1972

Chlortetracycline and Sulfamethazine Supplementation for Feedlot Lambs

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CHLORTETRACYCLINE AND SULFAMETHAZINE SUPPLEMENTATION FOR FEEDLOT LAMBS

BY

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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Animal Science, South Dakota
State University

1972

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SUPPLEMENTATION FOR FEEDLOT LAMBS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. L. B. Embry, Professor of Animal Science, for his guidance and supervision during the preparation of this manuscript.

The author also wishes to acknowledge American Cyanamid Co. for financial support and for providing the drugs used in these experiments and Dr. L. Slyter for supervision of the second experiment.

Appreciation is also extended to June Byers, wife of the author for her encouragement during the preparation of this manuscript and for typing the final copy.

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INTRODUCTION

Antibiotic feed supplements have been extensively used in major livestock producing countries for more than 15 years. In the United States, more than 1.25 million kg are used annually as diet supplements. The wide acceptance of antibiotics by livestock producers has been based on established benefits such as increased growth rate, improved feed conversion, and reduced mortality and morbidity from clinical and subclinical infections (Hays, 1969). Expenditures for antibiotics used as feed additives totaled $42 million in 1965 while the total spent for feed additives approached $142 million (Prather, 1965; Baker, 1969). It is evident that antibiotics make up a large part of the total feed additives used in livestock diets.

A wide variety of antibacterial compounds have been used in diets for nonruminant livestock and a number of these have also been tested for ruminant animals. Of these compounds, chlortetracycline has received more attention than other antibacterial agents in research with cattle and sheep. While the response to chlortetracycline additions has been favorable as computed across experiments, the response has been inconsistent in many experiments. To improve feedlot performance more consistently, combinations of antibacterials have been proposed to increase

the effectiveness of antibacterial therapy.

One of the combinations that has gained interest in recent years is that of chlortetracycline with sulfamethazine. Sulfamethazine by itself has not appeared to be effective as a feed additive in improving feedlot performance, but experimental evidence indicates that it improves the effectiveness of chlortetracycline when added in combination.

The basis for this study was to more precisely delineate the responses to be expected when supplementing feedlot lambs with a high level of chlortetracycline, sulfamethazine, or the combination of both antibacterial agents under a variety of feedlot conditions and types of diets. Responses measured under these various regimes included average daily gain, feed utilization, death losses, adaptation time to various diets, general health and incidence of disease.

REVIEW OF LITERATURE

Mode of Action of Antibiotics

The mode of action of antibiotics in producing growth promoting effects could be a combination of various factors. Those commonly proposed include metabolic effects, nutrient-sparing effects, disease-control effects or a combination of two or more of these.

Metabolic Effects. Evans et al. (1955) reported increased urine output and decreased body temperature with chlortetracycline-supplemented lambs indicating a possible decrease in metabolic rate as a result of chlortetracycline. Braude and Johnson (1953) observed the same effect on urine flow with pigs supplemented with chlortetracycline. Tillman and MacVicar (1956) also observed a decrease in urine output and a lower rectal temperature when chlortetracycline was fed to lambs. Research with gnotobiotic animals, however, has not substantiated this theory of antibiotic action. The beneficial effects derived appear to be more logically explained as indirect effects on the metabolism of digestive tract microflora populations.

Nutrient-Sparing Effects. The nutrient-sparing effect theory has received a considerable amount of research support. The response to antibiotics is generally greater when included in an inadequate diet (Hays, 1969), or in a diet that usually results in less rapid and efficient gains (Burroughs, et al. 1959). This response suggests an improved

utilization of nutrients at critical or suboptimal levels, and it could be attributed to nutrient synthesis by intestinal organisms, reduced competition from bacteria for critical nutrients or improved absorption. A depression in growth of organisms considered to be competitive with the host animal for dietary needs could produce a nutrient-sparing effect. Research reported by March and Biely (1952) indicates that the bacteria most affected by chlortetracycline are lactobacilli. The lactobacilli require amino acids in relatively similar proportional amounts as does the pig, and studies have shown that levels and sources of protein that support maximum growth in the pig are also near optimum for the multiplication of lactobacilli in the intestinal tract (Kellogg et al. 1964). Though there is ample evidence that antibiotics will markedly enhance the performance of animals fed low protein or slightly inadequate diets, there is evidence that the effect on nutrient utilization is other than direct. Nutrition and antibiotic response relationships appear to be secondary to the disease-control effect of antibiotic supplementation.

Disease-Control Effects. The major benefits derived from the inclusion of antibiotics as routine feed additives appear to result from their suppression or control of subclinical or nonspecific diseases (Hays, 1969). The buildup of nonspecific infections in environments used on a continuous basis by livestock can depress performance of animals

with no outward evidence of a disease problem. Routine feeding of antibiotics has been most effective in these types of environments. The relative improvement in growth rate is generally inversely related to the well-being and growth rate of the animals fed without antibiotics. As a result of reduced levels of infection in animals, less bacterial toxins are produced with a decrease in irritation of the intestinal wall causing the intestinal wall to become thinner resulting in an increase in absorption of nutrients from the intestinal tract (Rusoff, 1954; Taylor, 1957; Jukes, 1969). Antibiotic feeding shifts intestinal characteristics and animal performance toward that of gnotobiotic (pathogen free) animals which lends support for the disease-control theory as the major mode of action of antibiotics as feed additives.

Systemic Distribution of Tetracycline

The most commonly used antibiotics as feed additives for ruminants are the tetracyclines (chlortetracycline and oxytetracycline). In contrast to metabolism of other drugs such as penicillin or dihydrostreptomycin, the tetracyclines are taken up by and concentrated within tissue cells, resulting in tissue concentrations of tetracycline greatly in excess of cardiovascular levels. Actual systemic distribution of tetracyclire closely resembles that of radiocalcium. It appears to bind calcium by a chelating mechanism providing a possible explanation for its great affinity for

mineralization regions of growing bones and teeth. In addition, tetracycline also accumulates in the parathyroid glands which is interesting in that the parathyroid is an important regulator of mineral metabolism. High levels of tetracycline are also found in the pancreatic islets, largely in the form of insulin-zinc-tetracycline complexes. Accumulations of tetracycline are also noted in cells associated with the reticulo-endothelial system several of which are the Kupfer cells of the liver, cells in the white pulp area of the spleen and in the lymph glands.

Excretion of stored tetracycline is a slow process largely because of the nature in which this drug is fixed in structural components of the body. Tetracycline taken up by the bone is firmly bonded and may be retained for several months in small animals and up to several years in large animals. It appears to be stable as found in the body and when excreted it is still intact and biologically active (Ullberg, 1969).

Effect of Antibiotics on Feedlot Performance of Ruminants

Much of the data reported in the literature on various aspects of livestock production has been in the English system. For this reason, data are presented using the same system as the authors.

Beef Cattle. Antibiotics, such as chlortetracycline, oxytetracycline and bacitracin have been tested and used

quite extensively at low levels (70 mg/head daily) in beef cattle diets to increase gains and improve feed efficiency. The use of these low levels of antibiotics has also been effective in reducing the number of abscessed livers in feedlot cattle.

Burroughs et al. (1959) summarized the results of 112 trials at college experiment stations which involved the feeding of low levels of antibiotics to feedlot cattle. The antibiotics (chlortetracycline and oxytetracycline) stimulated weight gain on an average of 4% with an average feed saving of 3%. They also noted that cattle fed diets which resulted in less rapid and efficient gains showed a greater percentage response to an antibiotic. Average daily gain and feed conversion showed a 5.6% and 7.0% improvement on low-gaining diets; whereas, the response to chlortetracycline on higher-gaining diets was 4.3% in gain with 3.7% improvement in feed conversion.

Data for more recent trials which involved antibiotics for beef cattle have been summarized by Bertrand (1968). Data based on 5,352 head of growing-wintering cattle showed an 8.9% increase in daily weight gain and a 5.4% improvement in feed conversion as a result of feeding low levels of chlortetracycline, oxytetracycline or bacitracin at approximately 70 mg/head daily. Four thousand head of finishing cattle fed one of these antibiotics without stilbestrol showed a 6.7% increase in weight gain with

a 4.9% increase in feed conversion over control animals. Another 4,800 head of finishing cattle fed the antibiotics with diethylstilbestrol showed a 3.7% and 4.2% improvement in weight gain and feed efficiency respectively. Feeding low levels of bacitracin showed a positive response of 3.6% in weight gain and 2.7% in feed conversion in a summary of research involving 10,000 head of beef cattle in 28 feedlot trials and 12 college experiment station trials.

Data presented in these reviews suggest that growing-wintering cattle respond somewhat more to low level continuous feeding of antibiotics than finishing cattle in the feedlot. Age of cattle and level of forage in the diet are probably factors contributing most to the differences. Young cattle involved in stresses of disease, shipping and diet adjustment are more likely to show a favorable response to antibiotic supplementation than older animals. Also, cattle on high-roughage, slow-gaining diets appear to show more response to antibiotic supplementation than cattle on high-grain, faster-gaining diets.

Chlortetracycline for Sheep. Chlortetracycline has been used in animal feeds since 1949 when Stokstad et al. (1949) discovered the growth-promoting effect of spent mash obtained from the manufacture of chlortetracycline when fed to chickens. By 1951 chlortetracycline was a standard ingredient in broiler mashes (Bird, 1969). The significance of antibiotics as additives in diets for rum-

inants, especially feedlot lambs, was not substantiated as rapidly.

Colby et al. (1950) administered 100 mg chlortetracycline daily by capsule to 19 lambs fed a 90% milo diet. The experiment was terminated after 14 days because the lambs supplemented with chlortetracycline were off-feed, sick and losing weight rapidly. This was the first experiment reported using chlortetracycline for lambs and the results were not encouraging. Later research indicated that probably the primary reason for the unfavorable response was the use of capsules and daily handling required for administering the chlortetracycline.

In many of the early studies where chlortetracycline was tested, varying levels of the drug were fed. Jordan and co-workers conducted several experiments which involved varying levels of drug supplementation. Jordan and Bell (1951) fed chlortetracycline at 5 or 15 mg daily to suckling lambs and reported 18 and 10% increases in weight gains respectively for these treatments over controls. They also supplemented fattening lamb diets with 6 or 10.8 mg chlortetracycline daily and found 25 and 11% increases in weight gain respectively with a 20% increase in feed conversion for both treatments. In subsequent experiments Jordan (1952) supplemented lambs with chlortetracycline at 7.2, 10.0, 10.8 and 14.4 mg/lb of diet. The diets used were approximately 50% alfalfa hay and 50% corn grain. He

reported no adverse effects due to chlortetracycline administration and noted that supplemented lambs were easier to get on full feed. Lambs supplemented with chlortetracycline appeared to be more thrifty and tended to be more efficient in feed conversion than control lambs. Chlortetracycline supplementation also decreased the number of death losses attributed to overeating. In a 64-day period, chlortetracycline supplementation resulted in a slight decrease in average daily gain; whereas, a 105-day period showed an increase in average daily gain. In another experiment where similar 50% grain diets were fed, Jordan (1954) reported a 10% improvement in feed conversion when chlortetracycline was fed at 10 mg/lb of feed for feeder lambs. In a later experiment, Jordan (1958) supplemented lambs fed 50% roughage diets with 40 mg daily of chlortetracycline. There was no effect on weight gain or feed efficiency. He noted a problem with scours in all lots, and the lambs fed chlortetracycline cleared up quicker than those not fed chlortetracycline in the 59- and 70-day trials. Also reported was a decrease in death losses attributable to enterotoxemia with chlortetracycline-supplemented diets.

Several other workers also supplemented varying levels of chlortetracycline with approximately 50% roughage diets. Bridges et al. (1953) reported the results of three experiments where chlortetracycline was added to diets for fattening lambs at levels of 1.1 to 15 mg/lb of feed. The

diet used was 49% alfalfa hay and 51% concentrates which consisted of milo and cottonseed meal. An improvement in feed efficiency was noted with low level supplementation of chlortetracycline (2.2 to 5.0 mg/lb of feed). In an 84-day trial, there was a slight improvement in feed conversion and average daily gain. A greater improvement in average daily gain and feed efficiency was obtained when the antibiotic was fed in a 112-day experiment. Lambs receiving the chlortetracycline supplements scoured and went off-feed for several days at the beginning of the trials. However, chlortetracycline supplementation resulted in a significant decrease in death losses due to enterotoxemia. Supplementing feeder lambs with chlortetracycline at 5.5 to 7.6 mg/lb of 50% grain diet resulted in an increased rate of gain and improved feed conversion in a 100-day experiment reported by Hatfield et al. (1954).

Chlortetracycline was fed at 10 mg/lb with or without B vitamins to 120 fattening lambs by Bohman et al. (1955). A diet consisting of 50% clover hay with wheat and barley as concentrates was used in this study. Chlortetracycline additions produced slight but insignificant increases in weight gain and improvements in feed conversion in this 56-day trial.

Using 798 old-crop, mixed-breed lambs consisting of a high percentage of unthrifty animals, Johnson et al. (1956) fed diets of approximately 50% roughage consisting

of alfalfa meal and corn cob meal at the start which was dropped to 34% roughage in 10 days. Cracked corn and alfalfa-molasses meal made up the concentrate portion of the diet. These workers reported that lambs supplemented with chlortetracycline at 10 mg/lb of diet showed a significant ($P<.05$) improvement in weight gains and feed efficiency over the control lot and two other lots receiving higher levels of chlortetracycline in a 49-day trial. Lambs supplemented with chlortetracycline at 25 mg/lb of feed for 21 days and then not supplemented for the rest of the trial showed a depression in weight gains and feed conversion for the 49-day trial. Lambs supplemented with 25 mg chlortetracycline for 21 days and then 10 mg for the remainder of the trial showed only a slight advantage in weight gains and feed efficiency over the control group. Using 200 lambs per treatment, death losses were 14 for the control, zero for the 25-10 mg chlortetracycline lot, zero for the 10 mg lot and 30 for the 25-0 lot. All death losses in the lot that received 25 mg chlortetracycline for 21 days and then none for the next 28 days occurred after chlortetracycline supplementation had ceased.

Several researchers have conducted experiments with lambs using a variety of roughage levels with antibiotics to determine if different responses would be observed with diets differing in roughage content. Elliott and Ellsworth (1953) used different ratios of roughage to grain in diets

supplemented with 10 or 20 mg/lb of feed of chlortetracycline to determine the relationships between chlortetracycline additions and roughage levels of feeder lamb diets. Roughage-to-grain ratios used were 80:20, 60:40 and 40:60. Responses due to chlortetracycline supplementation were greater with diets which contained the higher levels of roughage than with the higher-grain diets. As the percent of grain increased, average daily gain also increased and responses to chlortetracycline administration became more variable and less significant. This would indicate that responses to feeding chlortetracycline may be influenced by roughage levels fed.

Jordan et al. (1956) also experimented with varying roughage-to-grain ratios. When feeding roughage-to-grain in ratios of 45:55 or 35:65, they observed no significant changes in weight gain or feed conversion by supplementing chlortetracycline at 21.6 mg/day or by changing the ratio of grain to roughage.

In six feeding trials involving varied roughage levels and sources, Kunkel et al. (1956) reported a significant improvement in feed efficiency when adding chlortetracycline at 5, 7.5, 10 or 15 mg/lb of diet. Chlortetracycline additions tended to increase daily gain to a greater extent with diets higher in roughage content. Chlortetracycline supplementation decreased the problem of scouring on self-fed, high-grain diets and decreased the percent-

age of death losses due to enterotoxemia from 4.3% for controls to none for all lambs supplemented with chlortetracycline. Also noted was a depression in feed consumption during the early part of the trial which lasted several days in lots supplemented with chlortetracycline.

Oxytetracycline for Sheep. Another antibiotic similar to chlortetracycline that has received a considerable amount of research effort in studies with lambs is oxytetracycline. Kinsman and Riddell (1952) tested the effect of feeding oxytetracycline at 15 mg/lb of diet on the performance of creep-fed suckling lambs. Rate of gain was not influenced, whereas feed efficiency was improved 7.7% as a result of oxytetracycline supplementation. Hatfield and Garrigus (1953) also fed oxytetracycline in creep diets for suckling lambs. They supplemented oxytetracycline at 7.4 mg/lb of total diet for feeder lambs and showed an 8.9% increase in rate of gain. In 1958, Reynolds et al. also supplemented feeder lambs with oxytetracycline at 7.5 mg/lb of diet and reported a 4.7% increase in rate of gain with a 3.7% improvement in feed efficiency although neither response was statistically significant.

In a series of six sequential experiments with 70-lb lambs, Hale et al. (1959) supplemented lambs with oxytetracycline at 7.5 mg/lb of diet. The diets varied in roughage content from 35% to 65%. They observed an increase in rate of gain averaging 13% over all six studies. In a

later report, Hale et al. (1960) showed a 12% increase in weight gains with a 6% improvement in feed conversion. This was due to supplementing oxytetracycline at 7.5 mg/lb of diet (50% concentrate) as averaged over five experiments involving 70-lb Texas feeder lambs. A total of 222 lambs were used in these five comparisons.

Butcher and Raleigh (1962) fed oxytetracycline at 70 mg daily for 7 days and 7.5 mg/lb of diet thereafter to one hundred twenty-eight 70-lb weanling wether lambs. They were fed a 70% roughage diet. Rate of gain was increased 10.8% while feed efficiency was improved 9.2%. In subsequent investigations at the same station, Packett and Butcher (1963) fed 45% concentrate diets to lambs supplemented with oxytetracycline at 10 mg/lb of diet. They reported a 35% increase in weight gains in an experiment lasting 86 days. These results were not supported by later studies at the same station reported by Harris et al. (1963). These workers fed 50% concentrate diets to 72 weanling wether lambs. They found that feeding oxytetracycline at 5 or 10 mg/lb of diet actually depressed weight gains slightly.

Oxytetracycline appears to be effective in promoting gains and improving feed conversion under most feedlot conditions tested with lambs. The responses to supplementation at 10 to 15 mg/lb of diet appear to be favorable as averaged over all studies. The responses have been

similar to those obtained from chlortetracycline supplementation with similar inconsistencies between studies appearing with both antibiotics. The responses obtained from both drugs tend to be greater on high-roughage, slow-gaining type diets and when the lambs are under stress conditions. This is in agreement with responses obtained with feeder cattle fed either of these antibiotics at low levels.

Other Antibacterials for Sheep. Oleandomycin has received less experimental interest in lamb diets than the other previously discussed antibiotics.

In 1958, Reynolds et al. reported on the use of several levels of oleandomycin in 50% concentrate diets for finishing feeder lambs. Daily gains and feed conversion were increased on an average of 12% and 10% over three experiments by supplementation of oleandomycin at 1 mg/lb of diet. Feeding 3 mg/lb of diet resulted in a 25% increase in weight gain and a 10% improvement in feed conversion in one experiment. High levels (7.5 mg/lb of diet) were not effective in improving weight gains or feed conversion.

Hale et al. (1960) conducted seven experiments with 70-lb Texas feeder lambs supplementing a 50% concentrate diet with several levels of oleandomycin. The results averaged over all experiments showed increases in rate of gain and improvements in feed conversion of 9.6% and 5.4%

with 1 mg; 18.9% and 9.6% with 3 mg; and 4.8% and -1.8% with 7.5 mg/lb of diet of oleandomycin.

Low levels of oleandomycin (1 to 3 mg/lb of diet) appear to be effective in promoting gains and feed conversion in finishing lambs; however, FDA clearance for its use has not been obtained.

Hygromycin was tested by Jordan and Hanke (1958) at 21.2 mg/day for lambs. They found no effect on rate of gain and decreases in feed intake. Perry et al. (1959) also conducted studies with hygromycin for 75-lb lambs using 3.5 mg/lb of diet. No effect was observed on weight gain or feed conversion. These studies indicate hygromycin to be ineffective in diets for feedlot lambs at the levels tested. It is not cleared for use in lamb diets by the FDA.

Chlorohydroxyquinoline, a synthetic compound which has a broad spectrum of antibacterial and antifungal activity, was investigated in lamb diets by Welch et al. (1965). A total of one hundred fifty-four 60-lb lambs were used in two experiments. In the first trial which involved poorly doing culled lambs, levels of 15.5 and 31 mg/lb of diet increased daily gain 32% and 27% and improved feed conversion 16% and 8%. In a second experiment, smaller responses were detected even when 62.5 mg/lb of diet were used. Results of these two experiments indicate chlorohydroxyquinoline may have some potential in lamb rations. However, there is not enough evidence to date to evaluate this com-

pound, and it is not cleared for use in lamb diets.

Penicillin was administered to lambs by Colby et al. (1950) at the rate of 100 mg/day by capsule. It was reported to cause lambs to go off feed, lose weight and have diarrhea for a week. The techniques used in this study influenced the results and they may not be typical of actual conditions. Kinsman and Riddell (1952) also supplemented creep-fed diets with penicillin at 15 mg/lb of feed. No effects on rate of gain were noted while feed efficiency was decreased. Zimmer (1958) reported a 13% depression in rate of gain and a 10% reduction in feed efficiency in a 56-day trial with 87-lb lambs on a 75% concentrate diet with penicillin at 10 mg/lb of feed. Thus it appears that penicillin is not effective in improving rate of gain or feed efficiency for feedlot lambs.

Antibacterial Combinations for Ruminants

The synergistic effect of feeding combinations of antibacterials has been of interest recently. The most widely used combination in the ruminant area is that of chlortetracycline and sulfamethazine.

Calhoun and Shelton (1970) supplemented lamb diets with a combination of chlortetracycline and sulfamethazine or with chlortetracycline alone. Both antibacterials were added at 55 mg/kg of feed. One hundred twenty 31-kg Texas feeder lambs were used in this study with a high-concentrate

diet composed of 70% dry rolled sorghum. In two experiments initiated in November, chlortetracycline alone or the combination of chlortetracycline and sulfamethazine increased average daily gain and improved feed efficiency. The response due to the combination was not any greater than the response to chlortetracycline alone. In two winter-to-spring trials, the combination of chlortetracycline and sulfamethazine increased average daily gain and improved feed conversion while chlortetracycline alone did not affect these parameters.

Drug combinations at several levels were used by Ternus and Vetter (1970). They fed chlortetracycline and sulfamethazine to lambs in combination at 50 or 100 mg/kg of diet for each drug. Seventy-two lambs averaging 29 kg were used in a 77-day trial and 72 were also used in each of two 56-day trials. In the 77-day trial, both levels of the drug combinations significantly ($P<.01$) increased average daily gain. In the 56-day trials, only the 100 mg combination level increased average daily gain ($P<.01$). There was no significant change in feed efficiency resulting from either level of the drugs.

Drain et al. (1966) used chlortetracycline, sulfamethazine and the combination of both in starter diets for feeder cattle. Each drug when used was added at 350 mg daily. In this 4-week trial, chlortetracycline additions produced a 14% increase in weight gains ($P<.05$), sulfa-

methazine additions did not affect weight gain, and the combination of chlortetracycline and sulfamethazine resulted in a 22% increase in weight gain ($P<.05$) with a 14% improvement in feed efficiency, ($P<.05$).

A series of experiments were conducted by Perry et al. (1971) using 350 mg daily of chlortetracycline, sulfamethazine or both in starter diets for conditioning feeder cattle after transit. High-roughage diets were used with corn silage or hay at full feed. Chlortetracycline additions resulted in consistent increases in average daily gain in all trials with a general improvement in feed efficiency. Sulfamethazine additions did not significantly affect daily gain or feed efficiency. The most benefit resulted when chlortetracycline and sulfamethazine were used together producing a significant increase in average daily gain ($P<.01$) and an improvement in feed conversion.

Combinations of chlortetracycline and sulfamethazine for lambs appear to produce more consistent responses in improving weight gains and feed efficiency than either compound alone. The levels tested are much higher than the levels formerly used in lamb diets. High level supplementation of these drugs in combination for conditioning feeder cattle show responses similar to those observed with feeder lambs. The combination appears to promote greater and more consistent improvements in weight gains and feed conversion.

Effect of Antibiotics on Diet Digestibility

Since the ruminant animal depends to a great extent on the microbial population in the rumen, the use of antibiotics and their effect on the bacterial population of the rumen and consequently on digestion of dietary components is of particular interest.

Diet digestibility was studied by Thompson and Grainger (1954) using low-quality roughages for wether lambs supplemented with chlortetracycline at 10 mg/lb of diet. A 10-day preliminary period followed by a 10-day collection period was the procedure followed in this study. Anorexia followed within 48 to 72 hours after chlortetracycline administration with a return to normal appetite in 2 to 3 days. Apparent crude fiber digestion was reduced from 71% to 60% as a result of chlortetracycline supplementation. There was also a decrease in apparent dry matter digestion but it was nonsignificant. No effect was observed on nitrogen retention.

Evans et al. (1955, 1957) studied the effects of prolonged administration of chlortetracycline at levels ranging from 1 to 10 mg/lb of feed on roughage digestion by lambs. The procedure used involved a 10-day preliminary period followed by three consecutive 10-day collection periods. The basal diet was composed of 80% corn cobs and 20% concentrate. They found a decreased appetite 40 to 72 hours after initiating chlortetracycline supple-

mentation with a return to normal consumption within 96 hours when using the 10-mg level. An initial 18.4% decrease in apparent crude fiber digestion with the 10-mg level was noted in the first collection period followed by a return to the digestibility of the control by the third collection period. This would indicate an adjustment to chlortetracycline with time. Apparent dry matter digestion also was depressed by chlortetracycline supplementation with apparent digestion decreasing with increasing levels of chlortetracycline fed. Apparent digestion of dry matter, nitrogen-free extract, and organic matter followed that of crude fiber showing an improvement in digestion with time following antibiotic supplementation.

Apparent digestion of components of a 1:1 prairie hay-concentrate diet as affected by chlortetracycline administration was studied by Tillman and MacVicar (1956). Using 10-day preliminary and 10-day collection periods they found that feeding 10 mg chlortetracycline daily resulted in a decrease in apparent dry matter digestion. The feeder lambs fed chlortetracycline had significantly lower rectal temperatures and excreted more urine indicating a possible decrease in metabolic rate. Supplementing lambs with chlortetracycline at 15.4 mg/100 lb of body weight resulted in a decrease in apparent dry matter, crude protein, crude fiber, nitrogen-free extract and energy digestion. They also noted that chlortetracycline-

supplemented lambs were slower to get on full feed and feed intake for these lambs was depressed for the first 4 days.

The effect of chlortetracycline supplementation at 500 mg/day for steers was studied by Chance et al. (1953). They used fistulated steers and reported that chlortetracycline increased rate of passage of dry matter, crude fiber, crude protein and nitrogen-free extract from the rumen.

Bell et al. (1951) used a 10-day preliminary period followed by a 15-day collection period with steers to determine the effects of adding chlortetracycline at 200 mg daily on apparent digestibility of dietary components. They noted anorexia conditions occurring within 48 to 72 hours after initiating chlortetracycline supplementation. They also reported that chlortetracycline caused a decrease in apparent crude fiber, dry matter and nitrogen-free extract digestibility.

When feeding steers 500 mg chlortetracycline/day, Lassiter et al. (1954) reported a decrease in apparent dry matter digestion from 64% for controls to 60.5% for chlortetracycline supplemented steers. Apparent crude fiber digestion was also decreased from 35.5% to 22.7% when chlortetracycline was added. A 10-day preliminary period followed by a 10-day collection period was used in this study with a diet comprised of 50% alfalfa hay.

Horn et al. (1955) reported the effects of supple-

menting diets for steers with 32 or 100 mg chlortetracycline daily on apparent digestibility of dietary components. They found a decrease in apparent crude fiber digestibility from 54.6% to 50.4% and a decrease in apparent crude protein digestibility from 66.8% to 58.4% due to adding chlortetracycline. Apparent nitrogen retention was also decreased by chlortetracycline supplementation.

The effect of feeding 75 mg chlortetracycline daily to steers as it affected apparent diet digestibility was studied by Erwin et al. (1956). The only significant effect observed was a decrease in apparent ether extract digestibility. No effect was noted on apparent dry matter, crude fiber or crude protein digestion.

Chlortetracycline appears to reduce diet digestibility during adaptation to low level supplementation.

Chlortetracycline supplementation to ruminants results in an alteration of the rumen microbial population (Hungate et al. 1955). Cellulose digestion was shown to be reduced by feeding 240 mg chlortetracycline daily for 4 years in studies conducted by Lambert and Jacobson (1956). In vitro digestion of cellulose was reduced from 45.3% to 34.4% with Solka Floc and from 59.0% to 45.1% with alfalfa hay. After removing chlortetracycline from the diet, cellulose digestion returned to normal.

Many of the researchers that conducted digestion

studies allowed only 10-days for adaptation to the diets and antibiotics fed. This appears to be an insufficient amount of time to allow for complete adaptation to the antibiotics, and therefore depressed digestion of dietary components was generally observed. When sufficient time for adaptation is allowed, digestibility values do not appear to show the depression reported in many of the studies. This is supported by evidence in several of the studies where nutrient digestion was originally depressed but equal the non-antibiotic controls in subsequent collection periods. Digestion of diet components appears to return to normal after a suitable period of adaptation to the antibiotic supplements. The studies with cattle and sheep indicate that similar responses are observed with both species when chlortetracycline is fed.

METHODS OF PROCEDURES

Four feedlot experiments were conducted with ewe and wether lambs to determine lamb responses in terms of feedlot performance due to feeding chlortetracycline, sulfamethazine or the combination of the two drugs. These treatments were applied to feedlot adaptation, growing and finishing types of studies. Parameters employed to measure feedlot performance included weight gains, efficiency of feed utilization, feed consumption, incidence of various diseases and lamb mortality. Weight gains, feed consumption and feed efficiency are calculated based on lambs finishing the trials. An average feed intake was subtracted for lambs that died during the course of an experiment.

Carcass data was not obtained for any of the experiments due to a required 22-day withdrawal period for lambs receiving sulfamethazine or the combination drug treatments during which time all lambs were fed alike.

A fifth experiment was a metabolism study conducted to determine the effects of the combination drug supplement on digestion of nutrients and nitrogen balance. Two time periods of adaptation were studied using all-grain or all-roughage diets with soybean meal or urea as sole sources of supplemental nitrogen.

Experiment 1

This experiment initiated in June of 1969, was a 113-day growing study involving 192 early-weaned native ewe and wether lambs averaging about 15 kilograms. They were obtained from the flock at the Dryland and Irrigation Research Station at Newell. The lambs were separated from the ewes and weighed 2 days prior to trucking 480 kilometers to Brookings for the experiment. On the day following arrival, the lambs were weighed to obtain shrunk weights and were drenched with thiabendazole for control of internal parasites. They were then separated into ewes and wethers, stratified according to weight and randomly allotted into 12 pens of 16 lambs per pen for 4 experimental treatments replicated 3 times. The treatments used were 0 or 55 mg/kg diet of chlortetracycline, sulfamethazine or both.

The diets fed in this study consisted of a complete mix of 20% alfalfa hay and 80% concentrates. The composition of the basal diet was 20% ground alfalfa hay, 75.9% rolled corn grain, 2.5% soybean meal (44% protein), 0.3% urea (45% nitrogen), 0.4% dicalcium phosphate, 0.4% ground limestone and 0.5% trace mineral salt. A vitamin A premix was added to supply 1100 I.U./kg of diet. Premixes with the appropriate drugs were substituted for an equal weight of corn grain to provide the levels under test.

The lambs were fed in unpaved pens with no shade or

shelter. They were raised to a full feed gradually over a 2-week period. Individual weights were taken at 21-day intervals.

Experiment 2

The second experiment was initiated in June of 1970 and was also a growing type study with early-weaned ewe and wether native lambs. The lambs were from the same flock as those for experiment 1 but averaged about 21 kilograms. In contrast to the first study, this experiment was conducted at the Newell substation, and the lambs were not moved before starting the experiment as was the case in experiment 1. The lambs were separated from the ewes, weighed, sorted as to ewes and wethers, stratified by weight, and then randomly allotted on the basis of sex and weight into 12 pens of 10 lambs for 4 experimental treatments replicated 3 times. Diets, experimental treatments, feeding and management conditions used in this study were the same as for the first experiment. The lambs were weighed at 2, 4 and 6 weeks and at 21-day intervals thereafter. This study lasted 93 days. A full feed was arrived at after gradual increases over a 2-week period of time.

Experiment 3

Experiment 3 was initiated in May of 1970. It lasted for 21 days and was designed to be an adaptation study to determine the effects of antibacterials on feedlot perform-

ance during early stages of adaptation of stressed lambs as measured by weight gains, feed consumption, feed utilization, incidence of disease and death losses. The five hundred fifty-two 30-kg ewe and wether Texas feeder lambs used in this study were gate cut on arrival in 48 pens of 11 or 12 lambs each. On the following day the lambs were drenched with thiabendazole (dosage for heavily parasitized lambs) for control of internal parasites and were vaccinated with a clostridium perfringens toxoid to prevent overeating disease problems. The next day they were ear tagged and weighed and the experiment was started. The treatments used were 0 or 100 mg daily of chlortetracycline, sulfamethazine or both entailing four treatments replicated 12 times. Weights were again taken 21 days after the start of the experiment.

Rations for this experiment consisted of 227 g of a grain-protein supplement which provided zero or 100 mg daily of each antibacterial and alfalfa-brome hay fed ad libitum. Antibacterial premixes substituted for an equal amount of corn grain in the control supplement to provide levels of the drugs under test. The composition of the control supplement was 94% rolled corn grain, 3.0% dicalcium phosphate and 3.0% trace mineral salt. Vitamin A was added to provide 2000 I.U. per lamb daily. Feeding and management procedures were the same as in experiment 1, and the experiments were conducted at the same location.

Experiment 4

This experiment was a study designed to determine the effects of feeding 100 mg daily of chlortetracycline, sulfamethazine or both on feedlot performance of finishing lambs. Also tested in this experiment were four protein supplements with each of the four antibacterial treatments.

Three hundred eighty-four ewe and wether Montana feeder lambs were used in this study. They arrived in November, 1970, and were held 1 week before initiating the experiment. The lambs were ear tagged, weighed and allotted by sex and weight into 32 pens of 12 lambs per pen. They were divided into two weight groups averaging 34 and 40 kg. One pen per treatment was allotted from each weight group resulting in replication of the 4 x 4 factorial design being represented by weight groups.

The rations were comprised of a 1:1 ratio of corn silage to rolled corn grain full-fed on an as-fed basis and 136 g of protein supplement. The supplements contained 40% protein provided by soybean meal; corn grain and urea; corn grain, urea and soybean meal; or corn grain, urea and dehydrated alfalfa meal. Urea levels were held constant in the latter 2 supplements with the soybean meal and dehydrated alfalfa meal replacing part of the urea in the corn-urea ration.

Composition of the supplements was as shown in table 1.

Table 1. Ingredient Composition of Diets Used in Experiment 4

Ingredient	Supplement Composition[a]			
	control	corn-urea	corn-urea-dehy.	corn-urea-SBM
	%	%	%	%
Rolled corn grain	90.0	78.3	54.0	73.2
Soybean meal (44% protein)	--	--	--	5.9
Urea (45% nitrogen)	--	11.7	11.0	11.0
Dehydrated alfalfa meal	--	--	25.0	--
Ground limestone	5.0	5.0	5.0	5.0
Trace mineral salt	5.0	5.0	5.0	5.0

[a]Vitamin A added to supply 2000 I.U. per lamb per day.

Premixes with the drugs were substituted for an equal weight of soybean meal in the control supplement and for corn grain in supplements with urea to provide the 100 mg levels in 136 g of the supplements. Dicalcium phosphate and trace mineral salt were provided free access.

The lambs were started on 1.360 kg of corn silage per head daily and were changed to the 1:1 ratio of corn grain to corn silage over a 2-week period of time by gradual reductions of the corn silage intake and increases in corn grain. Feeding and management procedures were the same and at the same location as for experiment 1. The lambs were weighed every 21 days. The heavy group was marketed after 63 days while the light group was fed for 83 days

before marketing.

Experiment 5

To supplement the feedlot trials, a metabolism study was conducted using diets with and without chlortetracycline and sulfamethazine in combination at 100 mg of each per day to determine effects on diet digestibility and nitrogen balance. High-roughage (corn silage) and high-grain (rolled corn grain) diets were tested with and without the drugs using soybean meal or urea as sources of supplemental nitrogen resulting in a 2 x 2 x 2 factorial designed experiment.

Forty-eight 40-kg shorn wether lambs were allotted to one of eight pens, each of which was fed one of the eight experimental diets. The control diets used are listed in the table 2 with ingredients expressed on a 100% dry-matter basis.

Table 2. Ingredient Composition of Control Diets Used in Experiment 5

	Rolled corn grain		Corn silage	
Ingredient	SBM	Urea	SBM	Urea
Rolled corn grain	90.2	96.62	--	--
Corn silage	--	--	83.6	95.8
Soybean meal (44% protein)	7.8	--	14.4	--
Urea (45% nitrogen)	--	1.15	--	2.2
Trace mineral salt	1.0	1.0	1.0	1.0
Ground limestone	1.0	1.0	--	--
Dicalcium phosphate	--	--	1.0	1.0
Sodium sulfate	--	0.23	--	0.44

Vitamin A was added to the mixes to provide 2000 I.U./kg of diet. The corn grain diets were fed as complete mixes and were composed as shown in the preceding table. Supplements were fed with corn silage to provide the composition of the corn silage diets listed in table 2. All diets were calculated to contain 12% protein on a dry basis. Each diet was fed once daily to two of the eight pens of lambs with one of the pens on each diet receiving a previously weighed packet of combination drug premix which provided 100 mg chlortetracycline and 100 mg sulfamethazine daily for each lamb. The drugs were diluted with ground corn grain to insure uniform mixing with the rest of the diets when fed.

The lambs were started on the experimental diets in March and increased to a full feed in about 10 days. After 13 days from the initiation of the experimental diets, three of the six lambs in each pen were randomly selected and were placed in metabolism crates equipped to collect feces and urine. They were allowed to become accustomed to the crates and individual ad libitum intakes were determined over 3 days. Feed offered was then reduced to 90% of the ad libitum intake and fed at this level through the collection period. The collection of urine and feces was initiated 3 days later and continued for 5 days.

A collection period of 5 days was considered adequate since DuBose and Embry (1956) found a high repeatability in

24-hour fecal dry-matter excretions by steers and lambs when feed intake was constant. They considered that more than 3 or 4 daily collections would not likely improve the accuracy of digestibility data.

Urine volume and feces weights were determined daily and 10% aliquots of both were frozen and composited daily. Feed samples were also taken daily and composited for 5 days starting 2 days prior to beginning fecal and urinary collections.

Upon termination of the first collection period, the second group of lambs was placed in the collection crates. Feeding, collections and sampling procedures were the same for this group as for the first group of lambs. The lambs involved in the second collection period were fed the antibacterials for 31 days before initiating collections as compared to 20 days for the first group of lambs.

During the course of the metabolism study, no attempt was made to equalize feedstuff consumption either within or between treatments. Urine samples were frozen for later nitrogen analysis via Macro Kjeldahl. Fecal samples were frozen and later dried in a forced draft oven at 80 C to determine dry matter, and dried feces samples were used for nitrogen and energy analysis. Nitrogen in feed and feces was determined by Macro Kjeldahl. Energy content of feed and feces was determined on an automated adiabatic oxygen bomb calorimeter. Data for individual

experiments were analysed for significance using the least squares method of analysis of variance. Duncans new multiple range test was used to test significance of treatment means.

RESULTS

Feedlot Performance Studies

Experiment 1

Daily weight gains for lambs in all treated groups were greater than for the controls (table 3). The differences amounted to 5.4%, 15.0% and 17.0% over controls for the chlortetracycline, sulfamethazine and chlortetracycline-sulfamethazine groups respectively. Gains for the lambs fed sulfamethazine or the chlortetracycline-sulfamethazine combination were significantly different ($P<.01$) from the control lambs or those fed chlortetracycline. These lambs were weaned at approximately 15 kg and were trucked 480 km, and so they were subjected to a considerable amount of stress prior to starting the experiment.

Lambs supplemented with sulfamethazine or the drug combination consumed more feed than the control or chlortetracycline groups. Differences were significant ($P<.05$) for the sulfamethazine or drug combination groups over those fed chlortetracycline and for the drug combination over controls. In the latter comparison, the increase amounted to 6.6%. Feed requirements per unit of gain were improved ($P<.05$) for all treated groups over the control lambs. The relative differences were 6.7%, 9.5% and 8.9% for the chlortetracycline, sulfamethazine or drug combination supplemented groups over control lambs.

Losses listed in the table do not include those

Table 3. Feedlot Performance of Early-Weaned Lambs

(Experiment 1: June 5 to September 26, 1969-113 days, shipped 480 km prior to experiment)

Item	Control	Chlortetracycline	Sulfamethazine	Chlortet-Sulfameth.[a]
No. lambs	44	48	43	44
Initial weight, kg	15.9	15.0	15.0	15.5
Final weight, kg	43.2	43.7	46.5	47.3
Average daily gain, g	241[b]	254[b]	277[c]	282[c]
Average daily feed consumption, kg	1.222[b,c]	1.201[b]	1.271[c,d]	1.303[d]
Kg feed/kg gain	5.07[b]	4.73[c]	4.59[c]	4.62[c]
Death losses	2	0	3	3

[a] Drugs courtesy American Cyanamid with the chlortetracycline-sulfamethazine supplied as Aureo S-700. Each drug added at 55 mg/kg of diet when fed alone or in combination.

[b, c, d] Means within same line having different superscript letters differ significantly: average daily gain ($P<.01$), feed conversion ($P<.05$), feed consumption ($P<.05$).

against which the experimental treatments were expected to be ineffective such as urinary calculi or physical injury. Death losses were low in the experiment and none resulted when feeding chlortetracycline.

Experiment 2

Lambs used in this experiment were from the same source as those for experiment 1; however, these lambs were 6 kg heavier than those used in the first experiment. Also these lambs were fed at the same location as raised which caused less stress to the lambs than was the case in experiment 1 where the lambs were shipped 480 km before starting the experiment.

Weight gains for all treated groups were greater than for the control lambs although the differences were smaller than in experiment 1 (table 4). The increases in rate of gain over the controls were 5.6%, 3.8% and 7.8% for the chlortetracycline, sulfamethazine and drug combination supplemented groups respectively.

Feed consumption was similar for all treatment groups. For this reason trends in feed efficiency followed those of weight gain. The improvements over the control amounted to 7.8%, 4.7% and 8.3% respectively for the chlortetracycline, sulfamethazine and drug combination supplemented lambs. No death losses occurred in any of the treatment groups.

Table 4. Feedlot Performance of Early-Weaned Lambs

(Experiment 2: June 2 to September 3, 1970-93 days, fed at same location as raised)

Item	Control	Chlor-tetracycline	Sulfa-methazine	Chlortetracycline-Sulfamethazine[a]
No. lambs	29	29	29	30
Initial weight, kg	21.3	20.9	21.8	21.4
Final weight, kg	42.8	43.6	44.4	44.5
Average daily gain, g	232	245	241	250
Average daily feed consumption, kg	1.318	1.320	1.320	1.320
Kg feed/kg gain	5.75	5.35	5.48	5.27
Death losses	0	0	0	0

[a]Drugs courtesy American Cyanamid with the chlortetracycline-sulfamethazine supplied as Aureo S-700. Each drug added at 55 mg/kg diet when fed alone or in combination.

Table 5. Feedlot Performance During Adaptation of Texas Feeder Lambs

(Experiment 3: May 15 to June 5, 1970-21 days)

Item	Control	Chlor-tetracycline	Sulfa-methazine	Chlortetracycline-Sulfamethazine[a]
No. lambs	138	138	138	137
Initial weight, kg	30.5	30.0	30.0	29.7
Final weight, kg	36.8	36.1	35.7	36.4
Average daily gain, g	286[b]	291[b]	272[b]	318[c]
Average daily feed consumption, kg	1.21	1.21	1.21	1.21
Kg feed/kg gain	4.23	4.16	4.45	3.81
Death losses	0	0	0	0

[a]Drugs courtesy American Cyanamid with the chlortetracycline-sulfamethazine supplied as Aureo S-700. Each drug added at 100 mg daily when fed alone or in combination.

[b], [c]Means within same line having different superscript letters differ significantly ($P<.05$).

Experiment 3

This experiment involved only an initial adaptation period of 21 days. Lambs were started on this experiment early after arrival in the feedlot.

Early stages of feedlot adaptation following shipping and raising the lambs to full feed caused feed intake to be largely controlled and for these reasons, feed intakes were similar for all treatments.

Weight gains for lambs supplemented with the chlortetracycline-sulfamethazine combination were greater ($P<.05$) than all other treatment groups. The difference amounted to 11.2% over the control groups (table 5). Lambs fed chlortetracycline gained similar to controls while lambs fed sulfamethazine gained slightly slower than controls.

As a result of similar feed intakes over all treatments, the faster gaining lambs were also more efficient. Feed efficiency was improved 10% as a result of using the drug combination.

Experiment 4

This experiment involved two weight groups and four protein supplements with each antibiotic treatment. There were no significant interactions between antibacterials and weight groups or protein supplements, or between weight groups and protein supplements. Performance data are presented in tables 6, 7 and 8 by antibacterial treatments, weight groups and types of protein supplements respectively.

Table 6. Performance of Feeder Lambs as Affected by Antibacterial Treatments

(Experiment 4: November to February 1970-Average of 73 days)

Item	Control	Chlor-tetracycline	Sulfa-methazine	Chlortetracycline-Sulfamethazine[a]
No. lambs	87	94	93	91
Initial weight, kg	37.3	37.6	37.3	37.0
Final weight, kg	50.7	51.2	50.9	51.3
Average daily gain, g	185[b]	188[b]	185[b]	198[c]
Average daily feed consumption, kg air dry				
Corn silage	0.56	0.58	0.56	0.58
Corn grain	0.84	0.86	0.84	0.86
Supplement	0.136	0.136	0.136	0.136
Total	1.54	1.58	1.54	1.58
Kg feed/kg gain	8.29	8.38	8.31	7.99
Death losses	9	2	3	4

[a] Drugs courtesy American Cyanamid with the chlortetracycline-sulfamethazine supplied as Aureo S-700. Each drug added at 100 mg daily when fed alone or in combination.

[b, c] Means within same line having different superscript letters differ significantly ($P<.05$).

Table 7. Performance of Feeder Lambs as Affected by Weight Groups (Experiment 4)

Item	Light group	Heavy group
No. lambs	179	186
Days on feed	83	63
Initial weight, kg	35.1	39.4
Final weight, kg	49.9	52.0
Average daily gain, g	179[a]	200[b]
Feed consumption, average total air dry, kg	1.51[a]	1.61[b]
Feed conversion, kg feed/kg gain	8.44[a]	8.05[b]
Death losses	12	6

[a, b]Means within same line having different superscript letters differ significantly ($P<.01$).

Table 8. Performance of Feeder Lambs as Affected by Type of Protein Supplement (Experiment 4)

	Type of supplement			
Item	SBM	Urea	Urea-SBM	Urea-Dehy.
No. lambs	91	91	90	93
Days on feed (ave.)	73	73	73	73
Initial weight, kg	37.3	37.2	37.2	37.2
Final weight, kg	51.5	50.3	50.7	51.3
Average daily gain, g	195	180	185	193
Average daily feed consumption, air dry basis				
corn silage	0.57	0.56	0.57	0.59
corn grain	0.86	0.83	0.85	0.87
supplement	0.136	0.136	0.136	0.136
total	1.566	1.526	1.546	1.596
Kg feed/kg gain	8.03	8.47	8.41	8.28
Death losses	5	4	6	3

Weight gains of lambs fed chlortetracycline or sulfamethazine alone were similar to controls while the lambs fed the combination of these two drugs gained 7.0% faster than the controls. Daily gains for the combination-fed group were significantly greater ($P<.05$) than any of the other treatments. The heavy group of lambs also gained significantly faster ($P<.01$) than the light group and the difference amounted to 11.7%. Rate of gain appeared to be lower on urea or urea-soybean meal supplemented diets than for the soybean meal supplemented diets or the urea-dehydrated alfalfa meal supplemented diets although the differences were not significant.

Chlortetracycline or drug combination supplemented lambs consumed 2.6% more feed than control or sulfamethazine supplemented groups although these differences were not significant. The heavy group of lambs consumed a greater ($P<.05$) amount of feed per day than the light group and the difference amounted to 6.6%. Urea-dehydrated alfalfa meal supplemented lambs also consumed more feed than the other groups.

Lambs fed the drug combination were 3.4% more efficient in feed conversion than controls. Feed conversion for lambs fed the other drug treatments was similar to the control lambs. The heavier group of lambs were 4.6% more efficient in feed conversion ($P<.01$) than the light group of lambs. Lambs supplemented with soybean meal were more

efficient than lambs fed any of the other supplements.

Death losses were greater for the controls than for the lambs fed antibacterials and the percent death losses were 10.3%, 2.1%, 3.2% and 4.4% for the controls, chlortetracycline, sulfamethazine and drug combination groups respectively. Death losses were also greater for the light groups of lambs (6.7%) than for the heavy group (3.2%).

Digestion and Nitrogen Balance Study

Experiment 5

Supplementation of corn grain diets with the chlortetracycline-sulfamethazine combination resulted in apparent digestion coefficients for dry matter, energy and nitrogen similar to those for the no drug controls when soybean meal was used as the supplemental nitrogen source during both periods (table 9). When urea was fed without the antibacterial supplement, digestion of nutrients was slightly higher than when soybean meal was fed. When urea was used as the nitrogen source in the corn grain diets with the drug combination, apparent digestion coefficients were lower than the no drug controls during period 1 (day 20 to 25), but were fully equal to those of the controls during period 2 (day 31 to 36). While the apparent depressing effect of the drug combination with urea was consistent, it was not statistically significant and was overcome during period 2.

Apparent digestibility values were lower for lambs fed corn silage than those obtained with corn grain, especially when urea was used as the sole supplemental nitrogen source. Antibacterial supplementation depressed apparent digestion of the corn silage diets with either soybean meal or urea. There appeared to be no major difference between nitrogen sources as to this effect of the antibacterials. It was largely overcome by the second collection period and

Table 9. Effects of Dietary Treatments on Apparent Digestion Coefficients and Nitrogen Retention (Experiment 5: March to May, 1971)

Item	No drug controls				Drug combination[a]			
	Corn silage		Corn grain		Corn silage		Corn grain	
	SBM	Urea	SBM	Urea	SBM	Urea	SBM	Urea
No. lambs								
Period 1	3	3	3	3	3	3	3	3
Period 2	3	3	3	3	2	3	3	3
Dry matter digestion, %								
Period 1	73.04	65.03	85.87	88.20	69.45	63.42	86.05	85.63
Period 2	73.41	67.34	88.77	89.97	72.52	65.99	90.26	91.69
Energy digestion, %								
Period 1	73.05	64.27	84.80	87.37	69.11	62.92	84.47	83.90
Period 2	73.30	62.87	87.58	89.36	72.02	65.47	89.56	90.73
Nitrogen digestion, %								
Period 1	74.07	69.75	76.86	78.01	70.39	64.18	76.98	76.06
Period 2	74.83	69.88	80.75	81.97	70.52	70.80	82.59	85.16
Nitrogen retention, % of N intake								
Period 1	20.98	18.45	30.12	18.06	15.26	-26.99	22.74	13.38
Period 2	21.14	27.69	33.54	31.63	27.19	6.74	20.05	23.47
Nitrogen retention, grams/day								
Period 1	3.44	2.55	7.94	4.00	2.85	-4.75	7.02	2.91
Period 2	4.38	4.61	7.91	6.67	6.04	0.65	5.35	6.04

[a] Chlortetracycline-sulfamethazine courtesy American Cyanamid and supplied as Aureo S-700. Each drug was fed at 100 mg daily.

Table 10. Main Effects of Parameters Measured in Metabolism Study

Item	Diet type		Nitrogen source		Antibacterials		Period	
	Corn grain	Corn silage	SBM	Urea	None	CTC-SMZ[a]	First	Second
Apparent dry matter digestion, %	88.31[b]	69.61[c]	80.75[b]	77.16[c]	78.95	78.96	77.09[d]	80.83[e]
Apparent energy digestion, %	87.22[b]	69.15[c]	80.51[d]	75.86[e]	77.82	78.55	76.24[d]	80.14[e]
Apparent nitrogen digestion, %	79.80[d]	71.89[e]	77.22	74.48	75.77	75.93	73.29	78.40
Apparent nitrogen retention, % of nitrogen intake	24.12	15.94	26.01	14.05	25.20	14.86	14.00[d]	26.06[e]
Apparent nitrogen retention, g/day	5.98[d]	2.97[e]	6.11[d]	2.84[e]	5.19	3.76	3.24[d]	5.70[e]

[a] 100 mg each chlortetracycline and sulfamethazine fed daily. Supplied as Aureo S-700, courtesy American Cyanamid.

[b, c, d, e] Means within same line under each main heading having different superscript letters differ significantly; [b, c] ($P<.01$), [d, e] ($P<.05$).

Table 11. Interactions Involving Dry Matter Digestion[a]

Item	Corn grain		Corn silage	
	Soybean meal	Urea	Soybean meal	Urea
Dry matter digestion, %	87.74	88.87	73.77	65.45

[a]Least squares analyses indicate this interaction to be significant, ($P<.05$)

Table 12. Interactions Involving Nitrogen Retention, as a Percent of Nitrogen Intake[a]

Item	No drug control				100 mg each CTC&SMZ daily			
	SBM		Urea		SBM		Urea	
	Corn silage	Corn grain	Corn silage	Corn grain	Corn silage	Corn grain	Corn silage	Corn grain
Nitrogen retention, % of nitrogen intake	21.06	31.83	23.07	24.84	29.76	21.39	-10.13	18.42

[a]Interaction was significant ($P<.05$) as tested by least squares analysis

was not statistically significant.

Supplementation with the drug combination caused no significant independent effects on apparent digestion of dry matter, energy or nitrogen or on nitrogen retention (table 10). Apparent dry matter and energy digestion were higher ($P<.01$) on corn grain diets than on corn silage diets. These parameters were also higher when soybean meal rather than urea was used as the nitrogen source (dry matter, $P<.01$; energy, $P<.05$) and during the second period as compared to the first ($P<.05$). Apparent nitrogen digestibility showed the same trends as for apparent dry matter and energy digestion with digestion being higher ($P<.05$) on corn grain diets as compared to corn silage diets. Apparent dry matter digestion (table 11) on corn grain diets was similar regardless of the nitrogen source used. With corn silage, urea supplemented diets were definitely lower ($P<.05$) in dry matter digestion than soybean meal supplemented diets.

Apparent nitrogen retention during the first collection period was greater for lambs fed corn grain diets supplemented with soybean meal (table 9). This was true whether or not the drug combination was fed, although nitrogen retention with either nitrogen source was lower when the antibacterials were fed. Nitrogen retention was improved for lambs fed the urea supplements during the second period resulting in similar nitrogen retention as with

soybean meal in corn grain diets. However retention was still somewhat less for lambs fed the antibacterials in comparison to the no drug controls.

With corn silage diets, nitrogen retention was similar whether soybean meal or urea was used as the nitrogen source when no drugs were fed. When the antibacterials were also fed, nitrogen retention was greatly depressed on the urea supplemented diets but not with soybean meal. There was a pronounced improvement in nitrogen retention by the second collection period, but still considerably less than for lambs fed urea without the antibacterials. Although apparent nitrogen retention (grams/day) was quite variable (table 10), it was higher in corn grain than corn silage diets ($P<.05$), higher in soybean meal supplemented diets than in urea diets ($P<.01$) and higher in the second period ($P<.05$) as compared to the first. The apparent differences in nitrogen retention between types of diets, nitrogen supplements and antibacterial additions were significant and are shown in table 12.

DISCUSSION

The results of these feedlot and metabolism studies confirm those of a number of previous researchers working in this area. Chlortetracycline when added to diets to provide approximately 70 to 100 mg of drug daily resulted in inconsistent improvements in rate of gain and feed conversion. Chlortetracycline increased weight gain and feed conversion in the two experiments with early-weaned lambs, but not in the adaptation or the finishing studies with the heavier lambs. This is in agreement with data reported by Calhoun and Shelton (1970) and with a review of earlier lamb studies by Ott (1968) where chlortetracycline was used at varying levels under a variety of feedlot conditions. In the majority of feedlot studies cited by Ott (1968) chlortetracycline either did not affect feedlot performance or only slightly increased rate of gain and/or feed efficiency. Also, chlortetracycline tended to be more beneficial when added to high-roughage diets than high-concentrate diets although it caused initial decreases in digestibility of dietary components on diets with 50% or greater roughage levels.

Sulfamethazine also showed inconsistent responses. Increases in weight gain and feed conversion were obtained when fed to early-weaned lambs shipped 480 km prior to the experiment. However, it did not show any benefit when fed

to lambs in the other three experiments. No evidence with lambs is available with which to compare the responses obtained in these studies; however, data reported by Drain et al. (1966) and Perry et al. (1971) where sulfamethazine was fed to feeder cattle showed no responses in weight gain or feed conversion from supplementing this drug.

The combination drug treatment which provided 70 to 100 mg each of chlortetracycline and sulfamethazine daily increased rate of gain and improved feed conversion in all of the feedlot situations tested and reported herein. This is in agreement with data reported by Calhoun and Shelton (1970) and Ternus and Vetter (1970) which also indicated that the chlortetracycline-sulfamethazine combination was an effective treatment in improving feedlot performance of feeder lambs. Similar responses were reported by Drain et al. (1966) and Perry et al. (1971) using this drug combination for feeder cattle. The combination drug treatment appears to be more effective in improving feedlot performance than either chlortetracycline or sulfamethazine alone in all of the feedlot situations tested and reported in these studies.

In the digestion and balance study, lambs fed the antibacterials had lower apparent digestion coefficients for dry matter, energy and nitrogen during the first collection period with both corn grain and corn silage diets when urea served as the supplemental nitrogen source. When soybean

meal was used, only the corn silage diets suffered depressed apparent digestion when feeding the drugs during period 1. Digestion coefficients were similar for both antibacterial supplemented and unsupplemented lambs on corn silage diets and for these same groups on corn grain diets during the second period, indicating that adaptation to the drugs was essentially completed by the end of the second period - 36 days after the experiment was started.

Apparent nitrogen retention was also depressed during period 1 when the antibacterials were fed. The depression was especially severe on the urea-supplemented corn silage diets where a negative nitrogen balance resulted during the first period with the drug combination. Nitrogen retention was still lower on this treatment during the second collection period but considerable improvement had resulted over the first period. On all other treatments, the antibacterial supplemented lambs showed nitrogen retentions similar to the unsupplemented controls during the second period. These data indicate that antibacterials decrease nitrogen utilization on high-roughage diets where urea is used at high levels as the main source of supplemental nitrogen.

SUMMARY

Four feedlot studies and one metabolism study were conducted using feedlot lambs to determine the effects of supplementing chlortetracycline, sulfamethazine or the combination of both at 55 mg/kg diet or 100 mg daily on feedlot performance and diet digestibility under varying conditions.

Native lambs were used in two experiments with shipping stress being a factor in one of the experiments. Texas feeder lambs were used in an adaptation experiment and Montana feeder lambs were used in a finishing experiment.

Chlortetracycline supplementation tended to increase weight gains in all experiments although the improvement was not significant in any of the experiments. The greatest responses were in the first two experiments with early-weaned lambs where supplementation resulted in 5.4% and 5.6% increases in weight gains and 6.7% and 7.8% improvements in feed conversion for shipped and unshipped lambs respectively.

Sulfamethazine additions significantly increased weight gains 15% and improved feed conversion 9.5% in the first experiment with early-weaned lambs shipped prior to the experiment. With the early-weaned lambs fed at the location where raised, sulfamethazine supplementation effected a 3.8% increase in weight gain and a 4.7% improvement

in feed conversion.

Supplementation with the combination of chlortetracycline and sulfamethazine effected the greatest increases in weight gains and improvements in feed conversion in all four experiments. This treatment resulted in a 17.0% increase in weight gain, an 8.9% improvement in feed conversion and a 6.6% increase in feed consumption in the study with the early-weaned lambs shipped 480 km before feeding. With early-weaned lambs fed at the same location as raised, a 7.8% increase in weight gain with an 8.3% improvement in feed conversion was obtained. This treatment also resulted in an 11.2% increase in weight gains with a 10% improvement in feed conversion in a feedlot adaptation study with Texas feeder lambs. In the finishing study also involving types of protein supplements, weight gain was 7.2% higher with a 3.4% improvement in feed conversion when feeding the drug combination.

A digestion and nitrogen balance study involving corn grain and corn silage diets with soybean meal or urea as nitrogen sources was conducted with and without the drug combination fed at 100 mg daily. Similar apparent digestibility values were obtained with soybean meal or urea supplements with corn grain diets while digestibility was lower on corn silage diets when urea was used rather than soybean meal. When the antibacterials were added, apparent digestion values were decreased during period 1 on corn

grain diets with urea and on corn silage with either urea or soybean meal. The depressing effects of the drug supplements were largely overcome during the second collection period as evidenced by similar digestion coefficients for lambs fed and those not fed the drugs. Based on the results of this metabolism study, after adaptation the drug combination does not appear to significantly affect apparent digestion of dry matter, energy or nitrogen. The combination of high levels of antibacterials and high levels of urea would be contraindicated during early stages of feedlot adaptation. The need for adequate protein intake during critical stages of adaptation, and the apparent benefit from antibacterial supplements would support the use of antibacterial compounds with preformed protein during this stage.

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