THE VALUE OF TRACE MINERALS IN BOVINE FATTENING RATIONS

by

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TABLE OF CONTENTS

INTRODUCTION

All forms of life require a number of inorganic elements for normal growth and reproduction. While virtually all the elements of the periodic table have been found in living cells, not all of these are essential to life. When an element is required in relatively high concentrations in order to maintain normal growth and reproduction of the organism, it is usually thought of as a micronutrient element. In this class are such nutrients as calcium, phosphorus, sodium, chlorine, magnesium, sulfur and potassium. In contrast to this group of elements, there are required in very small amounts, the micronutrients or "trace elements".

Ogilo-elements, trace elements, micro-nutrients, micro-elements and minor elements are terms which have been applied to a group of elements occurring in biologic systems in such small concentrations that they have usually been found present qualitatively but not measured quantitatively. They have in common the difficulty of measurement because of low concentrations which varies from $1x10^{-6}$ to less than $1x10^{-16}$ gram per gram of wet tissue, reported Valee (1952). Elvehjem (1954) reported that there are 20 or more trace minerals occurring commonly in foods in trace amounts or in amounts less than 0.005 per cent. Of this group, six may be listed as important to ruminants. These include, copper, cobalt, iodine, iron, manganese and zinc.

These experiments were planned to determine whether or not trace minerals are of benefit when added to a typical fattening ration. In two experiments sorghum grain was the principle grain, and in the other two corn was used as the principle grain. In all the experiments, prairie hay was used as the roughage. The value of trace minerals was based on total gains, feed required per cwt. of gain, dressing percentage, and carcass grades.

REVIEW OF LITERATURE

Iron

Maynard and Loosli (1956) reported that the animal body contains only about 0.004 per cent of iron, yet this mineral plays a central role in life processes. As a constituent of the respiratory pigment, hemoglobin, iron was needed for the functioning of the organs and tissues in the body. Over half of the iron present in the body was in the form of hemoglobin. According to Dukes, (1955), "hemoglobin, the pigment of the erythocytes is a complex, iron containing, conjugated protein composed of a pigment and a simple protein. The pigment is ferroheme and the protein is globin". Oxygen is transported in the blood, due to the property of hemoglobin, and released to tissues throughout the body. The level of hemoglobin in the blood differed with species, according to Underwood (1956). He stated that sheep blood normally contained 10-11 grams of hemoglobin per 100 ml. of blood, and cattle blood contained 11-12 grams of hemoglobin per 100 ml. of blood. Dukes (1955) reported the amount of iron in the hemoglobin molecule was only 0.34 per cent.

The dietary need for iron is small, yet when this small amount is not supplied to the body, an anemic condition results. This condition is characterized by a microcytic and hypochromic anemia. Iron deficiency anemia seldom occurs, but it is noted most in certain species during the suckling period, since milk is very low in iron. Knopp et al. (1935) reported that feeding milk exclusively to calves produced a nutritional anemia, and to overcome this deficiency of iron in the milk, farm animals were born with a store of iron in their bodies which normally sufficed until they begin to eat food that supplied sufficient iron. The store of iron in the new born was influenced by the diet of the mother during gestation. In certain areas in the world, forages grown on certain types of soil may not contain a sufficient amount of iron for proper hemoglobin formation. Becker and Henderson (1940) observed that in certain parts of Florida the cattlemen had ceased trying to raise their own replacements because of large losses and the constant development of an anemic condition. They found that iron prevented this anemia.

According to Hahn et al. (1939) (1943) the need of the body for iron determines the absorption of this element in some manner. In the anemic animal iron was promptly assimilated. Iron was absorbed primarily from the small intestine through the mucosal epithelium and was stored mainly in the liver. The plasma was the means of transportation from the gastro-intestional tract to its point of mobilization into hemoglobin. Iron released during normal blood-cell destruction could be used over and over again to form hemoglobin, practically without loss. Iron was not excreted to any appreciable amount, therefore the dietary need was greatly reduced. Copper was needed for conversion of iron into hemoglobin. If copper was not present, the animal could still assimilate iron from food, but it only stored it in the liver and could not use it for hemoglobin formation. Chase et al. (1952) reported that less iron was absorbed from the gastro-intestional tract in copper-deficient animals. Iron was stored mainly in the liver, spleen, and red bone marrow, largely in the form of ferritin, an iron-protein complex.

Most feeds commonly fed to farm animals contain liberal amounts of this element, and there is no need to supply additional iron in the rations. Conley et al. (1954) reported that a daily intake of 60 mg. of iron was sufficient to maintain normal concentrations of hemoglobin and of serum iron in growing calves up to 600-800 pounds of weight. Too much iron in the ration may interfere with phosphorous absorption and cause rickets.

Copper

Copper is present in all living matter. The presence of copper in animals was recognized as early as 1833 but it was not until Hart et al. (1928) announced that copper, in addition to iron, was essential for the formation of hemoglobin that its specific function became known. Elvehjem (1935) concluded that "in the animal body, copper is not concerned with the assimilation of iron, but with the transformation of the ingested iron into hemoglobin". Dukes (1955) reported that copper was not a constituent of hemoglobin, but it does occur as a copper-protein compound called hemocuprein in the blood cells. It probably acts as a catalyst in hemoglobin formation and erythro-poesis. When the essential traces of copper were not present, the animal would still assimilate iron from food, but it merely stored the iron in the liver, and was unable to make hemoglobin. Chase et al. (1952) discovered there was less absorption of iron from the gastrointestional tract of rats deficient in copper than in rats supplied with adequate copper, thus showing that copper favors the absorption of iron.

Dukes (1955) reported that copper occurred only in small amounts in the blood--the concentration being about 0.1 mg. per 100 ml. of blood.

Its distribution between plasma and corpuscles was about equal. Winthrobe et al. (1953) stated that red cell copper tended to remain constant while the plasma copper varied under a great variety of circumstances. When copper was given orally, it was fairly quickly absorbed, and was deposited in the liver, muscles, kidneys and bone marrow. From here it was very slowly eliminated into the bile and urine. The liver is the main storage depot for copper, and is usually able to hold considerable quantities over a period of several months. A large store of copper at birth served the purpose of providing for growth needs during the suckling period, according to McDougall (1947). Comar et al. (1948) noted that during the first one and one-half months of life the liver of the calf exhibited a greater selective accumulation of absorbed copper than was observed with older animals. This mineral was also a constituent or activator of several enzymes according to Dukes (1955).

In a few areas of the world the soil has been reported as being so deficient in copper that serious anemia and other nutritional diseases were produced in livestock, particularly ruminants. The first of these was noted in northern Europe where a wasting disease of cattle and sheep was characterized by diarrhea, lack of appetite and anemia. It was corrected by copper therapy. For many years, it has been recognized in Florida that cattle would not thrive on certain areas of poor sandy soil. Young cattle were mostly affected and were often stunted from this disease, which was called "salt sick". It was found these conditions were due to a serious lack in the forage of copper. A deficiency of copper was believed to be the cause of the condition of sheep in Australia called "stringy" or "steely" wool. This wool was peculiar in that it had no crimp. Palmer (1949) fed adequate copper to sheep suffering from "steely" wool and found they recovered, and the wool increased in diameter, crimp, and ultimate tensile strength. Coast disease of cattle and sheep in Australia seems to be due to a deficiency of cobalt and copper. If the sheep were given adequate copper and cobalt, this would not occur. In coast disease, Marston et al. (1948) found lesions in the wool were the first symptoms to appear. They further stated that enzootic ataxia or "sway back" was a disease characterized by nervous symptoms, and was caused by a deficiency of copper. This affected the lambs and was corrected by feeding copper to the pregnant ewes. In this disease the assimilation of copper was apparently prevented by an excess of lead and zinc which interfered with the utilization. In another disease of this type, "teartness", the utilization of copper is impaired by an excess of molybdenum in the forage. "Copper Pine" of calves has been reported in England by Jameison and Allcroft (1950). This condition was due, "to a low copper status in the animal not because of a deficiency in the pastures, but to some factor present or absent in the pastures which interferes with the metabolism of copper in calves".

According to Davis et al. (1946) symptoms of copper deficiency included the lowering of the copper content of the liver and blood, bleaching of hair in cattle, and abnormal wool growth in sheep. Slow growth, failure to fatten, and in extreme cases anemia were other symptoms. Nervous symptoms and bone malformations have also been reported.

Marnard and Loosli (1956) reported that the requirement of ruminants for copper was very small, being only one-tenth that of iron. The copper requirements depended to a large extent on the amount of other elements present such as molybdenum. Under normal conditions the daily copper requirement was 50 mg. for cattle and 5 mg. for sheep. If excess molybdenum was present more copper was required to offset its effects. Normal rations contain sufficient copper, and using excess copper supplements should be avoided because of its toxic effects. Marston and Lee (1948) reported that chronic ingestion of toxic quantities of copper by sheep lead to hemoglobinuria and hemolytic icterus. They also noted that certain breeds were able to withstand larger amounts than others. If a copper supplement is to be used, the ration must be checked, and only enough copper should be added to correct the deficiency.

Zinc

Modern work has shown that zinc is an essential element in the nutrition of animals. There was little information available, however, concerning this subject. In early work Newell and McCollum (1933) stated that "zinc is probably not an essential nutritional factor in the growth of the rat". Later Stern et al. (1935) reported that in their experiments the growth of rats on a synthetic diet which was low in zinc was markedly retarded as compared to control animals which received enough zinc in the diets. There also was an interference with the development of the fur coat. In further work with rats, Hove et al. (1937) showed that a deficiency of zinc resulted in the impairment of absorption from the intestine. Sadasivian (1951) reported that the lack of this element interfered with the development and mineralization of bones, and it caused a marked lowering of the fat content of livers of rats.

Zinc occurs in the enzyme systems in the body. Carbonic anhydrase was reported by Keilin and Mann (1939) to contain a necessary mineral which was zinc. They reported carbonic anhydrase as being a respiratory enzyme found in red blood cells, and that it played the important role of eliminating carbon dioxide from the body. This mineral was found as a part of the enzyme, uricase, and a part of crystalline insulin, reported Dukes (1955). According to Harrow and Mazur (1955) the zinc content of the pancreas of diabetics was about one half the normal amount, thus suggesting that zinc may be concerned with the storage and utilization of insulin.

According to Morrison (1956), excess calcium ties up the zinc in the rations for swine and causes a disease known as parakeratosis. This may be overcome by adding more zinc to the ration. The disease was characterized by a mange-like condition of the skin, diarrhea, and anorexia.

The actual requirement for zinc by animals is not known but it seems unlikely that a deficiency should occur because of the high zinc content in plants. Smith and Larson (1946) found that too much zinc in the ration produced an anemic condition in rats. They further stated that this could be corrected by feeding or adding copper to the ration. Davis (1951), working with beef cattle, reported that cattle appeared to be quite resistant to comparatively high levels of zinc, and if rations did not contain more than 19 p.p.m., normal growth and development occurred. Feaster et al. (1954) fed excess amounts of zinc to cattle and found that most of the zinc not used by the body was excreted in the feces and not absorbed. They found the accumulation of zinc to be highest in the soft tissue, liver, pancreas, and kidneys.

Manganese

Manganese is essential in the diet of animals, but only traces of this element are needed. In early work it was discovered that manganese played an important role in reproduction. Skinner et al. (1932) reported that female rats which were reared on whole milk fortified with copper and iron did not attain sexual maturity as soon as those receiving the same ration supplemented with manganese. When manganese was added to the diet, the frequency of oestrum was increased. It was observed by Andrews et al. (1953) and Bentley and Phillips (1951) that cows which were fed low manganese rations were slower to develop sexually, as was determined by the first visible signs of extrus. They also observed that bulls on a low manganese diet exhibited delays in reaching sexual maturity, and produced poor quality semen. Tutt (1934) working with cows which failed to become pregnant, used manganese therapy as a successful treatment. In many cases animals failed to conceive and if they did the young were born either dead or died in a few hours after birth.

Probably a manganese deficiency will show up in the chicken before it will in other animals because of its higher dietary needs. Perosis or "slipped tendon" is a malformation of the bones due mainly to a lack of manganese in the ration. Wilgus et al. (1937) reported the addition of .0025 to .015 per cent of manganese in the diet was sufficient to almost entirely prevent perosis. Wachtel et al. (1943) stated that in rats a deficiency of manganese caused "poorer bone formation, averaging about five per cent less ash than normal bones". They further stated that in some cases where the calcium-phosphorus ratio was high, these effects were more pronounced. According to Maynard and Loosli (1956), when rats were fed a low manganese diet, bone changes appeared in the second generation. Other symptoms in the rat included a rough hair coat and nervousness. Smith et al. (1944) found that a manganese deficiency in the diet of the rabbit caused deformed front legs, shorter humeri than normal, lower ash, and breaking strength of bones.

The activating effect of manganese of various tissue enzymes, particularly arginase suggests strongly that it is an essential mineral throughout the animal kingdom. Maynard and Loosli (1956) reported the formation of bone depends on the enzyme activity of manganese.

Manganese is stored mainly in the liver and kidneys of animals. "Its absorption from the intestional tract is very slow and incomplete under normal conditions. The degree of absorption depends on the acidity of the gastric juice and solubility of manganese compounds" reported Von Oettinger (1935).

Manganese is widely distributed in ordinary feeds in small amounts. This small amount is usually adequate for the requirements of animals. Working with beef cows, Totusek et al. (1955) found that "a high intake of manganese (250-500 p.p.m.) did not affect productivity during the year or in three previous years". Observations on weight, condition, and blood plasma phosphorus of the cows at various times indicated a possible detrimental influence from a continuous high intake of manganese. Bentley and Phillips (1951) reported that approximately 20 p.p.m. in the diet (9 mg. per pound) was the optimum amount to feed dairy cows. They further stated that 10 p.p.m. was on the marginal or deficient zone, and cattle could tolerate safely up to 65 p.p.m. in their diets.

Iodine

Iodine functions in a unique role among the trace minerals. It is an indispensable constituent of thyroxine, a hormone in the thyroid gland. Kendall (1919) isolated a crystalline product from the thyroid gland, containing about 65 per cent iodine, which he called thyroxine. Thyroxine is an iodine containing amino acid present in the protein thyroglobin. Seidell and Fenger (1912) reported that there was a very marked seasonal variation in the percentage of iodine present in the thyroid glands of cattle and sheep. There was approximately three times as much iodine present in the glands during the summer months as there was during the winter months. They further stated the glands were largest during periods of lowest content. The animal body contains less than 0.0004 per cent iodine and more than half of this iodine is in the thyroid gland, according to Maynard and Loosli (1956).

The importance of the thyroid gland in the regulation of metabolism, reproduction, lactation, and certain other processes is well known, and it is agreed that adequate dietary iodine is necessary for the normal functioning of the body. Thyroxine controls the rate of metabolism in the animal body. If the thyroid gland is removed or becomes non-functional in early life, there is a stunting of growth and impaired sexual development. In mature animals, there is a physical sluggishness, and hair and skin show a premature aging. If animals are fed feed grown from iodine deficient soil, goiter, an enlargement of the thyroid gland, results. This enlargement is a compensatory hypertrophy or an attempt to supply more thyroxine by the formation of more tissue. Goiter seldom occurs in mature cattle and sheep, and it is most likely to occur in the young at birth when there is a deficiency of iodine in the ration of the mother during gestation. Andrews et al. (1948) found that iodine added to the ration of the ewe significantly increased the iodine content of the thyroid gland of the newborn lamb. It was shown by Welch (1940) that goiter could be prevented in new-born animals during the latter part of the gestation period. Iodine deficiency usually resulted in the birth of dead or weak "big necked" calves. Sometimes they were born hairless. Lambs were born with practically the same symptoms. In both cases, the enlarged thyroid gland was readily seen. Calves and lambs, if born alive, soon died if the deficiency was severe.

There are a few areas in the United States where the soil is deficient in iodine. The two main areas are near the Great Lakes and in the Pacific Northwest. In these areas iodine must be supplied in the ration. The daily requirement for the iodine is extremely small. Pope and associates (1957) suggested that .01 per cent stabilized iodized salt (containing 0.0078 per cent iodine) in the grain portion of the rations of sheep and cattle would furnish several times the daily requirement. Iodine need not be supplied every day because the thyroid gland has a considerable capacity to store the element. Certain elements and feeds have a marked influence on the intake of iodine. Hatfield et al. (1944) found "the presence of flourine in the ration increased the per cent of iodine in the thyroid glands of lambs both under conditions of adequate and inadequate iodine intake". High calcium in the drinking water may promote goiter. Soybeans sometimes produce a compound which slows down the thyroid-secreting activity of the gland. Talmage et al. (1954) reported that feeding commercial phenothiazine preparations may result in a reduced thyroid uptake of iodine in cattle and sheep.

Cobalt

One of the most recent minerals discovered to be essential for ruminants is cobalt. This mineral is essential for the prevention of progressive emaciation and anemia. This condition was first reported in grazing stock in Western Australia. Underwood and Filmer (1935) found that a wasting disease of sheep and cattle (enzootic marasmus) was due to a deficiency of cobalt in the herbage the animals grazed. Since this discovery, baffling diseases of ruminants the world over have been traced to a lack of cobalt. Several cobalt deficient areas have been discovered in the United States. Florida, Maine, New Hampshire, Michigan, New York and Wisconsin have all been reported as cobalt deficient areas. "Coast disease" of sheep, Marston et al. (1948), and "Pine disease" of cattle, Jamieson and Allcroft (1950), reported in different parts of the world have been successfully treated with cobalt.

The symptoms of cobalt deficiency have been reported by many nutritionists. Bowstead et al. (1942), Marston (1952) and Stewart (1952) have all given the deficiency symptoms in sheep and cattle. These symptoms were similar to those of general malnutrition. Animals became listless, lost their appetites, and became unthrifty and emaciated. In later stages they became weak and anemic, and finally died. Also reproduction was seriously impaired, and lambs and calves born from deficient mothers often survived only a few days. Young animals were more apt to be affected than mature animals.

Attempts to discover the action of cobalt in the animal body remained a mystery until the discovery was made that Vitamin B12 contained cobalt in its molecule. Maynard and Loosli (.956) have reported that this vitamin was essential for all species, but that it was not a dietary essential for cattle and sheep, because it was synthesized by rumen organisms, provided an appropriate supply of cobalt was present. In the absence of cobalt bacterial synthesis cannot occur. Therefore a cobalt deficiency in these animals was actually a deficiency of vitamin B12, as this vitamin was not present in the plants which comprised their feed. Hoekstra et al. (1952), Keener and Percival (1950), and Marston and Lee (1949) have all reported that when sheep were suffering from a severe cobalt deficiency, intravenous injections of vitamin B12 brought about an immediate and remarkable response in feed consumption, vigor and body weight gain. When cobalt sulfate was injected intravenously, it brought about a very slow response. They further stated that cobalt must be ingested if it was to be effective, and if it was injected into the blood stream, it was mostly excreted with little beneficial effect; thus showing that cobalt was needed in the rumen for the synthesis of Vitamin B12. These findings explain why no essential role for cobalt has been demonstrated for other animals. They require vitamin B12 in their food, and are unable to synthesize it; therefore cobalt deficiency has been observed only in ruminants. Hale et al. (1950) reported that other beneficial actions of cobalt may be brought about through production of the other members of the B-vitamin groups in the rumen.

Only mere traces of cobalt are required by sheep and cattle. A content on one part of cobalt in ten million parts of the ration on the dry basis, provided an ample amount according to Morrison (1956). He further stated that sheep required slightly more cobalt than cattle. The level of cobalt necessary to produce toxicity in calves was near 40 mg. per 100 pounds of body weight, according to Ely et al. (1948), and Dunn et al. (1952). Becker and Smith (1951) reported that levels up to 160 mg. of cobalt per hundred pounds of body weight daily could be tolerated by yearling sheep for at least eight weeks without harmful effects. This intake was nearly 1600 times the estimated requirement for these sheep. This indicates that the occurrence of cobalt toxicity in ruminants under practical conditions was extremely unlikely. Dunn et al. (1952) and Ely et al. (1953) have shown that intravenously injected methionine was effective in reducing the toxicity of intravenously administered cobalt. An excess of cobalt may produce polycythemia in certain cases when fed or injected.

Most excess cobalt is removed from the body in the urine. Rothery et al. (1953) reported that "the highest concentrations of cobalt were found in the liver, heart, kidney, and pancreas, although muscle, by reason of its relatively greater mass, equaled liver as a site of total cobalt storage".

Trace Minerals in Rations

Much work has been done all over the United States in an attempt to determine the value of trace minerals in ruminant rations, and to determine when they should be used. In many cases conflicting results have been obtained. This may be due to a mineral deficiency in the soil in certain areas and a sufficient supply in other areas. The quality and curing of roughage also influences the value of trace minerals in most cases.

In digestion experiments with lambs, Swift et al. (1951) and Chappel et al. (1955) fed corn cobs as the main roughage. They found the addition of alfalfa ash or a trace mineral mixture resulted in highly significant increases in the digestion of organic matter and crude fiber. The appetite of the lambs was also improved. Chappel et al. (1952), working with sheep in Oklahoma, found that alfalfa ash was the only mineral supplement that appeared to favorably affect the digestion of a corn cob roughage diet. They attributed the action of the trace minerals to a more favorable rumen bacteria which were capable of efficiently digesting a low quality roughage. Summers et al. (1957) reported that alfalfa ash, when added to a corn cob diet and fed to wethers did not affect the digestibility of cellulose, organic matter or crude protein. In some cases daily retention was significantly improved by the presence of the alfalfa ash in the rations. Plumlee et al. (1953) reported that feeding trace minerals depressed the appetite of cattle, and controlled the intake of ground corn cobs when they were fed. The trace mineral cattle grew at a slower rate than the controls. This was in contrast to Beeson et al. (1952) and Burroughs et al. (1950) who found that the ash of alfalfa meal improved corn cob digestion materially. In a sheep experiment where wheat straw was the main roughage, Tillman and MacVicor (1955) found that the addition of alfalfa ash increased the digestibility of organic matter and crude fiber, thus indicating that straw was deficient in some mineral or minerals supplied by alfalfa ash.

At Kansas State College, three experiments were conducted with calves on a wintering ration of sorghum silage, milo grain, cottonseed meal and prairie hay. Smith and Cox (1953), Baker et al. (1955) and Smith et al.

(1956) found that trace minerals had very little effect when added to the rations. Smith et al. (1954) substituted corn for the milo grain in a similar experiment and found no effect or advantage for the use of trace minerals in this ration. Dent et al. (1956) conducted an experiment with two groups of Hereford calves fed grass silage, grain, limited hay with salt, steam bone meal and di-calcium phosphate free choice. The other group received the same ration plus trace minerals in the salt. The control group gained 1.76 pounds while the group having free access to trace minerals gained 2.11 pounds daily. Increased total ration consumption was noted in the animals receiving the trace mineral supplement. Alfalfa ash, when fed at the rate of two pounds daily, did not increase the digestibility of oat silage according to Staheli and Neumann (1958). Nelson (1955) stated that it was not advantageous to add trace minerals to the rations of cattle grazing native grass and being fed a protein supplement during the winter months.

Klosterman et al. (1953) have shown that a ration for fattening steers composed of ground ear corn, soybean meal and poor quality timothy hay was deficient in trace minerals. The cattle responded to a trace mineral mixture of Fe, Cu, Co, Mn, and Zn. They gained significantly faster and were more efficient. Part of this effect appeared to be elicited through improved rumen function. Bentley et al. (1954) obtained the same results on a similar ration. They indicated that cobalt seemed to be the main trace mineral giving the response. In other experiments, Bentley and Moxon (1952), Klosterman et al. (1956) and Bentley et al. (1952) have shown that alfalfa ash added to typical cattle fattening rations would increase the daily gain over control lots. In the experiment of Bentley and Moxon (1952), the mineral fed steers consumed 25 per cent more corn cob meal daily, indicating that appetite was improved by feeding minerals. The mineral mixture improved the daily gains by 43 per cent or from 1.34 to 1.92 pounds daily for the supplemented rations.

When trace minerals were added to roughage rations in which prairie hay was the roughage, somewhat different results exist as to the actual value. Tillman et al. (1954) and Nelson et al. (1951) reported that neither alfalfa ash nor a complete mineral mixture improved the digestibility of prairie hay. In an experiment by Gossett and Riggs (1956), dehydrated alfalfa leaf meal and trace minerals were added to a ration composed of prairie hay fed free choice, two pounds of cottonseed meal and four pounds of milo grain. The trace mineral mixture contained 20.0 per cent $MnSo_4$, 40.0 per cent $FeSo_4$, 0.933 per cent $CoCo_3$, 2.0 per cent $CuSo_4$, and 0.589 per cent $ZnSo_4$. This mixture was fed at the rate of 0.5 per cent of the concentrate. They found the trace minerals did not change the performance of the steers. Work done in Kansas by Swenson and Underbjerg (1953), Swenson et al. (1955) and (1956) indicate that the addition of trace minerals to beef cattle rations adequately supplemented had little effect on growth rate and gains. The trace minerals improved the general appearance and hair of the cattle. Trace minerals also increased the size of erythrocytes in two cases.

EXPERIMENTAL MATERIALS, METHODS AND PROCEDURES

All of the yearling animals used in the four tests were purchased as calves and were wintered and grazed at Manhattan, Kansas, prior to being used in the fattening tests reported here. In experiments I, II, and III the lot fed additional trace minerals had received additional trace minerals in a prior wintering trial. The gain of the control and the trace mineral lots in experiments I, II, and III were approximately the same up until the fattening tests started which are reported in this paper. The steers were allotted to their respective lots initially on the basis of weight.

In experiment IV the 20 yearling heifers were assigned to their respective treatments on the basis of weight and prior treatment.

In experiment I the trace minerals were supplied in a mineralized salt, and the cattle were allowed free choice of this. The trace mineral salt contained the following minerals: manganese carbonate, 0.400 per cent; iron oxide, 0.250 per cent; copper carbonate, 0.060 per cent; sodium thiosulphate, 0.100 per cent; sodium carbonate, 0.100 per cent; cobalt carbonate, 0.022 per cent; potassium iodide, 0.010 per cent; and sodium chloride 99.058 per cent.

The trace minerals fed in experiments II, III, and IV were in a premix which was added to the protein concentrate. This was fed to supply the following amounts in milligrams per head daily in the fattening ration; manganese 56.3; iodine 1.97; cobalt 1.25; iron 46.13; copper 3.65; and zinc, 3.42.

The cattle were individually weighed twice at the start and close of each experiment and were weighed periodically during the trial. At the start of an experiment the animals were fed the concentrate portion of their rations twice daily until they were receiving a full feed of grain and then they were placed on a self-feeder. Prairie hay was either kept before the cattle at all times or fed in amounts readily eaten. Salt was available free choice at all times except in experiment I where the trace mineralized salt was offered free choice to one lot and plain salt was offered free choice to the other lot. A tenth of a pound of ground limestone was fed per head daily along with the protein concentrate. The longest fattening period was 127 days in experiment I and the shortest was 99 days in experiment II. The average length was 109 days.

The carcass data was acquired by college personnel with the cooperation of the packers buying the animals. The carcasses were graded by an official U.S.D.A. meat grader each year. The following U.S.D.A. grades for beef cattle were used; prime, choice, good, commercial, utility, cutter, and canner. Each grade was divided into a third of a grade as top, average or low for that grade. The following values were assigned for the degree of marbling: 5, moderate; 6, modest; 7, small amount; 8, slight amount; 9, traces.

Table 1 shows the mineral content of feeds similar to those used in these four experiments.

EXPERIMENTAL RESULTS AND DISCUSSION

Experiment I

The feeds used in this experiment consisted of coarse ground sorghum grain, cottonseed oil meal pellets (solvent extracted), prairie hay, and ground limestone. The cottonseed oil meal pellets were fed at the rate of two pounds per head daily and ground limestone was fed at the rate of one-tenth pound per head daily as a supplemental source of calcium. Salt was allowed free choice to lot 1 while lot 2 received a trace mineralized salt free choice.

Table 1. Mineral content of feeds[1]. (Moisture free basis)

	Protein	Na	K	Cl	Ca	Mg	P	Fe	Sol. $SO_4^{=}$	Cu	Co	Mn	Mo
	Per cent									p.p.m.[3]			
	Soybean Meal (6)[2]												
Average	48.2	.018	1.88	.073	0.23	0.26	0.72	.016	.09	20.	.21	43.	2.4
Minimum	47.3	.012	1.30	.010	0.10	0.20	0.64	.012	.02	13.	.19	35.	1.7
Maximum	49.2	.024	2.32	.127	0.30	0.30	0.81	.023	.12	29.	.30	48.	3.3
	Cottonseed Meal, Solvent Extracted (2)												
Average	44.9	.010	1.03	.052	0.11	0.37	1.29	.015	.23	22.	.32	24.	4.1
Minimum	44.6	.004	0.91	.051	0.11	0.35	1.25	.014	.12	21.	.29	24.	3.8
Maximum	44.7	.016	1.15	.054	0.11	0.39	1.33	.016	.35	24.	.36	24.	4.5
	Yellow Corn (5)												
Average	10.6	.003	0.35	.050	0.01	0.10	0.32	.004	.02	4.	.23	9.	2.5
Minimum	10.4	.002	0.32	.038	0.01	0.07	0.27	.003	.01	2.	.10	4.	0.7
Maximum	10.8	.003	0.36	.056	0.02	0.12	0.39	.005	.05	6.	.30	14.	4.0
	Milo Grain (1)												
	9.7	.008	0.38	.091	0.05	0.06	0.49	.002		14.	.14	16.	6.7
	Prairie Hay, Mostly Bluestem (8)												
Average	5.5	.014	0.78	.136	0.32	0.30	0.15	.012	.03	25.	.17	53.	1.0
Minimum	4.9	.003	0.50	.105	0.24	0.17	0.10	.005	.01	8.	.08	35.	0.2
Maximum	6.0	.038	1.02	.164	0.36	0.41	0.23	.020	.07	51.	.32	61.	1.7

[1]Glendening et al. (1952).
[2]Figures following name of feed indicate number of samples analyzed.
[3]p.p.m. may be converted to per cent by multiplying by 10^{-4}.

Table 2. Trace minerals in a sorghum grain ration. August 1 to December 6, 1952—127 days.

Management	Self fed grain in drylot	Self fed grain in drylot plus trace minerals
Lot number	1	2
Number of steers in lot	10	10
Av. initial wt. per steer	702	714
Av. final wt. per steer	1039	1045
Av. gain per steer	337	331
Av. daily gain per steer	2.65	2.60
Av. feed per head daily, lbs:		
Ground sorghum grain	19.31	19.08
Cottonseed pellets	2.00	2.00
Prairie hay	5.90	5.92
Ground limestone	.10	.10
Salt	.03	---
Trace mineral salt[1]	---	.02
Av. feed per cwt. gain, lbs:		
Ground sorghum grain	726.63	732.20
Cottonseed pellets	75.25	76.73
Prairie hay	222.19	227.40
Ground limestone	3.76	3.83
Salt	1.02	.92
Av. cost of feed per cwt. gain	$25.96	$26.25
Av. dressing per cent	60.1	60.6
Carcass grades:		
Choice	4	1
Choice-	3	3
Good+	2	1
Good	1	3
Good-	---	2
Degree of marbling[2]	6.5	7.5

[1]The trace mineral salt contained the following minerals: manganese carbonate, .400 per cent; iron oxide, .250 per cent; copper carbonate, .060 per cent; sodium thiosulphate, .100 per cent; sodium carbonate; .100 per cent; cobalt carbonate, .022 per cent; potassium iodide, .010 per cent; sodium chloride, 99.058 per cent.

[2]Scores for degree of marbling: moderate, 5; modest, 6; small amount, 7.

The addition of trace minerals to this ration had very little effect on the rate of gain or feed efficiency. The control carcasses graded slightly higher than the carcasses of the trace mineral cattle and the degree of marbling was in favor of the control steers.

There was no advantage to be noted for the addition of trace minerals in this fattening trial where sorghum grain was the principle grain.

Experiment II

During this 99 day fattening trial the steers were fed ground corn, soybean pellets (expeller process), prairie hay, ground limestone and salt. One of the lots also received trace minerals added to the protein concentrate in the form of a premix. The protein was fed at the rate of $1\frac{1}{2}$ pounds per head daily while the ground limestone was fed at the rate of one-tenth pound per head daily.

The addition of trace minerals to the ration of lot 2 increased the gain .58 of a pound daily over lot 1 fed no trace minerals. This increase was the most noticeable during the last 30 days of the test. Lot 2 fed the trace minerals ate more grain and utilized it more efficiently. The grain was self fed in this test. The carcasses of the trace mineral steers graded slightly higher and the amount of marbling was in their favor.

In this experiment the addition of a trace mineral premix to a corn fattening ration was of definite value. The trace minerals lowered the cost of feed $2.13 per cwt. of gain.

Table 3. Trace minerals in a corn ration. July 31 to November 7, 1953—99 days.

Management	Self fed grain in drylot	Self fed grain in drylot plus trace minerals
Lot number	1	2
Number of steers in lot	10	10
Av. initial wt. per steer	738	727
Av. final wt. per steer	980	1026
Av. gain per steer	242	299
Av. daily gain per steer	2.44	3.02**
Av. feed per head daily, lbs:		
Soybean pellets	1.44	1.46
Corn	14.09	15.88
Prairie hay	4.88	4.62
Ground limestone	.09	.10
Salt	.09	.08
Trace minerals[1]	No	Yes
Av. feed per cwt. gain, lbs;		
Soybean pellets	58.88	48.41
Corn	576.61	525.25
Prairie hay	166.81	153.14
Ground limestone	3.84	3.30
Salt	3.72	2.57
Av. cost of feed per cwt. gain	$21.23	$19.10
Av. dressing per cent	60.6	60.7
Carcass grades:		
Choice	—	1
Choice-	—	3
Good+	2	3
Good	4	2
Good-	3	—
Commercial+	—	1
Av. degree of marbling[2]	8.3	7.2

**Significant at the 1.0 per cent level.

[1]The trace minerals were fed as a trace mineral premix added to the soybean pellets to furnish the following amounts in milligrams per head daily in the ration: manganese, 56.3; iodine, 1.97; cobalt, 1.25; iron, 46.13; copper, 3.65, and zinc, 3.42.

[2]Scores for degree of marbling: small amount, 7; slight amount, 8; traces, 9.

Experiment III

The yearling steers in this test were fed a total of 104 days. During this period they were fed ground sorghum grain, prairie hay, soybean meal (expeller process), salt and ground limestone. Lot 2 received added trace minerals with their protein supplement. The protein was fed at the rate of $1\frac{1}{2}$ pounds per head daily and the ground limestone at the rate of one-tenth pound per head daily. Salt was allowed free choice in both lots of cattle.

Trace minerals added to the ration of lot 2 increased gain only slightly, .07 of a pound per head daily. Lot 2 ate slightly less grain, which was self fed and utilized it a little more efficiently. Carcass data was similar for both lots of steers.

The use of trace minerals in this test produced little beneficial value as far as daily gain, feed efficiency or cost of feed per cwt. of gain was concerned. Similar results were obtained in experiment I where sorghum grain was also used in the fattening ration.

Experiment IV

During this 104 day dry lot full feeding trial, the following feeds were fed: ground corn, soybean meal (expeller process) $1\frac{1}{2}$ pounds per head daily, prairie hay in amounts readily eaten, ground limestone, one-tenth pound per head daily and salt offered free choice. Both lots were handled identically except one lot received a trace mineral premix which was added to the soybean meal.

The addition of trace minerals to the ration of lot 2 increased the daily gain .37 of a pound over lot 1 fed no trace minerals. Lot 2 fed

Table 4. Trace minerals in a sorghum grain ration. August 1 to November 12, 1955--104 days.

Management	Self fed grain in drylot	Self fed grain in drylot plus trace minerals
Lot number	1	2
Number of steers in lot	10	10
Av. initial wt. per steer	845	854
Av. final wt. per steer	1103	1119
Av. gain per steer	258	265
Av. daily gain per steer	2.48	2.55
Av. feed per head daily, lbs:		
Soybean meal	1.51	1.51
Sorghum grain	19.73	19.20
Prairie hay	6.60	6.65
Salt	.01	.01
Ground limestone	.10	.10
Trace minerals[1]	no	yes
Av. feed per cwt. gain, lbs:		
Soybean meal	60.89	59.28
Sorghum grain	795.31	753.39
Prairie hay	266.27	261.16
Salt	.46	.45
Ground limestone	3.91	3.81
Av. cost of feed per cwt. gain	$23.53	$22.42
Av. dressing per cent	60.5	60.6
Carcass grades:		
Choice	—	1
Choice-	1	—
Good+	3	4
Good	3	4
Good-	3	1
Av. degree of marbling[2]	7.1	6.4

[1]The trace minerals were fed as a trace mineral premix added to the soybean meal to furnish the following amounts in milligrams per head daily in the ration: manganese, 56.3; iodine, 1.97; cobalt, 1.25; iron, 46.13; copper, 3.65 and zinc, 3.42.

[2]Scores for degree of marbling: moderate, 5; modest, 6; and small amount, 7.

trace minerals ate slightly more grain and utilized it more efficiently. The carcasses of the heifers fed trace minerals averaged 0.15 of an inch more fat over the 12th rib. Little or no difference was noted in regard to grade, rib eye size, marbling and firmness.

The addition of trace minerals to a corn fattening ration in this test was of definite value. It cost $2.11 more to place 100 pounds of gain on the control heifers than the trace mineral heifers. Similar results were obtained in experiment II.

SUMMARY

In the final analysis of experiments I and III, (Table 7), there appeared to be no advantage for the addition of trace minerals to fattening rations consisting of sorghum grain, a protein concentrate, prairie hay, ground limestone and salt offered free choice.

The addition of trace minerals to a corn fattening ration had a definite value as was shown in experiments II and IV, (Table 8). The cattle gained .47 of a pound more per head daily when trace minerals were added to the ration. An analysis of variance demonstrated this difference in gain was highly significant in each of these two experiments which were summarized to give this final result. The ration consisted of soybean meal, ground corn, prairie hay, ground limestone and salt offered free choice. The trace minerals were added to the protein supplement.

Feed efficiency was improved by the addition of trace minerals in experiment II and IV, (Table 8). The trace mineral cattle required 9.2 pounds less protein concentrate, 53.5 pounds less corn, and 17 pounds less prairie hay to produce 100 pounds of weight. These findings are in

Table 5. Trace minerals in a corn ration. July 24 to November 5, 1957—104 days.

Management	Self fed grain in drylot	Self fed grain in drylot plus trace minerals
Lot number	1	2
Number of heifers in lot	10	10
Av. initial wt. per heifer	716	717
Av. final wt. per heifer	977	1016
Av. gain per heifer	261	299
Av. daily gain per heifer	2.51	2.88**
Av. feed per head daily, lbs:		
Soybean meal	1.49	1.47
Corn	16.61	17.43
Prairie hay	3.60	3.51
Ground limestone	.09	.09
Salt	.02	.02
Trace minerals[1]	no	yes
Av. feed per cwt. gain, lbs:		
Soybean meal	59.25	51.22
Corn	661.87	606.35
Prairie hay	143.30	122.24
Ground limestone	3.56	3.04
Salt	1.00	1.00
Av. cost of feed per cwt. gain	$22.95	$20.64
Av. dressing per cent	59.6	59.6
Carcass grades:		
Choice	—	1
Choice-	4	4
Good+	3	3
Good	2	1
Good-	1	1

**Significant at the 1.0 per cent level.

[1]The trace minerals were fed as a trace mineral premix added to the soybean meal to furnish the following amounts in milligrams per head daily in the ration: manganese, 56.3; iodine, 1.97; cobalt, 1.25; iron, 46.13; copper, 3.65 and zinc, 3.42.

Table 6. Carcass characteristics of heifers fattened with and without trace minerals added to the ration.

Tag No.	U.S.D.A. grade after ribbing	Size of rib eye sq. in.	Fat over rib eye tenth of in.	Marbling[1]	Firmness[2]
		Control lot			
267	G+	10.05"	.600"	7	3
268	G+	11.31"	.567"	7	3
270	G	12.55"	.634"	7	4
271	C-	13.65"	.470"	5	3
272	C-	12.56"	.800"	6	3
273	C-	12.42"	.600"	6	3
274	G	13.16"	.534"	7	3
275	G-	12.91"	.834"	8	3
276	G+	12.76"	.717"	7	3
277	C-	11.96"	.400"	6	3
Average		12.33"	.616"	6.6	3.1
		Trace mineral lot			
243	C-	12.06"	.817"	6	3
244	G+	12.01"	.634"	7	3
245	G+	12.41"	.967"	7	3
246	G-	11.42"	.800"	8	3
247	C	11.77"	.667"	5	3
248	G+	12.17"	.717"	6	4
249	C-	12.60"	.717"	6	3
251	C-	12.73"	.850"	6	3
252	C-	12.20"	.784"	6	3
253	G	11.43"	.784"	8	3
Average		11.98"	.773"	6.5	3.1

[1]Scores for degree of marbling; moderate, 5; modest, 6; small amount, 7; slight amount, 8.
[2]Scores for degree of firmness: moderately firm, 3; modestly firm, 4.

Table 7. Summary of experiments I and III, trace minerals in sorghum grain rations.

Management	Self fed grain in drylot	Self fed grain in drylot plus trace minerals
Lot number	1	2
Av. no. of steers in lot	20	20
Av. initial wt. per steer	774	784
Av. final wt. per steer	1071	1082
Av. gain per steer	297	298
Av. daily gain per steer	2.57	2.58
Av. feed per head daily, lbs:		
Protein	1.76	1.76
Sorghum grain	19.52	19.14
Prairie hay	6.25	6.29
Ground limestone	.10	.10
Trace minerals[1]	no	yes
Av. feed per cwt. gain, lbs:		
Protein	68.07	68.00
Sorghum grain	760.97	742.80
Prairie hay	244.23	244.28
Ground limestone	3.84	3.82
Salt	.74	.69
Av. cost of feed per cwt. gain	$24.75	$24.34
Av. dressing per cent	60.3	60.6
Carcass grades:		
Choice	4	2
Choice+	4	3
Good+	5	5
Good	4	7
Good-	3	3
Av. degree of marbling[2]	6.8	7.0

[1]A trace mineralized salt was used in the first experiment while a trace mineral premix was added to the protein concentrate for the third experiment.

[2]Scores for degree of marbling: modest, 6; small amount, 7; very small amount, 8.

Table 8. Summary of experiments II and IV, trace minerals in corn rations.

Management	Self fed grain in drylot	Self fed grain in drylot plus trace minerals
Lot number	1	2
Av. no. of steers and heifers	20	20
Av. initial wt. per animal	727	722
Av. final wt. per animal	979	1021
Av. gain per animal	252	299
Av. daily gain per animal	2.48	2.95
Av. feed per head daily, lbs:		
Soybean meal	1.47	1.47
Corn	15.35	16.66
Prairie hay	4.24	4.07
Ground limestone	.09	.10
Salt	.06	.05
Trace minerals[1]	no	yes
Av. feed per cwt. gain, lbs:		
Soybean meal	59.07	49.82
Corn	619.24	565.80
Prairie hay	155.06	137.69
Ground limestone	3.70	3.17
Salt	2.36	1.79
Av. cost of feed per cwt. gain	$21.99	$19.87
Av. dressing per cent	60.0	60.2
Carcass grades:		
Choice	—	2
Choice-	5	7
Good+	5	6
Good	6	3
Good-	4	1
Commercial	—	1
Av. degree of marbling[2]	7.5	6.8

[1]The trace minerals were added in the form of a premix to the protein concentrate in both experiments.
[2]Scores for degree of marbling: modest, 6; small, 7; very small, 8.

agreement with Bentley and Moxon (1952), Klosterman et al. (1953) and Bentley et al. (1952) who have shown that trace minerals, when added to a corn fattening ration, increased gains substantially.

In analyzing these results it is interesting to note that trace minerals had no effect or value when added to a fattening ration in which sorghum grain was the principle grain. However, improved performance was obtained when trace minerals were added where corn was the grain in the ration. Apparently corn is either deficient in one or more of the trace minerals which were added or there is some other value in their presence, whereas this situation does not seem to exist when sorghum grain is the principal feed.

Glendening et al. (1952) analyzed corn and sorghum grain and found sorghum grain contained .002 per cent less iron, 10 p.p.m. more copper, 9 p.p.m. more cobalt, and 7 p.p.m. more manganese than did corn. Beeson (1941) reported that sorghum grain contained 6 p.p.m. less zinc and 320 p.p.b. less iodine than did corn.

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THE VALUE OF TRACE MINERALS IN BOVINE
FATTENING RATIONS

by

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It is commonly believed that there is no trace mineral deficiency in Kansas. The feed analysis that have been made bear out this belief. However it is possible that for some reason the trace minerals may not be readily available in feeds or perhaps not in the proper ratio to supply the demands of cattle on fattening rations. With this thought in mind, four experiments were conducted to study the value of adding the following trace minerals to fattening rations commonly used in Kansas: cobalt, copper, iron, iodine, manganese, and zinc.

Each of the four trials consisted of two lots of 10 animals. One of the two lots in each experiment was supplied with additional trace minerals. The average length of the fattening trials was 109 days. Hereford steers were used in the first three experiments while Hereford heifers were used in the last experiment. A trace mineralized salt was used as a source of trace minerals for the first trial and a trace mineral premix was added to the protein concentrate the last three experiments.

In summarizing experiments I and III, there appeared to be no advantage for the addition of trace minerals to a fattening ration consisting of sorghum grain, protein concentrate, prairie hay, ground limestone, and salt which was offered free choice.

The addition of trace minerals to a corn fattening ration had definite value as was shown in experiments II and IV. The cattle gained .47 of a pound more per head daily on the average for the two trials when trace minerals were added to the ration. An analysis of variance demonstrated this difference in gain to be highly significant in each of these experiments. The ration used consisted of soybean meal, corn, prairie hay, ground limestone, and salt which was offered free choice. The trace minerals were in a premix form and added to the protein supplement. Feed efficiency was improved considerably by the addition of trace minerals.

In analyzing these results it is interesting to note that trace minerals had no apparent value when added to a fattening ration in which sorghum grain was the principle grain fed. However, improved performance was obtained when trace minerals were added to the corn fattening ration.