8-1974

Some effects of urea and sulfur additions to corn silage for growing-finishing heifers

Roger D. Brooks

To the Graduate Council:

I am submitting herewith a thesis written by Roger D. Brooks entitled "Some effects of urea and sulfur additions to corn silage for growing-finishing heifers." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

C. C. Chamberlain, Major Professor

We have read this thesis and recommend its acceptance:

J. B. McLaren, D. O. Richardson

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Roger D. Brooks entitled "Some Effects of Urea and Sulfur Additions to Corn Silage for Growing-Finishing Heifers." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

C. C. Chamberlain, Major Professor

We have read this thesis
and recommend its acceptance:

J. B. McLaren

Don O. Richardson

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

SOME EFFECTS OF UREA AND SULFUR ADDITIONS TO CORN SILAGE FOR GROWING-FINISHING HEIFERS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

Roger D. Brooks

August 1974

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to the following persons for their contribution to his education and the writing of this thesis:

To Dr. C. C. Chamberlain, major professor, for planning and leading the research on which this thesis was written, for his helpful suggestions in the writing of this thesis and for the personal guidance given to the author while a student at The University of Tennessee.

To Drs. J. B. McLaren and D. O. Richardson for serving with Dr. C. C. Chamberlain as the graduate committee and for the assistance and advice they gave the author while at The University of Tennessee.

To Mr. Hugh Felts and his staff at Greeneville for purchasing, feeding, weighing and marketing of the heifers used in this study.

To Drs. W. L. Sanders and J. B. McLaren for their assistance with the statistical analysis and interpretation of the results.

To Mr. Marvis Fryer for making the chemical analysis of the feeds used in this study.

To Mrs. Linda Sharp for her assistance in the calculation of the feed and cattle weight data and for typing most of the rough draft of the thesis.

To Mrs. Joan Greene for typing the final draft of the thesis.

To Dr. John D. Smalling and Professor E. R. Lidvall for their encouragement, friendship and guidance throughout the author's college career.

To his parents, Mr. and Mrs. Kenneth Brooks, for their encouragement, love, patience and tremendous financial support throughout all of his years in school.

To his brother, Gregory, for helping feed and care for the author's livestock while the author was away from home.

ABSTRACT

A six-year study with growing-finishing beef heifers was conducted to: 1. Compare cottonseed meal (CSM) and urea as protein supplements for corn silage; 2. To evaluate cattle performance when sulfur was added to urea-treated corn silage; 3. Test the value of different levels of urea additions to corn silage if the N:S ratio is held constant; and 4. Compare organic and inorganic sources of sulfur added to urea-treated corn silage.

Each year 40 or 48 medium or good grade heifer calves (450-500 pounds) were allotted into eight lots of five or six each. Two lots were randomly assigned to each treatment. The finishing period was divided into a silage phase and a concentrate phase. The heifers were weighed every 28 days and subjectively evaluated at the beginning and end of each feeding phase. When the heifers reached an average condition grade of good, they were slaughtered.

During the silage phase the CSM-supplemented heifers gained significantly faster ($P < .05$) than the urea-supplemented heifers. At the end of the total feeding period the CSM-supplemented heifers had a higher Average Daily Gain (ADG) than the urea-supplemented heifers, but the difference was non-significant ($P > .05$). There was no significant difference ($P > .05$) between groups in feed conversion due to source of protein.

During 1968 and 1969 sulfur-supplemented heifers required significantly more ($P < .05$) silage dry matter per pound of gain than heifers fed urea-treated corn silage without added sulfur. However, there was

no significant difference ($P > .05$) in ADG between treatments in any feeding phase. Also, there was no significant difference ($P > .05$) in ADG or feed efficiency between groups of heifers fed urea-treated corn silage with and without added sulfur in 1970-1973.

In 1970 and 1971 when ten pounds and 20 pounds of urea were added per ton of corn silage with the N:S ratio held constant, there was no significant difference ($P > .05$) in ADG or feed efficiency in any of the groups of heifers due to silage treatment.

Sodium sulfate and methionine-hydroxy-analogue (MHA) were compared as sulfur sources in 1972 and 1973. There was no significant difference ($P > .05$) in ADG or feed conversion in any feeding phase due to sulfur source.

Grain was not fed during the silage phase in 1968 and 1969 but was fed during the silage phase of the 1970-73 trials. All heifers in all years were fed to the same slaughter weight and grade, but the heifers in 1970-73 averaged 44 fewer days on feed and required less feed per pound of gain than those in 1968 and 1969.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

TABLE PAGE

CHAPTER I

INTRODUCTION

Beef cattle production is an important segment of Tennessee agriculture. The United States Department of Agriculture (1974) reported that Tennessee farmers owned 2,690,000 cattle and calves as of January 1, 1974. The University of Tennessee Agricultural Extension Service (1972) reported that the cash receipts from marketing cattle and calves accounted for 25.6 percent of the total farm marketing in Tennessee in 1971. To properly feed and further improve the feeding of these cattle is a great challenge to the cattle feeder and animal nutritionist.

Corn silage is a widely used stored livestock feed primarily fed to cattle in confinement or during the winter months. According to the Tennessee Department of Agriculture (1973) 162,000 acres of corn in the state were used to produce 2,349,000 tons of corn silage in 1972. Corn silage yields more total digestible nutrients per acre than most other forage crops (Ensminger, 1970).

During recent years the use of non-protein-nitrogen (NPN), primarily as urea, to replace natural protein in cattle rations has rapidly increased. Colby (1973) recently estimated the tonnage of urea going into the feed trade at over a million tons annually. The addition of urea to a low protein feed elevates the crude protein equivalent content of the feed. For example, a corn silage containing 2.3 percent crude protein equivalent (wet basis) at the time of ensiling was increased to 3.7 percent crude protein equivalent when ten pounds of urea was added per ton of green chop at the time of ensiling (Ensminger, 1970).

The fact that urea can be used to increase the crude protein equivalent content of feeds has been accepted. However, it has not been resolved whether cattle would perform as well when the added nitrogen came from urea rather than a natural protein source such as cottonseed meal (CSM). Also the addition of urea widens the nitrogen to sulfur (N:S) ratio which poses the question of whether to add sulfur to a urea containing feed in order to maintain a normal N:S ratio. Sulfur is an essential nutrient used in the formation of amino acids cystine and methionine. It has been suggested that organic sources of sulfur such as methionine-hydroxy-analogue (MHA) may be superior to inorganic sources such as sodium sulfate. A fourth question raised by cattle feeders using large amounts of corn silage for growing and finishing cattle was whether the addition of corn (energy) during the silage feeding (forage) phase would economically improve animal performance and shorten the concentrate feeding period.

This study was designed to help answer these questions. This paper summarizes the results of six years of investigation (1968-1973) with corn silage which was supplemented with corn, CSM, urea, limestone and MHA to study the effects of these ration ingredients on the production of market beef heifers in Tennessee.

CHAPTER II

LITERATURE REVIEW

Role of Sulfur

Sulfur is a principal mineral constituent of the animal body accounting for approximately 0.15 percent of a steer's total body weight (Maynard and Loosli, 1969). Sulfur-containing compounds function in nature as structural entities (collagen), as catalysts (enzymes), as oxygen carriers (hemoglobin), as electron carriers (cytochromes), as hormones (insulin), as vitamins (thiamine and biotin) and in other ways (Johnson, Goodrich and Meiske, 1970).

Sulfur has an important role in protein structure. The sulfur-containing amino acids, cysteine and methionine, supply sulfhydryl groups and hydrophobic thioether groups, respectively, which affect the structure of proteins and their interactions. Another important sulfur-containing amino acid is cystine. (Maynard and Loosli, 1969) report that the sulfur needs of the body are primarily a matter of amino acid nutrition. Amino acids are the "building blocks" from which body protein is made.

Natural feeds high in protein are usually good sources of sulfur. Rations composed of natural plant and animal components generally contain adequate sulfur to meet requirements of ruminant animals. However, the organic and inorganic sulfur contents of plant material vary widely between species and among individuals within species depending on soil sulfur supply (Moir, Somers and Bray, 1967). The nitrogen to sulfur ratio (N:S) of plant material widens under soil sulfur-deficient conditions and may result in a sulfur deficiency in animals receiving feeds grown on such soils.

Loosli (1952) suggested that the ratio of nitrogen to sulfur should be about 15:1 to satisfy nutritional requirements in ruminants. The amino acid composition of ruminal bacteria shows a relatively uniform sulfur amino acid content with a N:S ratio of approximately 15:1. The National Research Council, NRC, (1970) lists a sulfur requirement for growing and finishing beef steers and heifers at 0.1 percent of the ration dry matter.

Most of the research work with sulfur reviewed indicated only a few cases in which a sulfur deficiency had been shown in ruminants when the ration consisted of natural feedstuffs. Jacobson et al. (1967) reported a sulfur deficiency in lactating Holstein cows after nine weeks on a diet of 6.3 parts corn silage and 1.0 part concentrate fed ad lib. Most other research work reported the sulfur content of natural feeds adequate to prevent deficiency symptoms (Lofgreen, Weir and Wilson, 1953; Bolsen, Woods and Klopfenstein, 1973).

While most researchers feel that the sulfur level of natural feeds is adequate to meet the requirements of the ruminant, many are in agreement that there may be a deficiency of sulfur in rations in which urea replaces natural protein sources. Urea is an alternative source of nitrogen for ruminant feeding which came into prominence in America during World War II due to the shortage of commonly used protein supplements. "There is a large body of experimental evidence that the ruminant protein requirement can be satisfied in part and even wholly from dietary non-protein-nitrogen" -- NPN -- (Moir et al., 1967). Urea is commonly used as a source of NPN. Feeding urea to ruminants has been shown to be effective in increasing the animals' nitrogen retention under some circumstances (Moir, et al., 1967; Starks, et al., 1953).

The reason ruminants can use urea, a nutritionally inadequate protein source for other classes of animals, is because of the microbial population of the rumen. Within the rumen, dietary NPN, as well as proteins, is large degraded to ammonia which is known to be the main nitrogen source for many microbial bacteria (Bryant and Robinson, 1963). The synthesis of protein by bacteria from NPN may provide the ruminant animal with its amino acid requirement. These bacteria have a N:S ratio of approximately 15:1 which is very close to the N:S ratio of leaf proteins.

Since urea has become accepted as a ruminant feed ingredient and in view of the known relationship between rumen bacteria and the N:S ratio there has been considerable interest shown in the additions of sulfur to urea-containing rations. It has been observed that the addition of urea to a natural feed such as corn silage widened the N:S ratio of the feed, in some cases approaching 20-30:1. Researchers have added sufficient sulfur to many urea-containing rations to narrow the N:S ratio to a range of 15:1 to as low as 5:1 (Thompson et al., 1972; Lofgreen et al., 1953; Thomas, 1971). The results of adding sulfur to urea-containing rations have been inconsistent in that sulfur additions were beneficial in some trials but showed no advantage in others. Thompson et al., (1972) found no significant advantage from the addition of sulfur to the rations of growing and finishing beef cattle while Burroughs, Shively, and Wolf (1966) found that the addition of sulfur to the rations of growing-finishing beef cattle resulted in improved average daily gains (ADG) and improved feed efficiency for approximately a three-month period.

Much of the early basic work with sulfur in ruminants was done with sheep on purified diets (Thomas et al., 1951; Starks et al., 1953; Starks et al., 1954). This work indicated a definite need for sulfur in the diet of the ruminant. Other studies with sheep (Lofgreen et al., 1953), beef cattle (Thompson et al., 1972; Bolsen et al., 1973) and dairy cattle (Davis, Williams and Loosli, 1954; Jacobson et al., 1967) used sulfur additions to rations made primarily of natural feeds. Animal performance from dietary sulfur additions to natural feeds was variable. There has been in vitro work (Barton, Bull and Hemken, 1971) with sulfur studying the effect of sulfur on digestion.

Sulfur Work--Sheep

Thomas et al. (1951) fed lambs on purified diets to establish the need for sulfur. In the first experiment eight lambs, approximately nine months old, were allotted into two groups of four lambs each. One group was fed a urea-plus-sulfur diet and the other a sulfur-deficient diet. Because the lambs did not eat the purified diets readily they all lost weight during the first 60 days. Thereafter, those on the urea-plus-sulfur diet gained weight while those on the sulfur-deficient diet continued to lose weight. Three lambs on the sulfur-deficient diet died after 128 to 146 days. In a second trial lambs on the sulfur-deficient diet lost weight from the beginning of the trial. Two died after 90 days. All the urea-plus-sulfur lambs gained in body weight and appeared in good condition after 150 to 266 days on the diet. In a third trial after one lamb on the sulfur-deficient diet died, sulfates were added to the diet of the remaining three animals and they began gaining weight within a few days.

Symptoms of sulfur deficiency in lambs as reported by Thomas et al. (1951) included depraved appetities, chewing on wooden pens, and pulling and consuming wool from their bodies. Samples of rumen material revealed marked changes in the number and type of microflora in the sulfur-deficient animals. Lambs fed sulfur-deficient diets were always in negative balance for both sulfur and nitrogen while those fed the urea-plus-sulfur diet were in positive balance consistently. The rate of wool growth was less in lambs fed sulfur deficient diets.

From this study it was concluded: (1) that lambs have a dietary requirement for sulfur which can be met by inorganic sulfates, and (2) in the absence of dietary sulfur, urea nitrogen apparently had limited utilization since lambs fed sulfur deficient diets were consistently in negative nitrogen and sulfur balance.

Starks et al. (1953) conducted a similar study using a paired feeding technique. In each case the lamb on the sulfur deficient diet limited the intake level. The balance studies showed similar nitrogen-sulfur retention patterns to those of Thomas et al. (1951) and that elemental sulfur can be used to meet the sulfur needs of sheep. They reported additional deficiency symptoms of excessive lacrimation, profuse salivation, dullness, weakness and cloudy eyes.

Starks et al. (1954) conducted a second experiment with growing lambs to compare the utilization of elemental sulfur, sodium sulfate and DL-methionine; and to study the quantitative requirements of the three compounds for growing lambs. The lambs were fed ad libitum a basal purified ration containing 0.052 percent sulfur with 92 percent of the nitrogen from urea, supplemented with three levels each of elemental sulfur (0.2%, 0.4% and 0.6%), sodium sulfate (0.89%, 1.33% and 1.78%) and DL-methionine (0.2%, 0.5% and 0.7%). All lambs receiving the sulfur-deficient basal ration lost weight throughout the trial. Weight gains of lambs on the sulfur-supplemented rations were significantly greater than those on the basal ration ($P < 0.001$). There were no significant differences ($P > .05$) among the sulfur sources or levels within each source. The rations having the lowest level of each sulfur supplement furnished adequate or nearly adequate sulfur as judged by weight gain and wool growth. Elemental sulfur is unpalatable and four of the 12 lambs on this supplement had to be removed from the trial because they would not eat. Two of the sodium sulfate supplemented lambs at the highest levels also stopped eating and were removed from the trial.

Using a purified ration in which urea furnished 92 percent of the nitrogen for growing-fattening lambs, Albert et al. (1956) compared methionine, sodium sulfate and elemental sulfur as sulfur sources. On the basis of total sulfur they found that about 70 percent less sulfur was needed as methionine and about 50 percent less as sulfate sulfur.

The data suggests that sodium sulfate is used more efficiently than elemental sulfur. Comparing elemental sulfur and sulfate sulfur for the production of wool proteins Hale and Garrigus (1953) used S^{35} as a tracer. Sulfur from each source appeared in the wool indicating that both sources can be synthesized into wool protein by sheep. However, the S^{35} activity of the wool suggested that sulfate sulfur was better utilized for the synthesis of cystine. Further comparison of sulfate and elemental sulfur by Goodrich and Tillman (1966) showed that gain, feed consumption and gain/100 grams of feed were significantly ($P < .01$) greater for sheep fed sulfate sulfur compared with those fed elemental sulfur.

Lofgreen _et al._ (1953) added 0.2 percent sodium sulfate to a ration made up of approximately 87 percent natural feeds, but with urea furnishing 40 percent of the total nitrogen, to determine if the addition of sodium sulfate would prove beneficial to growing-fattening lambs. The lambs were fed _ad lib_ for 180 days. The added sulfur did not affect body weight gains, feed efficiency, nitrogen retention, serum sulfate levels or wool growth. The basal ration contained 0.23 percent total sulfur and 0.15 percent inorganic sulfur and had a N:S ratio of 9.3 to 1. In this case the natural feeds apparently supplied adequate sulfur for the 180 day feeding period even with 40 percent of the total nitrogen supplied as NPN.

Sulfur Work--Dairy Cattle

Since high producing dairy cows secrete large amounts of sulfur into their milk in relation to the sulfur ingested, the possibility of a naturally occurring deficiency exists. Davis et al. (1954) conducted studies to (1) determine the sulfur content of concentrate feeds and (2) find whether the addition of sulfates to a concentrate mixture containing urea would improve the lactation performance of dairy cows. The N:S ratio found in 29 different types or grades of concentrates ranged from 2:1 for cane molasses to 17:1 for soybean oil meal (SBM). In the lactation study 18 Holstein cows, three groups of six each, were fed for eight weeks to determine the effect of the sulfur content of feeds on milk yield. Group I received a concentrate containing SBM, Group II received a low sulfur ration with urea added to supply crude protein equivalent but no SBM; Group III was also fed the urea-containing concentrate mix but enough sodium sulfate was added to equal the estimated sulfur content of Group I. All rations were adequate for crude protein based on accepted standards. There were no significant differences in milk yield between groups, and feed intakes and utilization were very similar. Highest yields were from cows receiving SBM. It was concluded that unless feeds from sulfur-deficient soils were used there is little chance of sulfur deficiency in dairy cattle for at least eight weeks when the concentrate feed contains 3 percent or less NPN.

Jacobson et al. (1967) produced a sulfur deficient ration of natural feeds. In this experiment 24 mature lactating Holstein cows, two groups of 12 cows each, received the same corn silage which contained 0.09 percent sulfur on a dry matter basis. Both groups received the same concentrate mixture except that 0.9 percent $NaSO_4 \cdot 10H_2O$ was added for the sulfur supplemented group. The corn silage and concentrate mixture were fed ad lib at a constant ratio of 6.3 parts silage to 1.0 parts concentrate for nine weeks. Voluntary feed intake and milk production were significantly higher for the sulfur supplemented group by the ninth week of the experiment. Changes in body weight for both groups were very small and not statistically significant.

In the same study the effects of dietary sulfur on amino acids of the blood and rumen contents were determined. No significant differences between treatments were found in either blood or rumen amino acids. However, they reported the following: "Seven of the plasma free amino acids of both groups decreased significantly with time ... The essential sulfur-containing amino acid, methionine, decreased to about half the initial level ... Cystine dropped ... to about one-seventh the initial level ... Considered together, the sulfur-containing amino acids dropped more than any other amino acids, an effect attributed to the low-sulfur diet or to poor conversion or insufficient sulfur supplementation in the other group ... The data show that a low sulfur diet can lead to reduced plasma-free amino acids, including the sulfur-containing amino acids, and that reduced quantities of amino acids available to the host can cause reductions in voluntary dry matter intake and milk production." The work reported here shows that a ration of all natural feedstuffs may provide less than optimal amounts of sulfur to maintain plasma levels of amino acids in lactating dairy cows.

Sulfur Work--Beef Cattle

Research was conducted by Thompson et al. (1972) to compare sources of supplemental nitrogen added to high concentrate rations with and without elemental sulfur for growing-finishing beef cattle. For the 164-day feeding trial 40 Hereford and 40 Angus steers averaging 575 pounds were used. Added sulfur reduced the calculated N:S ratio of the feed from 15:1 to 5:1. Feed was offered *ad libitum*. ADG and feed per unit gain were unaffected by source of supplemental nitrogen. Addition of elemental sulfur 1) lowered feed consumption, 2) improved feed efficiency, and 3) did not affect ADG in this experiment. However, ADG was suppressed in steers receiving added sulfur in another experiment by the same workers. Suppressed feed consumption by the addition of elemental sulfur may have influenced feed utilization. These workers found no significant advantage to the addition of sulfur to cattle rations to reduce the N:S ratio below 15:1 in this or other experiments they have conducted.

The effects of methionine and ammonium sulfate as supplemental sulfur sources for beef cattle fed SBM or urea supplemented high-corn rations was studied by Bolsen et al. (1973). Eighty-four mixed breed yearling steers averaging 695 pounds were randomly assigned to 12 lots. Two lots were assigned to each of six rations differing only in amounts of urea, SBM, and sulfur. The steers were kept in dirt lots and always had access to feed and water during the 120-day trial. Feed efficiency, carcass grade and dressing percent were not significantly different among treatments. Difference in ADG was not significant although steers on SBM rations had the highest daily gains while those on the urea plus high sulfur had the lowest. Edwards et al. (1972) added sulfur at the rate of one part sulfur to ten parts NPN to the ration of steers fed corn silage free choice with a limited feed of corn grain and enough dry urea to meet the N.R.C. requirements for total protein. In this experiment the ADG and total dry matter per pound of gain favored the sulfur additions in the 182-day trial, but again the differences were not significant.

Burroughs et al. (1966) conducted three experiments with yearling steers in which part of the cattle received sulfur supplementation part or all of the feeding period (195 to 264 days). The performance of these cattle was compared to that of cattle not receiving sulfur. The rations were basically the same except for the sulfur addition.

The addition of sulfur to the high-urea supplements fed in each of the experiments resulted in improved feedlot performance of cattle for approximately a three month period. This improved performance occurred irrespective of whether the sulfur was added during the first three months or the last three months of the feedlot period. During the initial period (approximately three months = average of experiments) of sulfur feeding liveweight gains were stimulated seven percent, feed consumption increased four percent and feed per unit gain was reduced by three percent. When sulfur was continued in the feed for a second three-month period, feedlot performance was decreased. Liveweight gain was seven percent less, feed consumption was reduced by two percent, and it took six percent more feed per pound of gain. Based on these results Burroughs et al. (1966) suggested the use of additional sulfur in rations containing high urea supplements only during the last three months the cattle are in the feedlot. It appeared from these experiments that 0.03 to 0.06 pounds of added sulfur as flowers of sulfur per animal daily was as beneficial as 0.33 pounds of Glauber's salt.

Methionine-hydroxy-analogue-calcium (abbreviated M-analogue or MHA) was used in an experiment with beef cattle by Burroughs and Trenkle (1969 a) to test the benefits of a different source of sulfur added to a protein supplement in which urea supplied all the crude protein equivalent. M-analogue is an organic chemical compound containing sulfur and resembles the chemical structure of methionine. M-analogue has properties which under rumen pH conditions help protect it against microbial destruction within the forepart of the digestive tract of cattle but it is readily absorbed into the blood stream as it enters the true stomach. Once absorbed M-analogue goes immediately to the liver which transforms it into an additional supply of methionine above that capable of being supplied to the liver by unprotected dietary methionine. This additional supply of methionine should promote protein synthesis and weight gains in cattle. Three grams of M-analogue per head per day was believed to be near the optimum level for feedlot cattle. Hereford and Angus heifer calves averaging 460 pounds were fed for 151 days. M-analogue was added at the rate of three grams per head per day and compared to urea-containing-control rations without added sulfur. M-analogue gave good results throughout all of the 151-day trial and the response was consistent in each of the four lots receiving this additive. The ADG in the four all-urea control lots was 2.16 pounds compared with 2.44 pounds in the four M-analogue supplemented lots, a difference of 13 percent. Control lots used 676 pounds of feed per 100 pounds of gain while the M-analogue lots used only 607 pounds or ten percent less feed per pound of gain.

Burroughs and Trenkle (1969 b) basically repeated the experiment using yearling steers averaging 740 pounds. Steers receiving the three gram level of M-analogue added to the all-urea supplement gained seven percent faster with seven percent better feed conversion than controls during their first 72 days in the feedlot. Cattle on higher levels of M-analogue did not respond as well. However, steers receiving sulfate sulfur with the all-urea supplement gained 12 percent faster with nine percent better feed conversion than controls. It is noted that this is a better than normal response for the sulfate sulfur addition.

Sulfur Work--*In Vitro*

Barton, Bull, and Hemken (1971) conducted an *in vitro* digestion trial to study 1) the effect of varied levels of sulfur upon cellulose digestion in a purified diet consisting of 60 percent cellulose, 36 percent starch, and 4 percent urea and 2) to test the effects of the level of sulfur upon acid detergent fiber (ADF) digestion in corn fodder pellets which contained 23.5 percent ADF and 6.4 percent lignin. There was a significant increase in cellulose digestion due to increasing levels of sulfur in the dry matter (DM) of the substrate. The level of sulfur at which cellulose digestion was optimum was 0.15 percent DM. A significant increase in ADF digestion was observed up to a level of 0.17 percent total sulfur.

Sulfur level also influences starch digestion by rumen micro-organisms *in vitro*. Kennedy, Mitchell and Little (1971) added sulfur to a simplified medium of starch, urea, NaCl and buffer and got a 56 percent increase in starch digestion.

CHAPTER III

EXPERIMENTAL PROCEDURE

The feeding experiments were conducted over a six-year period from 1968 to 1973 at the Tobacco Experiment Station near Greeneville, Tennessee. The first two years of work were a continuation of a previous three-year study (Vickers, 1971) to determine the effects of the maturity of corn silage at harvest on the performance of beef heifers. In these experiments ten pounds each of urea and limestone were added per ton of green chop corn when harvested at three stages of maturity: late milk, early dough and late dough. The last three years of experimental work reported here (1971, 1972, 1973) were a continuation of work reported by Thomas (1971) in which an attempt was made to determine if it was essential to add sulfur to urea-limestone treated corn silage to maintain a proper nitrogen to sulfur ratio. During the 1972 and 1973 experiments methionine-hydroxy-analogue (MHA) was added to the ration of one of the experimental groups of heifers in an effort to determine if MHA has any effect upon feedlot performance. The procedures used in conducting these feeding experiments are discussed in this chapter.

Production of Silage

The corn for silage was grown on Class I land comprised of 80 percent Huntington silt loam and 20 percent Lindside slit loam. A medium maturing hybrid corn recommended by The University of Tennessee

Agricultural Extension Service was planted each year at a rate that produced 16,000 to 18,000 plants per acre. Each fall after the corn was harvested for silage small grains were sown for a cover crop and used for winter pasture. Fertilization each year was basically the same. Before the small grain residue was plowed under each spring the field was top dressed with 50 pounds of nitrogen and 12 tons of cattle manure per acre. Before the corn was planted 160 pounds of nitrogen, 27 pounds of phosphorus and 50 pounds of potassium per acre were broadcast on the field. For weed control the recommended rates of either Simazine or Atrazine were used.

Stages of Maturity

In 1968 and 1969 the corn was harvested for silage at three stages of maturity: late milk, early dough and late dough. After 1969 all of the silage was harvested at the same stage of maturity each year. Data reported by Thomas (1971) showed that there was no significant differences ($P > .05$) in either feedlot performance on in condition scores, due to the stage of maturity at which the silage was harvested. In 1970 the corn was harvested at the early dough stage of maturity. In 1971, 1972 and 1973 the corn was harvested for silage at a maturity stage between early dough and late dough.

Harvesting and Storage of Silage

The green chop was harvested each year with a field chopper set for 0.5 inch cut. Before the green chop was blown into the silo each wagon load was weighed. Urea, limestone, and sodium sulfate were broadcast over each load at the desired rate for each treatment. Two upright silos measuring six feet by 21 feet with a capacity of approximately ten to eleven tons were filled for each treatment each year. The green chop normally had a minimum of one month of fermentation before the silos were opened and feeding began.

Chemical Analysis of Feeds

A chemical analysis of feed samples from each treatment was made each year according to A.O.A.C. (1965) recommendations. Silage samples from each silo and hay and grain samples were taken, processed and ground through a Wiley Mill before a proximate analysis was run to determine the chemical composition of each of the feedstuffs used in the experiments.

Description of Animals

Each year of the experiment from 1968 through 1972 forty beef heifer calves grading good and of the same weight were purchased. Prior to 1971 Tennessee feeder calves were graded into the medium, good and choice grades. Beginning in 1971 Tennessee feeder calves were graded into good, choice, and prime grades in an effort to keep Tennessee grades in line with U.S.D.A. standards. After this change all heifers bought for these experiments were graded good in the feeder calf sales. After a two to three week adjustment period at the Greeneville Station, the heifers were reweighed and regraded for type and condition. On the basis of weight, grade (both type and condition), weight changes during the adjustment period and predicted outcome, the heifers were allotted in uniform lots. Two lots containing five heifers each in 1968-1972 and six each in 1973 were randomly assigned to each treatment. Although the animal feeding phase of the experiment each year extended into the winter following the silage harvest, the year of harvest and cattle purchase will be used to describe the experiments each of the six years.

Feeding Phase

During the silage feeding phase the heifers were fed corn silage *ad libitum* once a day with increases or decreases in daily feed levels based on the amount of feed left in the trough from the previous day. Except in 1968 the dry matter content of the silage used in all treatment comparisons varied by approximately three percent or less based upon laboratory feed analysis. In 1968 there was a difference of over seven percent in dry matter content of the silage used in two treatment comparisons. This difference has not been accounted for. Each heifer also received approximately two pounds of good quality alfalfa-orchardgrass hay per head per day. In 1968 and 1969 the silages in the first treatment (late milk), second treatment (late dough) and third treatment (early dough) were treated with ten pounds of urea and ten pounds of limestone per ton at the time of ensiling. The fourth treatment (early dough) was treated with ten pounds of urea, ten pounds of limestone and 1.5 pounds of sodium sulfate per ton green weight to maintain a calculated nitrogen to sulfur ratio of about 12:1.

In 1970 silage for all treatments was harvested at the early dough stage of maturity and in 1971 all silage was harvested at a maturity stage between early and late dough. During these two years the first treatment had no urea or limestone added to the green chop. However, the cattle on this treatment received one pound of cottonseed meal (42%) per head per day as a protein supplement spread over the silage at each feeding period to give approximately the same nitrogen intake level as in treatments two and three. Silage in treatment two contained ten pounds of urea plus ten pounds of limestone per ton of green chop. This was comparable to treatment three in 1968 and 1969. Silage in treatment three in 1970 and 1971 was supplemented with ten pounds of urea, ten pounds of limestone and 1.5 pounds of sodium sulfate per ton of green chop. This treatment for 1970 and 1971 compares with treatment four in 1968 and 1969. In 1970 and 1971 each ton of green silage in treatment four had 20 pounds of urea, ten pounds of limestone and three pounds of sodium sulfate added. Although this doubled the quantity of urea nitrogen present, the additional sodium sulfate maintained the 12:1 nitrogen to sulfur ratio used in treatment three. All heifers on treatments two, three and four received five pounds of corn and cob meal per head per day during the silage phase. Treatment one heifers were fed five pounds of corn and cob meal plus one pound of cottonseed meal per head per day. All heifers on each treatment were fed corn silage ad libitum once a day top-dressed with the grain and two pounds of alfalfa-orchardgrass hay per head per day.

In 1972 and 1973 silage for all treatments was harvested at a maturity stage between early and late dough. Treatment one heifers were fed four pounds of corn and cob meal plus one pound of cottonseed meal per head per day. This made all heifers on all treatments receiving five pounds of concentrate per head per day. Treatments two and three were the same in 1972 and 1973 as in 1970 and 1971 (urea treated silage + hay + five pounds of corn-and-cob meal per head per day). Cattle on treatment four in 1972 and 1973 received corn silage _ad libitum_ which had ten pounds of urea and ten pounds of limestone added per ton at harvest. They also received five pounds of corn-and-cob meal and two pounds of alfalfa-orchardgrass hay per head per day plus six grams methionine hydroxy analog. This should supply sulfur to the heifers equivalent to the sulfur level of treatment three.

The length of the silage feeding phase for the heifers during the different years was as follows: 1968--106 days, 1969--126 days, 1970--125 days, 1971--140 days, 1972--111 days, and 1973--104 days. At the end of the silage phase the heifers were weighed on two consecutive days and given a condition grade. After this the heifers were gradually put on the full fed grain phase of the experiment. Approximately the first 7-14 days of the full fed grain period was an adjustment period during which silage feeding was gradually reduced and grain was increased. The heifers were full fed grain until the average slaughter or condition grade was "Good". This grain feeding period lasted as follows: 1968--96 days, 1969--90 days, 1970--35 days, 1971--42 days, 1972--33 days, and 1973--70 days. The reason for shorter grain feeding periods beginning with 1970 is due to the grain feeding during the silage phase which began with the heifer experiments in 1970. Prior to this no grain was fed during the silage phase. Each year all of the heifers were weighed and graded on two consecutive days at the beginning and end of each phase and at 28 day intervals throughout the experiment.

Carcass Data

At the conclusion of each experiment, the cattle were weighed and evaluated before trucking to a packing plant approximately 70 miles away where they were again weighed and were slaughtered. Hot carcass weights were obtained. Using live weight at the feedlot and hot carcass weight, dressing percent was determined. Carcass grades, conformation, maturity, and marbling scores were made by a U.S.D.A. grader after the carcasses had chilled 48 hours. Ribeye area, fat thickness, and percent kidney fat were estimated according to procedures set forth by the American Meat Science Association (Schoonover *et al.*, 1967).

Statistical Analysis of Data

Significance of treatment effects were determined by an analysis of variance and a Student Newman Keuls multiple range test. The following model was found appropriate to describe the expected variation:

$$Y_{ijk} = \mu + y_i + t_j + l(ty)_{ij} + e_{ijk}$$

where Y is the expected or predicted performance; μ is Mu, the overall mean; y is effect due to year, $i = 1 - 6$; t is effect due to treatment, $j = 1 - 5$; l is lot within treatment and e is the error term or normal expected variation.

Table I shows the experimental design of this project by years. Treatments with the same letter were compared in the analysis for this study.

TABLE I

EXPERIMENTAL DESIGN AND TREATMENT COMPARISONS[a]

Year	1 Plain Silage + CSM	2 10# Urea 10# Lime Per Ton	3 10# Urea 10# Lime 1.5# S Per Ton	4 20# Urea 10# Lime 3.0# S Per Ton	5 10# Urea 10# Lime Per Ton + MHA
1968		B	B		
1969		B	B		
1970	A	AC	CD	D	
1971	A	AC	CD	D	
1972	A	AC	CE		E
1973	A	AC	CE		E

[a]An analysis of variance for these comparisons is given in the appendix tables.

CHAPTER IV

RESULTS AND DISCUSSION

Comparison of CSM-Supplemented and Urea-Limestone Treated Corn Silages

Comparison of cattle weight gains, daily feed consumption and feed conversion for heifers receiving corn silage plus CSM and those receiving urea-treated corn silage during 1970, 1971, 1972 and 1973 are shown in Tables II, III, and IV. This data is for the first 28 days of the silage feeding phase, the total silage feeding phase, and the total feeding period, respectively. During the 1970 and 1971 silage feeding phase heifers on untreated corn silage were fed five pounds of corn and cob meal plus one pound of CSM per head per day while those on the urea treated corn silage received only the five pounds of corn and cob meal per head per day. The CSM-supplemented heifers were fed only four pounds of corn and cob meal during 1972 and 1973 along with the one pound of CSM. This made the daily concentrate allowance equal at five pounds for all treatments for 1972 and 1973.

First 28 Days

Year to year variations in average daily gains (ADG) during the first 28 days are shown by treatment in Table II. When the four years were averaged together the difference in ADG was non-significant ($P > .05$). During the four years, ADG of the CSM-supplemented heifers for the first 28 days was 2.14 pounds compared to 2.12 pounds for the

TABLE II

PERFORMANCE DURING THE FIRST 28 DAYS OF THE SILAGE PHASE OF HEIFERS FED CSM-SUPPLEMENTED AND UREA-LIMESTONE TREATED CORN SILAGES

	Year									
	1970		1971		1972		1973		4 Year Average	
	CSM[a]	U+L[cd]	CSM[a]	U+L[cd]	CSM[b]	U+L[cd]	CSM[b]	U+L[cd]	CSM	U+L
No. of animals/yr.	10	10	10	10	10	10	12	12		
Lots/treatment/yr.	2	2	2	2	2	2	2	2		
Av. wt./head, lbs.										
Initial	548	552	515	505	542	535	529	548	534	535
28 day wt.	602	597	566	573	622	616	584	591	594	594
ADG	1.93	1.61	1.83	2.44	2.85	2.89	1.95	1.54	2.14	2.12
Feed/head/day, lbs.										
Corn sil.-as fed	20.71	21.00	21.07	21.00	21.46	20.68	23.36	25.36	22.40[e]	22.01[f]
Corn sil.-ADM[g]	5.28	5.71	5.23	4.83	7.21	7.09	8.04	7.86	6.44	6.37
Hay	2.00	2.00	1.93	1.93	2.00	2.00	2.00	2.00	1.98	1.98
Corn and cob meal	4.82	4.82	5.00	5.00	4.00	5.00	4.00	5.00	4.46	4.96
CSM	.96		1.00		1.00		1.00		.99	
Feed/lb. of gain, lbs.										
Corn sil.-as fed	10.74	13.07	11.50	8.62	7.53	7.17	13.51	16.45	10.82	11.33
Corn sil.-ADM[g]	2.74	3.64	2.85	1.98	2.53	2.46	4.12	5.10	3.06	3.30
Hay	1.04	1.27	1.05	.79	.70	.69	1.03	1.30	.96	1.01
Corn and cob meal	2.50	3.07	2.73	2.05	1.40	1.73	2.05	3.24	2.17	2.52
CSM	.50		.55		.35		.51		.48	
Total ADM[g]	6.78	7.98	7.18	4.82	4.98	4.88	7.71	9.64	6.67	6.83

TABLE II (continued)

[a]5 pounds of corn and cob meal + 1 pound of CSM added daily to the silage.

[b]4 pounds of corn and cob meal + 1 pound of CSM added daily to the silage.

[c]5 pounds of corn and cob meal added daily to the silage.

[d]U = Urea (10#/ton); L = Limestone (10#/ton).

[e,f]Means in the same row for the 4 year average that are superscripted with different letters are significantly different ($P < .05$).

[g]Air Dry Matter.

TABLE III

PERFORMANCE OF HEIFERS FED CSM-SUPPLEMENTED AND UREA-LIMESTONE TREATED CORN SILAGES DURING THE SILAGE PHASE

	Year									
	1970		1971		1972		1973		4 Year Average	
	CSM[a]	U+L[cd]	CSM[a]	U+L[cd]	CSM[b]	U+L[cd]	CSM[b]	U+L[cd]	CSM	U+L
No. of animals/yr.	10	10	10	10	10	10	12	12		
Lots/treatment/yr.	2	2	2	2	2	2	2	2		
Av. wt./head, lbs.										
Initial	548	552	515	505	542	535	529	548	534	535
Final	793	775	791	725	782	779	739	741	776	755
ADG	1.96	1.75	1.97	1.57	2.16	2.20	2.02	1.86	2.03[e]	1.85[f]
No. of days	125	125	140	140	111	111	104	104	120	120
Feed/head/day, lbs.										
Corn sil.-as fed	32.46	30.34	33.29	25.85	26.55	26.59	27.96	27.40	30.07[e]	27.55[p]
Corn sil.-ADM[g]	8.28	8.25	8.26	5.95	8.92	9.12	8.53	8.49	8.50[e]	7.95[p]
Hay	2.00	2.00	1.99	1.99	2.00	2.00	2.00	2.00	2.00	2.00
Corn and cob meal	4.96	4.98	5.00	5.00	4.00	5.00	4.00	5.00	4.49	5.00
CSM	.99		1.00		1.00		1.00		1.00	
Feed/lb. of gain, lbs.										
Corn sil.-as fed	16.56	17.39	16.85	16.46	12.29	12.10	13.83	14.75	14.88	15.18
Corn sil.-ADM[g]	4.22	4.73	4.18	3.79	4.13	4.15	4.22	4.57	4.19	4.31
Hay	1.02	1.15	1.01	1.27	.93	.91	.99	1.08	.99	1.10
Corn and cob meal	2.53	2.85	2.55	3.19	1.85	2.28	1.98	2.69	2.23	2.75
CSM	.51		.51		.46		.50		.50	
Total ADM[g]	8.28	8.73	8.25	8.25	7.37	7.34	7.69	8.34	7.91	8.16

TABLE III (Continued)

[a]5 pounds of corn and cob meal + 1 pound of CSM added daily to the silage.

[b]4 pounds of corn and cob meal + 1 pound of CSM added daily to the silage.

[c]5 pounds of corn and cob meal added daily to the silage.

[d]U = Urea (10#/ton); L = Limestone (10#/ton)

[e,f]Means in the same row for the 4 year average that are superscripted with different letters are significantly different ($P < .05$).

[g]Air Dry Matter.

TABLE IV

PERFORMANCE OF CSM-SUPPLEMENTED AND UREA-SUPPLEMENTED HEIFERS DURING THE TOTAL FEEDING PERIOD[a]

	Year									
	1970		1971		1972		1973		4 Year Average	
	CSM[b]	U+L[de]	CSM[b]	U+L[de]	CSM[c]	U+L[de]	CSM[c]	U+L[de]	CSM	U+L
No. of animals/yr.	10	10	10	10	10	10	12	12		
Lots/treatment/year	2	2	2	2	2	2	2	2		
Av. wt./head, lbs.										
Initial	548	552	515	505	542	535	529	548	534	535
Final	845	821	841	810	839	838	834	849	840	830
ADG	1.86	1.68	1.79	1.67	2.06	2.11	1.75	1.73	1.87	1.80
No. of days	160	160	182	182	144	144	174	174	165	165
Feed/head/day, lbs.										
Corn sil.-as fed	26.44	24.78	26.46	20.74	20.83	20.85	17.11	16.71	22.71[f]	20.77[g]
Corn sil.-ADM[h]	6.74	6.74	6.56	4.77	7.00	7.15	5.25	5.18	6.39[f]	5.96[g]
Hay	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Corn and cob meal	6.78	6.74	7.10	7.08	6.38	6.97	7.86	8.54	7.03[f]	7.33[g]
CSM	1.07	.30	1.00	.24	1.00	.22	.99	.39	1.02[f]	.29[g]
Feed/lb. of gain, lbs.										
Corn sil.-as fed	14.24	14.74	14.77	12.38	10.10	9.91	9.77	9.65	12.22	11.67
Corn sil.-ADM[h]	3.63	4.01	3.66	2.85	3.39	3.40	2.98	2.99	3.42	3.31
Hay	1.08	1.19	1.12	1.20	.97	.95	1.14	1.16	1.08	1.13
Corn and cob meal	3.65	4.01	3.95	4.24	3.09	3.31	4.49	4.93	3.80	4.12
CSM	.58	.18	.56	.14	.48	.11	.57	.23	.55	.17
Total ADM[h]	8.94	9.39	9.29	8.43	7.93	7.77	9.18	9.31	8.85	8.73

TABLE IV (Continued)

	Year									
	1970		1971		1972		1973		4 Year Average	
	CSM[b]	U+L[de]	CSM[b]	U+L[de]	CSM[c]	U+L[de]	CSM[c]	U+L[de]	CSM	U+L
Grades										
Initial type	9.7[i]	9.9	9.5	9.4	11.3	11.7	10.3	10.6	10.2	10.4
Initial condition	8.1	8.1	7.6	7.6	8.3	8.3	7.7	7.8	8.0	8.0
End of sil. cond.	9.7	9.4	10.1	9.9	9.5	9.9	9.1	9.2	9.6	9.6
Final condition	10.5	11.1	10.9	10.3	10.3	10.9	10.4	11.2	10.5	10.9

[a]Total feeding period = silage and concentrate phases.

[b]5 pounds of corn and cob meal + 1 pound CSM added daily to the silage.

[c]4 pounds of corn and cob meal + 1 pound CSM added daily to the silage.

[d]5 pounds of corn and cob meal + 1 pound CSM added daily to the silage.

[e]U = Urea (10#/ton of silage); L = Limestone (10#/ton of silage).

[f,g]Means in the same row for the 4 year average that are superscripted with different letters are significantly different ($P < .05$)

[h]Air Dry Matter.

[i]9 = Low Good; 10 = Average Good.

urea-supplemented heifers. There was no significant difference (P > .05) in daily silage dry matter consumption between the two treatments. There also were no significant differences (P > .05) in silage dry matter per pound of gain during the first 28 days for the two treatments. This indicates that heifers fed the ration containing urea adjusted to feed as rapidly as those receiving their supplemental protein from natural sources (CSM).

Silage Phase

During the silage phase for the four years (Table III, pages 29 and 30) the CSM-supplemented heifers gained 2.03 pounds per head per day while the urea-supplemented heifers gained 1.85 pounds per day. The difference of 0.18 pounds per day in ADG was significant (P < .05). As shown in Table III, pages 29 and 30, those heifers supplemented with CSM also consumed a significantly greater (P < .05) amount of corn silage on an air dry basis (8.50 vs. 7.95 pounds) than the heifers eating urea-treated corn silage. There was no significant difference (P > .05) in feed required per pound of gain for the two groups.

In addition to the increased consumption of silage noted above another possible explanation for the difference in ADG between the CSM-supplemented and urea-supplemented heifers may be explained by average daily crude protein consumption. Using the crude protein analysis of the feeds multiplied by average daily feed consumption, heifers supplemented with CSM consumed 0.11 pound more crude protein per day than heifers eating the urea-treated corn silage. This additional crude protein per head per day for the CSM-supplemented group may be explained as follows: (1) The CSM-supplemented heifers ate more silage dry matter per day (8.50 pounds vs. 7.95 pounds), (2) During 1970 and 1971 the CSM group received an additional pound of concentrate which was not fed to the urea group, and (3) Although the addition of 0.5 percent urea to corn silage theoretically would elevate the crude protein equivalent by 1.4 percent, lab analysis showed that it was elevated only 1.12 percent in the urea-treated silage fed to these heifers. This difference may be explained by leaching out of the urea and/or the loss of nitrogen as ammonia.

Total Feeding Period

The total feeding period, which averaged 165 days for the four year period, is composed of the silage feeding phase (an average of 120 days) and a concentrate feeding phase (an average of 45 days). All heifers were fed one pound of CSM per day during the concentrate phase. This resulted in the CSM-supplemented heifers eating 168 pounds of CSM while the urea-supplemented heifers consumed 17 pounds of urea plus 48 pounds of CSM during the entire feeding period. Heifers supplemented with CSM had an ADG of 1.87 pounds while those heifers fed the urea-treated corn silage had an ADG of 1.80 pounds (Table IV, pages 31 and 32). This difference was non-significant ($P > .05$). Previous work of Thomas (1971) indicated that there were no carryover effects of silage treatment during the silage phase into the concentrate phase. The CSM-supplemented heifers consumed significantly more ($P < .05$) corn silage dry matter

(6.39 vs. 5.96 pounds) and total concentrate (8.05 vs. 7.62 pounds) per day than the urea-supplemented heifers. However, there was no significant difference ($P > .05$) between the treatments in pounds of feed per pound of gain.

Two Year Comparison of Urea-Limestone and Urea-Limestone-Sulfur Treated Corn Silages Without Grain During the Silage Phase

In order to put maximum pressure upon the silage the heifers were not fed any grain during the silage feeding period in 1968 and 1969. These treatments were part of an earlier study to evaluate the effect of maturity at harvest on the feeding value of corn silage. These results were previously reported by Vickers (1971) and by Thomas (1971). Weight changes and feed consumption for heifers fed urea-treated corn silages with and without added sulfur during 1968 and 1969 are presented in Tables V, VI and VII for the first 28 days, the silage phase, and total feeding period, respectively. These treatments will subsequently be referred to as sulfur-supplemented and non-sulfur-supplemented, respectively.

First 28 Days

During the first 28 days (Table V) sulfur-supplemented heifers fed urea-treated silage with sodium sulfate added at the rate of 1.5 pounds per ton had an ADG of 1.25 pounds for the two years while the heifers fed urea-treated silage without added sulfur gained 1.49 pounds per day. However, the difference in ADG was not significant ($P > .05$) due to difference in gain between years. In

TABLE V

PERFORMANCE OF HEIFERS FED UREA-LIMESTONE AND UREA-LIMESTONE-SULFUR TREATED CORN SILAGES DURING THE FIRST 28 DAYS OF THE SILAGE PHASE

	Year					
	1968		1969		2 Year Average	
	U+L	U+L+S[b]	U+L	U+L+S	U+L	U+L+S
No. animals/yr.	10	10	10	10	10	10
Lots/treatment/yr.	2	2	2	2	2	2
Av. wt./head, lbs.						
Initial	501	500	505	524	503	512
28 day wt.	553	543	536	551	545	547
ADG	1.86	1.54	1.11	.96	1.49	1.25
Feed/head/day, lbs.						
Corn sil.-as fed	26.07	24.79	22.57	22.39	24.32[c]	23.59[d]
Corn sil.-ADM[e]	6.99	8.48	5.76	6.11	6.38	7.30
Hay	2.00	2.00	2.00	2.00	2.00	2.00
Feed/lb. gain, lbs.						
Corn sil.-as fed	14.04	16.13	20.39	23.22	17.22	19.68
Corn sil.-ADM[e]	3.76	5.52	5.20	6.34	4.48	5.93
Hay	1.08	1.30	1.80	2.08	1.44	1.69
Total ADM[c]	4.84	6.82	7.00	8.42	5.92	7.62

[a]No concentrate fed during the silage phase.

[b]U = Urea (10#/ton); L = Limestone (10#/ton); S = Sodium Sulfate.

[c,d]Means in same row for the 2 year average that are superscripted with different letters are significantly different ($P < .05$).

[e]Air Dry Matter.

TABLE VI

PERFORMANCE OF HEIFERS FED UREA-LIMESTONE AND UREA-LIMESTONE-SULFUR TREATED CORN SILAGES DURING THE SILAGE PHASE[a]

	Year					
	1968		1969		2 Year Average	
	U+L	U+L+S[b]	U+L	U+L+S	U+L	U+L+S
No. animals/yr.	10	10	10	10	10	10
Lots/treatment/yr.	2	2	2	2	2	2
Av. wt./head, lbs.						
Initial	501	500	505	524	503	512
Final	633	615	614	648	624	632
ADG	1.25	1.08	.87	.98	1.06	1.03
Total days	106	106	126	126	116	116
Feed/head/day, lbs.						
Corn sil.-as fed	30.40	29.68	28.61	28.88	29.51	29.28
Corn sil.-ADM[c]	8.15	10.15	7.30	7.89	7.73[d]	9.02[e]
Hay	2.00	2.00	2.00	2.00	2.00	2.00
Feed/lb. of gain, lbs.						
Corn sil.-as fed	24.41	27.36	33.07	29.35	28.74	28.34
Corn silage-ADM[c]	6.54	9.36	8.43	8.01	7.49	8.69
Hay	1.60	1.85	2.30	2.04	1.95	1.95
Total ADM[c]	8.14	11.21	10.73	10.05	9.44	10.64

[a]No concentrate fed during the silage phase.

[b]U = Urea (10#/ton); L = Limestone (10#/ton); S = Sodium Sulfate (1.5#/ton).

[c]Air Dry Matter.

[d,e]Means in the same row for the 2 year average that are superscripted with different letters are significantly different ($P < .05$).

TABLE VII

TOTAL FEEDING PERIOD PERFORMANCE OF HEIFERS FED UREA-LIMESTONE AND UREA-LIMESTONE-SULFUR TREATED CORN SILAGES[a]

	Year					
	1968		1969		2 Year Average	
	U+L	U+L+S[b]	U+L	U+L+S	U+L	U+L+S
No. animals/yr.	10	10	10	10	10	10
Lots/treatment/yr.	2	2	2	2	2	2
Av. wt./head, lbs.						
Initial	501	500	505	524	503	512
Final	821	808	762	785	792	797
ADG	1.58	1.52	1.19	1.21	1.39	1.37
No. of days	202	202	216	216	209	209
Feed/head/day, lbs.						
Corn sil.-as fed	17.50	17.11	17.81	17.97	17.66	17.54
Corn sil.-ADM[c]	4.69	5.85	4.54	4.91	4.62[d]	5.38[e]
Hay	2.00	2.00	2.00	2.00	2.00	2.00
Corn and cob meal	7.11	7.11	6.05	6.09	6.58	6.60
Feed/lb. of gain, lbs.						
Corn sil.-as fed	11.04	11.22	14.97	14.87	13.01	13.05
Corn sil.-ADM[c]	2.96	3.84	3.82	4.06	3.39[e]	3.95[f]
Hay	1.27	1.31	1.68	1.65	1.48	1.48
Corn and cob meal	4.49	4.67	5.08	5.03	4.79	4.85
Total ADM[c]	8.72	9.82	10.58	10.74	9.66	10.28
Grades						
Initial type	9.5[f]	9.3	9.7	9.5	9.6	9.4
Initial condition	8.4	8.2	7.7	7.6	8.1	7.9
End of sil. cond.	8.8	8.4	8.0	7.5	8.4	8.0
Final condition	10.8	10.2	9.6	9.8	10.2	10.0

[a]Total feeding period includes silage and concentrate phases. No concentrate fed during the silage phase.

[b]U = Urea (10#/ton); L = Limestone (10#/ton); S = Sodium Sulfate (1.5#/ton).

[c]Air Dry Matter

[d,e]Means in the same row for the 2 year average that are superscripted with different letters are significantly different ($P < .05$).

[f]7 = Average Standard; 8 = High Standard; 9 = Low Good; 10 = Average Good.

1968 the urea-supplemented heifers outgained the sulfur-supplemented heifers 1.11 to 0.96 pounds per day. The sulfur-supplemented heifers consumed significantly more ($P < .05$) silage per day on an air dry basis than heifers eating the urea-treated corn silage without sulfur. The sulfur-supplemented heifers required 5.93 pounds of silage dry matter per pound of gain as compared to 4.48 pounds for the non-sulfur group but the difference was not statistically significant ($P > .05$).

Silage Phase

Early differences in ADG disappeared by the end of the silage phase. At the end of the silage phase the non-sulfur-supplemented and sulfur-supplemented heifers had ADG's of 1.06 and 1.03 pounds, respectively (Table VI, page 37). The difference was non-significant ($P > .05$). Although the sulfur-supplemented heifers ate significantly more ($P < .05$) silage dry matter per day, the differences in feed per pound of gain were not significant ($P > .05$) between the two treatments during the silage phase in 1968 and 1969.

Total Feeding Period

The total feeding period which included the silage phase of 116 days and concentrate phase of 93 days lasted an average of 209 days in 1968 and 1969. During this period the non-sulfur-supplemented heifers gained 1.39 pounds per head per day compared to 1.37 pounds for the sulfur-supplemented heifers. The difference was not significant ($P > .05$). The sulfur-supplemented heifers did eat significantly more ($P < .05$) silage dry matter per day and required significantly more ($P < .05$) silage dry matter per pound of gain. Grain consumption and conversion (Table VII, page 38) was similar for the two treatments with no significant differences ($P > .05$) due to silage treatment during the silage phase.

Four Year Comparison of Urea-Limestone and Urea-Limestone-Sulfur Treated Corn Silages with Grain During the Silage Phase

During the silage phase in 1970, 1971, 1972, and 1973 all heifers were fed 5.0 pounds of corn and cob meal per head per day. The value of the feeding of corn during the silage period was studied by Corrick and Hobbs (1968). They found that the addition of 6.0 pounds of ground shelled corn per head per day to urea-limestone treated corn silage rations did not affect the utilization of urea or the consumption of silage when corn silage was fed *ad lib*. Cattle weights, grades, gains, daily feed consumption and feed requirement per unit of gain are shown for heifers fed urea-treated corn silages with and without additional sulfur during 1970-1973 in Tables VIII, IX and X. Data presented in these tables are for the first 28 days, silage feeding phase and total feeding period, respectively. The urea-limestone treated silage had ten pounds of urea and ten pounds of limestone added per ton of green chop while the urea-limestone-sulfur treated silage had ten pounds of urea, ten pounds of limestone and 1.5 pounds of sodium sulfate added per ton.

TABLE VIII

PERFORMANCE DURING THE FIRST 28 DAYS OF THE SILAGE PHASE OF HEIFERS FED UREA-LIMESTONE AND UREA-LIMESTONE-SULFUR TREATED CORN SILAGES[a]

	Year									
	1970		1971		1972		1973		4 Year Average	
	U+L	U+L+S[b]	U+L	U+L+S	U+L	U+L+S	U+L	U+L+S	U+L	U+L+S
No. animals/yr.	10	10	10	10	10	10	12	12		
Lots/treatment	2	2	2	2	2	2	2	2		
Av. wt./head, lbs.										
Initial	552	556	505	515	535	534	548	525	535	533
Final	597	600	573	561	616	630	591	575	594	592
ADG	1.61	1.57	2.44	1.63	2.89	3.42	1.54	1.76	2.12	2.10
Feed/head/day, lbs.										
Corn sil.-as fed	21.00	20.86	21.00	21.00	20.68	20.68	25.36	25.18	22.01	21.93
Corn sil.-ADM[c]	5.71	5.72	4.83	5.33	7.09	7.76	7.86	8.13	6.37[d]	6.74[e]
Hay	2.00	2.00	1.93	1.93	2.00	2.00	2.00	2.00	1.98	1.98
Corn and cob meal	4.82	4.82	5.00	5.00	5.00	5.00	5.00	5.00	4.96	4.96
Feed/lb. of gain, lbs.										
Corn sil.-as fed	13.07	13.27	8.62	12.90	7.17	6.04	16.45	14.27	11.33	11.71
Corn sil.-ADM[c]	3.56	3.64	1.98	3.28	2.46	2.27	5.10	4.61	3.28	3.45
Hay	1.24	1.27	.79	1.18	.69	.59	1.30	1.13	1.01	1.04
Corn and cob meal	3.00	3.07	2.05	3.07	1.73	1.46	3.24	2.83	2.50	2.61
Total ADM[c]	7.80	7.98	4.82	7.53	4.88	4.32	9.64	8.57	6.79	7.10

TABLE VIII (continued)

[a]Approximately 5 pounds of corn and cob meal fed daily during the silage phase.

[b]U = Urea (10#/ton); L = Limestone (10#/ton); S = Sodium Sulfate (1.5#/ton)

[c]Air Dry Matter.

[d,e]Means in the same row for the 4 year average that are superscripted with different letters are significantly different ($P < .05$).

TABLE IX

PERFORMANCE DURING THE SILAGE PHASE OF HEIFERS FED UREA-LIMESTONE AND UREA-LIMESTONE-SULFUR CORN SILAGES

	Year									
	1970		1971		1972		1973		4 Year Average	
	U+L	U+L+S[b]	U+L	U+L+S	U+L	U+L+S	U+L	U+L+S	U+L	U+L+S
No. animals/yr.	10	10	10	10	10	10	12	12		
Lots/treatment/yr.	2	2	2	2	2	2	2	2		
Av. wt./head, lbs.										
Initial	552	556	505	515	535	534	548	525	535	533
Final	770	775	725	740	779	808	741	720	754	761
ADG	1.74	1.75	1.57	1.60	2.20	2.46	1.86	1.88	1.84	1.92
No. of days	125	125	140	140	111	111	104	104	120	120
Feed/head/day, lbs.										
Corn sil.-as fed	30.34	29.15	25.85	30.88	26.59	26.24	27.40	26.94	27.55[c]	28.30[d]
Corn sil.-ADM[e]	8.25	7.99	5.95	7.84	9.12	9.84	8.49	8.70	7.95[c]	8.59[d]
Hay	2.00	2.00	1.99	1.99	2.00	2.00	2.00	2.00	2.00	2.00
Corn and cob meal	4.98	4.96	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.99
Feed/lb. gain, lbs.										
Corn sil.-as fed	17.39	16.64	16.46	19.25	12.10	10.66	14.75	14.37	15.18	15.23
Corn sil.-ADM[e]	4.73	4.56	3.79	4.89	4.15	4.00	4.57	4.64	4.31	4.52
Hay	1.15	1.14	1.27	1.24	.91	.81	1.08	1.07	1.10	1.07
Corn and cob meal	2.85	2.83	3.19	3.12	2.28	2.03	2.69	2.67	2.75	2.66
Total ADM[e]	8.73	8.53	8.25	9.25	7.34	6.84	8.34	8.38	8.16	8.25

TABLE IX (Continued)

[a]5 pounds of corn and cob meal fed daily during the silage phase.

[b]U = Urea (10#/ton); L = Limestone (10#/ton); S = Sodium Sulfate (1.5#/ton)

[c,d] Means in the same row for the 4 year average that are superscripted with different letters are significantly different ($P < .05$).

[e]Air Dry Matter.

TABLE X

TOTAL FEEDING PERIOD PERFORMANCE OF HEIFERS FED UREA-LIMESTONE AND UREA-LIMESTONE-SULFUR TREATED CORN SILAGES: 1970-1973

	Year									
	1970		1971		1972		1973		4 Year Average	
	U+L	U+L+S[b]	U+L	U+L+S	U+L	U+L+S	U+L	U+L+S	U+L	U+L+S
No. of animals/yr.	10	10	10	10	10	10	12	12		
Lots/treatment/yr.	2	2	2	2	2	2	2	2		
Av. wt./head, lbs.										
Initial	552	556	505	515	535	534	548	525	535	533
Final	821	832	810	812	838	853	849	827	830	831
ADG	1.68	1.73	1.67	1.63	2.11	2.21	2.21	1.74	1.80	1.83
No. of days	160	160	182	182	144	144	174	174	165	165
Feed/head/day, lbs.										
Corn sil.-as fed	24.78	23.85	20.74	24.61	20.85	20.59	16.71	16.51	20.77[c]	21.39[d]
Corn sil.-ADM[e]	6.74	6.54	4.77	6.25	7.15	7.72	5.18	5.33	5.96[c]	6.46[d]
Hay	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Corn and cob meal	6.74	6.74	7.08	7.09	6.97	7.13	8.54	8.65	7.33	7.40
CSM	.30	.30	.24	.24	.22	.22	.39	.40	.29	.29
Feed/lb. gain, lbs.										
Corn sil.-as fed	14.74	13.83	12.38	15.08	9.91	9.29	9.65	9.51	11.67	11.93
Corn sil.-ADM[e]	4.01	3.79	2.85	3.83	3.40	3.48	2.99	3.07	3.31	3.54
Hay	1.19	1.16	1.20	1.23	1.11	.90	1.16	1.15	1.17	1.11
Corn and cob meal	4.01	3.91	4.24	4.35	3.31	3.22	4.93	4.99	4.12	4.12
CSM	.18	.18	.14	.14	.11	.10	.23	.23	.17	.16
Total ADM[e]	9.39	9.04	8.43	9.55	7.93	7.70	9.31	9.44	8.77	8.93

TABLE X (continued)

	Year									
	1970		1971		1972		1973		4 Year Average	
	U+L	U+L+S[b]	U+L	U+L+S	U+L	U+L+S	U+L	U+L+S	U+L	U+L+S
Grades										
Initial type	9.9[f]	10.0	9.4	9.5	11.7	10.9	10.6	10.3	10.4	10.2
Initial condition	8.1	8.1	7.6	7.8	8.3	8.3	7.8	7.6	8.0	8.0
End of sil. cond.	9.4	9.6	9.9	10.2	9.9	10.2	9.2	8.9	9.6	9.7
Final condition	11.1	11.0	10.3	10.7	10.9	10.7	11.2	10.4	10.9	10.7

[a]Total Feeding Period included silage phase and concentrate phase.

[b]U = Urea (10#/ton); L = Limestone (10#/ton); S = Sodium Sulfate (1.5#/ton).

[c,d]Means in the same row for the 4 year average that are superscripted with different letters are significantly different ($P < .05$).

[e]Air Dry Matter.

[f]8 = High Standard; 9 = Low Good; 10 = Average Good; 11 = High Good.

First 28 Days

There was some yearly variation in ADG's for the first 28 days between the heifers on the urea-limestone and urea-limestone-sulfur corn silages as shown in Table VIII, pages 41 and 42. This yearly variation pattern is similar to that previously reported by Vickers (1971). During the first 28 days the heifers fed the urea-limestone treated silage averaged gaining 2.12 pounds per day for the four years while heifers fed the urea-limestone-sulfur treated silage averaged 2.10 pounds per day. This difference was not significant ($P > .05$). The sulfur-supplemented heifers ate a significantly greater ($P < .05$) amount of silage dry matter per day. The heifers that did not receive additional sulfur required less silage dry matter per pound of gain during the first 28 days, but the difference was not significant ($P > .05$).

Silage Phase

During the entire silage phase which included the first 28 days heifers fed silage to which sulfur had been added ate significantly more ($P < .05$) silage per day. The heifers fed the urea-limestone-sulfur-supplemented silage gained faster than the heifers fed urea-limestone corn silage. Sulfur-supplemented heifers gained 1.92 pounds per head per day compared to 1.84 pounds for the non-sulfur supplemented heifers, however, this difference was not significant ($P > .05$). There was no significant difference ($P > .05$) between treatments with respect to feed required per pound of gain.

Although a four year average of the two treatments for the first 28 days and for the silage phase did not indicate much difference in ADG or feed conversion for the two treatments, Tables VIII, pages 41 and 42, and IX, pages 43 and 44, show that there were some year by year variations. One possibility in explaining these yearly performance variations could be variation in the sulfur content. However, the silages used were not analyzed for sulfur.

Total Feeding Period

The entire feeding period (silage plus concentrate phases) averaged 165 days during the four years, 1970-1973. Animal performance and feed conversion were only slightly different for the urea-limestone and urea-limestone-sulfur treated corn silages (Table X, pages 45 and 46). Heifers which received the added sulfur during the silage phase had an overall ADG of 1.83 pounds compared to 1.80 for those which did not get the added sulfur. The difference was non-significant ($P > .05$). Heifers fed the sulfur-supplemented silage ate significantly more ($P < .05$) silage per day on an air dry basis (6.46 vs. 5.96 pounds), but there was no significant difference ($P > .05$) between treatments for silage or concentrate required per pound of gain for the total feeding period.

A Comparison of Animal Performance and Feed Efficiency With and Without Grain During the Silage Phase

Although it was not an objective of this study and the differences were not statistically analyzed, an economically important observation was made between the average animal performance in 1968-69 (Table VII, page 38) and in 1970-73 (Table X, pages 45 and 46). During 1968 and 1969 heifers on the urea-limestone and urea-limestone-sulfur treatments were not fed any grain during the silage phase. An average of the data for these two treatments from Table VII, page 38, for the total feeding period shows that these heifers were on feed 209 days which included a full feeding period of 93 days and gained 287 pounds for an overall ADG of approximately 1.38 pounds. During the total time on feed these heifers ate 418 pounds of hay, 3678 pounds of corn silage and 1377 pounds of grain per head. Their condition grade at the end of the silage phase was 8.4 and 8.0 (High Standard) and their final condition grade was Average Good (10.2) and 10.0).

Heifers fed the urea-limestone and urea-limestone-sulfur treated corn silages in 1970, 1971, 1972, and 1973 were fed five pounds of corn and cob meal per head daily during the silage phase. An average for the two treatments given in Table X, pages 45 and 46, for the four years indicates that the heifers were on feed an average of 165 days including a full feeding period of 45 days. During this time they gained 297 pounds for an ADG of approximately 1.81 pounds. While making this gain the heifers consumed 330 pounds of hay, 3478 pounds of corn silage and 1215 pounds of grain per head. Their condition grade at the end of the silage phase was 9.6 and 9.7 (Low to Average Good), and their final condition grade was High Good (10.9 and 10.7).

Heifers fed five pounds of corn and cob meal during the silage phase in 1970-73 had higher ADG's on less feed and required less total feeding time. They required 44 fewer total days on feed, including 48 fewer days on full concentrate feed, 88 pounds less hay, 200 pounds less corn silage and 162 pounds less corn and cob meal to reach a slightly higher slaughter grade than heifers which were not fed grain during the silage phase.

This study shows a probable advantage to grain feeding during the silage phase and supports the earlier work of Corrick and Hobbs (1968) which also showed an advantage to the feeding of grain during the silage phase.

Comparison of Two Levels of Urea and Sulfur Added to Corn Silage

In 1970 and 1971 heifers were fed corn silage treated with (1) 10 pounds urea + 10 pounds limestone + 1.5 pounds sodium sulfate per ton of green chop and (2) corn silage treated with 20 pounds urea + 10 pounds of limestone + 3.0 pounds sodium sulfate per ton of green chop at the time of ensiling. Urea and sulfur were increased at the same relative rate in order to maintain a constant N:S ratio. Corrick and Hobbs (1968) had added 20 pounds of urea per ton of corn silage without a detrimental effect on the cattle, but with no favorable response to this higher level of urea. However, they did not add sulfur. Thus there was the possibility that the alteration of the nitrogen-sulfur ratio might have been a limiting factor in the use of the higher level of urea as reported by Corrick and Hobbs (1968). Sulfur was added to the silage in this study to test this hypothesis and to maintain the normal N:S ratio with increased nitrogen levels.

Tables XI, XII and XIII show the comparisons for the two levels of urea and sulfur in terms of animal weights, feed consumption and feed conversion during 1970 and 1971. Data for the first 28 days, silage phase and total feeding period is given in Tables XI, XII and XIII, respectively.

First 28 Days

ADG during the first 28 days for heifers fed silage treated with ten pounds of urea and 1.5 pounds sodium sulfate per ton of green chop was 1.60 pounds compared to 1.69 pounds for heifers fed silage treated with 20 pounds urea and 3.0 pounds sodium sulfate per ton. This difference was non-significant ($P > .05$). Heifers fed silage with the lower level of urea and sulfur ate significantly more ($P < .05$) silage dry matter per day than those on the higher level. However, there was no significant difference ($P > .05$) between treatments for silage dry matter per pound of gain.

Silage Phase

During the silage phase the heifers fed silage treated with the higher level of urea and sulfur had an ADG of 1.72 pounds compared to 1.68 pounds for those fed the lower level. The difference was not significant ($P > .05$). During the 133 day silage feeding phase there was no significant difference ($P > .05$) between treatments for silage air dry matter consumed per day or per pound of gain.

TABLE XI

PERFORMANCE DURING THE FIRST 28 DAYS OF THE SILAGE PHASE OF HEIFERS FED CORN SILAGE SUPPLEMENTED WITH TWO LEVELS OF UREA AND SULFUR[a]

	Year					
	1970		1971		2 Year Average	
	Low[b]	High[c]	Low	High	Low	High
No. of animals/yr.	10	10	10	10	10	10
Lots/treatment/yr.	2	2	2	2	2	2
Av. wt./head, lbs.						
Initial	556	558	515	521	536	540
28 day wt.	600	605	561	569	581	587
ADG	1.57	1.68	1.63	1.70	1.60	1.69
Feed/head/day, lbs.						
Corn sil.-as fed	20.86	20.43	21.00	19.64	20.93[e]	20.04[f]
Corn sil.-ADM[d]	5.72	5.35	5.33	4.95	5.53[e]	5.15[f]
Hay	2.00	2.00	1.93	1.93	2.00	1.93
Corn and cob meal	4.82	4.82	5.00	5.00	4.91	4.91
Feed/lb. of gain, lbs.						
Corn sil.-as fed	13.27	12.17	12.90	11.55	13.09	11.86
Corn sil.-ADM	3.64	3.19	3.28	2.91	3.46	3.05
Hay	1.27	1.19	1.18	1.14	1.23	1.17
Corn and cob meal	3.07	2.87	3.07	2.94	3.07	2.91
Total ADM[d]	7.98	7.25	7.53	6.99	7.76	7.13

[a]Approximately five pounds of corn and cob meal fed daily during the silage phase.

[b]Low = 10# Urea/ton + 10# Limestone/ton + 1.5# Sodium Sulfate/ton.

[c]High = 20# Urea/ton + 10# Limestone/ton + 3.0# Sodium Sulfate/ton.

[d]Air Dry Matter

[e,f]Means in the same row for the 2 year average that are superscripted with different letters are significantly different ($P < .05$).

TABLE XII

PERFORMANCE OF HEIFERS FED CORN SILAGE SUPPLEMENTED WITH TWO LEVELS OF UREA AND SULFUR DURING THE SILAGE PHASE[a]

	Year					
	1970		1971		2 Year Average	
	Low[b]	High[c]	Low	High	Low	High
No. of animals/yr.	10	10	10	10	10	10
Lots/treatment/yr.	2	2	2	2	2	2
Av. wt./head, lbs.						
Initial	556	558	515	521	536	540
Final	775	781	740	751	758	766
ADG	1.75	1.78	1.60	1.65	1.68	1.72
No. of days	125	125	140	140	133	133
Feed/head/day, lbs.						
Corn sil.-as fed	29.15	29.06	30.88	28.96	30.02[d]	29.01[e]
Corn sil.-ADM[f]	7.99	7.62	7.84	7.30	7.92	7.46
Hay	2.00	2.00	1.99	1.99	2.00	2.00
Corn and cob meal	4.96	4.96	5.00	5.00	4.98	4.98
Feed/lb. of gain, lbs.						
Corn sil.-as fed	16.64	16.29	19.25	17.59	17.95[e]	16.94[f]
Corn sil.-ADM[f]	4.56	4.27	4.89	4.43	4.73	4.35
Hay	1.14	1.12	1.24	1.21	1.19	1.17
Corn and cob meal	2.83	2.78	3.12	3.04	2.98	2.91
Total ADM[f]	8.53	8.17	9.25	8.68	8.90	8.43

[a]Five pounds of corn and cob meal fed daily during the silage phase.

[b]Low = 10# Urea/ton + 10# Limestone/ton + 1.5# Sodium Sulfate/ton.

[c]High = 20# Urea/ton + 10# Limestone/ton + 3.0# Sodium Sulfate/ton

[d,e]Means in the same row for the 2 year average that are superscripted with different letters are significantly different ($P < .05$).

[f]Air Dry Matter.

TABLE XIII

PERFORMANCE DURING THE TOTAL FEEDING PERIOD OF HEIFERS FED CORN SILAGE SUPPLEMENTED WITH TWO LEVELS OF UREA AND SULFUR[a]

	Year					
	1970		1971		2 Year Average	
	Low[b]	High[c]	Low	High	Low	High
No. of animals/yr.	10	10	10	10	10	10
Lots/treatment/yr.	2	2	2	2	2	2
Av. wt./head, lbs.						
Initial	556	558	515	521	536	540
Final	832	830	812	803	822	817
ADG	1.73	1.70	1.63	1.55	1.68	1.63
No. of days	160	160	182	182	171	171
Feed/head/day, lbs.						
Corn sil.-as fed	23.85	23.78	24.61	23.14	24.23[d]	23.46[e]
Corn sil.-ADM[f]	6.54	6.23	6.25	5.83	6.40[d]	6.03[e]
Hay	2.00	2.00	2.00	2.00	2.00	2.00
Corn and cob meal	6.74	6.85	7.09	7.02	6.92	6.94
CSM	.30	.30	.24	.24	.27	.27
Feed/lb. of gain, lbs.						
Corn sil.-as fed	13.83	13.99	15.08	14.93	14.46	14.46
Corn sil.-ADM[f]	3.79	3.66	3.83	3.76	3.81	3.71
Hay	1.16	1.18	1.23	1.29	1.20	1.24
Corn and cob meal	3.91	4.03	4.35	4.53	4.13	4.28
CSM	.18	.18	.14	.15	.16	.17
Total ADM[f]	9.04	9.05	9.55	9.73	9.30	9.40
Grades						
Initial type	10.0[g]	10.2	9.5	9.7	9.8	10.0
Initial condition	8.1	8.2	7.8	8.0	8.0	8.1
End of sil. cond.	9.6	9.4	10.2	10.4	9.9	9.9
Final condition	11.0	11.0	10.7	10.3	10.9	10.7

[a]Five pounds of corn and cob meal fed daily during the silage phase; Total feeding period = Silage phase + concentrate phase.

[b]Low = 10# Urea/ton + 10# Limestone/ton + 1.5# Sodium Sulfate/ton.

[c]High = 20# Urea/ton + 10# Limestone/ton + 3.0# Sodium Sulfate/ton.

TABLE XIII (Continued)

[d,e]Means in the same row for the 2 year average that are superscripted with different letters are significantly different ($P < .05$).

[f]Air Dry Matter.

[g]8 = High Standard; 9 = Low Good; 10 = Average Good; 11 = High Good.

Total Feeding Period

At the end of the entire feeding period, an average of 171 days, there was no significant difference ($P > .05$) in ADG between treatments. Heifers fed the lower level of urea and sulfur had an ADG of 1.68 pounds compared to 1.63 pounds for those fed the higher level of urea and sulfur. Heifers fed silage with the lower level of urea and sulfur (Table XIII, pages 54 and 55) consumed a significantly larger ($P < .05$) amount of corn silage per day on an air dry basis. However, there was no significant difference ($P > .05$) between treatments for silage dry matter or grain per pound of gain for the total time on feed.

It must be concluded that there was no advantage to the addition of the higher levels of urea and sulfur to corn silage for growing and finishing heifers as measured by weight gains or feed efficiency.

A Two Year Comparison of Sodium Sulfate and MHA as Sulfur Sources

During 1972 and 1973 one group of heifers was fed silage treated with ten pounds of urea and ten pounds of limestone plus 1.5 pounds of sodium sulfate per ton at the time of ensiling. Another treatment was fed silage treated with similar levels of urea and limestone plus six grams of methionine-hydroxy-analogue (MHA) per head per day in the concentrate. These levels provided equal amounts of sulfur to each treatment. Both groups received equal levels of concentrates. The purpose of this comparison was to determine if an organic source of sulfur (MHA) was superior to an inorganic source (sodium sulfate). Albert et al. (1956) have suggested that methionine is more efficiently used than sodium sulfate. Burroughs and Trenkle (1969 a) suggested that MHA was superior to inorganic sulfur since MHA was absorbed into the blood stream and used more readily. They obtained consistent improvements in ADG and feed efficiency when feeding MHA throughout the feeding trial. There was a short period of improvement using inorganic sulfur additions, but it did not persist throughout the entire feeding period.

Cattle weights, gains, feed consumption and feed conversion data is given in Tables XIV, XV and XVI for the first 28 days, the silage phase and total feeding periods, respectively.

First 28 Days

Heifers receiving the MHA made a gain of 2.34 pounds per head per day for the first 28 days while those heifers receiving the sodium sulfate had an ADG of 2.59 pounds. Although the heifers on the inorganic source of sulfur had a higher ADG, the difference was non-significant ($P > .05$). It did approach significance ($P < .10$). There was no significant difference ($P > .05$) between treatments in feed per pound of gain during the first 28 days.

Silage Phase

ADG of the heifers supplemented with sodium sulfate and MHA during the silage phase was similar (2.17 vs. 2.15 pounds). There was little difference in ADG for the silage phase during either year (Table XV). Heifers fed the sodium sulfate-supplemented corn silage ate significantly more ($P < .05$) silage dry matter per day

TABLE XIV

PERFORMANCE DURING THE FIRST 28 DAYS OF THE SILAGE PHASE OF HEIFERS FED CORN SILAGE SUPPLEMENTED WITH SULFUR AND METHIONINE-HYDROXY-ANALOGUE[a]

	Year					
	1972		1973		2 Year Average	
	U+L+S[b]	U+L+MHA[c]	U+L+S	U+L+MHA	U+L+S	U+L+MHA
No. of animals/yr.	10	10	12	12		
Lots/treatment/yr.	2	2	2	2		
Av. wt./head, lbs.						
Initial	534	558	525	546	530	552
28 day wt.	630	644	575	592	603	618
ADG	3.42	3.05	1.76	1.63	2.59	2.34
Feed/head/day, lbs.						
Corn sil.-as fed	20.68	20.68	25.18	26.43	22.93[d]	23.56[e]
Corn sil.-ADM[f]	7.76	7.11	8.13	8.54	7.95	7.83
Hay	2.00	2.00	2.00	2.00	2.00	2.00
Corn and cob meal	5.00	5.00	5.00	5.00	5.00	5.00
Feed/lb. of gain, lbs.						
Corn sil.-as fed	6.04	6.79	14.27	16.26	10.16	11.53
Corn sil.-ADM[f]	2.27	2.34	4.61	5.25	3.44	3.80
Hay	.59	.66	1.13	1.23	.86	.95
Corn and cob meal	1.46	1.64	2.83	3.08	2.15	2.36
Total ADM[f]	4.32	4.64	8.57	9.56	6.45	7.11

[a]Five pounds of corn and cob meal fed daily during the silage phase.

[b]U = Urea (10#/ton); L = Limestone (10#/ton); S = Sulfur (1.5#/ton).

[c]U = Urea (10#/ton); L = Limestone (10#/ton); MHA = Methionine Hydroxy Analogue (6 gm. per head per day).

[d,e]Means in the same row for the 2 year average that are superscripted with different letters are significantly different ($P < .05$).

[f]Air Dry Matter.

TABLE XV

PERFORMANCE OF HEIFERS FED CORN SILAGE SUPPLEMENTED WITH INORGANIC SULFUR AND METHIONINE-HYDROXY-ANALOGUE DURING THE SILAGE PHASE[a]

	Year					
	1972		1973		2 Year Average	
	U+L+S[b]	U+L+MHA[c]	U+L+S	U+L+MHA	U+L+S	U+L+MHA
No. of animals/yr.	10	10	12	12		
Lots/treatment/yr.	2	2	2	2		
Av. wt/head, lbs.						
Initial	534	558	525	546	530	552
Final	808	826	720	743	764	785
ADG	2.46	2.41	1.88	1.89	2.17	2.15
No. of days	111	111	104	104	107.5	107.5
Feed/head/day, lbs.						
Corn sil.-as fed	26.24	26.43	26.94	26.43	26.59	26.43
Corn sil.-ADM[d]	9.84	9.09	8.70	8.54	9.27[e]	8.82[f]
Hay	2.00	2.00	2.00	2.00	2.00	2.00
Corn and cob meal	5.00	5.00	5.00	5.00	5.00	5.00
Feed/lb. of gain, lbs.						
Corn sil.-as fed	10.66	10.98	14.37	16.26	12.52	13.62
Corn sil.-ADM[d]	4.00	3.78	4.64	5.25	4.32	4.52
Hay	.81	.83	1.07	1.06	.94	.95
Corn and cob meal	2.03	2.08	2.67	2.64	2.35	2.36
Total ADM[d]	6.84	6.69	8.38	8.95	7.61	7.83

[a]Five pounds of corn and cob meal fed daily during the silage phase.

[b]U = Urea (10#/ton); L = Limestone (10#/ton); S = Sulfur (1.5#/ton).

[c]U = Urea (10#/ton); L = Limestone (10#/ton); MHA = Methionine Hydroxy Analogue (6 gm. per head per day).

[d]Air Dry Matter

[e,f]Means in the same row for the 2 year average that are superscripted with different letters are significantly different ($P < .05$).

TABLE XVI

PERFORMANCE DURING THE TOTAL FEEDING PERIOD OF HEIFERS FED UREA-TREATED CORN SILAGE SUPPLEMENTED WITH INORGANIC SULFUR AND METHIONINE-HYDROXY-ANALOGUE[a]

	Year					
	1972		1973		2 yr. Average	
	U+L+S[b]	U+L+MHA[c]	U+L+S	U+L+MHA	U+L+S	U+L+MHA
No. of animals/yr.	10	10	12	12		
Lots/treatment/yr.	2	2	2	2		
Av. wt./head, lbs.						
Initial	534	558	525	546	530	552
Final	853	869	827	848	840	859
ADG	2.21	2.16	1.74	1.74	1.98	1.95
No. of days	144	144	174	174	159	159
Feed/head/day, lbs.						
Corn sil.-as fed	20.59	20.72	16.51	16.76	18.55	18.74
Corn sil.-ADM[d]	7.72	7.13	5.33	5.41	6.53[e]	6.27[f]
Hay	2.00	2.00	2.00	2.00	2.00	2.00
Corn and cob meal	7.13	7.06	8.65	8.62	7.89	7.84
CSM	.22	.22	.40	.40	.31	.31
Feed/lb. of gain, lbs.						
Corn sil.-as fed	9.29	9.59	9.51	9.67	9.40	9.63
Corn sil.-ADM	3.48	3.30	3.07	3.12	3.28	3.21
Hay	.90	.93	1.15	1.15	1.03	1.04
Corn and cob meal	3.22	3.27	4.99	4.98	4.11	4.13
CSM	.10	.10	.23	.23	.17	.17
Total ADM[d]	7.70	7.60	9.44	9.48	8.59	8.55
Grades						
Initial type	10.9[g]	11.4	10.3	10.5	10.6	11.0
Initial condition	8.3	8.6	7.6	7.9	8.0	8.3
End of sil. cond.	10.2	10.3	8.9	9.4	9.6	9.9
Final condition	10.7	11.1	10.4	10.9	10.6	11.0

[a]Total feeding period is Silage Phase and Concentrate Phase.

[b]U = Urea (10#/ton); L = Limestone (10#/ton); S = Sodium Sulfate (1.5#/ton).

[c]U = Urea (10#/ton); L = Limestone (10#/ton); MHA = Methionine Hydroxy Analogue (6 grams per head per day).

TABLE XVI (continued)

[d]Air Dry Matter.

[e,f]Means in the same row for the 2 year average that are superscripted with different letters are significantly different ($P < .05$).

[g]8 = High Standard; 9 = Low Good; 10 = Average Good.

than the MHA group. Feed per pound of gain was not significantly different (P > .05) between treatments.

Total Feeding Period

The total feeding period lasted an average of 159 days during 1972 and 1973. For the total period there was no significant difference (P > .05) in ADG due to sulfur source. As shown in Table XVI, pages 60 and 61, ADG's were similar between treatments each year. Heifers receiving the inorganic source of sulfur had an ADG of 1.98 pounds while those receiving MHA had an ADG of 1.95 pounds. Feed consumption was similar for the two treatments and there was no significant difference between treatments in the required feed per pound of gain.

It can be concluded from these results that there is no advantage to one source of sulfur over the other measured in terms of animal gains or feed efficiency in any stage of growing and finishing beef heifers.

Carcass Data

Average carcass data by year and treatments are presented in Table XVII. Previous work by Vickers (1971) with silages cut at different stages of maturity did not show any carcass differences due to silage maturity. In an earlier study Thomas (1971) analyzed part of the first three years of this six year study and found no significant differences (P < .05) in carcass characteristics due to treatment of the corn silage with urea, limestone or sodium

TABLE XVII

CARCASS DATA

Treatment	Final Greeneville Wt.	Drift[a] %	Hot Carcass Wt.	Dress[b] Wt.	Fat Thickness	Ribeye Inches Sq.	Carcass Grade
1968							
10# U+L	808	2.6	477	58.1	0.32	10.1	10.4[d]
10# U+L+1.5# S[c]	821	2.9	459	56.9	0.34	9.8	9.3
1969							
10# U+L	762	1.5	429	56.2	0.35	10.0	10.7
10# U+L+1.5# S	784	2.0	450	57.3	0.42	9.8	10.6
1970							
CSM	792	2.8	486	57.4	0.33	10.0	10.5
10# U+L	770	2.8	472	57.4	0.34	10.7	11.1
10# U+L+1.5# S	775	2.8	473	56.8	0.33	10.9	11.0
20# U+L+3.0# S	781	2.5	474	57.1	0.31	10.5	11.0
1971							
CSM	841	1.4	490	58.3	0.56	9.7	10.1
10# U+L	812	1.7	469	57.8	0.41	9.9	9.8
10# U+L+1.5# S	812	1.6	476	58.6	0.41	10.4	9.8
20# U+L+3.0# S	803	1.2	483	60.2	0.50	10.4	10.0
1972							
CSM	839	3.6	486	57.9	0.36	10.8	10.4
10# U+L	838	3.8	482	57.5	0.41	10.8	11.0
10# U+L+1.5# S	853	4.0	493	57.8	0.44	10.7	10.4
10# U+L+MHA[e]	869	3.9	501	57.6	0.36	11.5	9.9

TABLE XVII (Continued)

Treatment	Final Greeneville Wt.	Drift[a] %	Hot Carcass Wt.	Dress[b] %	Fat Thickness	Ribeye Inches Sq.	Carcass Grade
1973							
CSM	834	2.9	489	58.7	0.48	10.5	10.0
10# U+L	849	2.5	499	58.7	0.40	10.6	9.9
10# U+L+1.5# S	827	2.9	482	58.4	0.40	10.4	9.8
10# U+L+MHA	848	3.3	495	58.5	0.50	10.1	10.2

[a] $\frac{\text{Loss in wt. from Greeneville to Knoxville}}{\text{Greeneville weight}} \times 100.$

[b] $\frac{\text{Hot carcass wt.}}{\text{Greeneville wt.}} \times 100.$

[c] U = Urea per ton of silage; L = Limestone (10#/ton); S = Sodium Sulfate per ton of silage.

[d] 9 = Low Good; 10 = Average Good; 11 = High Good.

[e] MHA = Methionine-hydroxy-analogue.

sulfate. Likewise there were no differences observed in carcass characteristics in this study.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this six-year study with growing-finishing beef heifers were: 1. To compare CSM and urea as sources of supplemental protein for corn silage; 2. To test the value of adding sulfur to urea-treated corn silage to narrow the N:S ratio; 3. To compare animal performance when different levels of urea were added to corn silage with the N:S ratio held constant; and 4. To compare an organic and inorganic source of sulfur added to urea-treated corn silage.

Each year 40 or 48 heifer calves (450-500 pounds) grading medium or good were purchased at Tennessee feeder calf sales for this study. After an adjustment period of approximately two weeks, the heifers were allotted into eight uniform lots of five or six each. Lots were randomly assigned to treatments with two lots per treatment. The feeding period was divided into a silage phase and a concentrate phase. Grain was not fed during the silage phase in 1968 and 1969 but was fed in 1970-73. The heifers were weighed every 28 days and graded at the beginning and end of each feeding phase. The feeding trial was ended when the heifers reached an average condition grade of "Good". At this time the heifers were marketed for slaughter and carcass data was obtained.

When cattle supplemented with CSM were compared with those fed urea-treated corn silage there was no significant difference ($P > .05$)

in ADG during the first 28 days. At the end of the silage phase CSM-supplemented heifers had a significantly higher ($P < .05$) ADG. CSM-supplemented heifers had a slightly higher ADG for the total feeding period but the difference was non-significant ($P > .05$). There was no significant difference ($P > .05$) in feed per pound of gain due to protein source in any phase of the feeding period.

During 1968 and 1969 when the heifers were not fed any grain during the silage phase a comparison was made between urea-treated corn silages with and without added sulfur. There was no significant difference ($P > .05$) in ADG or feed conversion due to treatment in any phase except that sulfur-supplemented heifers used significantly more ($P < .05$) silage dry matter per pound of gain for the total feeding period.

Heifers eating urea-treated corn silage in 1970-73 supplemented with sulfur ate significantly more ($P < .05$) silage dry matter per day in all feeding phases than those eating urea-treated silage without added sulfur. However, there was no significant difference ($P > .05$) in ADG or feed per pound of gain in any phase due to treatment.

Additions of ten pounds and 20 pounds of urea per ton of corn silage with the N:S ratio held constant were compared in 1970 and 1971. There was no significant difference ($P > .05$) in ADG or feed efficiency in any of the phases due to treatment. It was concluded that the addition of more than ten pounds of urea per ton of corn silage is not economical and sulfur is not the limiting factor in the use of urea above this level.

When sodium sulfate and MHA were compared as sources of sulfur in 1972 and 1973 there was no significant difference ($P > .05$) in ADG or feed conversion in any feeding phase due to treatment.

Feeding grain during the silage phase in 1970-73 shortened the total feeding period by 44 days compared to those heifers not fed grain in the silage phase in 1968-69. It also reduced the amount of feed required per pound of gain when heifers were fed to the same weight and grade.

LITERATURE CITED

LITERATURE CITED

A.O.A.C. 1965. Official Methods of Analysis (10th ed.). Association of Official Agricultural Chemists. Washington, D.C.

Albert, W. W., U. S. Garrigus, R. M. Forbes and H. W. Norton. 1956. The sulfur requirement of growing-fattening lambs in terms of methionine, sodium sulfate and elemental sulfur. J. Anim. Sci. 15:559.

Barton, J. S., L. S. Bull and R. W. Hemken. 1971. Effects of various levels of sulfur upon cellulose digestion in purified diets and lignocellulose digestion in corn fodder pellets *in vitro*. J. Anim. Sci. 33:682.

Bolsen, K. K., Walter Woods and Terry Klopfenstein. 1973. Effect of methionine and ammonium sulfate upon performance of ruminants fed high corn rations. J. Anim. Sci. 36:1186.

Bryant, M. P. and I. M. Robinson. 1963. Apparent incorporation of ammonia and amino acid carbon during growth of selected species of ruminal bacteria. J. Dairy Sci. 46:150.

Burroughs, Wise, Jesse Shively and Dana Wolf. 1966. Sulfur additions to high-urea supplements for feedlot cattle. Iowa State University A. S. Leaflet R 82.

Burroughs, Wise and Allen Trenkle. 1969a. Initial experiment with methionine-hydroxy-analogue-calcium added to an all-urea supplement for finishing heifer calves. Iowa State University A. S. Leaflet R 122.

Burroughs, Wise and Allen Trenkle. 1969b. Different levels of methionine-hydroxy-analogue-calcium added to all-urea versus all-plant protein supplements for finishing lambs and yearling steers. Iowa State University A. S. Leaflet R 128.

Colby, R. W. 1973. NPN Feed Products. Proc. 18th Ann. Texas Nutrition Conf., Texas A and M Univ. College Station, P. 36.

Corrick, J. A. and C. S. Hobbs. 1968. Performance of feeder heifers fed corn silages treated with 10, 15 and 20 pounds of urea per ton. Tennessee Farm and Home Science Progress Report No. 68:15.

Davis, R. F., C. Williams and J. K. Loosli. 1954. Studies on sulfur to nitrogen ratios in feeds for dairy cows. J. Dairy Sci. 37:813.

Edwards, R. L., G. C. Skelley, Jr., P. A. Bellew and W. E. Billon. 1972. Effects of dietary sulfur on steer performance. J. Anim. Sci. 35:263.

Ensminger, M. E. 1970. The Stockman's Handbook. 4th ed. The Interstate Printers and Publishers, Inc. Danville, Illinois.

Goodrich, R. D. and A. D. Tillman. 1966. Effects of sulfur and nitrogen sources and copper levels on the metabolism of certain minerals by sheep. J. Anim. Sci. 25:484.

Hale, W. H. and U. S. Garrigus. 1953. Synthesis of cystine in wool from elemental sulfur and sulfate sulfur. J. Anim. Sci. 12:492.

Jacobson, D. R., J. W. Barnett, S. R. Carr and R. H. Hatton. 1967. Voluntary feed intake, milk production, rumen content, and plasma-free amino acid levels of lactating cows on low sulfur and sulfur-supplemented diets. J. Dairy Sci. 50:1248.

Johnson, W. H., R. D. Goodrich and J. C. Meiske. 1970. The role of sulfur in ruminant nutrition. International Minerals and Chemical Corporation, Skokie, Illinois. Technical Release: 70-11A.

Kennedy, L. G., G. E. Mitchell, Jr. and C. O. Little. 1971. Influence of sulfur on in vitro starch digestion by rumen microorganisms. J. Anim. Sci. 32:359.

Lofgreen, G. P., W. C. Weir and J. F. Wilson. 1953. Gains in weight, nitrogen retention and wool growth of lambs fed a ration containing urea supplemented with sodium sulfate. J. Anim. Sci. 12:347.

Loosli, J. K. 1952. Meeting the sulfur requirements of ruminants. Feed Age 2:44.

Maynard, L. A. and J. K. Loosli. 1969. Animal Nutrition. 6th ed. McGraw-Hill Book Company, New York.

Moir, R. J., M. Somers and A. C. Bray. 1967. Utilization of dietary sulfur and nitrogen by ruminants. The Sulphur Inst. J. 3:15.

N. R. C. 1970. Nutrient Requirements of Farm Animals, No. 4. Nutrient Requirements of Beef Cattle. National Research Council, Washington, D. C.

Starks, P. B., W. W. Hale, U. S. Garrigus and R. M. Forbes. 1953. The utilization of feed nitrogen by lambs as affected by elemental sulfur. J. Anim. Sci. 12:480.

Starks, P. B., W. W. Hale, U. S. Garrigus, R. M. Forbes and M. F. James. 1954. Response of lambs fed various levels of elemental sulfur, sulfate-sulfur and methionine. J. Anim. Sci. 13:249.

Tennessee Crop Reporting Service. 1973. Tennessee Agricultural Statistics Annual Bulletin T-10.

Thomas, D. T. 1971. The effects of additions of urea and sulfate sulfur to corn silage at varying stages of maturity used for the production of market beef heifers in Tennessee. Thesis, Univ. of Tenn.

Thomas, W. E., J. K. Loosli, H. H. Williams, and L. A. Maynard. 1951. The utilization of inorganic sulfate and urea nitrogen by lambs. J. Nutr. 43:515.

Thompson, L. H., M. B. Wise, R. W. Harvey and E. R. Barrick. 1972. Starea, urea and sulfur in beef cattle rations. J. Anim. Sci. 25:474.

United States Department of Agriculture. 1974. Cattle. Statistical Reporting Service.

University of Tennessee Agricultural Extension Service. 1972. Beef Cattle Special Progress Report SP189.

Vickers, R. T. 1971. Effects of corn plant maturity at ensiling on the performance of feeder heifers. Thesis, Univ. of Tenn.

APPENDIX

TABLE XVIII

ANALYSIS OF VARIANCE FOR ADG: 1970-73

Source	Df	Mean square		
		First 28 days	Silage phase	Overall
Year	3	3.079**	.444**	.303**
Treatment	4	.020	.040	.013
Treatment x year	8	.187	.036	.010
Lot(treatment year)	16	.044	.013	.009

**p < .01.

TABLE XIX

ANALYSIS OF VARIANCE FOR SILAGE CONSUMPTION AND CONVERSION DURING THE FIRST 28 DAYS: 1970-73

		Mean square			
		Silage/day		Silage/lb. of gain	
Source	Df	As fed	Dry matter	As fed	Dry matter
Year	3	43.644**	12.062**	95.871**	8.492**
Treatment	4	.917	.195**	1.277	.242
Treatment x year	8	.376	.122	5.043	.468
Lot(treatment year)	16	.073	.007	2.327	.178

**P < .01.

TABLE XX

ANALYSIS OF VARIANCE FOR SILAGE CONSUMPTION AND CONVERSION DURING THE SILAGE PHASE: 1970-73

Source	Df	Mean square			
		Silage/day		Silage/lb. of gain	
		As fed	Dry matter	As fed	Dry matter
Year	3	24.512**	3.874**	46.896**	.395*
Treatment	4	7.948**	.542**	.258	.119
Treatment x year	8	5.381	.699	1.738	.195
Lot(treatment year)	16	.027	.003	.626	.056

*P < .05.

**P < .01.

TABLE XXI

ANALYSIS OF VARIANCE FOR AVERAGE DAILY FEED CONSUMPTION DURING THE TOTAL FEEDING PERIOD: 1970-73

		Mean square		
		Silage/day		Concentrate
Source	Df	As fed	Dry matter	per day
Year	3	87.565**	5.812**	4.691**
Treatment	4	4.724**	.329**	.248**
Treatment x year	8	3.226	.422	.121
Lot(treatment year)	16	.015	.001	.009

**P < .01.

TABLE XXII

ANALYSIS OF VARIANCE FOR FEED PER POUND OF GAIN DURING THE TOTAL FEEDING PERIOD: 1970-73

		Mean square		
		Silage		
Source	Df	As fed	Dry matter	Concentrate
Year	3	39.841**	.572**	4.213**
Treatment	4	.346	.058	.016
Treatment x year	8	1.263	.157	.017
Lot(treatment year)	16	.353	.030	.051

**P < .01

VITA

The author was born April 6, 1950, in Greeneville, Tennessee. He has lived with his parents, Mr. and Mrs. Kenneth Brooks, and brother, Gregory, on a beef cattle and tobacco farm in Hawkins County, Tennessee. The author attended Rogersville High School where he served as vice-president and later president of the Rogersville Chapter of Future Farmers of America. Upon graduation from high school in 1968 he enrolled in the College of Agriculture at The University of Tennessee, Knoxville.

At The University of Tennessee, the author was chosen as a member of Phi Eta Sigma Freshman Honorary Fraternity and was accepted into the Gamma Sigma Delta Honor Society of Agriculture. He was a member of the livestock judging team and the Block and Bridle Club. In June 1972, the author received his B.S. degree in Animal Husbandry. Following graduation he worked with the Rogersville, Tennessee, and Ewing, Virginia, livestock markets and also worked as a livestock buyer.

The author entered Graduate School at The University of Tennessee, Knoxville, in January 1973 and began work toward a M.S. in Animal Science. Through a cooperative program the author worked from July 1973 through December 1973 in a feedlot at Morristown, Tennessee, owned by Valleydale Packers, Inc. In addition to the working experience he collected data for a special problem report on preconditioning feeder calves. The author returned to school in January 1974 to complete work on his M.S. degree.