found that adding trace minerals to a fattening ration for calves, containing either corn or sorghum grain, significantly increased ($P < .05$) gains. Nelson et al. (1957) observed that steers on range grass supplemented with cottonseed meal had greater gains than when part of the cottonseed meal was replaced with urea as a protein source. When trace minerals were present in the urea supplement, there was no difference in gains. Nelson also noted that the steers utilized little if any of the urea without the addition of trace minerals. Thomas et al. (1953) found that steers supplemented with soybean meal gained significantly faster ($P < .01$) than steers supplemented with urea. However, when trace minerals were added to the urea there was no difference in gain of steers when supplemented with the urea or soybean meal. Klosterman et al. (1956) fed a full feed of ground ear corn and two levels of protein, 1.5 pounds or 0.75 pounds of soybean meal per day to fattening cattle. Trace minerals were added as follows per day: iron, 800 mg.; manganese, 200 mg.; copper, 25 mg.; zinc, 14 mg.; and cobalt, 0.5 mg. The addition of the trace minerals significantly increased ($P < .05$) the rate of gain at both protein levels. However, the increase was greater at the higher protein level. Klosterman noted that the lower protein ration was deficient in both protein and trace minerals, but the addition of protein was of little benefit

without the addition of trace minerals.

Renbarger et al. (1964) supplied trace minerals to an all barley ration, for fattening calves, in the following amounts: Fe, 1000 mg.; Cu, 40 mg.; Co, 3 mg.; Zn, 300 mg.; Mn, 163 mg.; and I, 1 mg. When zinc, cobalt, and iron were added to the ration, the daily gain was 3.19 pounds compared to 2.60 pounds for the control group. When all six trace minerals were added, the daily gain was 3.03 pounds. Feed efficiency was also increased by adding trace minerals. It appeared from these results that adding trace minerals other than zinc, cobalt, and iron would be of no benefit.

Perry et al. (1960), working with fattening lambs, found no advantage from feeding trace minerals. Hubbert et al. (1958) got no added response in cellulose digestibility when each trace mineral was added individually to a deficient medium obtained from the rumen of a steer fed a high corn cob ration. Moody et al. (1958) could attribute no effect on production to trace minerals when dairy cows were fed a ration of high-quality alfalfa hay plus grain mix. Nelson et al. (1956), in a series of experiments, obtained no response when trace minerals were added to the diet of two and three year old stocker cows during winter grazing, weanling heifer calves fed prairie hay free choice, yearling and two year old steers on grass or reproducing cows. Gossett and Riggs (1956) reported no response to trace mineral supplementation of diets for growing beef calves fed poor quality prairie hay. No advantage was obtained by adding trace minerals to rations for fattening steers (Gossett et al. 1962, McCarter et al. 1961, Pope et al. 1959).

Formica et al. (1957) reported that trace minerals somewhat depressed

gains of fattening cattle. Plumlee et al. (1953) also reported that the appetite of beef calves was depressed when trace minerals were fed.

AVAILABILITY OF CHELATED TRACE MINERALS

Cardon (1963) stated that for all practical purposes, trace minerals are tied up as mineral-organic complexes. These metal-organic compounds are really chelated complexes. Trace minerals are powerful co-chelators, and the nutritional importance of trace minerals is related to their ability to form these complexes. Animal feeds contain a variety of substances which can act as chelating agents for trace minerals present in the rations. All too often, the complexes, so produced, are insoluble, and its availability for absorption is reduced. Because solubility is necessary for absorption, anything which reduces solubility will, of necessity, reduce availability. Therefore, one may add special chelating agents to the ration which will form soluble complexes with the trace minerals.

Rubin and Princiotto (1963), reporting on some of the chemistry of the chelating phenomenon, defined metal chelates as "cyclic structures of metal atoms and organic ligand formed by donation of electrons from the ligand donor atoms, usually oxygen, nitrogen, or sulfur, to the electron acceptor metal ion. The chemical bond formed in this manner may vary in characteristics from the covalent to the almost completely ionic type. The typically five or six membered ring structure of the chelate may be a labile one with the metal ion in a loose and tenuous equilibrium with the organic ligand or may be of the rigid geometry and tight metal-binding characteristics of the metal porphyrins."

Little work has been done regarding chelated trace minerals in rumin-

ants, however, there has been much interest in the swine and poultry field during the last few years. Kratzer et al. (1959) reported that 150 ppm of zinc must be added to a basal ration containing 25.5 ppm of zinc to get optimum growth and perosis prevention in turkey poults. However, when 227 ppm of Ethylenediaminetetracetic acid (EDTA) was added to the basal ration, the zinc required was reduced to 40 ppm. Scott and Zeigler (1963), working with chicks, reported that when five mg. of zinc was added per kilogram of diet, the addition of 300 mg. of EDTA resulted in markedly improved growth. Green et al. (1961) found that EDTA decreased the fecal excretion of zinc and increased the urinary excretion and the liver storage of zinc in growing pigs. He also found that the addition of 200 ppm of zinc or 450 ppm of EDTA, to a basal ration containing 44 ppm of zinc, produced daily gains of 0.95 pound, 0.81 pound, and 0.57 pound, respectively. According to Green et al. (1962), the addition of EDTA to the ration of pigs significantly improved ($P < .01$) feed efficiency and also improved gain.

Darwish and Kratzer (1963) observed that 45 to 47 percent of orally given EDTA was absorbed in hens. It was found that EDTA was metabolized somewhat as shown by EDTA labeled carbon atoms being found in the carbon dioxide and urine.

Davis et al. (1962) studied the effect of EDTA, in combination with zinc, manganese, copper, and iron in rations for chicks. It was found that the addition of EDTA increased gain on a low zinc diet. It was also found that the highest level of zinc plus EDTA gave the same results as that level of zinc without EDTA, indicating that EDTA itself is not growth stimulating. Davis also obtained an increase in growth, with the addition of

EDTA to the diet, when manganese or copper were deficient in the ration. It was also shown in the work with manganese that EDTA itself does not promote growth. No response was obtained when EDTA was added to an iron deficient ration. Rubin and Princiotto (1963) reported that there is some absorption of the Fe EDTA complex. They also found that chelating cobalt with EDTA provided cobalt in a non-toxic biologically available form. Miller et al. (1963) reported that there was no increase in transfer of iron from chelates as measured by placental and mammary transfer with sows.

Other compounds are also used as chelating agents. Miles and Watts (1963) found that 400 grams of EDDHA (ethylenediamine di (o-hydroxy-phenylacetic acid) tends to promote rapid growth. When 1200 grams of EDDHA was added, growth was depressed.

The property of a chelating agent that may give it the ability to make trace minerals more available is the stability constant of the chelating agent. Kratzer and Vohra (1963) reported that a stability constant between 12 and 17 was the most favorable for growth promoting activity of chelates on zinc. Vohra and Kratzer (1964) found that EDTA and hydroxyethylethylenediaminetriacetic acid (HEDTA) stability constants of 14.5 and 16.5 improved the availability of zinc, in turkey poults, while 1,2-Diaminocyclohexanetetraacetic acid (CDTA) and Diethylenetriaminepentaacetic acid (DTPA), stability constants of 18 or over were not suitable for improving the availability of zinc. According to the same workers, the mechanism involved may be that the chelating agent has a stronger stability constant for the metal than the metal binding substance in the food. The mineral would then be complexed with the chelating agent in the gastrointestinal tract. After

absorption the metal might be available for specific body functions if it can be removed from the chelating agent. This means that the various systems in which the metal is required for proper functions (enzymes) should have a higher stability constant for the metal than the chelating agent. Thus the reason that CDTA and DTPA were not acceptable is that their stability constant was too high for the metal to be removed by the body. It was speculated here that chelating agents with stability constants below 13 may not be able to release zinc from its bound form, and a compound with a stability constant above 16.5 chelates the metal too strongly.

PROCEDURE

These experiments were conducted at the Nutrition Center located one mile west of the Montana State College campus, Bozeman, Montana. The experimental area consisted of eight pens, four separated but adjoining pens on each side of a feeding alley. Fenceline bunks were used with salt boxes located in the end of the bunk for each lot. There was one electrically heated watering cup per two lots. A board fence completely surrounded the feeding area. The surface of the feeding pens was covered with asphalt.

Upon arrival at the Nutrition Center, the calves were branded with the college brand and vaccinated for Blackleg and Infectious Bovine Rhinotracheitis (Red Nose).

The calves were hand fed twice daily. The feed was weighed and mixed in large cans and spread in the bunks. The same concentrate mixture, 80 percent barley and 20 percent beet pulp was fed to all lots. The grass hay fed was of approximately the same composition each year. Straw was used as bedding and it was added to the back half of the pen as needed. The front portion, next to the feed bunk, was kept as clean as possible.

Initial and final weights of heifers were taken after a 15 hour overnight shrink. The calves were individually weighed every 28 days throughout the feeding trial. All of the calves were ear-tagged for identification purposes.

Experiment I. Effect of Trace Mineral Supplements on the Performance of Fattening Heifer Calves.

Experiment I was designed to evaluate the addition of three commercial trace mineral mixtures to fattening rations fed heifer calves. The trace minerals added were: cobalt, copper, iron, manganese, iodine, and zinc. The experimental animals used in the experiment consisted of 32 head of Hereford heifer calves weighing approximately 515 pounds. The calves were bred and raised by the Montana Agricultural Experiment Station, Red Bluff Ranch, Norris, Montana. The calves were weaned October 9, 1962, and trucked to the Nutrition Center on the following day. The calves were grouped into four pens and fed a wintering ration of native hay and grain until the experiment began.

The 32 head of heifers were allotted to their respective lots prior to the start of the experiment. The heifers were stratified according to individual weights and randomly assigned to one of four lots. Each lot was randomly assigned to one of the four treatments.

All of the calves received the same basal ration, the only difference being the kind and amount of trace minerals in the protein supplement. The trace minerals added to each were as follows: Lot 5, received trace minerals; Lot 6, no trace minerals; Lot 7, chelated trace mineral; Lot 8, trace minerals plus high zinc. The design of the experiment, and the composition of the protein supplements with trace mineral additions are shown in Table I. The composition and cost of trace mineral supplements are shown in Appendix Table IV.

The protein supplement pellet was calculated to contain 20 percent

protein. Vitamin A was added to supply 5,000 I.U. per pound of supplement. The supplemental pellet was pelleted into a $\frac{1}{2}$ inch pellet. The calves were fed two pounds of supplement per head per day throughout the experiment. At the beginning of the experiment, the concentrate was gradually increased and the hay was decreased until the calves were eating three pounds of hay daily and receiving concentrate ad libitum. The concentrate supplied was a mixture of 80 percent steam rolled barley and 20 percent molasses beet pulp. The hay fed was native grass hay.

TABLE I. DESIGN OF THE EXPERIMENT AND COMPOSITION OF PROTEIN SUPPLEMENT AND TRACE MINERAL ADDITION -- EXPERIMENT I.

Lot No.	5	6	7	8
MSC Formula No.	306	304	307	305
Type of trace mineral	Trace mineral	No trace mineral	Chelated trace mineral	Trace mineral plus high zinc
Ingredients	Percent of rations			
Barley	45	45	45	45
Safflower meal	40	40	40	40
Diammonium phosphate	4	4	4	4
Calcium carbonate	5	5	5	5
Vitamin A <u>1/</u>	X	X	X	X
Salt	1	1	1	1
Molasses	5	5	5	5
Trace minerals <u>2/</u>	0.1	0.0	0.1	0.1

1/ Vitamin A added to provide 5,000 I.U. per pound.

2/ Trace mineral added to provide the following amounts per pound of supplemental feed. Trace mineral: Mn, 20 mg.; Fe, 30 mg.; Cu, 6 mg.; Zn, 4.09 mg.; I, 1.36 mg.; and Co, 1.04 mg. Chelated trace mineral: Mn, 7.5 mg.; Fe, 7.3 mg.; Cu, 2.2 mg.; Zn, 9.8 mg.; I, 3.9 mg.; and Co, 1.9 mg. Trace mineral plus high zinc: Mn, 45.5 mg.; Fe, 45.5 mg.; Cu, 4.5 mg.; Zn, 45.5 mg.; I, 0.45 mg.; and Co, 0.45 mg.

In addition to the trace mineral treatments, one half of the calves in each lot were injected three times with 5,000 I.U. of vitamin A. One injection was given prior to the fattening period December 6, 1962 and the other two injections on March 7, 1963 and April 25, 1963.

The 144-day fattening period began February 28, 1963 and was terminated July 22, 1963. The heifers were sold on the basis of carcass grade and yield to a slaughtering plant at Butte, Montana. Carcass data were obtained at the time of slaughter.

Experiment II. Effect of Trace Mineral Supplements on the Performance of Wintering Heifer Calves Under Drylot Conditions.

Experiment II was designed to determine the effects of three commercial trace mineral supplements on the performance of heifer calves fed a wintering ration. The trace minerals added were the same as Experiment I except for the trace mineral containing the high level of zinc. Higher levels of trace minerals were used than in the preceding experiment as shown in Table II and Appendix Table IV. The animals used in this experiment consisted of 38 heifer calves weighing approximately 425 pounds. Twenty-four Hereford heifers were bred and raised by the Montana Agricultural Experiment Station,

TABLE II. DESIGN OF THE EXPERIMENT AND COMPOSITION OF PROTEIN SUPPLEMENT AND TRACE MINERAL ADDITION -- EXPERIMENT II.

Lot No.	5	6	7	8
MSC Formula No.	362	361	363	364
Type of trace mineral	Trace mineral	No trace mineral	Trace mineral plus high zinc	Chelated trace mineral
Ingredients	Percent of rations			
Barley	20	20	20	20
Wheat millrun	40	40	40	40
Alfalfa, dehydrated	5	5	5	5
Soybean meal	10	10	10	10
Cottonseed meal	10	10	10	10
Linseed meal	5	5	5	5
Calcium carbonate	3	3	3	3
Dicalcium phosphate	1	1	1	1
Molasses	5	6	5	6
Vitamin A <u>1/</u>	X	X	X	X
Trace minerals <u>2/</u>	1.0	0.0	1.0	0.2

1/ Vitamin A added to supply 30,000 I.U. per pound.

2/ Trace mineral added to provide the following amounts per pound of supplemental feed. Trace mineral: Mn, 200 mg.; Zn, 41 mg.; Fe, 300 mg.; Cu, 60 mg.; Co, 10.4 mg.; I, 13.6 mg.; and Mg, 908 mg. Trace mineral plus high zinc: same as trace mineral but Zn, 545 mg. Chelated trace mineral: Mn, 15 mg.; Zn, 19.5 mg.; Fe, 14.5 mg.; Cu, 4.4 mg.; Co, 3.7 mg.; and I, 7.7 mg.

Red Bluff Ranch, Norris, Montana. Four Angus heifer calves were bred and

raised at the Montana State College Experiment Farm, Bozeman, Montana. The remaining ten heifers used in the experiment were purchased from a Hereford breeder in the Gallatin Valley.

The Red Bluff heifers were weaned on October 8, 1963, and were trucked to the Nutrition Center at Bozeman the following day. The Angus heifers and the purchased heifers arrived at the Nutrition Center during the next week. The calves were grouped into four pens and fed grass hay until the wintering trial was initiated.

The calves were allotted to their respective lots prior to the start of the experiment. The heifers were stratified according to individual weights and randomly assigned to one of the four lots. It was planned that six heifers from the Red Bluff Ranch, one Angus heifer, and three purchased heifers would be assigned to each lot. However, two purchased heifers had to be removed from Lot 8 due to sickness. Each lot was randomly assigned to receive one of four treatments.

All of the calves received the same basal ration, the only difference being the trace minerals supplied in the protein supplement. The trace minerals added to each treatment were as follows: Lot 5, trace mineral; Lot 6, no trace mineral; Lot 7, trace mineral plus high zinc; Lot 8, chelated trace mineral.

The protein supplement was calculated to supply 20 percent protein, and vitamin A was added to supply 30,000 I.U. per pound of supplement. The protein supplement was made into crumbles. The design of the experiment and the composition of the supplemental crumbles with trace mineral additions are shown in Table II. The composition and cost of the trace

mineral supplements are shown in Appendix Table IV.

The heifers were given one pound of supplement per head per day throughout the experiment. The concentrate mixture (80 percent steam rolled barley and 20 percent molasses beet pulp) was held equal between lots. At the beginning of the trial, each calf received three pounds of the concentrate mix. This amount was increased one pound every two weeks for the duration of the experiment. In addition to the concentrate and supplement, the calves received grass hay ad libitum.

The 84-day wintering trial began November 21, 1963 and ended February 13, 1964.

Experiment III. Effect of Trace Mineral Supplementation on the Performance of Heifer Calves on a Fattening Ration.

The 38 head of heifer calves used in the previous wintering trial (Experiment II) were used in this fattening trial. The heifers remained in the same lots and on the same treatments of trace mineral (Table II) that they received during the wintering trial. The final weights of the wintering period were used as the initial weights of the fattening period.

The protein supplement was fed at the rate of one pound per day. The concentrate mixture, the same in composition as Experiment II, 80 percent steam rolled barley and 20 percent beet pulp, was gradually increased until the calves were consuming this ad libitum. The hay was simultaneously decreased with the increase in concentrate, until the calves were consuming three pounds daily. They were fed this level of hay for the remainder of the trial. The 135-day fattening period began on February 13, 1964 and ended June 27, 1964. The heifers were sold on the basis of carcass grade and yield to a slaughtering plant in Butte, Montana. Carcass data were obtained at the time of slaughter.

Experiment IV. The Effect of Trace Mineral Supplementation on the Performance of Yearling Heifers on a Fattening Ration.

This trial was designed to evaluate the effect of trace minerals on the performance of yearling heifers fed a fattening ration. The experimental animals used in this trial consisted of 32 yearling heifers, all from one ranch in western Montana. There were seven Angus heifers, and the remaining heifers were Hereford. The heifers weighed approximately 600 pounds at the start of the experiment. Upon arrival at the Nutrition Center, the heifers were given grass hay ad libitum and a small amount of concentrate before the trial began. The heifers were also injected with high levels of estrogen to abort any pregnant heifers.

The 32 heifers were allotted to their respective lots prior to the start of the experiment. The heifers were stratified according to individual weights and randomly assigned to one of four lots. Lots II, III, and IV had two Angus heifers per lot, and Lot I had one Angus heifer. Each lot was randomly assigned to one of four treatments. The treatments were the same as Experiment II (Table II). The trace minerals added to each lot were as follows: Lot 1, trace mineral; Lot 2, no trace mineral; Lot 3, chelated trace minerals; Lot 4, trace minerals plus high zinc. The design of the experiment is shown in Table III.

TABLE III. DESIGN OF EXPERIMENT AND TYPE OF TRACE MINERAL FED TO YEARLING HEIFERS ON A FATTENING RATION -- EXPERIMENT IV.

Lot No.	1	2	3	4
MSC Formula No. <u>1/</u>	362	361	364	363
	Trace mineral	No trace mineral	Chelated trace mineral	Trace mineral plus high zinc

1/ Composition of supplemental feeds are shown in Table II.

The same basal ration was fed to each lot. The heifers were given hay ad libitum at the start of the trial. The hay was gradually decreased as the concentrate mixture increased, until the heifers were eating three pounds of hay per day and receiving the concentrate mixture ad libitum. The concentrate was the same as in the preceding experiments. The protein supplement was fed at the rate of one pound per animal per day.

The 125-day trial began on November 26, 1963 and ended March 30, 1964. The heifers were sold on a carcass grade and yield basis to a slaughtering plant in Butte, Montana. Carcass data were taken at the time of slaughter.

RESULTS AND DISCUSSION

Experiment I

The pertinent data of this 144-day fattening trial concerning the average daily gains, feed consumption, efficiency of feed utilization, financial returns and carcass data are summarized in Table IV.

TABLE IV. AVERAGE WEIGHT GAINS, DAILY FEED INTAKE, FEED EFFICIENCY, FINANCIAL RETURNS AND CARCASS DATA FOR HEIFERS FED RATIONS DIFFERING IN THE AMOUNT OF TRACE MINERAL SUPPLEMENTATION-- EXPERIMENT I. (February 28, 1963 to July 22, 1963 -- 144 days).

Lot No.	5	6	7	8
Treatment	Trace mineral	No trace mineral	Chelated trace mineral	Trace mineral plus high zinc
No. of heifers	8	8	8	8
Average weights (lbs.)				
Initial	508	515	511	525
Final	799	800	805	817
Gain	291	285	294	292
Daily gain	2.02	1.98	2.05	2.02
Average daily feed consumption (lbs.)				
Barley	10.0	9.9	10.1	9.2
Beet pulp	2.5	2.5	2.6	2.3
Protein supplement	1.8	1.9	2.0	2.0
Hay	3.2	3.1	3.2	3.1
Salt	.06	.05	.05	.05
Feed per cwt. gain (lbs.)	868	882	874	824
Feed cost per cwt. gain ^{1/} (\$)	17.72	18.11	18.04	16.86
Financial return per heifer (\$)				
Initial cost @ \$26/cwt.	132.08	133.90	133.86	136.50
Feed cost	51.57	51.62	53.05	49.27
Trucking	2.54	2.58	2.56	2.62
Total investment	186.19	188.10	189.47	188.39
Gross return	191.92	190.44	190.81	195.05
Net return per heifer	5.73	2.34	1.34	6.66
Carcass grades				
Choice	7	6	6	7
Good	1	2 ^{2/}	2	1
Dressing percent	58.1	57.9	57.5	57.8

^{1/} Feed costs are given in Appendix Table I.

^{2/} Both carcasses cut dark which resulted in both being lowered one grade.

The heifers used were similar in size at the beginning of the experiment. Table IV shows that there existed a 17 pound spread between the average initial weights of heifers in the four lots. There was very little difference in gain between heifers in the four lots. However, all of the heifers in the trace mineral supplemented lots gained slightly more than the heifers in the control lot.

The fastest gaining group, Lot 7 (chelated trace minerals), gained only nine more pounds than the control heifers. The other two lots of heifers gained essentially the same as the greatest gaining group. There were no significant differences at the 5 percent probability level. The analysis of covariance for total weight gains is shown in Table V.

TABLE V. ANALYSIS OF COVARIANCE FOR WEIGHT GAINS IN POUNDS OF HEIFERS ON TRACE MINERAL TREATMENTS -- EXPERIMENT I.

Variation	Initial Wt.		Final Wt.		Adjusted			Calcu- lated	Tabu- lated
	DF	SS(X)	S(XY)	SS(Y)	DF	SS	MS	F	F(.05)
Treatment	3	1415	1312	1589	3	464	155	.18	4.6
Error	28	74249	87936	127849	27	23703	878		
Total	31	75664	89348	129438	30	24167			

Because the heifers within each lot were group fed in a bunk, a statistical analysis of the amount of feed required to produce 100 pounds of gain could not be conducted. However, as shown in Table IV, the heifers in Lot 8 required 44 pounds less feed per 100 pounds of gain than did heifers in Lot 5. On a percentage basis the heifers in Lot 8 required 15 percent less feed than heifers in Lot 5. There was little difference between heifers of Lot 5 (trace mineral), Lot 6 (no trace mineral) and Lot 7

(chelated trace mineral).

The average daily feed intake was quite similar between lots. It was planned that each calf was to receive two pounds of supplement daily. However, in Lots 5 and 6, a palatability problem was encountered for a month at the beginning of the trial. The pellets of these two lots were ground into crumbles and the problem was solved. This palatability problem may have been due to diammonium phosphate being used in the supplement. Due to the rejection of the pellets by the heifers in Lot 5 at the beginning of the trial, the planned trace mineral intake for heifers in this lot was lowered somewhat. The daily trace mineral intake from the trace mineral supplements, plus the calculated trace minerals from the feedstuffs are shown in Table VI.

TABLE VI. DAILY INTAKE OF TRACE MINERALS PER CALF FOR EXPERIMENT I.

Mineral	Mn	Fe	Cu	Zn <u>1/</u>	Co	I <u>2/</u>
Milligrams per day						
Lot 5 (Trace mineral)						
Supplement	36	54	11	7	1.9	2.4
Feedstuffs <u>3/</u>	255	1124	101	100	.9	
Total	291	1178	112	107	2.8	2.4
Lot 6 (No trace mineral)						
Supplement	---	---	---	---	---	---
Feedstuffs	251	1116	100	99	.9	
Total	251	1116	100	99	.9	
Lot 7 (Chelated trace mineral)						
Supplement	15	15	4	20	3.8	7.8
Feedstuffs	257	1141	102	101	.9	
Total	272	1156	106	121	4.7	7.8
Lot 8 (Trace mineral plus high zinc)						
Supplement	91	91	9	91	.9	0.9
Feedstuffs	246	1070	96	94	.8	
Total	337	1161	105	185	1.7	0.9

1/ No value given for zinc in grass hay.

2/ No value given for iodine in feedstuffs.

3/ National Research Council. Pub. 659. 1959.

The levels of trace minerals in the basal ration must have been adequate to meet the dietary needs of the animals. With the exception of zinc, the levels in the basal ration are greater than the suggested levels of trace minerals by Underwood (1962). There may also be an effect due to trace minerals in water (Pond and Hoefler, 1961). Although no value is given in the literature on the amount of iodine in feedstuffs, the feeds used in this experiment were apparently adequate due to the fact that no response was obtained when the trace minerals containing iodine were fed.

The proximate chemical analysis of the feed ingredients used in the experiment are given in Table VII.

TABLE VII. PROXIMATE CHEMICAL ANALYSIS OF FEEDS USED DURING THE FATTENING TRIAL OF EXPERIMENT I. 1/

	Moisture	Crude protein	Ether extract	Crude fiber	Ash	Phos-phorus	Cal-cium
	%	%	%	%	%	%	%
Steam rolled barley	8.5	11.0	2.5	3.9	2.8	0.35	0.21
Molasses beet pulp	6.3	9.5	0.4	15.5	5.9	0.014	0.57
Grass hay	6.0	7.8	2.0	32.4	7.2	0.09	0.71
MSC 304 (Lot 6 No T-M)	7.2	18.5	2.6	15.4	11.0	1.26	2.52
MSC 305 (Lot 8 High Zinc)	7.5	18.9	1.6	12.7	10.7	1.16	2.26
MSC 306 (Lot 5 T-M)	6.6	20.5	2.2	14.8	13.1	1.32	2.64
MSC 307 (Lot 7 Chelated T-M)	7.1	21.9	2.1	10.6	12.0	1.18	2.81

1/ The feed analysis was conducted by the Montana State College Chemistry Department.

The injection of vitamin A had no effect upon the weight gains of the heifers, Table VIII. The average daily gains between the control and injected groups were 2.01 and 2.02 pounds, respectively. There was no significant ($P > .05$) difference in gain when heifers were injected with the vitamin A.

There was no significant difference ($P > .05$) in carcass grades or dress-

ing percent as determined by the Chi-square (Steel and Torrie, 1960), due to the different trace mineral supplements. The heifers in Lots 5 and 8 each had seven choice carcasses, while heifers in Lots 6 and 7 had six choice carcasses per lot. However, the two carcasses in Lot 6 would have graded choice had they not cut dark. The dressing percents ranged from a high of 58.1 for the heifers in Lot 5 to a low of 57.5 for heifers in Lot 7.

TABLE VIII. EFFECT OF VITAMIN A INJECTIONS ON WEIGHT GAINS OF HEIFER CALVES FED A FATTENING RATION.

	Control	Heifers injected with 500,000 I.U. vitamin A
Initial weight (lbs.)	513	516
Final weight (lbs.)	803	807
Gain (lbs.)	290	291
Average daily gain (lbs.)	2.01	2.02

It was also noted that the calves that were fed the chelated trace minerals had no abscessed livers. Each of the other three lots had two condemnations. This would be of considerable importance if the chelated trace minerals would reduce the incidence of liver abscess. However, there was no significant differences ($P > .05$) among treatments in this experiment as shown by the Chi-square.

Experiment II.

The pertinent data of this 84-day wintering trial are summarized in Table IX.

There was considerable variation among the average weights of heifers in the four lots. Heifers in Lots 5 and 6 averaged 31 pounds heavier than the average of heifers in Lot 8. Part of this difference was because the two heifers that were removed in Lot 8 were the heavier heifers in the lot.

TABLE IX. AVERAGE WEIGHT GAINS, DAILY FEED INTAKE, FEED EFFICIENCY, AND FINANCIAL RETURNS FOR HEIFERS ON A WINTERING RATION DIFFERING IN TRACE MINERAL SUPPLEMENTATION -- EXPERIMENT II. (November 23, 1963 to February 13, 1964 -- 84 days).

Lot No.	5	6	7	8
Treatment	Trace mineral	No trace mineral	Trace mineral plus high zinc	Chelated trace mineral
MSC Formula No.	362	361	363	364
No. of heifers	10	10	10	8 ^{1/}
Average weight (lbs.)				
Initial	435	435	425	404
Final	557	569	566	535
Gain	122	134	141	131
Daily gain	1.45	1.60	1.68	1.56
Average daily ration (lbs.)				
Barley	4.3	4.3	4.3	4.3
Beet pulp	1.1	1.1	1.1	1.1
Supplement	0.93	0.93	0.93	0.93
Hay	8.8	9.2	9.1	7.4
Salt	0.03	0.03	0.03	0.04
Feed per cwt. gain (lbs.)	1038	970	920	854
Feed cost per cwt. gain (\$)	16.38	15.09	14.42	14.07
Financial return per heifer (\$)				
Initial cost @ \$27/cwt.	117.45	117.45	114.75	109.08
Feed cost ^{2/}	19.98	20.22	20.33	18.43
Trucking	1.52	1.52	1.49	1.41
Total investment	138.95	139.19	136.57	128.92
Gross return	122.54	125.18	124.52	117.70
Net return	-16.41	-14.01	-12.05	-11.22

^{1/} One calf died of bloat. One calf was removed because of pneumonia.

^{2/} Feed costs are given in Appendix Table I.

The heifers that received no trace minerals (Lot 6), gained more than heifers in Lots 5 (trace mineral) and Lot 8 (chelated trace mineral). Lot 7 (high zinc) was the fastest gaining group, but was only slightly higher than the heifers in Lot 6 (no trace mineral). There was no significant difference ($P > .05$) in gain between groups. The analysis of covariance is

shown in Table X.

TABLE X. ANALYSIS OF COVARIANCE FOR WEIGHT GAINS IN POUNDS OF HEIFERS ON A WINTERING TRIAL -- EXPERIMENT II.

Variation	DF	Initial		Final		Adjusted		Calcu-	Tabu-
		Wt.	S(XY)	Wt.	SS(Y)	DF	SS	lated	lated
		SS(X)		SS(Y)		MS		F	F(.05)
Treatment	3	5224	4785	6206	3	2182	727	1.80	2.89
Error	34	46952	55982	80064	33	13315	403		
Total	37	52176	60767	86270					

Because the heifers within each lot were group-fed in a bunk, a statistical analysis of the amount of feed required to produce 100 pounds of gain was not possible. However, from Table IX it can be seen that the heifers in Lot 8 (chelated trace minerals) were much more efficient than the other three groups. Lot 5 heifers (trace mineral) required almost 200 pounds more feed per 100 pounds of gain than heifers in Lot 8. The heifers in Lots 6 and 7 required 116 pounds and 66 pounds more feed respectively, than heifers in Lot 8. The heifers in Lot 7 (high zinc) were also considerably more efficient than the other two groups (Lots 5 and 6). These data would tend to indicate that the high zinc and chelated trace minerals, added to a wintering ration of grass hay and concentrate mix, would increase feed efficiency.

The daily intake of barley, beet pulp, and supplement was held constant among the four lots (Table IX). The heifers in Lots 5, 6, and 7 consumed about the same amount of hay. However, the heifers in Lot 8 (chelated trace mineral) consumed about 1.5 pounds less hay per day per animal. This might have been due somewhat to the smaller weights of the calves in Lot 8. The average daily intake of trace minerals from the trace mineral supplement,

and the calculated trace minerals in the feedstuffs are shown in Table XI.

TABLE XI. DAILY INTAKE OF TRACE MINERALS PER CALF ON A WINTERING RATION -- EXPERIMENT II.

Mineral	Co	Cu	Fe	Mn	Zn <u>1/</u>	I <u>2/</u>
Milligrams per day						
Lot 5 (Trace mineral)						
Supplement	10.4	60	300	200	41	13.6
Feedstuffs <u>3/</u>	.9	140	820	350	35	----
Total	11.3	200	1120	550	76	13.6
Lot 6 (No trace mineral)						
Supplement	---	---	---	---	--	---
Feedstuffs	.9	145	842	363	35	---
Total	.9	145	842	363	35	---
Lot 7 (High zinc)						
Supplement	10.4	60	300	200	545	13.6
Feedstuffs	.9	144	837	360	35	---
Total	11.3	204	1137	560	580	13.6
Lot 8 (Chelated trace mineral)						
Supplement	3.7	4	15	15	20	7.7
Feedstuffs	.8	122	743	304	35	---
Total	4.5	126	758	319	55	7.7

1/ No values given for zinc in grass hay.

2/ No values given for iodine in feedstuffs.

3/ National Research Council. Pub. 659. 1959.

In this experiment, as in the preceding experiment, the basal ration was apparently adequate in trace minerals as measured by weight gains. The heifers in Lot 6 (no trace mineral) actually had a higher intake of copper, iron, and manganese than did heifers in Lot 8 (chelated trace minerals). This was due to the increased intake of feed by calves in Lot 6. If values of zinc were given for grass hay, it is possible that the calculated intake of zinc for heifers in Lot 6 would be higher than for heifers in Lot 8. Since no values are given for iodine in feedstuff it is not possible to calculate daily intake of iodine. However, it appears that the feedstuffs

were adequate since no effects were obtained when trace minerals, containing iodine, were fed. If there was an effect of trace minerals on feed efficiency, it may have been due to the zinc. It may be that the zinc is tied up in the intestinal trace and an adequate amount is not being absorbed by the animal. By adding extra zinc (Lot 7) or chelating the zinc with a soluble agent (Lot 8), more zinc may have been available to the animal and this may have resulted in the increased feed efficiency.

The proximate chemical analysis of the feed ingredients used in Experiment II are shown in Table XII.

TABLE XII. PROXIMATE CHEMICAL ANALYSIS OF FEEDS USED IN WINTERING RATIONS FOR CALVES -- EXPERIMENT II. 1/

	Moisture	Crude protein	Ether extract	Ash	Crude fiber	Phos- phorus	Cal- cium
	%	%	%	%	%	%	%
Steam rolled barley	9.6	11.1	2.3	2.4	5.4	0.33	0.05
Molasses beet pulp	8.9	9.0	0.4	4.6	16.9	0.06	0.39
Grass hay	5.8	7.5	2.7	8.6	27.4	0.20	0.27
MSC 361 (Lot 6 No T-M)	8.9	24.8	3.7	6.9	7.8	0.71	1.38
MSC 362 (Lot 5 T-M)	8.6	24.9	2.8	8.4	8.1	0.80	1.38
MSC 363 (Lot 7 High zinc)	8.6	25.3	2.6	7.1	8.8	0.67	1.22
MSC 364 (Lot 8 Chelated T-M)	8.6	19.6	3.2	7.3	8.6	0.75	1.28

1/ The feed analysis was conducted by the Montana State College Chemistry Department.

Experiments III and IV.

It was thought that because Experiments III and IV were similar with respect to treatment, the data could be grouped together to be analyzed.

It was found that the three lots of cattle supplemented with trace minerals gained significantly faster ($P < .05$) than the control lot (Table XIII).

Duncan's (1955) multiple range test was used to test significance

among means. Correction factors were used to adjust means. There was no difference among treatments with respect to carcass grades or number of liver condemnations. It was also noted from the analysis of covariance that there was a significant interaction between groups of cattle and treatments. The groups of cattle varied with respect to age and pretreatment handling. According to Snedecor (1956), the results of an interaction can be interpreted in two different ways. Therefore, due to the interaction, it was decided that Experiments III and IV should be discussed separately.

TABLE XIII. ANALYSIS OF COVARIANCE FOR COMBINED WEIGHT GAINS IN POUNDS FOR EXPERIMENTS III AND IV.

Variation	DF	Initial		Final		Adjusted		Calcu-	Tabu-
		Wt.	S(XY)	Wt.	SS(Y)	DF	SS	lated	lated
		SS(X)				MS		F	F
Treatments	3	4148	477	9317	3	16605	5535	3.23	2.76*
Group of cattle	1	32621	33895	35221	1	1038	1038		XX
Treat X group of cattle	3	41796	44550	80694	3	34122	11371	6.65	4.12**
Error	62	62776	79017	203816	61	104356	1711		
Total	69	141341	156985	329028					

* (P < .05)

** (P < .01)

Experiment III. Fattening Heifer Calves.

The pertinent data of this 135-day fattening trial concerning the average daily gain, feed consumption, efficiency of feed utilization, financial returns, and carcass data are summarized in Tables XIV and XV.

In this experiment, the heifers in Lot 8 were considerably lighter than the other three lots of heifers. The heifers in Lots 6 and 7 averaged approximately 30 pounds more than heifers in Lot 8, and calves in Lot 5 were

20 pounds heavier than Lot 8.

TABLE XIV. AVERAGE WEIGHT GAIN, AVERAGE DAILY RATION, FEED EFFICIENCY AND FINANCIAL RETURNS FOR FATTENING HEIFERS ON TRACE MINERAL TREATMENTS -- EXPERIMENT III. (February 13, 1964 to June 27, 1964 -- 135 days).

Lot No.	5	6	7	8
Treatment	Trace mineral	No trace mineral	Trace mineral plus high zinc	Chelated trace mineral
MSC Formula No.	362	361	363	364
No. of heifers	10	10	10	8
Average weight (lbs.)				
Initial	557	569	566	535
Final	818	828	877	805
Gain	261	259	311	270
Daily gain	1.93	1.92	2.30	2.00
Average daily ration (lbs.)				
Barley	10.6	10.2	12.1	10.8
Beet pulp	2.6	2.5	3.0	2.7
Supplement	1.0	1.0	1.0	1.0
Hay	2.9	3.0	3.0	2.9
Salt	0.05	0.05	0.04	0.05
Feed per cwt. gain (lbs.)	893	874	833	870
Feed cost per cwt. gain (\$) ^{1/}	18.42	17.93	17.29	18.05
Financial return per heifers (\$)				
Initial cost @ \$22/cwt.	122.54	125.18	124.52	117.70
Feed cost	48.08	46.44	53.77	48.74
Trucking	2.86	2.90	3.07	2.82
Total investment	173.48	174.52	181.36	169.26
Gross return	166.94	168.41	182.00	165.33
Net return	-6.54	-6.11	0.64	-3.93

^{1/} Feed costs are given in Appendix Table I.

The heifers in Lot 7 (high zinc) gained 0.30 pounds more per day than the next highest gaining group, Lot 8 (chelated trace minerals). The calves in Lot 7 gained approximately 0.40 pounds more per lot than calves in Lot 5 (trace mineral) and Lot 6 (no trace mineral). The heifers in Lot 8 gained

0.07 pounds more per day than heifers in Lots 5 and 6. The calves in Lot 5 (trace mineral) and Lot 6 (no trace mineral) gained essentially the same. Although there exists a large difference among treatments, there was no significance ($P > .05$). The analysis of covariance is shown in Table XVI.

TABLE XV. CARCASS DATA FOR FATTENING HEIFERS ON TRACE MINERAL TREATMENTS
-- EXPERIMENT III.

Lot No.	5	6	7	8
MSC Formula No.	362	361	363	364
Treatment	Trace mineral	No trace mineral	Trace mineral plus high zinc	Chelated trace mineral
No. of heifers	10	10	10	8
Carcass grade				
Average choice	5	1	4	2
Low choice	1	3	4	2
High good	3	3	1	1
Average good	-	1	1	2 <u>1/</u>
Low good	1	2	-	1
Carcass score <u>2/</u>	9.9	9.0	10.1	9.3
Marbling score <u>3/</u>	13.0	12.2	14.1	13.8
Dressing percent	56.5	56.6	57.1	57.0
Rib eye are/cwt. carcass (sq. in.)	2.10	2.21	2.07	2.13
Liver condition				
Condemned	-	2 <u>4/</u>	3	2 <u>5/</u>
Non-condemned	10	8	7	6

1/ One carcass cut dark.

2/ 10 = low choice, 9 = high good.

3/ 14 = average small, 13 = weak small, 12 = strong slight.

4/ One liver was condemned due to cirrhosis.

5/ One liver was condemned because of flukes.

The heifers within each lot were group-fed in the fence-line bunks, therefore, a statistical analysis of the feed efficiency was impossible.

The heifers in Lot 7 (high zinc) were somewhat more efficient than the other

three groups (Table XIV). Lot 7 heifers required 833 pounds of feed to produce 100 pounds of gain, while heifers in Lots 6 and 8 required 874 and 870 pounds of feed, respectively. The heifers in Lot 5 (trace minerals) required 893 pounds of feed to produce 100 pounds of gain. At this time it is not possible to explain the reason for the increase in feed efficiency and gain in Lot 7 (high zinc). The possible answer may be the addition of the high amounts of zinc. However, little if any response was obtained when zinc was fed in the chelated form.

TABLE XVI. ANALYSIS OF COVARIANCE FOR WEIGHT GAINS IN POUNDS OF HEIFERS ON A FATTENING RATION WITH DIFFERENT TRACE MINERAL TREATMENTS -- EXPERIMENT III.

Variation	DF	Initial Wt.		Final Wt.		Adjusted		Calculated F	Tabulated F(.05)
		SS(X)	S(XY)	SS(Y)	DF	SS	MS		
Treatment	3	6206	8109	27968	3	19899	6633	1.75	2.89
Error	34	135264	88474	183286	33	125417	3801		
Total	37	141470	96583	211254					

Plumlee et al. (1953) has reported that the appetites of beef calves were depressed when trace minerals were fed. In this experiment, it appeared that the trace minerals actually increased the appetites of the calves (Table XIV). The heifers in Lot 5 (trace minerals) consumed about 0.5 pounds more of concentrate mix per day than the heifers in the control lot. The calves in Lot 7 (high zinc) and Lot 8 (chelated trace mineral) consumed 2.4 and 0.8 pounds more of the concentrate mix, respectively, than did the control lot. Since the calves in Lot 7 were not extremely more efficient than the calves in Lot 6, it was apparently the increase in the daily feed intake that produced 52 pounds more of gain for calves in Lot 7 compared

to calves in Lot 6.

The average daily intake of trace minerals from the trace mineral supplement, and the calculated trace minerals in the feedstuffs are shown in Table XVII.

TABLE XVII. AVERAGE DAILY INTAKE OF TRACE MINERALS PER CALF ON A FATTENING RATION -- EXPERIMENT III.

Mineral	Co	Cu	Fe	Mn	Zn <u>1/</u>	I <u>2/</u>
Milligrams per day						
Lot 5 (Trace mineral)						
Supplement	10.4	60	300	200	41	13.6
Feedstuffs <u>3/</u>	.9	97	870	233	85	---
Total	11.3	157	1170	433	126	13.6
Lot 6 (No trace mineral)						
Supplement	---	---	---	---	---	---
Feedstuffs	.9	96	85	231	82	---
Total	.9	96	85	231	82	---
Lot 7 (High zinc)						
Supplement	10.4	60	300	200	545	13.6
Feedstuffs	1.0	107	970	255	97	---
Total	11.4	167	1270	455	642	13.6
Lot 8 (Chelated trace mineral)						
Supplement	3.7	4	15	15	20	7.7
Feedstuffs	.9	99	889	236	87	---
Total	4.6	103	904	251	107	7.7

1/ No values given for zinc in grass hay.

2/ No values given for iodine in feedstuffs.

3/ National Research Council. Pub. 659. 1959.

Although the iodine in the feedstuffs was not calculated, we can again assume that the iodine requirement was adequately met, in that the addition of trace minerals did not improve gain or feed efficiency. Since the addition of trace minerals did not improve gain and the high zinc trace mineral was similar to the trace mineral in all respects except zinc, it seems that

the added zinc may be the reason for increased gain, feed efficiency, and feed intake of the calves in Lot 7. The slight increase in gain and feed intake of the heifers in Lot 8 may be due to the chelation of zinc. It should be noted that the increase of feed intake by heifers in Lot 7 also increased the amount of trace minerals considerably (Table XVII). This may have been a factor in the increased gain and efficiency of heifers in Lot 7.

The proximate chemical analysis of the feed ingredients used in this experiment are shown in Table XII (Experiment II).

The carcass data of this experiment is shown in Table XV. The calves in Lots 7 and 5 graded approximately one-third of a grade higher than the calves in the other two lots. The calves in Lot 5 had gained approximately the same as calves in Lots 6 and 8, but apparently Lot 5 reached a higher carcass grade with the same amount of gain. It should be noted that Lot 7 calves gained approximately 0.4 pounds more per day for the 135-day period, but graded only slightly higher than the calves in Lot 5. Heifers in Lot 8 (chelated trace mineral) the lowest grading trace mineral group, graded 9.3 compared to 9.0 for the non-trace mineral supplemented group. There was no significant difference ($P < .05$), as shown by the Chi-square, grades due to treatments of trace minerals.

All three trace mineral supplemented groups had considerably more marbling than heifers in Lot 6 (no trace minerals). This could be due to the added manganese. It has been reported that manganese has a lipotropic action within the body. Thus the added manganese may cause the fat to be more dispersed throughout the body, particularly in the muscle tissue. This

difference however, was non significant ($P > .05$). There was little difference between lots with regard to dressing percent and rib eye area per 100 pounds of carcass weight.

With this experiment, as in Experiment I, there was a low incidence of liver condemnations. One liver from each of the heifers in Lots 6 and 8 was condemned for reasons other than abscesses. Therefore, since there was no condemnation in Lot 5 and only one in Lot 6, no effect could be attributed to chelated trace minerals for reducing liver abscess in this experiment.

Experiment IV. Yearling Heifers.

The pertinent data of this 125-day fattening period are summarized in Tables XVIII and XIX.

The heifers in the three trace mineral supplemented lots gained significantly more ($P < .05$) than the heifers in the no trace mineral lot, Table XX. Duncan's (1955) multiple range test was used to test significance between means. Correction factors were used to adjust means.

The heifers in Lot 1 (trace minerals) gained 0.49 pounds more per day than heifers in Lot 2 (no trace minerals) and 0.25 and 0.36 pounds more per day than heifers in Lots 3 and 4, respectively (Table XVIII). Heifers in Lot 3 (chelated trace minerals) gained 0.07 pounds more per day than heifers in Lot 4 and 0.24 more pounds than heifers in Lot 2. The heifers in Lot 4 (high zinc trace mineral) gained 0.17 pounds more per day than heifers in Lot 2. The differences between Lots 1, 3, and 4 were non-significant ($P > .05$).

The heifers within each treatment were group fed, therefore, a statis-

TABLE XVIII. AVERAGE WEIGHT GAINS, DAILY FEED INTAKE, FEED EFFICIENCY AND FINANCIAL RETURNS FOR FATTENING YEARLING HEIFERS ON TRACE MINERAL TREATMENTS -- EXPERIMENT IV. (November 26, 1963 to March 30, 1964 -- 125 days).

Lot No.	1	2	3	4
Treatment	Trace mineral	No trace mineral	Chelated trace mineral	Trace mineral plus high zinc
MSC Formula No.	362	361	364	363
No. of heifers	8	8	8	8
Average weight (lbs.)				
Initial	607	613	599	587
Final	917	862	878	857
Gain	310	249	279	270
Daily gain	2.48	1.99	2.23	2.16
Average daily ration (lbs.)				
Barley	13.3	11.4	12.6	12.7
Beet pulp	3.3	2.9	3.1	3.2
Supplement	1.0	1.0	1.0	1.0
Hay	3.7	3.8	3.8	3.7
Salt	0.04	0.06	0.04	0.05
Feed per cwt. gain (lbs.)	859	959	925	953
Feed cost per cwt. gain (\$)	17.58	19.38	18.87	19.47
Financial return per heifer (\$)				
Initial cost @ \$21/cwt.	127.47	128.73	125.79	123.27
Trucking	5.57	5.39	5.44	5.37
Feed cost ^{1/}	54.50	48.26	52.65	52.57
Total investment	187.54	182.38	183.79	181.21
Gross return	191.86	174.78	177.30	177.24
Net return	4.32	-7.60	-6.49	-3.97

^{1/} Feed costs are given in Appendix Table I.

tical analysis of the feed efficiency was not possible. However, as shown in Table XVIII, heifers in Lot 1 (trace minerals) were considerably more efficient than the heifers in the other three lots. The feed required per 100 pounds of gain was 859 pounds for heifers in Lot 1, compared to 959,

925, 953 pounds for heifers in Lots 2, 3, and 4, respectively. The chelated trace mineral lot required 34 pounds less feed per 100 pounds of gain than the control lot. The control lot and the high zinc supplemented lot were similar in feed efficiency.

TABLE XIX. CARCASS DATA FOR FATTENING YEARLING HEIFERS ON TRACE MINERAL TREATMENTS -- EXPERIMENT IV.

Lot No.	1	2	3	4
MSC Formula No.	362	361	364	363
Treatment	Trace mineral	No trace mineral	Chelated trace mineral	Trace mineral plus high zinc
No. of heifers	8	8	8	8
Carcass grades				
Choice	6	5	3	6
Good	2	3	5	2
Dressing percent	58.6	57.0	57.1	57.8
Rib eye area/cwt. carcass (sq. in.)	2.04	2.27	2.16	2.09
Liver condition				
Condemned	3	0	1	1
Non-condemned	5	8	7	7
Liver weight per cwt. carcass (lbs.)	1.92	1.91	2.03	1.91

TABLE XX. ANALYSIS OF COVARIANCE FOR WEIGHT GAINS IN POUNDS OF YEARLING HEIFERS ON A FATTENING RATION WITH DIFFERENT TRACE MINERAL TREATMENTS -- EXPERIMENT IV.

Variation	DF	Initial		Final		Adjusted		Calculated F	Tabulated F(.05)
		Wt. SS(X)	S(XY)	Wt. SS(Y)	DF	SS	MS		
Treatments	3	2969	2546	17485	3	15302	5011	3.76	2.96
Error	28	19481	23961	65068	27	35954	1332		
Total	31	22450	26507	82553	30				

As reported in the previous experiment, the daily feed consumption was increased when trace minerals were added to the ration (Table XVIII). Lot 1 (trace minerals) heifers consumed 2.3 pounds more concentrate per day than did the controls. Heifers in Lot 3 (chelated minerals) and Lot 4 (high zinc trace minerals) consumed 1.4 and 1.6 pounds more concentrate per day than the control lot.

The average daily intake of trace minerals from the trace mineral supplement and the calculated trace minerals in the feedstuffs are shown in Table XXI.

TABLE XXI. AVERAGE DAILY INTAKE OF TRACE MINERALS PER HEIFER ON FATTENING RATIONS -- EXPERIMENT IV.

Mineral	Co	Cu	Fe	Mn	Zn <u>1/</u>	I <u>2/</u>
Milligrams per day						
Lot 1 (Trace minerals)						
Supplement	10.4	60	300	200	41	13.6
Feedstuffs <u>3/</u>	1.1	122	1082	293	106	---
Total	11.5	182	1382	493	147	13.6
Lot 2 (No trace minerals)						
Supplement	---	---	---	---	---	---
Feedstuffs	1.0	114	982	264	91	---
Total	1.0	114	982	264	91	---
Lot 3 (Chelated trace minerals)						
Supplement	3.7	4	15	15	20	7.7
Feedstuffs	1.1	119	1041	287	101	---
Total	4.8	123	1056	302	121	7.7
Lot 4 (High zinc)						
Supplement	10.4	60	300	200	545	13.6
Feedstuffs	1.1	119	1052	286	102	---
Total	11.5	179	1352	486	647	13.6

1/ No values given for zinc in grass hay.

Apparently, the added trace minerals increased the gain and feed efficiency of the heifers. The added level of zinc did not improve the perform-

ance of the heifers when compared to the trace mineral supplemented group. Since the iodine did not appear to be deficient in the previous trials, it might be assumed that the iodine is not deficient here as the same feed was used as in Experiment II and III. Thus, the response could not be attributed to any particular mineral but rather to the minerals as a group. The chelating agent, may have been of importance, in that smaller amounts of trace minerals were added in the chelated trace mineral supplement yet a response was obtained equal to or greater than the high zinc supplement.

The proximate chemical analysis of the feed ingredients used in this experiment are shown in Table XII (Experiment II).

The carcasses of the heifers in Lot 1 (trace minerals) and Lot 4 (high zinc) graded higher than the heifers in the other two lots (Table XIX). Heifers in Lot 3 (chelated trace minerals), the second greatest gaining group, graded the lowest of the four groups. There was no significant difference ($P > .05$) in carcass grades as determined by the Chi-square method.

There was considerable difference between lots with regard to dressing percent. The heifers of Lot 1 (trace minerals) dressed 1.5 percent more than heifers in Lots 2 (no trace minerals) and 3 (chelated trace minerals). The heifers in Lot 4 (high zinc) had a dressing percent of 57.8 compared to 57.0 and 57.1 for Lots 2 and 3, respectively. The importance of the increase in dressing percent of heifers in lots fed trace mineral or high zinc, would be hard to assess since no response was noted for the heifers in the chelated trace mineral lot. There was no increase in rib eye area from trace mineral supplementation.

No effect could be attributed to chelated trace minerals for reducing the number of liver condemnations ($P > .05$). In this experiment as with the previous two fattening experiments, the number of liver abscesses has been low. In the last two experiments it has been observed that the fastest gaining groups have had the greatest number of abscessed livers.

SUMMARY

The effect of adding trace mineral supplements to wintering or fattening rations for heifers was studied. Weight gains, feed intake, feed efficiency, and carcass data were used to assess the value of the trace mineral supplements.

In Experiment I, 32 Hereford heifers were used to conduct this 144-day fattening trial. The treatments used were as follows: Lot 5, trace mineral; Lot 8, trace mineral with high zinc; Lot 7, chelated trace mineral; and Lot 6, control. All heifers received the same basal ration, the only difference being the minerals above. There was no difference in gain of heifers between lots. The heifers in Lot 8 were six percent more efficient in feed conversion than the control heifers.

In Experiments II, III, and IV, the levels of the trace minerals in the supplement were increased. Thirty-eight head of heifer calves were fed a wintering ration (Experiment II) for 84 days using the same treatments as above except in an increased amount. The heifers in Experiment III were the same as Experiment II except a fattening ration was fed for 135 days. The treatments were the same in Experiment II. There was no significant increase ($P > .05$) in gain for either experiment. However, there was a trend for higher gains with the high zinc supplements in both experiments. The high zinc also reduced feed per 100 pounds of gain in each experiment. There was a trend for increase daily consumption of concentrate for heifers in the trace mineral supplemented lots during the fattening phase. The heifers in the chelated trace mineral supplemented lot had an increased feed efficiency of 12 percent over the controls in the wintering trial. The heifers in Lots 5 and 7 both had higher carcass scores than the control lot,

9.9, 10.1, and 9.0, respectively. There was also a tendency for the heifers of all three of the trace mineral supplemented lots to have a higher marbling score than the control heifers.

In Experiment IV, 32 head of yearling heifers were fed a fattening ration for 125 days. The same treatments and rations were fed as in Experiment III. There was a significant increase in gain for the heifers of the three trace mineral lots over the controls ($P < .05$). There was no significant difference in gain ($P > .05$) between the heifers in the supplemented lots. The heifers in the supplemented lots also had an increase in daily concentrate consumption. Heifers in Lots 5 (trace minerals) and 7 (chelated trace minerals) had an increased feed efficiency of 11 and 5 percent over the controls. Heifers in Lots 5 and 8 (high zinc) had increased dressing percents over the controls, 58.6, 57.8, and 57.0, respectively.

The results of these experiments III and IV, indicate that supplementing a barley-beet pulp fattening ration with trace minerals increased the daily feed intake. The average daily gains of heifers on a fattening ration, supplemented with trace minerals, were also increased. The feed required per 100 pounds of gain was reduced, with the addition of trace minerals, when the experiments were compared as a group.

There was no effect of trace minerals on carcass grades or number of liver abscesses.

It would also appear from these experiments that the trace mineral with high zinc and chelated trace minerals gave the greatest response. This extra response was probably due to the extra zinc or increased availability of zinc in the chelated trace minerals.

From the results presented in this thesis, it appears that adding trace minerals to barley-beet pulp rations increased the performance of wintering and fattening heifers. However, before a definite statement on recommendations could be made, further tests should be conducted.

APPENDIX

APPENDIX TABLE I. COST OF FEED INGREDIENTS.

<u>Ingredient</u>	<u>Cost per ton</u>
Experiment I	
Steam rolled barley	\$44.00
Molasses beet pulp	39.60
Grass hay	20.00
Salt	32.40
Supplement No. 304 (No T-M)	61.75
Supplement No. 305 (High zinc)	61.75
Supplement No. 306 (Trace mineral)	61.95
Supplement No. 307 (Chelated)	63.55
Experiments II, III, and IV	
Steam rolled barley	\$44.00
Molasses beet pulp	39.60
Grass hay	20.00
Salt	32.40
Supplement No. 361 (No T-M)	67.96
Supplement No. 362 (Trace mineral)	69.39
Supplement No. 364 (Chelated)	71.45

APPENDIX TABLE II. GROSS ENERGY OF FEEDS USED IN EXPERIMENTS II, III,
AND IV.

<u>Ingredient</u>	<u>K Cal. per pound</u>
Steam rolled barley	1845.2
Molasses beet pulp	1793.0
Supplements 361, 362, 363, 364	1856.0

APPENDIX TABLE III. SOURCES OF TRACE MINERALS USED IN THE TRACE MINERAL SUPPLEMENTS.

Mineral	Trace mineral	Trace mineral plus high zinc	Chelated trace mineral ^{1/}
Source			
Experiment I			
Manganese	Manganese sulfate	Manganous oxide	Manganese sulfate
Iron	Ferrous carbonate	Iron carbonate	Ferrous sulfate
Zinc	Zinc oxide	Zinc oxide	Zinc sulfate
Copper	Copper oxide	Copper oxide	Copper sulfate
Cobalt	Cobalt carbonate	Cobalt oxide	Cobalt sulfate
Iodine	Ethylene diamine dihydriodide	Potassium iodide	Ethylene diamine dihydriodide
Experiments II, III, and IV			
Manganese	Manganese sulfate	Manganese sulfate	Manganese sulfate
Iron	Ferrous carbonate	Ferrous carbonate	Ferrous sulfate
Zinc	Zinc oxide	Zinc oxide	Zinc sulfate
Copper	Copper oxide	Copper oxide	Copper sulfate
Cobalt	Cobalt carbonate	Cobalt carbonate	Cobalt sulfate
Iodine	Ethylene diamine dihydriodide	Ethylene diamine dihydriodide	Ethylene diamine dihydriodide

^{1/} Chelating agents: sodium citrate, disodium ethylenediaminetetraacetate, Glycine, l-lysine, lactose, and sodium gluconate.

APPENDIX TABLE IV. CONTENT AND COST OF TRACE MINERAL SUPPLEMENTS.

Mineral	Trace mineral		
	Trace mineral <u>1/</u>	plus high zinc <u>2/</u>	Chelated trace mineral <u>3/</u>
	%	%	%
Experiment I			
Manganese	4.4	10.0	1.65
Zinc	0.9	10.0	2.15
Iron	6.6	10.0	1.60
Copper	1.32	1.0	0.49
Iodine	0.30	0.1	0.85
Cobalt	0.23	0.1	0.41
Experiments II, III, and IV			
Manganese	4.4	4.4	1.65
Zinc	0.9	12.0	2.15
Iron	6.6	6.6	1.60
Copper	1.32	1.32	0.49
Iodine	0.3	0.3	0.85
Cobalt	0.23	0.23	0.41

1/ Cost of trace mineral per pound: Experiment I, \$0.10; Experiment II, III, and IV, \$0.0975.

2/ Cost of trace mineral per pound: Experiment I, \$0.11; Experiment II, III, and IV, \$0.1088.

3/ Cost of chelated trace mineral per pound: Experiment I, \$0.90; Experiment II, III, and IV, \$0.90.

APPENDIX TABLE V. INDIVIDUAL WEIGHT GAINS OF HEIFERS FATTENED ON RATIONS DIFFERING IN TRACE MINERAL SUPPLEMENTS -- EXPERIMENT I.

Heifer No.	Initial weight (2-28-63)	Final weight (7-22-63)	Total gain	Average daily gain
<u>Lot No. 5 (T-M)</u>				
206	596	866	270	1.88
209	556	878	322	2.24
218	533	858	325	2.26
233	472	735	263	1.83
210	486	755	269	1.87
228	476	812	336	2.33
240	450	690	240	1.67
242	<u>492</u>	<u>798</u>	<u>306</u>	<u>2.13</u>
Average	508	799	291	2.02
<u>Lot No. 6 (No T-M)</u>				
213	532	848	316	2.19
220	460	740	280	1.94
230	492	815	323	2.24
236	508	750	242	1.68
237	586	858	272	1.89
239	512	810	298	2.07
241	504	770	266	1.85
243	<u>522</u>	<u>805</u>	<u>283</u>	<u>1.97</u>
Average	515	800	285	1.98

APPENDIX TABLE V. CONT.

Heifer No.	Initial weight (2-28-63)	Final weight (7-22-63)	Total gain	Average daily gain
<u>Lot No. 7 (Chelated T-M)</u>				
201	515	804	289	2.01
214	515	796	281	1.95
216	445	752	307	2.13
217	494	758	264	1.83
222	442	752	310	2.15
223	653	996	343	2.38
227	530	812	282	1.96
235	492	772	280	1.94
Average	<u>511</u>	<u>805</u>	<u>294</u>	<u>2.05</u>
<u>Lot No. 8 (High zinc T-M)</u>				
215	518	763	245	1.70
219	484	764	280	1.94
224	546	864	318	2.21
226	618	962	344	2.39
232	570	860	290	2.01
234	502	771	269	1.87
238	464	788	324	2.25
244	500	760	260	1.81
Average	<u>525</u>	<u>817</u>	<u>292</u>	<u>2.02</u>

APPENDIX TABLE VI. INDIVIDUAL WEIGHT GAINS OF HEIFERS WINTERED ON RATIONS DIFFERING IN TRACE MINERAL SUPPLEMENTS -- EXPERIMENT II.

Heifer No.	Initial weight (11-21-63)	Final weight (2-13-64)	Total gain	Average daily gain
<u>Lot No. 5 (T-M)</u>				
155	501	630	129	1.54
292	468	632	164	1.95
322	406	510	104	1.24
323	410	540	130	1.55
348	425	542	117	1.39
315	426	522	96	1.14
390	415	540	125	1.49
330	449	582	133	1.58
352	393	495	102	1.21
366	<u>460</u>	<u>581</u>	<u>121</u>	<u>1.44</u>
Average	435	557	122	1.45
<u>Lot No. 6 (No T-M)</u>				
241	453	606	153	1.82
280	505	686	181	2.15
305	373	494	121	1.44
324	407	558	151	1.80
344	388	508	120	1.43
393	408	560	152	1.81
397	428	533	105	1.25
319	440	546	106	1.26
361	485	600	115	1.37
382	<u>461</u>	<u>603</u>	<u>142</u>	<u>1.69</u>
Average	435	569	134	1.60

APPENDIX TABLE VI. CONT.

Heifer No.	Initial weight (11-21-63)	Final weight (2-13-63)	Total gain	Average daily gain
<u>Lot No. 7 (High zinc T-M)</u>				
160	500	664	164	1.95
325	390	540	150	1.79
331	397	552	155	1.85
337	418	524	106	1.26
346	403	532	129	1.53
353	364	506	142	1.69
367	436	582	146	1.74
331	448	582	134	1.60
336	394	524	136	1.62
369	498	650	152	1.81
Average	425	566	141	1.68
<u>Lot No. 8 (Chelated T-M)</u>				
185	410	545	135	1.61
399	410*	516	106	1.89
308	384	504	120	1.43
327	423	546	123	1.46
332	383	497	114	1.36
340	396	548	152	1.81
358	403	576	173	2.06
340	430	546	116	1.38
Average	404	535	131	1.61

* Added 28 days after start of trial.

APPENDIX TABLE VII. INDIVIDUAL WEIGHT GAINS OF HEIFER CALVES FATTENED ON RATIONS DIFFERING IN TRACE MINERAL SUPPLEMENTS -- EXPERIMENT III.

Heifer No.	Initial weight (2-13-64)	Final weight (6-27-64)	Total gain	Average daily gain
<u>Lot No. 5 (T-M)</u>				
155	630	835	205	1.52
292	632	918	286	2.12
322	510	764	254	1.88
323	540	834	294	2.18
348	542	810	268	1.99
315	522	788	266	1.97
390	544	804	260	1.93
330	582	907	325	2.41
352	495	712	217	1.61
361	<u>581</u>	<u>808</u>	<u>227</u>	<u>1.68</u>
Average	557	818	261	1.93
<u>Lot No. 6 (No T-M)</u>				
241	606	838	232	1.72
280	686	876	190	1.41
305	494	734	220	1.63
324	558	852	294	2.18
344	508	792	284	2.10
393	560	818	258	1.91
397	533	772	239	1.77
319	546	833	287	2.13
361	600	858	258	1.91
382	<u>603</u>	<u>908</u>	<u>305</u>	<u>2.26</u>
Average	569	828	259	1.92

APPENDIX TABLE VII. CONT.

Heifer No.	Initial weight (2-13-64)	Final weight (6-27-64)	Total gain	Average daily gain
<u>Lot No. 7 (High zinc T-M)</u>				
160	664	928	264	1.96
325	540	793	253	1.87
331	552	868	316	2.34
337	524	730	206	1.53
346	532	914	382	2.83
353	506	752	246	1.82
367	582	926	344	2.55
331	582	926	344	2.55
336	524	898	374	2.77
369	650	1032	382	2.83
Average	566	877	311	2.30
<u>Lot No. 8 (Chelated T-M)</u>				
185	545	851	306	2.27
399	516	768	252	1.87
308	504	640	136	1.01
327	546	832	286	2.12
332	497	765	268	1.99
340	548	847	299	2.21
358	576	920	344	2.55
340	546	815	269	1.99
Average	535	805	270	2.00

APPENDIX TABLE VIII. INDIVIDUAL WEIGHT GAINS OF YEARLING HEIFERS FATTENED ON RATIONS DIFFERING IN TRACE MINERAL SUPPLEMENTS -- EXPERIMENT IV.

Heifer No.	Initial weight (11-26-63)	Final weight (3-30-64)	Total gain	Average daily gain
<u>Lot No. 1 (T-M)</u>				
268	644	924	280	2.24
272	597	942	345	2.76
275	615	924	309	2.47
281	585	840	255	2.04
282	564	878	314	2.51
283	614	1012	398	3.18
295	605	930	325	2.60
296	628	882	254	2.03
Average	607	917	310	2.48
<u>Lot No. 2 (No T-M)</u>				
270	610	796	186	1.49
271	586	834	248	1.98
274	564	780	216	1.73
286	638	883	245	1.96
294	656	900	244	1.95
300	622	880	258	2.06
302	585	875	290	2.32
278	640	945	365	2.44
Average	613	862	249	1.99

APPENDIX TABLE VIII. CONT.

Heifer No.	Initial weight (11-26-63)	Final weight (3-30-64)	Total gain	Average daily gain
<u>Lot No. 3 (Chelated T-M)</u>				
267	625	928	303	2.42
269	594	868	254	2.03
276	572	883	311	2.49
289	578	878	300	2.40
291	632	912	290	2.32
297	596	848	252	2.02
298	585	798	213	1.70
301	<u>612</u>	<u>910</u>	<u>298</u>	<u>2.38</u>
Average	599	878	279	2.23
<u>Lot No. 4 (High zinc T-M)</u>				
265	592	875	283	2.26
266	590	866	276	2.21
287	560	808	248	1.98
279	624	930	306	2.45
284	612	880	278	2.22
285	548	790	242	1.94
288	596	860	264	2.11
290	<u>572</u>	<u>848</u>	<u>276</u>	<u>2.21</u>
Average	587	857	270	2.16

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