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TO BEEF HEIFERS.

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DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

James Keith Davis, B.S., M.S.

* * * * * *

The Ohio State University
1970

Approved by

[Signature]

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INTRODUCTION

One of the greatest challenges confronting animal husbandry today is to increase the efficiency of animal protein production. Irrespective of advances in breeding, feeding and management for meat producing animals, the animal scientist is faced with the task of supplying a vastly expanding need for highly nutritious, lean meat as efficiently as the producers of vegetative food nutrients. It is difficult to accurately predict food consumption trends because of rapidly changing eating habits which are highly influenced by the economic conditions present in a society. However, projection of recent data (Swift and Co. 1968; U.S. Dept. of Agriculture, 1968a) indicates that by 1980 the per capita consumption of beef in the United States will be approximately 118 lb. When converting this amount to a live weight basis, the projection approaches 200 lb. which indicates that under these conditions an average market bovine will produce enough beef for only about five persons. Considering the present beef per capita consumption of approximately 106 lb., 40% more beef will be needed
by 1980 to offset the population increases, assuming the per capita consumption remains at its present level. However, when applying the projected per capita consumption rate of 118 lb., an approximate increase of 59% in beef production will be needed by 1980 to meet the demands of the consumer. In spite of advanced technology in animal production, it is increasingly more difficult for beef producers to meet the demands of the consumer and to cope with rising costs of production. Therefore, it becomes quite evident that methods of increasing productivity of the beef animal are needed. In addition, the increased removal of productive land from agriculture points out the needs for developing methods and techniques for increasing the ability of the bovine to convert feedstuffs into high yielding, high quality beef.

The growth rate of an animal is influenced by its genetic potential for growth and the environmental, nutritional, climatic and managerial conditions to which it is exposed. Increased growth of a beef animal is often described as an increase in body weight or body size without consideration of efficiency of the increase or the relative change in proportion of tissues in the animal's body. Growth has been defined as a correlative increase in body mass (Schloss, 1911). Brody (1964) has defined growth
as a biologic synthesis producing new biochemical units
as a result of cell division (which increases cell numbers)
and an increase in cell size. From a food production view-
point, the three tissues of the body which are of impor-
tance are muscle, fat and bone. The proportionate increase
in mass of these three tissues has become increasingly more
important because of the need to produce animals with a
maximum of edible lean meat and a minimum of fat and waste.
During growth, the utilization sequence of dietary nutri-
ents indicates that after nervous tissue develops, bone,
muscle and fat develop successively. Therefore, it appears
to be of sufficient importance that methods and techniques
be developed to more efficiently utilize dietary nutrients
for more rapid development of nervous, bone and muscle
tissues while minimizing the deposition of fat tissues
during the growth process which ultimately result in an
increase in the ratio of muscle to fat in the animal.

From a metabolic viewpoint, the ruminant and non-
ruminant animals possess two major differences in utili-
ization of feedstuffs (Johnson, 1966). The ruminant ani-
mal has the capacity to utilize energy in the form of
short-chain volatile fatty acids. Non-ruminant animals
possess an adaptive enzyme system to facilitate diges-
tion, whereas the ruminant animal maintains a large
microbial population in the gastrointestinal tract.
Moody (1969) and Armstrong and Blater (1957) have indicated that the ratio of acetic to propionic acids produced by microbial action is important in the degree of fat deposition in the animal body. Roughages, particularly silages (Putman, Yarns and Davis, 1966; Moody, 1969; Mitchell et al., 1969; Oltjen and Davis, 1965; Weiss et al., 1967; Church, 1969) when fed as a major constituent of the diet, usually result in high acetic acid concentrations.

The soluble digestive products are metabolized in the liver where preparation for utilization as body nutrients takes place. The liver receives blood which contains the absorbed nutrients from the intestines via the hepatic portal system and delivers it into the vena cava via the hepatic vein (Bloom and Fawcett, 1962). Because of the strategic anatomical location of the liver relative to the circulatory system all nutrients absorbed from the gastrointestinal tract must pass through this organ except for some lipids that are absorbed and transported to the circulatory system via the lymphatic system. The physical integrity of liver tissue is therefore an important factor in maximum utilization of feedstuffs. It has been shown that cattle with abscessed livers perform less efficiently and grow more slowly than cattle with healthy livers (Garrigus et al., 1957; Wise et al., 1968).
Certain antibiotics have been shown to reduce the incidence and severity of liver abscesses (Dinusson et al., 1964; Haskins et al., 1967; Powell, Durham and Gann 1968; Blam, 1969) and to combat low-grade, subclinical infections in sheep, cattle, swine and poultry (Hays, 1969; Bird, 1969; Whitehair and Pomeroy, 1969). In addition, the use of antibiotics in feeds has altered the rumen microbial activity (Purser, Klopfenstein and Cline, 1965) and effected the rate and efficiency of growth (Hays, 1969; Kolari et al., 1960; Perry et al., 1958; Teague, Griffo and Rutledge, 1966).

Trends toward selection of cattle which produce leaner beef carcasses and more efficient feedlot growth have focused considerable attention on antibiotics and feed additives which result in improved growth rate with less expenditure of feedstuffs. Therefore, these studies were undertaken to determine the efficiency of the antibiotic, lincomycin, on the rate and efficiency of growth when fed separately and in combination with diethylstilbestrol in high roughage, low-energy diets. The studies were designed to investigate the effect of lincomycin on the incidence of liver abscesses, liver tissue structure, rumen pH and qualitative and quantitative carcass characteristics of beef heifers.
A vast amount of literature has accumulated regarding the efficacy of antibiotics in livestock feeding programs. Within the past 15 years, the acceptance of the use of antibiotic supplementation in animal feed has become widespread. The adoption of the use of antibiotics in feeds has resulted from the establishment of beneficial responses for growth rate and feed utilization and for curbing low-grade, sub-clinical infections. It has been stated that in excess of 2.7 million lb. of antibiotics are used annually in livestock feeds in the United States alone (Hays, 1969).

The most common antibiotics for ruminants which have been shown to be efficacious are chlortetracycline, oxytetracycline and bacitracin. In addition, oleandomycin, penicillin, streptomycin and tylosin have shown various degrees of response in swine. However, chlortetracycline and oxytetracycline have shown the most promising results for improving performance in cattle.

By definition, antibiotic means "against life". This
term is readily misinterpreted because many antibiotics are fed to livestock for their therapeutic values, their ability to control liver abscesses, their growth promoting properties and in most cases their ability to improve the utilization of feedstuffs. Maynard and Loosli (1969) have described antibiotics as a compound synthesized by a living organism which inhibits the growth of other micro-organisms (bacteriostatic) or actually destroys other micro-organisms (bactericidal). According to Maynard and Loosli (1969) antibiotics were recognized as growth promotants in poultry and swine as early as 1949. Much of the early work reported came about from studies with vitamin B\textsubscript{12}. The crude sources of fermented by-products used for vitamin B\textsubscript{12} studies contained an "animal protein factor" which resulted in an increased growth rate (Stokstad and Jukes, 1950; Stokstad et al., 1949).

The mode of action of growth promoting antibiotics is not well understood but several workers have postulated theories regarding their activity. There are three possible ways in which antibiotics may exert their effects on animals and all three involve the intestinal microflora (Jukes and Williams, 1953; Jukes, 1955; Hays, 1969; Maynard and Loosli, 1969). Hays (1969) has described the "metabolic", "nutrient-sparing" and "disease-controlling"
effects of antibiotics. The bactericidal or bacteriostatic properties of antibiotics may affect the metabolic rate by altering the number and/or activity of microorganisms that synthesize growth factors.

There is evidence accumulating that suggests antibiotics may have a sparing effect on proteins and may actually replace part of the requirements for some essential amino acids (Maynard and Loosli, 1969). The protein-sparing effect is supported by the fact that bacitracin, chlortetracycline, erythromycin, oxytetracycline and streptomycin have their site of action at the ribosomes which suggests an effect upon protein synthesis (Gottlieb and Shaw, 1967a). In addition, bacitracin and penicillin are associated with cell wall synthesis; bacitracin and streptomycin are associated with membrane function; and streptomycin functions in RNA synthesis (Gottlieb and Shaw, 1967a).

Hays (1969) summarized disease controlling effects of antibiotics by concluding that their presence in feeds tends to suppress subclinical and nonspecific diseases. Hill, Branion and Slinger (1952) and Coates et al. (1951) have shown that the growth promotion effects of antibiotics in healthy chicks are negligible.

Brown, Warren and Ruffin (1969) have shown that
chlortetracycline and copper additions to rations improved daily gain and feed efficiency of growing swine, although the carcasses were not significantly different when evaluated for leanness. Teague et al. (1966) reported a 13-year study in which chlortetracycline significantly increased the daily gain of swine from weaning to 120 lb. only. They also found that when the daily gain began to decline in the latter stages of growth, antibiotic supplementation increased the feed efficiency, even though growth rate decreased. Feeding chlortetracycline at 0.5 gm. and 1.0 gm. daily to sows, Messersmith et al. (1966) showed significant increase in farrowing rates. Bunch et al. (1963) studied the growth response in swine when administering chlortetracycline, copper oxide and copper sulfate. They found that each of the additives significantly improved daily gain and feed efficiency when fed to 200 lb. and when fed to 125 lb. and withdrawn thereafter, with the exception of copper sulfate in the latter case.

Harris et al. (1963) compared the use of fluorine, diethylstilbestrol and oxytetracycline for fattening lambs and reported that oxytetracycline at the levels of 10 and 20 gm./ton did not have any significant effects on growth or feed utilization when compared to diethylstilbestrol and fluorine. Heinemann and Fanelli (1963)
studied the effects of diethylstilbestrol, chlortetracycline and penicillin alone and in all possible combinations on steers fed alfalfa soilage. More rapid gains and greater feed utilization were observed in every case studied and they also reported that penicillin had a significant effect in preventing bloat. Packett and Butcher (1963) showed that dietary oxytetracycline significantly increased daily gain in fattening lambs, but not as greatly as sodium citrate. Work reported by Butcher and Raleigh (1962) showed an improvement in feed utilization and daily gain in lambs fed oxytetracycline. However, Costain and Lloyd (1962) reported an inverse relationship between dietary calcium and level of serum oxytetracycline was not accompanied by an increase in gain.

Perry et al. (1954) reported that administration of chlortetracycline to suckling calves at the level of 24 mg./cwt. decreased scours and gave an apparent growth stimulation. Yearling steers given 75 mg. chlortetracycline/head daily gained significantly more than non-treated controls and required 18% less feed/unit gain. When feed intake was limited, chlortetracycline had no effect on growth rate or feed efficiency. A depression of appetite was observed for the first four days after introducing chlortetracycline in the diet. When chlortetracycline was fed in combination with diethylstil-
bestrol, there was a 5.4% increase in gain over diethylstilbestrol alone (Perry et al. 1958). When 80 mg. chlortetracycline/head daily was fed, a higher carcass grade resulted.

Beeson et al. (1957) indicates that when diethylstilbestrol was fed alone and in combination with chlortetracycline to cattle the carcasses contained less fat and more protein and water than when chlortetracycline was fed alone. The feed efficiency was 1.6 times as great when chlortetracycline was fed with diethylstilbestrol.

Working with young, immature dairy heifers, Loosli and Wallace (1950), Jacobson, Kaffetzakis and Murley (1951), Knodt, Ross and Stein (1953), McKay, Riddell and Fitzsimmons (1952), Voelker and Cason (1951) and Rusoff and Davis (1951) have shown an increase in weight gains when chlortetracycline was administered. Bridges et al. (1953), Jordan (1952) and Colby, Rau and Miller (1950) fed chlortetracycline to lambs and reported a depression of growth, however other studies have shown positive weight-gain responses from chlortetracycline in lambs (Luther et al., 1954a; Murphree et al., 1954; Bell, Smith and Erhart, 1954).

Dyer, Ensminger and Blue (1957) demonstrated that the inclusion of chlortetracycline alone or in combination with
diethylstilbestrol could significantly increase the rate of gain in steers. The vitamin A storage in the liver was significantly increased by oxytetracycline. Kesler (1954) reported that Holstein calves fed oxytetracycline gained weight appreciably more rapidly than did the controls during the first eight weeks of the trial. However, the feeding of oxytetracycline after the first eight weeks did not significantly improve the gains when compared to non-treated controls. Oxytetracycline-treated calves also gained more rapidly in structural growth as measured by the height of the withers. With oxytetracycline in the diet, there was a reduction of in vitro cellulose digestion.

Pritchard, Riddell and Durrell (1955) studied the effect of oxytetracycline on the growth of dairy calves. Their work indicated that oxytetracycline was effective in reducing or eliminating antibiotic-susceptible pathogenic organisms that were thought to cause scours. Oxytetracycline did not result in a significant increase in gain when administered at 15 mg. or 60 mg. per hundred lb. body weight. Lassiter, Denton and Rust (1955) pointed out that crystalline oxytetracycline did not significantly affect the average daily gain, skeletal growth, feed consumption or feed efficiency when fed to young dairy calves. In agreement with Pritchard et al. (1955), it was found that oxytetracycline did exert a preventive influence on the incidence of scours.
Hanson and Ferrin (1956) have shown that oxytetracycline and bacitracin were effective for improving the rate of growth and feed efficiency in swine. Other workers have reported similar results in swine (Terrill et al., 1952; Lehrer et al., 1953; Lasley et al., 1953). These workers generally agree that oxytetracycline and bacitracin are effective in reducing the incidence of scours in swine. Tomlin, Wallace and Combs (1958) reported that the feed consumption of pigs was reduced when oxytetracycline was fed as compared to chlortetracycline. Pigs completely avoided feed containing erythromycin.

Sherman et al., (1959) reported that oxytetracycline significantly increased daily gain with or without diethylstilbestrol and did not affect the carcass quality. Agreeing were Hubbert et al. (1959) who reported that oxytetracycline resulted in a consistent weight gain advantage over controls although the difference was not significant. Hale et al. (1959) reported that oxytetracycline increased rate of gain in lambs by 13%, but had no effect on the carcass grade. Bradley, Parsons and Garrigus (1960) observed a significant increase in daily gain when oxytetracycline was fed with and without diethylstilbestrol implants to grazing steers.

Tetracycline, an antibiotic produced by the reduction of chlortetracycline and oxytetracycline, failed to improve
the rate of growth in swine when compared to chlortetracycline. However, it did improve feed efficiency (Horvath and VanderNoot, 1954). The optimum level of tetracycline for swine was found to be 15 gm./ton of feed.

Moenomycin, a new antibiotic developed solely for use in animal nutrition, has shown effectiveness against gram-positive bacteria (Waldroup, 1970 a,b). The antibiotic is also effective against some gram-negative bacteria including Pasteurella, Brucella and Listeria. The mode of action of moenomycin is thought to be an inhibition of biosynthesis of the bacterial cell wall. Moenomycin shows promise of increasing gains and feed efficiency of steers.

The use of antibiotics in poultry rations is a common practice. They are used as feed additives or added to the drinking water for the prevention and treatment of bacterial diseases (Siegmund, 1967). Bacitracin and erythromycin are less effective for growth promotion in poultry. This is largely due to the fact that a great deal of the activity is destroyed in the gastrointestinal tract by either enzymes or acids. With poultry, cattle, sheep and swine, antibiotics are used at therapeutic levels to prevent and treat conditions produced by stress, shock or adverse environmental conditions.

It seems possible that antibiotics may act through their influence on microbial population in the gastro-
intestinal tract (Mitchell et al. 1969). Antibiotics have generally been effective when fed with a high roughage diet and it may be due to the alteration in activity of the rumen microflora. Bacitracin was shown to significantly reduce the total volatile fatty acid concentration. Chlortetracycline reduced the total volatile fatty acid concentration, but not significantly. Neomycin and tylosin did not affect the fatty acid concentration. The antibiotic treatment did not affect the acetic:propionic acid ratio in the rumen.

Klopfenstein, Purser and Tyznik (1964) demonstrated a significant increase of in vitro rumen protozoal concentration as a result of chlortetracycline treatment. There was a significant increase of in vitro gas production after 1 hr. of fermentation when chlortetracycline was added. Purser et al. (1965) found a significant increase in protozoal concentration following tylosin and chlortetracycline administration while there was a marked decrease in bacteria count due to tylosin. It was suggested that the reduction of bacteria could be due to the inhibitory effect of the antibiotic or the reduction or absence of essential metabolites for a particular bacterial species as a result of tylosin treatment.

Purser and Moir (1966) pointed out that the pH variations in the rumen reflect the degree of microbial activi-
ty. Uhart and Carroll (1967) have shown that lactic acidosis was produced when steers were rapidly changed from a roughage diet to one containing 90.0% grain. It was suggested that the lactic acidosis may be a result of alteration of microbial activity and caused the cattle to go “off feed”. The initial pH of the rumen contents was 6.98. The cattle stopped eating when the pH reached 4.81 and resumed eating when the pH returned to 6.78.

Erwin, Dyer and Ensminger (1955) demonstrated that chlortetracycline significantly increased digestibility of ether extract. Kesler and Knodt (1952) observed a decrease in cellulose digestion in calves when oxytetracycline was fed. Chance et al. (1953) reported a distinct increase in bacteria count of the rumen content and feces when chlortetracycline was included in the diet. Horn, Snapp and Gall (1953) found that rumen contents containing chlortetracycline showed a decreased ability to digest fiber. Similar results were observed by Radisson et al. (1953). Calves receiving chlortetracycline had greater rumen development and a lower acid concentration in the rumen contents than non-treated controls (Mann, Masson and Oxford, 1954). The rumen reached optimum pH for bacterial and protozoal action much earlier in chlortetracycline-treated calves. Perry, Beeson and Hornback (1953) suggested that the effects of chlortetracycline depend on the stage of rumen development and type of ration fed.
At least two organisms have been reported as the causative agents of liver abscesses. Corynebacterium pyogenes was isolated from abscessed cattle livers by Pellegri (1939) and Sphaerophorus necrophorus was found to be the most predominant organism in abscessed cattle livers (Newson, 1938; Madin, 1949). The predominance of the latter organisms was confirmed by North Carolina workers (Wise et al., 1968) who suggested that S. necrophorus and C. pyogenes are probably present on the skin and mucous membranes and are presumably present in the rumen and stomach of both healthy and diseased animals. However, these organisms have practically no penetrating ability in normal, healthy mucous membranes.

Jensen, Flint and Grinar (1954) have postulated that these organisms may gain entry into the hepatic portal system through inflamed ruminal epithelium. Once they gain entry, they are transported to the liver via the portal system where they become highly pathogenic and induce necrosis resulting in abscessed livers. Rumen parakeratosis may be the inflammatory factor which allows penetration (Wise et al., 1968). Harvey et al. (1968) support these findings and suggested that liver abscesses are formed secondarily to rumen lesions as a result of the entry into the portal system by bacteria from the rumen. Smith (1944) examined 1807 cattle of
which 17.8% had liver abscesses. Of those with abscesses, 62.0% also had ruminal lesions. Of 1485 cattle without abscessed livers, only 18.0% had ruminal lesions. Jensen, Flint and Griner (1954) have also shown a significant relationship between liver abscesses and ruminal lesions.

These findings have been substantiated more recently by Elam (1969) who pointed out the rumenitis-liver abscess syndrome is due to some type of damage to the epithelium of the rumen which permits bacteria which are normally present in the rumen to penetrate the ruminal wall and enter the portal system. Inflammation of the ruminal epithelium is the primary stage of the rumenitis-liver condition and the abscessed liver is a secondary stage. Epithelial damage may be due to physical injury, viral damage, toxic materials, an irritation caused by the feed, a rapid change in energy level of the diet or excessive intake of high energy feeds.

It appears that high concentrate-type rations and rations with oyster shells are conducive to producing liver abscesses in ruminants (Wise et al., 1968; Karr et al., 1968; Larson Embry and Luther, 1968). Wise et al. (1968) have extensively reviewed the effects of high concentrate feeding on cattle and have concluded that there is a high degree of association among high energy rations, rumen lesions and liver abscesses. The high
incidence of liver abscesses in cattle with rumen lesions may be due to an alteration of the concentration of metabolites resulting from the breakdown of feedstuffs in the rumen.

Abscessed livers not only result in the loss of the liver proper at slaughter, but also lowers the performance of feedlot cattle (Powell, Durham and Gann, 1968). Steers and heifers without liver abscesses had higher average gains, marbling scores, dressing percent and calculated carcass weight gain. Garrigus et al. (1967) reported an approximate 11% difference in daily gain between cattle with healthy livers and those with abscessed livers. Wise et al. (1968) substantiated these reports and showed a highly significant difference in daily gain of cattle with abscessed livers and those without.

There have been conflicting reports on the use of non-protein nitrogen and the incidence of liver abscesses. Wise et al. (1962) demonstrated that 83% of a small group of steers fed a corn-urea base diet had liver abscesses. However, Wise, Blumer and Barrick (1963) produced liver abscesses in 60% of the steers fed a corn-soybean base diet. Reporting results of all-concentrate diets with urea and soybean meal as protein sources, Oltjen and Davis (1965) indicated that 29% of the cattle fed urea as the only source of protein had liver abscesses and nearly
50% of those had been treated with diethylstilbestrol. Haskins et al. (1967) indicated, however, that neither the level nor source of protein had any bearing on the incidence or severity of liver abscesses.

The use of antibiotics, particularly chlortetracycline, has been fairly conclusively shown to reduce the incidence of liver abscesses in cattle. Harvey et al. (1968) have shown that on all-concentrate rations, 33.3% of all cattle without chlortetracycline had some degree of liver damage due to abscesses. However, when 75 to 85 mg. chlortetracycline/head daily were fed, only 3.0% of the cattle had abscessed livers. Similar responses have been shown by others (Bohman, Wade and Hunter, 1957; Bolsen et al., 1968). Dinusson et al. (1964) have demonstrated the effectiveness of zinc bacitracin for controlling liver abscesses in cattle.

Hepatic necrosis in rats has been prevented by the addition of chlortetracycline in the diet (Jukes, 1955). The mechanism of action of antibiotics for controlling liver necrosis is thought to be an inhibition of toxin-producing bacteria in the lower intestine for necrosis of the left lobe in rats and in the small intestine for necrosis of the right lobe because of the anatomical structure of the portal blood system.

Gyorgy et al. (1951) found chlortetracycline to be
most effective for controlling liver abscesses followed
in order by oxytetracycline, streptomycin and sulfa-
guanidine. Chloramphenicol, polymyxin and penicillin were
ineffective in preventing liver necrosis.

Lincomycin:

In 1962, a group of researchers published a series of
articles on a new antibiotic, lincomycin, in which they
reported it to be uniquely different than the other anti-
biotics possessing antimicrobial activity against gram-
positive organisms (Mason, Dietz and deBoer, 1962; Clapp and
Lincomycin was discovered in fermentation broth of Strepto-
myces lincolnensis var. lincolnensis sp. n. The organisms
which produce lincomycin were originally found in soil
samples taken from the vicinity of Lincoln, Nebraska but
is present in soils in many other locations (Herrell, 1969).

Hoeksema et al. (1964) have described the structure of
lincomycin as containing trans-1-methyl-4-propyl-L-proline
(referred to as propylhygric acid or FHA) and methyl 6-amino-
6, 8-dideoxy-1-thio-D-erythro-α-D-galacto-octopyranoside
(referred to as methylα-thiolincosaminide or MTL). The
following is the structure:
Several analogues of lincomycin have been described by Bble (1967). Lincomycin B (U-21699) has $-\text{CH}_2\text{CH}_3$ replacing $-\text{CH}_2\text{CH}_2\text{CH}_3$ in the PHA moiety of lincomycin. The S-ethyl analogue (U-11.921) has $-\text{S-C}_2\text{H}_5$ in place of $-\text{S-CH}_3$ in the MTL moiety. The N-demethyl analogue (U-11.973) has $-\text{H}$ instead of $-\text{CH}_3$ in the PHA moiety. The fourth analogue (U-20-943) is a combination of the S-ethyl analogue and the N-demethyl analogue. This analogue contains the PHA moiety of N-demethyl and the MTL moiety of the S-ethyl analogue. Magerlein, Birkemeyer and Kagan (1966) reported the isolation of N-ethyl analogue of lincomycin. It appears that S. lincolnensis var. lincolnesia is capable of producing several lincomycin-like compounds. However, Herrell (1969) indicates that none of the analogues are as effective for treating infectious diseases as is lincomycin.

Since Mason, Diets and deBoer (1962) reported its discovery, lincomycin has been the subject of intensive investigations in efforts to define its mode of action. However, in comparison to other antibiotics used to improve growth
performance in animals, there are relatively few reports on lincomycin in the literature. Josten and Allen (1964) are credited with reporting the first information regarding the mechanism of action of lincomycin. Using S. aureus, these workers demonstrated that lincomycin interfered with protein synthesis and that synthesis of DNA was inhibited. The inhibition did not occur immediately, but approximately 15 minutes after the administration of lincomycin. The synthesis of RNA was not affected by lincomycin. Supporting the work of Josten and Allen (1964), Chang, Sih and Weisblum (1966) found that the site of action of lincomycin was the 50S subunit of the ribosomes. Lincomycin inhibited the binding of phenylalanine-sRNA to the messenger ribosome. They also found that the inhibition of protein synthesis was greater in Bacillus stearothermophilus than E. coli. The site of action of lincomycin at the 50S subunit of the ribosomes was confirmed by Vasquez (1966a,b), Monro and Vazquez (1967) and Apirion (1967).

Chang and Weisblum (1967) and Apirion (1967) have reported antagonistic effects between erythromycin and lincomycin for protein synthesis. It was concluded that the antagonism was due to competition for the same binding site on the ribosomes. The combined inhibitory effect of lincomycin and chlortetracycline on protein synthesis is additive because the site of action for lincomycin is the 50S
subunit and the site of action for chlortetracycline is the 3OS subunit (Chang and Weisblum, 1967).

It appears that the metabolism of lincomycin occurs in renal and hepatic cells. In patients with severe renal insufficiency, Reinars and McIntosh (1965) reported that peak concentrations, half-life and pharmacologic time-concentration of lincomycin were increased when compared to patients with normal renal function. Bellamy, Bates and Reinars (1966) concluded that the metabolism of lincomycin was severely affected by liver dysfunction. The type or severity of liver disease had no effect on the reduced metabolism of lincomycin in the hepatic cells.

Lewis, Clapp and Gray (1962) described the antimicrobial activity of lincomycin as follows: (1) gram-positive bacteria are more sensitive than gram-negative bacteria to lincomycin in vitro and in vivo. (2) the gram-positive organisms sensitive to lincomycin are *Staphylococcus aureus*, *Diplococcus pneumoniae*, *α-Streptococcus*, *β-Streptococcus*, *Streptococcus faecalis* and *Clostridium*. (3) gram-negative organisms with sensitivity to lincomycin are *Coli-Aerogenes*, *Proteus*, *Pseudomonas* and *Salmonella*, and (4) lincomycin is not cross-resistant with penicillin, streptomycin, tetracycline, chloramphenicol, erythromycin or neomycin.

An extensive review of the literature regarding the therapeutic effects of lincomycin has been made by Herrell
(1969), Holloway (1969) and Donohoe (1969). Herrell (1969) concluded that most skin and soft tissue infections resulting from gram-positive organisms can be effectively controlled by lincomycin. Holloway (1969) has indicated that lincomycin showed certain degrees of effectiveness for treatment of bacterial infections of the cardio-vascular and skeletal systems. Donohoe (1969) described the value of lincomycin for treating certain respiratory infections including diphtheria, tonsillitus, and pneumonia. Also, lincomycin has been used for treating urogenital, odontogenic and ophthalmic infections as well as infections of the central nervous system.

Very few reports are found in the literature regarding the use of lincomycin in treatment of infections in large animals. However, Peardon et al. (1965) and Arakawa, Mohls and Todd (1967) have reported that lincomycin is very effective for treatment of bovine coccidiosis.

Lincomycin may have some effect on the intestinal microflora in rabbits (Gray and Lewis, 1966). Post-mortem examination of rabbits which died after oral administration to 150 mg. and intravenous injections of 0.5 mg./2.2 lb. body weight of lincomycin indicated that only gram-negative organisms were present in the intestinal contents which normally contain predominantly gram-positive organisms. Profuse diarrhea and death occurred on the fourth to
seventh day after treatment. Necropsy indicated a static condition of the cecum and stomach.

Although lincomycin has been used extensively as a therapeutic agent in human medicine, only a minute amount of information regarding the efficacy of lincomycin on growth performance of animals has been published. Neff, Barbiers and Northam (1967) suggested that the antibiotic may have growth promoting properties for chickens, turkeys, cattle and swine, and according to Herrell (1969) a paper was published by Reyntens and Keppens (1966) who indicated that lincomycin increased the fattening rate of cocks.

Stob et al. (1968) reported incomplete data from a factorial experiment using diethylstilbestrol, melengestrol acetate and lincomycin treatments for fattening heifers. When analyzed for the effects of lincomycin only, without consideration of the various combination of lincomycin with diethylstilbestrol and melengestrol acetate, the antibiotic showed a depressing effect on performance. Regardless of the combination and interaction effects, 45 mg. of lincomycin fed orally/head daily decreased daily gains by 5.0% (P < .05), reduced feed efficiency by 1.0% and feed consumption by 4.0%, but slightly improved the carcass quality. However, when fed in combination with diethylstilbestrol, lincomycin resulted in a significant increase (P < .05) in daily gain, 7.0% increase in feed efficiency
and 4.0% increase in feed consumption. When fed with melengestrol acetate, lincomycin increased daily gain 13.0% (P < .05), while melengestrol acetate alone increased daily gain 16.0% (P < .01). Feed efficiency for melengestrol acetate and lincomycin-melengestrol acetate combination was identical, but the combination resulted in 3.0% reduction in daily feed intake. When compared to diethylstilbestrol, lincomycin-melengestrol acetate combination did not increase daily gain, but improved feed efficiency 3.0%.

In an experiment designed to investigate the stability of lincomycin and its growth promoting effects in liquid supplements, Stob et al. (1969) reported incomplete data, but indicated that the addition of the antibiotic resulted in slower gains which were not improved by the addition of melengestrol acetate. Lincomycin combined with sulfamethazine also resulted in a reduction of daily gain. The lincomycin was dissolved in water and added to a liquid supplement containing 29.0% urea (32% N) at the rate of 45 mg./lb. supplement.

**Diethylstilbestrol**

Numerous reports are found in the literature regarding the efficacy of diethylstilbestrol on growth performance of animals. Work has been reported on the use of
diethylstilbestrol for cattle, sheep, swine and poultry and the general consensus is that the results are fairly consistent within a species regardless of ration. Even though much of the data has been published in field day reports, Extension circulars and Experiment Station bulletins, there are ample data in scientific publications to suggest that the administration of diethylstilbestrol increases rate and efficiency of growth in animals.

In a review of the effects of diethylstilbestrol on growth rate, Casida et al. (1959) concluded that there was a marked species difference in the response to the hormone and that the nature of the diet influenced the responsiveness within species.

Work reported by Andrews, Beeson and Johnson (1950, 1954), Clegg and Cole (1954), O'Mary and Gullison (1956) and O'Mary et al. (1956) has indicated that a consistent increase in feed efficiency and growth rate was obtained with subcutaneous implants of diethylstilbestrol in steers. Andrews, Beeson and Johnson (1954) reported that subcutaneous implants of 60, 80 and 120 mg. of diethylstilbestrol resulted in a significant increase in daily gain. Feed efficiency was significantly improved at the 80 and 120 mg. levels, but the 60 mg. level did not significantly affect feed/unit gain. The diethylstilbestrol treatment had no effect on dressing percentage but decreased the carcass
grade. Luther et al. (1954 a,b) demonstrated a 35% improvement in daily gain when 10 mg. diethylstilbestrol were administered orally. However, implants of 50 mg. diethylstilbestrol showed a 42% improvement in gain.

Reporting the results of 16 field trials, Clegg and Carroll (1957) concluded that subcutaneous implants of 15 mg. diethylstilbestrol produced the same results as 10 mg./head daily administered orally in rate of gain, feed efficiency and carcass grade. However, when 60 mg. diethylstilbestrol were implanted, there were significant increases in growth rate and feed efficiency, but the carcass grade was lowered. This work agrees with that of Andrews, Beeson and Johnson (1954).

Clegg and Cole (1954) and Dinusson, Andrews and Beeson (1950) reported significant increases in growth rate of heifers when diethylstilbestrol was implanted. However, it appears that the response of diethylstilbestrol in heifers is not as great as in steers. Working with bulls, Klosterman et al. (1955b) demonstrated a daily gain increase of 0.20 lb. over non-treated bulls and 0.62 lb. more than non-treated steers when 80 and 132 mg. diethylstilbestrol were implanted. Klosterman, Cahill and McClure (1969) pointed out that oral diethylstilbestrol plus Synovex-H implants improved the growth rate and feed efficiency of heifers.
Because of early observations of undesirable side effects at high levels of implanted diethylstilbestrol, most workers have suggested that pellets containing 24 mg. of the hormone appear to be most effective for improving gain and feed efficiency without impairing the carcass acceptability or developing undesirable side effects (O'Mary et al., 1956; Andrews, Beeson and Johnson, 1950, 1954; Clegg and Cole, 1954; Clegg and Carroll, 1956, 1957; Luther et al., 1954b; Casida et al., 1959).

Burroughs et al. (1954) demonstrated that diethylstilbestrol administered orally as a feed additive could significantly improve daily gain and feed efficiency in cattle. This report prompted others to work with the more simplified oral administration. Perry et al. (1955), Burroughs et al. (1955), Beeson et al. (1955) and Andrews et al. (1956) reported the use of oral administration of diethylstilbestrol. It was the general consensus of these workers that 10 mg. diethylstilbestrol/head daily significantly improved the growth rate and feed efficiency of feedlot cattle without producing objectionable side effects or drug residues in the tissues. This level was subsequently approved for use in cattle feeds (Tokheim, 1970).

Although most of the literature reports data on cattle fed in groups, the efficacy of diethylstilbestrol on feed efficiency has been conclusively shown to be favorable.
However, since many of these reports are for group feeding trials, the true feed utilization is difficult to appraise. Casida et al. (1959) reported that the feed utilization/unit gain is related to its energy content. Cattle treated with diethylstilbestrol usually consume 10 to 15% less feed/unit gain than non-treated cattle. It appears that the effect of diethylstilbestrol is positively correlated with the energy content of the ration. Clegg and Cole (1954) reported that steers implanted with diethylstilbestrol consumed 2.5 lb. TDN/lb. gain less than non-treated steers.

Mitchell et al. (1955) reported feed efficiency studies with diethylstilbestrol-treated cattle. When weight was controlled and the live weight was the same for treated and non-treated steers, diethylstilbestrol-treated steers consumed only 71% as much feed as non-treated controls. After allowing the diethylstilbestrol-treated cattle to consume as much feed as the non-treated group, the treated group weighed 35.3 lb. more than the non-treated control group and required 1.27 lb. less feed/lb. gain. Adeyanju, Fowler and Burroughs (1969) reported that diethylstilbestrol increased feed consumption 5%, increased live weight gains 15% and reduced feed requirement/unit gain 10%.

Numerous reports are found in the literature regarding the effect of diethylstilbestrol on the composition and quality of the carcass. It is generally agreed that
diethylstilbestrol causes an increase in lean and a decrease in fat and carcass grade. In an extensive study on growth responses to diethylstilbestrol, Clegg and Cole (1954) indicated an acceleration of protein anabolism as a result of a slight increase in food consumption and a large increase in economy of gain. Diethylstilbestrol treatment resulted in a significant increase in nitrogen retention and these findings substantiated those of Whitehair, Gallup and Bell (1953) who treated lambs with diethylstilbestrol and observed an increase in nitrogen retention.

Clegg and Carroll (1956) demonstrated that diethylstilbestrol did not affect the percent of bone or moisture in the carcass of steers, but significantly increased the moisture content of heifer carcasses. There was a significant increase in cross-sectional area of the l. dorsi muscle due to diethylstilbestrol treatment. Goodrich et al. (1961) showed that diethylstilbestrol and diethylstilbestrol-dynafac combination significantly improved conformation grade as well as daily gain and feed efficiency. The response to these feed additives was not affected by different levels of protein in the diet. Wilson et al. (1963) reported a significant increase in carcass conformation with diethylstilbestrol treatment. However, Ogilvie et al. (1960) found that diethylstilbestrol had little effect on carcass conformation.
Wilson et al. (1963) reported that diethylstilbestrol treated steers had lower estimated percent carcass bone and fat but higher percent carcass lean, increased fat thickness and larger l. dorsi areas. Kastelic, Homeyer and Kline (1956) and Wallentine et al. (1961) reported contradictory results regarding fat thickness and l. dorsi area. Reports by O'Mary et al. (1952) and Wilkinson et al. (1955) indicated a decrease in fat thickness and weight of external fat and an increase in weight of bone and connective tissue as well as an increase in carcass length and viscera weight due to diethylstilbestrol treatment. However, they reported no significant difference in l. dorsi area or percent moisture in the muscles. Klosterman et al. (1955 a,b) reported that the percentage of moisture in heifer carcasses was significantly increased due to diethylstilbestrol but was not affected in steer carcasses. The l. dorsi area was not affected in steers but was significantly increased in heifers. Diethylstilbestrol increased the edible portion of the carcasses from steers and heifers.

There appears to be a greater tissue protein deposition with diethylstilbestrol treatment, but a reduction in carcass grade results. Stouffer et al. (1956), Wilson et al. (1963) and Ogilvie et al. (1960) have shown that diethylstilbestrol reduces the amount of intramuscular fat in the l. dorsi which could explain the decrease in carcass grade.
The mode of action of diethylstilbestrol is not clearly understood, but many attempts have been made to ascertain the physiological effects of the hormone. Adeyanju, Fowler and Burroughs (1969) have postulated that the growth stimulation is based on an increase in secretion of growth hormone and thus produces carcasses with higher lean:fat ratios with less caloric content per unit live weight gain. Studying the effect of diethylstilbestrol on metabolizable energy of the ration, they found that diethylstilbestrol resulted in a 4.0% increase in tissue protein. They theorized that since proteinaceous material contained three to four parts water to one part protein, it represented an increase of 16 to 20% in tissue gain. The presence of diethylstilbestrol did not significantly alter the metabolizable energy of corn grain or corn silage.

Clegg and Cole (1954) suggested that the action of diethylstilbestrol was mediated through the pituitary gland and that the weight of the pituitary and adrenal glands were significantly increased upon diethylstilbestrol treatment. The pituitary gland of diethylstilbestrol-treated heifers contained twice as much growth hormone as non-treated heifers, but there was no significant increase in secretory activity of the anterior pituitary which results in an increase release of protein anabolic hormones from the adrenal gland that possess androgenic properties. The increase in
weight of the adrenal gland appears to be a result of an
increased size of the adrenal cortex (Cahill et al., 1956
and Clegg and Carroll, 1956). The adrenal involvement may
be due to an inhibition of glucose-6-phosphate dehydrogenase
caused by diethylstilbestrol as reported by McKerns and

The growth promoting effect of diethylstilbestrol may
be influenced by an increase in volume of growth hormone.
Struempler and Burroughs (1959) worked with immature
ruminants and found the concentration of growth hormone
was not increased in the pituitary, but the pituitary gland
was larger, suggesting a larger volume of growth hormone per
unit weight.

A reduction in carcass grade was reported to be pro-
duced by diethylstilbestrol treatment (Clegg and Cole, 1954).
The reduction was due to larger, coarser muscle fibers,
darker colored lean and smaller amounts of intramuscular,
internal and external fat. Other changes in carcass com-
position as a result of increased pituitary activity were
heavier chucks and rounds with lighter loins and carcasses
showing staggy characteristics.

There have been some undesirable side effects reported
when high levels of diethylstilbestrol were administered.
Clegg and Cole (1954) reported that mammary gland develop-
ment occurred in steers and vaginal prolapses occurred in
heifers. Clegg and Carroll (1957) reported an elevation of
the tailhead and relaxation of the pelvic ligaments, and an
increase in size of teat, seminal vesicles and prostate
gland. Andrews, Beeson and Johnson (1954) reported an
elevation of the tailhead and an uneven topline. Marshall
et al. (1948) suggested that the uneven topline and tail­
head characteristics were due to a relaxation of the liga­
ment between the sacrum and ischium and in extreme cases,
there may be a partial dislocation of the sacro-iliac
cartilage.

The estrogenic activity of meats taken from animals
 treated with diethylstilbestrol has been of great concern.
However, when oral administration of diethylstilbestrol is
withdrawn at least 48 hr. prior to slaughter and 24 to 72
mg. pellets are implanted no less than 120 days before
slaughtering, there is no detectable estrogenic activity in
muscle tissue (Preston et al., 1956; Turner, 1956).

The growth promoting effects of diethylstilbestrol in
poultry and swine have been extensively studied. It appears
that diethylstilbestrol causes an increase of fat deposition
in poultry rather than a reduction of fat as reported in
cattle. Trenkle (1969) suggested that in avian species,
diethylstilbestrol administration resulted in increased
lipid synthesis and an increase in deposition of adipose
tissue. Lorenz (1943) demonstrated that the primary effects
of diethylstilbestrol when implanted in cockerels were increases in blood lipids, and visceral and subcutaneous fat deposition. In addition to an accelerated fat deposition, there also appears to be a reduction in moisture and protein content of muscle tissue of poultry (Andrews and Bohren, 1947).

The mode of action of diethylstilbestrol in poultry is apparently different than in cattle and sheep. Trenkle (1969) has reviewed the literature and concluded that there is no increase in nitrogen retention, but rather an increase in lipid synthesis. The absorption of lipids from the gastrointestinal tract is apparently not affected by diethylstilbestrol in poultry. Feeding diethylstilbestrol to poultry is not as effective as implantation and the administration of diethylstilbestrol does not result in consistent increases in weight gains or feed efficiency.

The effects of diethylstilbestrol treatment in swine have not significantly altered growth rate, feed efficiency or carcass composition and have retarded growth in some reports (Woehling et al., 1951; Pearson et al., 1952; Dinusson, Klosterman and Buchanan, 1951; Heitman and Clegg, 1957; Beeson et al., 1955).

Growth:

Most workers generally agree that an increase in body weight is the result of the growth phenomenon of animals.
However, some workers have been more specific in their description of growth. Brody (1964) suggested that growth was a biologic synthesis resulting in new biochemical units. Schloss (1911) defined growth as a correlative increase in body mass. Postnatal growth has been explained by Hafez (1963) as an increase in live weight of an animal, while development of an animal is regarded as the change in shape, conformation, components, faculties and functions of the body. The developmental changes are estimated by body or carcass measurements.

Growth of muscle is accomplished by an increase in the diameter and length of muscle fibers as a result of biosynthesis of new sarcomeric units (Lawrie, 1966; Hafez, 1963; Joubert, 1956 a, b). An increase in the weight of a muscle resulting from a high plane of nutrition may be due to increased intramuscular fat deposition rather than an increase in muscle fiber size. However, Joubert (1956a) has shown a highly significant correlation between plane of nutrition and degree of muscularity in sheep.

Hammond (1960) and Hafez (1963) have extensively studied the growth gradient of animals. Agreeing on their conclusions, they have indicated that postnatal growth begins at the head and proceeds in a wave-like fashion down the trunk. A secondary wave of growth begins at the extremities and proceeds upward with the point of junction of the two
waves of growth at the last rib, which corresponds with the final site of development. These workers have shown that tissues possess a definite pattern of growth with nerves, bones, tendons, muscles and fat developing in that order. Pomeroy (1955) points out that there is a gradient for fat deposition with increasing age. Subcutaneous fat accumulates first, followed in order by intramuscular fat, kidney fat and mesenteric fat.

Cattle have the largest muscle fibers at birth, followed by sheep and then swine (Hafez, 1963). However, at maturity the muscle fiber size is largest for the pig, followed by cattle then sheep (Joubert, 1956a) thus suggesting that during growth, the muscle fibers of the pig increase in size at a more rapid rate than in cattle or sheep. After reaching maximum growth, the absolute growth rate declines rapidly at first, but the rate of decline decelerates with time until maturity is reached. A typical growth curve of farm animals is sigmoid (Pomeroy, 1955). The point of inflection of the curve represents the period at which the absolute growth rate is greatest. The change in growth rate may be associated with the secretion rate of growth hormone and gonadotropic hormones from the anterior lobe of the pituitary gland (Hafez, 1963).

The nutrient priority within the animal is a function of metabolic rate of the tissues (Hammond, 1960; Hafez, 1963).
When adequate nutrients are supplied, all tissues receive ample nutrition. However, when nutrients are limited, fat deposition is retarded or completely stopped, depending upon the severity of the limitation. Studying the effects of relatively mild nutrition restriction at various weight intervals during growth, Suess, Tyler and Brungardt (1969) found that when changing the plane of nutrition from high to medium, the amount of fat deposition was controlled within muscles, but caused no retardation in the growth of muscle tissue. However, when the medium plane of nutrition was fed throughout the growing period, the control of fat deposition within the muscles was not so effective.

Elsley, McDonald and Fowler (1964) reported that when feed restriction is so severe as to cause weight loss, changes in the ratio of bone to muscle are expected. Brinks et al. (1962) have shown that under range conditions, growth is seasonal and follows the rainfall patterns. There is a time lag between the periods of rainfall and subsequent growth. An increase in cow weight during the winter months indicated higher productivity resulting in higher weaning weight of the calf whereas an increase in cow weight during the suckling period was negatively correlated with calf weight at weaning.

A major source of growth variations in animals is climate. Gain and feed efficiency may be reduced as much as 25% under extremely hot summer conditions of Southwestern
United States (Ray, Hale and Marchello, 1969). Seasonal differences were found to be far more important as a source of variation in performance of feedlot cattle than were sex or treatments of melengestrol acetate, diethylstilbestrol, Synovex-H, and implants of a combination of diethylstilbestrol and testosterone.

Cahill (1964) and Hedrick (1968) have extensively reviewed the sex influence on growth and composition of beef. They concluded that bulls grow faster than steers and steers grow faster than heifers. Carcasses from bulls tend to have larger L. dorsi areas/unit weight, more separable lean and less separable fat than carcasses from steers or heifers. Heifer carcasses tend to be somewhat fatter than those of steers or bulls when fed comparable rations for the same length of time and result in a lower yield of retail cuts than steer carcasses. The carcass grade appears to be similar for steers and heifers and is highly influenced by the feeding regime. Bull carcasses are generally lower in quality grade due primarily to a lack of intramuscular fat.

The sex influence upon growth rate of animals has been studied by Champagne et al. (1969). Bulls gained faster and more efficiently than steers and bulls had a higher dressing percent. Steers graded higher than bulls because of an increased rate of intramuscular fat deposition. Bulls yield approximately 5% more trimmed, boneless retail cuts
than steers indicating a differential in growth rate of muscle tissue and fat deposition between bulls and steers. There was a linear relationship between increasing percent yield and increasing age of castration in steers. There was no significant difference in tenderness between bulls and steers which were castrated at four different ages.

Hafez (1963) suggests that growth of beef cattle is influenced by genotype, birth weight, milk production of the dam, maternal care, age of dam, weaning age and weight, sex, nutrition, climate, adaptability and management. In addition, several workers point out that growth rate is influenced by breed and altitude (Peters, 1958; Davis and Hathaway, 1956; Lush et al., 1930; Damon et al., 1959), Tennessee workers (Cole et al., 1963; Cole et al., 1964; Ramsey et al., 1965) have extensively studied the effects of breed on growth and composition. In a comparison of steer carcasses from Angus and Hereford, Brahman and Santa Gertrudis, and Holstein and Jersey, they found Angus and Hereford to be fatter with less separable lean than the other four breeds. Holstein carcasses had the most separable lean and the least separable fat.
EXPERIMENTAL PROCEDURE

Data were assembled from eight groups of commercial beef heifers in a replicated experiment designed to investigate the efficacy of the antibiotic, lincomycin, on growth phenomena when fed with a high roughage, low energy type diet separately and in combination with diethylstilbestrol.

Because of space limitations in the facilities, the trials were conducted over a period of two years with the trials beginning in mid-December of 1967 and 1968, respectively, in an effort to minimize climatic and seasonal variations.

The experimental animals used in these trials were beef heifers of mixed breeding which were native to southern and southwestern Ohio. An attempt was made to obtain heifers from similar locations and sources in order to minimize variations in environmental and managerial conditions which may have ultimately affected the response of the experimental antibiotic and altered the incidence and severity of liver abscesses or other growth performance traits. The experiment was designed to provide two replicates of each of four treatments. The treatments by year
were non-treated negative control and lincomycin (trial I),
and diethylstilbestrol and the combination of lincomycin
and diethylstilbestrol (trial II).

Trial I:

A random selection within weight strata was used to
assign 60 heifers to four lots of 15 heifers each in trial
I. The heifers were individually weighed and sorted into
heavy, medium and light weight groups. Five heifers from
each weight group were selected at random and allotted to
each of the four lots. Upon initiation of the trial, all
heifers were ear tattooed and ear tagged for positive identi-
fication. Each heifer was intramuscularly injected with 2
cc. of a mixture of vitamin A, D, and E containing 500,000

Treatments were randomly assigned to each of two repli-
cated lots. Two replicates received no lincomycin treatment
and served as the negative control. Lincomycin, incorporated
by pre-mixing into a non-pelleted protein supplement, was
fed to the other two replicates at the rate of 45 mg./head
daily. All heifers in trial I, initially, and at 28-day
intervals during the trial, were individually weighed after
a 6 hr. standard shrink free from feed and water. Trial I
was designed to terminate by replication when the mean live
weight was 900 lb. and followed by slaughtering each heifer
in each replication.
**Trial II:**

Because of an extreme variation in initial weight of the heifers in trial II, 60 heifers were first sorted into a heavy weight and a light weight group. Fifteen heifers were then assigned to each of four lots according to weight stratification within each weight group. The same identification and vitamin injection procedures were followed as in trial I.

Treatment of 10 mg. diethylstilbestrol/head daily, incorporated into the non-pelleted protein supplement, was randomly assigned to two replicated lots. The other two replicated lots received a combination treatment of 45 mg. lincomycin and 10 mg. diethylstilbestrol/head daily. The combination treatment was also incorporated by pre-mixing into the non-pelleted protein supplement. All heifers in trial II were shrunk 12 hr. free from feed and water before weighing. Individual weights were taken at the initiation of the trial and at 28-day intervals during the trial. Trial II was designed to terminate by replication followed by slaughtering each replication when the mean live weight was 900 lb.

The ration ingredients and levels fed per/head daily by treatment groups are shown in table 1. Corn silage was hand fed *ad libitum* to all groups. In trial I, the corn silage contained an average of 69.70% moisture and 2.21% crude protein. In trial II, the corn silage contained an
Table 1. INGREDIENTS AND LEVELS FED PER HEAD DAILY BY TREATMENT GROUPS

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Treatment Groups</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Lincomycin</td>
<td>Diethylstilbestrol</td>
<td>Lincomycin and Diethylstilbestrol</td>
</tr>
<tr>
<td>Corn silage</td>
<td>ad libitum</td>
<td>ad libitum</td>
<td>ad libitum</td>
<td>ad libitum</td>
</tr>
<tr>
<td>Ground shelled corn</td>
<td>1% body wt.</td>
<td>1% body wt.</td>
<td>1% body wt.</td>
<td>1% body wt.</td>
</tr>
<tr>
<td>Protein supplement, lb.</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Lincomycin, mg.</td>
<td>----</td>
<td>45.00</td>
<td>----</td>
<td>45.00</td>
</tr>
<tr>
<td>Diethylstilbestrol, mg.</td>
<td>----</td>
<td>----</td>
<td>10.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Salt and Mineral</td>
<td>ad libitum</td>
<td>ad libitum</td>
<td>ad libitum</td>
<td>ad libitum</td>
</tr>
</tbody>
</table>
average of 68.85% moisture and 2.57% crude protein. Coarsely ground shelled corn was fed at the rate of 1.0% body weight to all groups. Adjustment in the allowance of ground shelled corn was made at 14-day intervals based on the lot average daily gain for the previous 28-day period. For the first adjustment in ground shelled corn (14 days after the initiation of the trials), the expected average daily gain, as indicated by Burroughs et al. (1963), for cattle on rations which were similar in energy and protein content to the one fed in these trials, was used to compute the corn allowance. The shelled corn contained an average of 13.26% moisture and 8.65% crude protein in trial I and 14.41% moisture and 8.65% crude protein in trial II.

A commercially prepared non-pelleted protein supplement was used for all groups. It contained 32.0% crude

<table>
<thead>
<tr>
<th>Items</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein, %</td>
<td>32.00</td>
</tr>
<tr>
<td>Crude fat, %</td>
<td>2.00</td>
</tr>
<tr>
<td>Crude fiber, %</td>
<td>10.00</td>
</tr>
<tr>
<td>Calcium, %</td>
<td>2.00</td>
</tr>
<tr>
<td>Phosphorus, %</td>
<td>0.75</td>
</tr>
<tr>
<td>Iodine, %</td>
<td>0.0004</td>
</tr>
<tr>
<td>Sodium chloride, %</td>
<td>3.50</td>
</tr>
<tr>
<td>Vitamin A, U.S.P. units/lb.</td>
<td>15000.00</td>
</tr>
<tr>
<td>Vitamin D2, U.S.P. units/lb.</td>
<td>3000.00</td>
</tr>
</tbody>
</table>
protein and consisted of 12.5% of the total protein in non-protein nitrogen. Table 2 shows the guaranteed nutrient analysis of the protein supplement fed to the non-treated control groups. It contained 2.0% crude fat, 10.0% crude fiber, 2.0% calcium, 0.75% phosphorus, 0.0004% iodine and 3.50% sodium chloride. The vitamin A level was 15000 U.S.P. units/lb. feed and vitamin D₂ level was 3000 U.S.P. units/lb. feed.

The treatments of lincomycin and diethylstilbestrol were incorporated into the protein supplement at the rate of 22.5 mg./lb. supplement and 5.00 mg./lb. supplement, respectively. The treated and non-treated protein supplements were top-dressed onto the silage and ground shelled corn at the rate of 2.00 lb./head daily to insure daily treatments of 45 mg. lincomycin/head and 10 mg. diethylstilbestrol/head in the respective treatment groups.

Mixing salt and commercial feeding mineral (table 1) were provided free choice to all groups. The mineral contained 21.0% calcium and 12.0% phosphorus. On the 21st day of both trials, all heifers were treated for worms with thiabenzadole.

The treatment of diethylstilbestrol was withdrawn 48 hr. prior to slaughter, but the treatment of lincomycin was continued until slaughter. The heifers were slaughtered at Eckert Packing Co., Troy, Ohio.
During slaughter, the gastrointestinal tract, lungs, udder, liver and heart were closely examined for the presence of abscesses or abnormal characteristics. In addition, the liver was closely inspected for indications of parasitism, healed abscesses or other tissue damage. The number and severity of liver abscesses and other liver abnormalities were recorded. A liver tissue sample was obtained from the edge of the medial lobe and fixed in Bouin's fixative solution.

After approximately 36 hr. of chilling, the following carcass data were obtained as outlined by Schoonover et al. (1967):

a. hot carcass weight
b. U.S.D.A. quality grade (nearest one-third)
c. marbling score
d. texture of marbling
e. firmness of lean
f. texture of lean
g. color of lean
h. U.S.D.A. conformation grade (nearest one-third)
i. longissimus dorsi area
j. fat thickness over the 12th rib
k. estimated % kidney, pelvic and heart fat
l. U.S.D.A. yield grade

From the above carcass data, the Beef Carcass Yield Grade Finder (U.S.Dept. of Agriculture, 1965, 1968b) was used to determine an estimate of yield by computing the yield grade of each carcass. In addition, the above data were used to calculate the percent retail yield of boneless, closely trimmed round, loin, rib and chuck for each carcass
as described by Murphey et al. (1960a,b).

The liver tissues, which were fixed in Bouin's fixative solution, were held in 70% alcohol and later cut at 7.0 micra, mounted on histological slides and stained with hematoxylin and eosin. Detailed observations were made on ten randomly selected slides from each treatment group to determine any histological changes in hepatic tissue structure due to treatment.

In vitro pH:

Rumen contents were obtained from two ruminal-fistulated wethers which were maintained on a diet of pelleted dehydrated alfalfa containing 15% crude protein. An in vitro fermentation technique as described by Johnson (1966) was used to investigate the effect of four levels of lincomycin alone and in combination with diethylstilbestrol on rumen pH. A 2x4 factorial design was employed to determine the pH of the rumen contents. Six observations were made for each of four levels of lincomycin with and without diethylstilbestrol. The levels of lincomycin/lb. feed investigated were 0.0 mg., 12.5 mg., 22.5 mg. and 42.5 mg. The levels of diethylstilbestrol/lb. feed were 0.0 mg. and 5.0 mg. The treatment levels of lincomycin and diethylstilbestrol were incorporated into the protein supplement as described in table 2 prior to placing them in the fermentation tubes.
Fermentation tubes with 90 ml. capacity were used in this study. To each tube were added 50 ml. of rumen contents containing no buffer, 2.0 gm. pure cellulose and 6.92 gm. of protein supplement containing the various treatments. Distilled water was then added to each tube to bring the total content to approximately 75 ml. An initial pH reading was taken for each observation. After 30 hr. of in vitro fermentation, a final pH reading was taken for each observation.

The data were subjected to the least-squares analysis of variance as suggested by Harvey (1960). A total of ten heifers were removed from the trials as described later.

Table 3. ANALYSIS OF VARIANCE

<table>
<thead>
<tr>
<th>Sources</th>
<th>Degrees of freedom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>110</td>
</tr>
<tr>
<td>Mean</td>
<td>1</td>
</tr>
<tr>
<td>Year (Diethylstilbestrol)</td>
<td>1</td>
</tr>
<tr>
<td>Treatment within Year 1</td>
<td>1</td>
</tr>
<tr>
<td>(Lincomycin with diethyl-</td>
<td></td>
</tr>
<tr>
<td>stilbestrol)</td>
<td></td>
</tr>
<tr>
<td>Treatment within Year 2</td>
<td>1</td>
</tr>
<tr>
<td>(Lincomycin without diethyl-</td>
<td></td>
</tr>
<tr>
<td>stilbestrol)</td>
<td></td>
</tr>
<tr>
<td>Repet within Treatment year</td>
<td>4</td>
</tr>
<tr>
<td>Regression</td>
<td>1</td>
</tr>
<tr>
<td>Residual</td>
<td>101</td>
</tr>
</tbody>
</table>
Table 3 shows the analysis of variance with the sources of variation and degrees of freedom. Because cattle in both trials were not treated with diethylstilbestrol, there was confounding of the data between year effects and diethylstilbestrol effects. Therefore, the comparisons made were between lincomycin and no lincomycin, diethylstilbestrol and lincomycin plus diethylstilbestrol, and the two aforementioned comparisons with any true year effect.
RESULTS AND DISCUSSION

Regardless of considerable advancement in beef production technology, producers are continually searching for ways of improving growth factors which increase the production of beef. Increased gains and improved feed utilization would result in a tendency to ease the competitive situation which exists in the beef production industry and create an opportunity for producers to realize more economic gain. Therefore, this study was devoted to the investigation of the effects of the antibiotic, lincomycin, when fed separately and in combination with diethylstilbestrol, on factors which are involved with the rate, efficiency and composition of growth.

The overall mean initial weight of the heifers was 438 lb. The range in initial weight was from 293 lb. to 613 lb. Because of this extreme range in initial weight, the heifers were assigned to groups on the basis of weight stratification and treatments were assigned to groups at random. In addition, due to this extreme variation, the data were all analyzed with initial weight as a covariant, with the exception of a portion of the data for carcass characteristics where carcass weight was the covariant for
computing partial correlations. Therefore, all data reported herein are adjusted for initial weight unless stated otherwise.

One heifer in the control group was removed from the trial on the 212th day because of parturition. One heifer in the lincomycin group died during the trials. The data were all adjusted accordingly. Post-mortem examination of the heifer revealed rumenstasis and lung congestion. The heifer had been on feed for 95 days prior to death. A static condition of the stomach and cecum contents was reported by Gray and Lewis (1966) after lincomycin treatment in rabbits. Death occurred in the rabbits from the fourth to the seventh day after oral and intravenous administration of 5.0 to 150 mg. lincomycin/2.2 lb. body weight. Severe diarrhea was reported in the rabbits prior to death, however diarrhea was not observed in the heifer that died in this study.

In addition, an insecure latch on a gate allowed eight heifers of the control group to get out of the pen for a period of three days. Therefore, the eight heifers were eliminated from all analyses and group mean data were adjusted accordingly.

Table 4 presents the means and standard errors for traits related to feedlot performance. There was no statistical difference between means for lincomycin and control
or diethylstilbestrol and lincomycin with diethylstilbestrol for final weight and carcass weight. However, the final weight, which is reflective of average daily gain, was greatest for lincomycin and diethylstilbestrol combination treated heifers, but the carcass weight was greatest for lincomycin treated heifers.

The dressing percentage was not emphasized in this study because the final live weight represents the feedlot weight taken at the termination of the trials. The cattle were transported 55 miles and shrunk overnight prior to slaughter. Therefore, the handling conditions just prior to slaughter may have had a sizable effect on packing plant live weights and resulting carcass weights.

The average daily gain for lincomycin treated heifers was 1.63 lb. and was not significantly different from the control (1.57 lb.). As was expected, treatment of diethylstilbestrol resulted in an increased growth rate ($P < .10$), realizing that the effect of diethylstilbestrol was confounded with the effect of year, but the increase was not as dramatic as has been reported by some workers (Andrews, Beeson and Johnson, 1950, 1954; Clegg and Cole, 1954; O'Mary and Cullison, 1956; O'Mary et al., 1956). The average daily gain for diethylstilbestrol treated heifers was 1.64 lb. Lincomycin treated heifers grew 3.8% faster than control heifers while the diethylstilbestrol treated heifers
Table 4. LEAST SQUARES MEANS AND STANDARD ERRORS FOR FEEDLOT PERFORMANCE TRAITS

<table>
<thead>
<tr>
<th>Traits</th>
<th>Overall</th>
<th>Control</th>
<th>Lincomycin</th>
<th>Diethylstilbestrol</th>
<th>Lincomycin plus Diethylstilbestrol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.E.</td>
<td>Mean</td>
<td>S.E.</td>
<td>Mean</td>
</tr>
<tr>
<td>Final weight, lb.</td>
<td>894.89</td>
<td>6.12</td>
<td>873.78</td>
<td>14.44</td>
<td>891.70</td>
</tr>
<tr>
<td>Carcass weight, lb.</td>
<td>528.17</td>
<td>4.64</td>
<td>514.89</td>
<td>10.95</td>
<td>538.45</td>
</tr>
<tr>
<td>Average daily gain, lb.</td>
<td>1.67</td>
<td>0.02</td>
<td>1.57</td>
<td>0.05</td>
<td>1.63</td>
</tr>
<tr>
<td>Feed/lb. gain, lb.</td>
<td>8.75</td>
<td>0.22</td>
<td>9.56</td>
<td>0.44</td>
<td>8.86</td>
</tr>
<tr>
<td>Cost/lb. gain, c</td>
<td>20.74</td>
<td>0.60</td>
<td>22.37</td>
<td>1.21</td>
<td>20.86</td>
</tr>
</tbody>
</table>

1/ Corn silage converted to a shelled corn moisture-equivalent of 13.8% for each treatment group.
2/ Excludes cost of lincomycin.
3/ Group means and S. E.
* P < .10.
gained 4.5% more rapidly (Table 5). When lincomycin and diethylstilbestrol were fed in combination, there appeared to be an added effect. The treatment of the antibiotic and hormone combination resulted in an average daily gain of 1.87 lb., which was somewhat \( P < .10 \) greater than diethylstilbestrol alone and was 17.8% greater than the control heifers. The average daily gain for the combination was 12.8% greater than diethylstilbestrol alone and 13.5% greater than lincomycin alone (Table 5).

The additional effect of lincomycin with diethylstilbestrol treatment supports the incomplete data reported by Stob et al. (1968). They observed an increase in growth rate of 6.0% with diethylstilbestrol alone, but when lincomycin was fed with diethylstilbestrol, the average daily gain was 13.0% greater than the controls. According to L. W. Davis (personal communication), there was an apparent synergistic effect for lincomycin plus diethylstilbestrol in trials conducted at the Upjohn Company Laboratories but the additive effects of combining the two treatments were greatest during the first 56 days of treatment. Stob et al. (1968) stated that lincomycin alone resulted in a 5.0% reduction of gain. However, their data were analyzed for all groups receiving lincomycin regardless of any other treatments and therefore may be reflecting responses of treatment other than lincomycin per se.
Table 5. AVERAGE DAILY GAIN, FEED/LB. GAIN AND COST/LB. GAIN FOR ENTIRE LENGTH OF TRIAL FOR TREATMENT GROUPS EXPRESSED AS A PERCENT OF OTHER TREATMENT GROUPS

<table>
<thead>
<tr>
<th>Traits</th>
<th>Treatment Groups</th>
<th>Control</th>
<th>Lincomycin</th>
<th>Diethylstilbestrol</th>
<th>Lincomycin plus Diethylstilbestrol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Daily Gain</td>
<td>Control</td>
<td>100.0</td>
<td>103.8</td>
<td>104.5</td>
<td>117.8</td>
</tr>
<tr>
<td></td>
<td>DES 1/</td>
<td>104.5</td>
<td>99.4</td>
<td>100.0</td>
<td>112.8</td>
</tr>
<tr>
<td></td>
<td>Lincomycin</td>
<td>103.8</td>
<td>100.0</td>
<td>99.4</td>
<td>113.5</td>
</tr>
<tr>
<td>Feed/lb. Gain</td>
<td>Control</td>
<td>100.0</td>
<td>92.7</td>
<td>90.7</td>
<td>83.0</td>
</tr>
<tr>
<td></td>
<td>DES 1/</td>
<td>90.7</td>
<td>102.2</td>
<td>100.0</td>
<td>91.5</td>
</tr>
<tr>
<td></td>
<td>Lincomycin</td>
<td>92.7</td>
<td>100.0</td>
<td>102.2</td>
<td>89.5</td>
</tr>
<tr>
<td>Cost/lb. Gain</td>
<td>Control</td>
<td>100.0</td>
<td>93.3</td>
<td>93.7</td>
<td>84.0</td>
</tr>
<tr>
<td></td>
<td>DES 1/</td>
<td>93.7</td>
<td>99.5</td>
<td>100.0</td>
<td>89.6</td>
</tr>
<tr>
<td></td>
<td>Lincomycin</td>
<td>93.3</td>
<td>100.0</td>
<td>99.5</td>
<td>90.0</td>
</tr>
</tbody>
</table>

1/ Diethylstilbestrol
The feed/lb. gain and cost/lb. gain for treatment groups, respectively, were not significantly different for lincomycin, diethylstilbestrol or lincomycin with diethylstilbestrol. However, some differences did exist among treatment groups for these two traits as revealed in tables 4 and 5. When corn silage was converted to a shelled corn moisture-equivalent of 13.8% and the remainder of the ration was considered on an as is basis, the feed/lb. gain for control heifers was 9.56 lb. The feed conversion for diethylstilbestrol treated heifers was 8.67 lb. which represents only 90.7% as much feed required/lb. gain as the control (table 5). Lincomycin treated heifers had a feed conversion of 8.86 lb. which was 92.7% of that required by the controls but was 102.2% of that required for diethylstilbestrol-treated heifers.

As was evidenced with growth rate for the entire length of the trial, there appeared to be an additional effect of the lincomycin plus diethylstilbestrol combination for feed/lb. gain. The combination treated heifers required only 7.93 lb. feed/lb. gain which was only 83.0% of that necessary for the controls. This represents a 17.0% improvement in feed/unit gain. Heifers receiving lincomycin plus diethylstilbestrol required only 91.5% of the amount of feed/lb. gain as heifers receiving diethylstilbestrol alone and 89.5%
of the amount for heifers receiving lincomycin alone.
Stob et al. (1968) reported that the lincomycin plus diethylstilbestrol combination improved feed efficiency 7.0%, whereas diethylstilbestrol alone improved feed efficiency only 4.0%. L. W. Davis (personal communication) indicated that 45 mg. of lincomycin, when fed with diethylstilbestrol to steers, improved feed efficiency from 3.3% to 4.9%.

Because of the similarity in feed/lb. gain for lincomycin and diethylstilbestrol treatments, the cost/lb. gain for these two treatment groups was almost identical regardless of any year effect (20.86 cents/lb. gain for lincomycin and 20.97 cents/lb. gain for diethylstilbestrol). The cost of each ingredient used to compute the cost/lb. gain is listed in table 6. The cost of diethylstilbestrol was

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Cost, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shelled corn, cwt.</td>
<td>2.00</td>
</tr>
<tr>
<td>Corn silage, ton</td>
<td>7.00</td>
</tr>
<tr>
<td>32% supplement, cwt.</td>
<td>5.00</td>
</tr>
<tr>
<td>Mineral, cwt.</td>
<td>8.00</td>
</tr>
<tr>
<td>Salt, cwt.</td>
<td>2.00</td>
</tr>
</tbody>
</table>

1/ Includes cost of diethylstilbestrol
absorbed in the cost of the supplement, but the cost of lincomycin was not included because no dollar value has been determined for this antibiotic. Table 5 shows that when fed separately lincomycin and diethylstilbestrol resulted in approximately 6.5% improvement in cost/unit gain. Again, as with growth rate and feed utilization, the combination of lincomycin plus diethylstilbestrol appeared to have a synergistic effect. The cost/lb. gain for the combination treated heifers was 18.78 cents as compared to 22.37 cents for the controls (table 4) and represents 16.05% improvement in cost of gain over controls (table 5). The combination treatment resulted in an approximate improvement of 10.0% in cost of gain over the treatment of lincomycin or diethylstilbestrol when fed separately.

The absences of statistically significant differences for feed/lb. gain and cost/lb. gain may possibly be explained by the fact that only two means (one for each replication) were considered for each treatment group resulting in a total of only eight degrees of freedom in the analysis of covariance. Since the treated heifers were fed as groups, no individual data were available for these two variables.

The growth responses to treatments for the first 112 days on feed are shown in table 7. The average daily gain for treatment groups is listed for 28-day weight intervals. Realizing that an extreme range in initial weight of the
heifers existed in this study, it is important to evaluate these data adjusted and unadjusted for initial weight because of the variation in ability of heifers to adapt to feeding rations and regimes.

Table 7. AVERAGE DAILY GAINS (LB.) FOR 28-DAY INTERVALS UNADJUSTED FOR INITIAL WEIGHT

<table>
<thead>
<tr>
<th>Weight Interval</th>
<th>Overall</th>
<th>Control</th>
<th>Lincomycin</th>
<th>DES 1/</th>
<th>Lincomycin plus DES 1/</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 days</td>
<td>1.47</td>
<td>1.40</td>
<td>1.46</td>
<td>1.34</td>
<td>1.51</td>
</tr>
<tr>
<td>56 days</td>
<td>1.89</td>
<td>1.89</td>
<td>1.89</td>
<td>1.78</td>
<td>2.00</td>
</tr>
<tr>
<td>84 days</td>
<td>1.83</td>
<td>1.77</td>
<td>1.89</td>
<td>1.75</td>
<td>1.92</td>
</tr>
<tr>
<td>112 days</td>
<td>1.73</td>
<td>1.71</td>
<td>1.76</td>
<td>1.63</td>
<td>1.84*</td>
</tr>
</tbody>
</table>

1/ diethylstilbestrol

* P < .10.

It is generally accepted that the first 3 or 4 weeks on feed are most important in determining the overall efficiency of growth. In this study, the overall average daily gain for the first 28 days was 1.47 lb. The average daily gain was not significantly affected by treatment for the first 28 days, however, some differences did exist. The average daily gain for the control heifers was 1.40 lb, while the diethylstilbestrol treated heifers gained only
96.1% (1.34 lb./day) as much as control heifers (table 8). Lincomycin treated heifers gained 4.3% more (1.46 lb./day) than the control heifers while the treatment of lincomycin plus diethylstilbestrol resulted in a 28-day growth rate of 108.2% of that of the control heifers.

Lincomycin alone resulted in an average daily gain increase of 8.6% over diethylstilbestrol alone. The lincomycin plus diethylstilbestrol combination resulted in a growth performance of 103.8% of that of lincomycin alone regardless of any year effects.

There were no statistically significant differences in average daily gain between treatment groups for the first 56 or 84 days of the trials. However, the same general trend existed as with the first 28-day average daily gain. The growth response to diethylstilbestrol alone was less than that of the controls in both instances. The average daily gain for lincomycin treated heifers was the same as control heifers at 56 days but was 7.0% greater at 84 days. The effect of the antibiotic and hormone combination appeared to be additive at 56 and 84 days. At 56 days, the average daily gain for the combination treated heifers was 5.7% greater than the control heifers and at 84 days, the combination was 8.4% greater.

For the first 112 days of the trial, the average daily gain for the heifers treated with the combination of
Table 8. WEIGHT GAINS AT 28-DAY INTERVALS UNADJUSTED FOR INITIAL WEIGHT AND EXPRESSED AS A PERCENT OF THE OTHER TREATMENT GROUPS

<table>
<thead>
<tr>
<th>Weight Intervals</th>
<th>Treatment Groups</th>
<th>Lincomycin</th>
<th>Lincomycin plus DES 1/</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 day</td>
<td>Control</td>
<td>100.0</td>
<td>104.3</td>
</tr>
<tr>
<td></td>
<td>DES 1/ Lincomycin</td>
<td>96.1</td>
<td>108.6</td>
</tr>
<tr>
<td></td>
<td>Lincomycin</td>
<td>104.3</td>
<td>100.0</td>
</tr>
<tr>
<td>56 day</td>
<td>Control</td>
<td>100.0</td>
<td>100.1</td>
</tr>
<tr>
<td></td>
<td>DES 1/ Lincomycin</td>
<td>93.8</td>
<td>106.1</td>
</tr>
<tr>
<td></td>
<td>Lincomycin</td>
<td>100.1</td>
<td>100.0</td>
</tr>
<tr>
<td>84 day</td>
<td>Control</td>
<td>100.0</td>
<td>107.0</td>
</tr>
<tr>
<td></td>
<td>DES 1/ Lincomycin</td>
<td>98.6</td>
<td>108.5</td>
</tr>
<tr>
<td></td>
<td>Lincomycin</td>
<td>107.0</td>
<td>100.0</td>
</tr>
<tr>
<td>112 day</td>
<td>Control</td>
<td>100.0</td>
<td>103.0</td>
</tr>
<tr>
<td></td>
<td>DES 1/ Lincomycin</td>
<td>95.3</td>
<td>109.1</td>
</tr>
<tr>
<td></td>
<td>Lincomycin</td>
<td>103.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

1/ Diethylstilbestrol
lincomycin and diethylstilbestrol was significantly greater
(P < .10) than the diethylstilbestrol treated heifers but when
fed separately, treatment of diethylstilbestrol or lincomycin
was not significantly different from the control. The
average daily gain at 112 days for the control heifers and
heifers treated with diethylstilbestrol, lincomycin, and
lincomycin plus diethylstilbestrol, respectively, was
1.71 lb., 1.63 lb., 1.76 lb. and 1.84 lb.

When unadjusted for initial weight, it appears that
diethylstilbestrol reduced the growth response during the
first 112 days. The average daily gain for diethylstilbes-
trol treated heifers was less than the control heifers for
28, 56, 84 and 112 day periods. Lincomycin improved the
average daily gain at 28, 84 and 112 day periods and was
equal to that of the controls at 56 days. In all cases,
lincomycin plus diethylstilbestrol resulted in an increase
in average daily gain over the controls, diethylstilbestrol
alone and lincomycin alone irrespective of any year effect.
Therefore, it appeared that when initial weight was not
adjusted, lincomycin alone or in combination with diethyl-
stilbestrol resulted in an improvement of growth rate over
control or diethylstilbestrol alone, respectively, during
the first 112 days on feed and that diethylstilbestrol
alone actually suppressed growth rate during this period of time.
In order to study the growth response after the heifers had adapted themselves to the ration and to reduce the variation in beginning weights, the growth data for the first 112 days were analyzed with initial weight as a covariant (tables 9 and 10). In the analysis of covariance, there were no statistically significant differences due to treatment at any weight interval, although respectable differences did occur. At 28 days, the lincomycin treated heifers gained 152.2% of that of the control heifers (1.72 lb. and 1.13 lb./day, respectively) while the combination of lincomycin and diethylstilbestrol resulted in a 33.6% (1.51 lb./day) increase and diethylstilbestrol alone resulted in an 18.4% (1.34 lb./day) increase over the controls. The average

<table>
<thead>
<tr>
<th>Weight Interval</th>
<th>Overall</th>
<th>Control</th>
<th>Lincomycin</th>
<th>DES 1/</th>
<th>Lincomycin plus DES 1/</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 day</td>
<td>1.43</td>
<td>1.13</td>
<td>1.72</td>
<td>1.34</td>
<td>1.51</td>
</tr>
<tr>
<td>56 day</td>
<td>1.89</td>
<td>1.90</td>
<td>1.88</td>
<td>1.77</td>
<td>2.00</td>
</tr>
<tr>
<td>84 day</td>
<td>1.83</td>
<td>1.78</td>
<td>1.88</td>
<td>1.74</td>
<td>1.92</td>
</tr>
<tr>
<td>112 day</td>
<td>1.73</td>
<td>1.71</td>
<td>1.75</td>
<td>1.62</td>
<td>1.84</td>
</tr>
</tbody>
</table>

1/ Diethylstilbestrol
daily gain for heifers treated with lincomycin alone was
28.4% greater than that of heifers treated with diethylstilbestrol only.

The growth response for all treatments diminished rapidly after 28 days. By the 56-day weight interval, the growth responses to separate treatments of diethylstilbestrol and lincomycin were below that of the control heifers. The decrease in growth performance at 56 days was most drastic for lincomycin treated heifers, but the average daily gain for those heifers treated with lincomycin was still 6.2% greater than that for heifers treated with diethylstilbestrol alone. At 56 days, the average daily gain for heifers treated with the combination of lincomycin plus diethylstilbestrol was 5.3% greater than those with either treatment separately, 13.0% greater than those treated with diethylstilbestrol alone and 6.6% greater than heifers treated with lincomycin alone.

There appeared to be a generalized recovery of the growth response for all treatment groups by the 84-day weight interval, however, the average daily gain for heifers treated with diethylstilbestrol only was 97.8% of that of the control heifers. The average daily gain for lincomycin treated heifers was 5.6% greater than for the controls and 8.1% greater than for diethylstilbestrol only. The combination of lincomycin plus diethylstilbestrol was
Table 10. AVERAGE DAILY GAIN FOR 28-DAY INTERVALS 
ADJUSTED FOR INITIAL WEIGHT EXPRESSED AS 
A PERCENT OF THE OTHER TREATMENT GROUPS

<table>
<thead>
<tr>
<th>Weight Intervals</th>
<th>Treatment Groups</th>
<th>Lincomycin Control</th>
<th>Lincomycin plus DES 1/</th>
<th>Lincomycin plus DES 1/</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 day</td>
<td>Control</td>
<td>100.0</td>
<td>152.2</td>
<td>118.6</td>
</tr>
<tr>
<td></td>
<td>DES 1/</td>
<td>118.6</td>
<td>128.4</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Lincomycin</td>
<td>152.2</td>
<td>100.0</td>
<td>128.4</td>
</tr>
<tr>
<td>56 day</td>
<td>Control</td>
<td>100.0</td>
<td>99.0</td>
<td>93.2</td>
</tr>
<tr>
<td></td>
<td>DES 1/</td>
<td>93.2</td>
<td>106.2</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Lincomycin</td>
<td>99.0</td>
<td>100.0</td>
<td>106.2</td>
</tr>
<tr>
<td>84 day</td>
<td>Control</td>
<td>100.0</td>
<td>105.6</td>
<td>97.8</td>
</tr>
<tr>
<td></td>
<td>DES 1/</td>
<td>97.8</td>
<td>108.1</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Lincomycin</td>
<td>105.6</td>
<td>100.0</td>
<td>108.1</td>
</tr>
<tr>
<td>112 day</td>
<td>Control</td>
<td>100.0</td>
<td>102.3</td>
<td>94.7</td>
</tr>
<tr>
<td></td>
<td>DES 1/</td>
<td>94.7</td>
<td>108.0</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Lincomycin</td>
<td>102.3</td>
<td>100.0</td>
<td>108.0</td>
</tr>
</tbody>
</table>

1/ Diethylstilbestrol
7.9% greater than that of the controls, 10.3% greater than for diethylstilbestrol alone and 2.1% greater than for lincomycin alone.

The 112-day growth response data for heifers when adjusted for initial weight were nearly identical as when unadjusted for initial weight. Diethylstilbestrol treated heifers gained only 94.7% as much as the controls while lincomycin treated heifers gained 102.3% as much as the controls and 108.0% as much as those that received diethylstilbestrol only. Heifers treated with lincomycin plus diethylstilbestrol gained 107.6% of that of the controls, 113.6% of that of heifers fed diethylstilbestrol only and 105.1% of that of the heifers fed lincomycin alone.

When evaluating these data after the variation in initial weight was removed and irrespective of any year effects, it appeared that there was a considerable growth response of heifers treated with lincomycin alone during the first 28 days, although the response was not statistically significant. Also, there was a sizable increase in growth response with the combination of lincomycin plus diethylstilbestrol but the response to the combination was not as great as the response to lincomycin alone.

Regardless of adjustment or unadjustment for variation in initial weight and irrespective of any year differences, it appeared that lincomycin alone and in combination with
diethylstilbestrol improved the growth rate during the first 112 days of feeding. However, when adjusted for variations in initial weight, the growth response to lincomycin alone appeared to diminish during the first 112 days. In all cases, except for the first 28 days when variations in initial weight were accounted for, diethylstilbestrol suppressed average daily gain up to 112 days. However, as indicated in tables 4 and 5, the growth response to diethylstilbestrol apparently improved after the first 112 days on feed.

The use of the antibiotics chlortetracycline and oxytetracycline alone and in combination with diethylstilbestrol for improving growth responses, has been conclusively shown (Perry et al., 1954; Perry et al., 1958; Beeson et al., 1957; Packett and Butcher, 1963; Dyer, Ensminger and Blue, 1957; Sherman et al., 1959). According to L. W. Davis (personal communication), steers fed lincomycin gained significantly faster (P <.01) than non-treated steers during the first 28 days, but the improvement in gain diminished with time and was not significantly different from that of the controls at 150 days. The same general effect was observed for lincomycin for the first 112 days in this study.

The decreased growth response at 56 days with and without initial weight adjustment followed by a recovery trend suggests that lincomycin might have altered the rumen
microflora between the periods of 28 and 56 days on feed, however, the heifers apparently adapted to the alteration by the 84th day. In a personal communication with M. Stob, it was pointed out that heifers treated with lincomycin went "off feed" for a few days immediately after administration of the lincomycin. However, it was further pointed out that the "off feed" condition may have been due to a change in antibiotics and not a result of lincomycin per se. The heifers had been started on an antibiotic treatment of chlortetracycline plus sulfamethazine and were abruptly switched to lincomycin. It was suggested that the rapid conversion from one antibiotic treatment to a different antibiotic treatment was the major cause of the digestive disturbance resulting in heifers going "off feed". It was also pointed out that when lincomycin was fed with liquid supplement, some heifers went "off feed", but to a lesser degree than when switched from one antibiotic treatment to another.

In this study, no feed refusal, diarrhea or symptoms of gastrointestinal disturbances were observed. However, a portion of this study was devoted to the in vitro investigation of rumen pH changes at different levels of lincomycin and with the addition of diethylstilbestrol.

The mean initial pH of all treatment groups was 6.84 with a standard error of ± 0.117. The mean pH for all
treatment groups was 5.33 with a standard error of ± 0.015. Figure 1 shows the relationship of rumen pH with increasing levels of lincomycin with and without diethylstilbestrol after 30 hr. of in vitro fermentation. Lincomycin plus diethylstilbestrol resulted in a significant (P < .05) increase in rumen pH over lincomycin alone. The effect of lincomycin was highly significant (P < .01) and there was a highly significant (P < .01) linear effect with increasing levels of lincomycin. When no lincomycin was added, the pH of the rumen contents without diethylstilbestrol was 5.18 and with diethylstilbestrol was 5.16. When 12.5 mg. of lincomycin were added/lb. feed, the pH of the rumen contents without diethylstilbestrol was 5.31 and with diethylstilbestrol was 5.38. With the addition of 22.5 mg. lincomycin/lb. feed, the pH of the rumen contents without diethylstilbestrol was 5.28 and with diethylstilbestrol was 5.39. When lincomycin was added at the rate of 42.5 mg./lb. feed, the rumen contents without diethylstilbestrol had a pH of 5.40, but the group with diethylstilbestrol had a pH of 5.52.

The highly significant (P < .01) linear effect of lincomycin indicates that as lincomycin is increased from zero to 42.5 mg./lb. feed, the rumen pH is significantly increased. The significant (P < .05) diethylstilbestrol effect points out that when diethylstilbestrol is added, pH of the rumen contents is increased. Although fiber and cellulose determine-
FIGURE 1. THE pH OF RUMEN CONTENTS AT DIFFERENT LEVELS OF LINCOMYCIN WITH AND WITHOUT DIETHYLSILBESTROL

Measurements and bacterial counts were not considered in this study, this significant alteration in pH of the rumen content suggests that the addition of lincomycin and diethylstilbestrol, separately and in combination, may inhibit the growth and multiplication of rumen microbes. Mitchell et al. (1969) reported that antibiotics altered the activity of rumen microflora and that chlortetracycline reduced the total volatile fatty acid concentration. However,
Klopfenstein, Purser and Tyznik (1964) reported an increase in rumen protozoal concentration after chlortetracycline administration. Tylosin and chlortetracycline have been shown to increase rumen protozoal counts but tylosin markedly decreased bacterial counts (Purser, Klopfenstein and Cline, 1965).

It has been shown that rumen pH is a measure of microbial activity (Purser and Moir, 1966) and that lactic acidosis may be a result of drastic alterations in rumen pH (pH 6.98 to pH 4.81) causing cattle to go "off feed" (Uhart and Carroll, 1967).

As indicated from the in vitro fermentation trial in the study, the acid content was greatest when lincomycin was not administered and the acid concentration lessened as increasing levels of lincomycin were added. Therefore, it appears unlikely that the addition of lincomycin would cause pH alterations severe enough to result in cattle going "off feed". However, since there was a highly significant (P < .01) linear effect with increasing levels of lincomycin, levels higher than 42.5 mg./lb. may have resulted in less microbial activity causing a more static rumen condition. This was observed by Gray and Lewis (1966) in rabbits fed lincomycin levels of 5.0 mg. to 150 mg./2.2 lb. body weight. It should also be pointed out that a lincomycin treated heifer died after 95 days on treatment
and post-mortem examination revealed a static rumen condition and congested lungs. However, since only one heifer in the treated group died and no others appeared sick, it was unlikely that the treatment of lincomycin was the causative agent.

According to L. W. Davis (personal communication), preliminary work in the Upjohn Laboratories revealed that treatment of lincomycin did not affect carcass characteristics. Those observations were fairly generally substantiated by this study, although some small differences did exist for treatment groups. The means and standard errors for selected measures of carcass muscling are shown in Table 11. The least squares mean for $d_1$ area was 73.12 cm$^2$ and the standard error was $0.58$ cm$^2$. There was very little difference in $d_1$ size among treatment groups and none were significantly different. The $d_1$ areas for the control, lincomycin, diethylstilbestrol, and lincomycin plus diethylstilbestrol, respectively, were 72.58 cm$^2$, 74.03 cm$^2$, 72.29 cm$^2$, and 73.58 cm$^2$. The $d_1$ area was largest for diethylstilbestrol treated heifers. This agrees with Clegg and Cole (1956) and Wilson et al. (1963) who reported a significant increase in $d_1$ area due to diethylstilbestrol treatment and Klosterman et al. (1955a, b) who reported a
Table 11. LEAST SQUARES MEANS AND STANDARD ERRORS FOR TRAITS INDICATIVE OF CARCASS MUSCLING AMONG TREATMENT GROUPS

<table>
<thead>
<tr>
<th>Traits</th>
<th>Overall</th>
<th>Control</th>
<th>Lincomycin</th>
<th>DES 1/</th>
<th>Lincomycin plus DES 1/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.E.</td>
<td>Mean</td>
<td>S.E.</td>
<td>Mean</td>
</tr>
<tr>
<td>1. dorsi area, cm²</td>
<td>73.12</td>
<td>0.58</td>
<td>72.58</td>
<td>1.37</td>
<td>72.29</td>
</tr>
<tr>
<td></td>
<td>74.03</td>
<td>1.09</td>
<td>73.58</td>
<td>1.09</td>
<td></td>
</tr>
<tr>
<td>1. dorsi area/ cwt. car., cm²</td>
<td>13.96</td>
<td>0.13</td>
<td>14.19</td>
<td>0.32</td>
<td>13.55</td>
</tr>
<tr>
<td></td>
<td>14.20</td>
<td>0.25</td>
<td>13.88</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>U.S.D.A. yield grade 2/</td>
<td>2.60</td>
<td>0.05</td>
<td>2.52</td>
<td>0.12</td>
<td>2.62</td>
</tr>
<tr>
<td></td>
<td>2.52</td>
<td>0.10</td>
<td></td>
<td></td>
<td>2.76*</td>
</tr>
<tr>
<td>Computed yield grade 3/</td>
<td>2.51</td>
<td>0.05</td>
<td>2.21</td>
<td>0.12</td>
<td>3.08</td>
</tr>
<tr>
<td></td>
<td>2.37</td>
<td>0.10</td>
<td></td>
<td></td>
<td>2.38</td>
</tr>
<tr>
<td>Calculated yield 4/</td>
<td>51.82</td>
<td>0.11</td>
<td>52.35</td>
<td>0.25</td>
<td>50.70</td>
</tr>
<tr>
<td></td>
<td>52.19</td>
<td>0.20</td>
<td></td>
<td></td>
<td>52.04</td>
</tr>
</tbody>
</table>

1/ Diethylstilbestrol
2/ Yield grade as determined by Federal Grader.
4/ Percent yield of boneless, trimmed retail cuts from round, loin, rib and chuck calculated from estimated percent kidney fat, 1. dorsi area, fat thickness and warm carcass weight.

* P < .05.
significantly larger cross-sectional l. dorsi area in heifers, but not in steers. On the other hand, O'Mary et al. (1952) and Wilkinson et al. (1955) found no significant increase in l. dorsi area due to the diethylstilbestrol treatment. The lincomycin treated heifers had slightly smaller l. dorsi areas than the control heifers while the lincomycin plus diethylstilbestrol treated heifers had cross-sectional areas slightly less than that of the heifers treated with diethylstilbestrol alone.

The same trend was observed for l. dorsi area/cwt. warm carcass. The l. dorsi area/cwt. carcass was larger for the control (14.19 cm²) and diethylstilbestrol (14.20 cm²) treated heifers while the l. dorsi area/cwt. carcass for heifers treated with lincomycin alone and the combination of lincomycin and diethylstilbestrol was smaller than the control. The overall mean numerical U.S.D.A. yield grade was 2.60. The U.S.D.A. yield grades for the control and diethylstilbestrol treated heifers were identical (2.52) and were lower than the overall mean. Heifers treated with lincomycin either alone or in combination with diethylstilbestrol had higher numerical U.S.D.A. yield grades and the combination treated heifers had a significantly higher (P < .05) U.S.D.A. yield grade than the heifers receiving diethylstilbestrol only. However, when computed from the
U.S.D.A. Beef Carcass Yield Grade Finder (U.S.Dept. of Agriculture, 1965), the computed yield grade for the combination treated heifers was lower than the controls. Moreover, when the yield in percent of boneless, trimmed retail cuts from the round, loin, rib and chuck was calculated as outlined by Murphey et al. (1960 a,b), the lincomycin plus diethylstilbestrol treated heifers were nearly the same as the controls (52.04% vs. 52.35%). The control heifers had the highest calculated yield (52.35%) and lincomycin treated heifers had the lowest calculated yield (50.70%). The diethylstilbestrol treated heifers were slightly higher in this respect than the lincomycin plus diethylstilbestrol heifers and slightly lower than the controls. This indicates some degree of discrepancy among the three methods of estimating carcass yield, however, only the U.S.D.A. yield grades of carcasses from lincomycin plus diethylstilbestrol treated heifers were significantly different from the carcasses of heifers treated with diethylstilbestrol only (P <.05). It should be pointed out that the numerical yield grade is inverse to the estimated percent yield of the carcass. Disregarding the discrepancy among these three methods, there was a highly significant (P <.01) partial correlation among all three of these estimates of carcass yield (table 16).

Table 12 shows the means and standard errors for measures
Table 12. LEAST SQUARES MEANS AND STANDARD ERRORS FOR TRAITS MEASURING CARCASS FATNESS AMONG TREATMENT GROUPS

<table>
<thead>
<tr>
<th>Traits</th>
<th>Overall Mean</th>
<th>Overall S.E.</th>
<th>Control Mean</th>
<th>Control S.E.</th>
<th>Lincomycin Mean</th>
<th>Lincomycin S.E.</th>
<th>DES 1/ Mean</th>
<th>DES 1/ S.E.</th>
<th>Lincomycin plus DES 1/ Mean</th>
<th>Lincomycin plus DES 1/ S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat thickness, cm.</td>
<td>11.98</td>
<td>0.34</td>
<td>11.13</td>
<td>0.81</td>
<td>12.50</td>
<td>0.66</td>
<td>12.09</td>
<td>0.64</td>
<td>12.23</td>
<td>0.64</td>
</tr>
<tr>
<td>Fat thickness, /cwt.</td>
<td>2.23</td>
<td>0.06</td>
<td>2.12</td>
<td>0.15</td>
<td>2.26</td>
<td>0.12</td>
<td>2.25</td>
<td>0.12</td>
<td>2.26</td>
<td>0.12</td>
</tr>
<tr>
<td>Bst. Kidney fat, %</td>
<td>1.88</td>
<td>0.06</td>
<td>1.89</td>
<td>0.14</td>
<td>2.21</td>
<td>0.11</td>
<td>1.82</td>
<td>0.11</td>
<td>1.61</td>
<td>0.11</td>
</tr>
</tbody>
</table>

1/ Diethylstilbestrol
of fatness in the carcass by treatment group. The least squares mean for all groups combined was 11.98 cm. for fat thickness and 2.23 cm. for fat thickness/cwt. carcass. As indicated from the fat thickness measurements, the control heifers had the least amount of external fat (11.13 cm.) at the 12th rib while the heifers in both groups treated with lincomycin had the greatest amount of external covering but the differences between means were not significant. The lincomycin treated heifers had 12.09 cm. fat thickness. Since carcass weights for lincomycin and lincomycin plus diethylstilbestrol treated heifers were slightly greater than those of the diethylstilbestrol treated and the control heifers (table 4), these data suggest that heifers treated with lincomycin, either alone or with diethylstilbestrol have a tendency to produce carcasses that are slightly less muscular and slightly more wasty as indicated by measures of muscle composition (l. dorsi area, l. dorsi area/cwt. carcass and estimates of carcass yield) and external fatness (fat thickness and fat thickness/cwt. carcass) irrespective of any year effects.

Nevertheless, the estimated percent kidney fat was less for heifers treated with diethylstilbestrol alone or with lincomycin (table 12) but the difference within their comparison groups was not significant (P < .05). The overall estimated kidney fat was 1.88% of carcass weight. The
estimated kidney fat for control heifers was 1.89%, for diethylstilbestrol treated heifers 1.82%, for lincomycin treated heifers 2.21%, and for the heifers that received the lincomycin plus diethylstilbestrol 1.61%. The relatively sizable difference between lincomycin and lincomycin plus diethylstilbestrol is not readily explained because of the similarities in the amount of external fat for the two treatments, but is perhaps due to experimental error or year effect.

The means and standard errors for carcass quality factors by treatment group are shown in table 13. As with the measures of carcass composition (tables 11 and 12), there were only small differences among treatment groups for carcass quality traits. All groups except that which received the diethylstilbestrol treatment had carcass quality grades of low choice (12.00) or above. The lower carcass grade (11.42) for diethylstilbestrol treated heifers was expected since diethylstilbestrol has been conclusively shown to decrease carcass quality grade (Clegg and Cole, 1954; Clegg and Carroll, 1957; Andrews, Beeson and Johnson, 1954). The quality grade was slightly higher for the control heifers but was not significantly different from those treated with lincomycin alone. The higher quality grade for the control heifers was reflective of the higher marbling score, however, it should be pointed out that the control heifers had a lower carcass
Table 13. LEAST SQUARES MEANS AND STANDARD ERRORS FOR CARCASS QUALITY TRAITS AMONG TREATMENT GROUPS

<table>
<thead>
<tr>
<th>Traits</th>
<th>Overall</th>
<th>Control</th>
<th>Lincomycin</th>
<th>DES 1/</th>
<th>DES 1/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean  S.E.</td>
<td>Mean  S.E.</td>
<td>Mean  S.E.</td>
<td>Mean  S.E.</td>
<td>Mean  S.E.</td>
</tr>
<tr>
<td>Quality grade 2/</td>
<td>12.12  0.14</td>
<td>12.52  0.33</td>
<td>12.46  0.26</td>
<td>11.42  0.26</td>
<td>12.09  0.26</td>
</tr>
<tr>
<td>Conformation grade 2/</td>
<td>11.86  0.13</td>
<td>11.90  0.30</td>
<td>12.16  0.25</td>
<td>11.30  0.24</td>
<td>12.08  0.24</td>
</tr>
<tr>
<td>Marbling 3/</td>
<td>5.39  0.11</td>
<td>5.62  0.25</td>
<td>5.60  0.21</td>
<td>5.35  0.20</td>
<td>4.99  0.20</td>
</tr>
<tr>
<td>Texture of marbling 4/</td>
<td>1.68  0.08</td>
<td>1.32  0.20</td>
<td>1.46  0.16</td>
<td>1.99  0.16</td>
<td>1.92  0.16</td>
</tr>
<tr>
<td>Firmness of lean 5/</td>
<td>2.36  0.07</td>
<td>2.09  0.18</td>
<td>2.18  0.14</td>
<td>2.71*  0.14</td>
<td>2.44  0.14</td>
</tr>
<tr>
<td>Texture of lean 6/</td>
<td>2.63  0.13</td>
<td>2.11  0.31</td>
<td>2.30  0.25</td>
<td>3.27*  0.24</td>
<td>2.84  0.24</td>
</tr>
<tr>
<td>Color of lean 7/</td>
<td>2.20  0.10</td>
<td>1.72  0.24</td>
<td>2.49  0.20</td>
<td>2.49  0.19</td>
<td>2.09  0.19</td>
</tr>
</tbody>
</table>

1/ Diethylstilbestrol
2/ 11.00 = high good; 12.00 = low choice
3/ 4.00 = slight; 5.00 = small; 6.00 = modest
4/ 1.00 = fine; 2.00 = medium; 3.00 = coarse
5/ 1.00 = very fine; 6.00 = very soft
6/ 1.00 = very fine; 6.00 = coarse
7/ 1.00 = very light cherry red; 6.00 = very dark red
* P < .10.
conformation grade than either lincomycin or lincomycin plus diethylstilbestrol treated heifers which had the higher conformation grades and nearly the same marbling score as the controls. Since the marbling score is of primary consideration in determining quality grade and lesser emphasis is placed on conformation grade, carcasses from the lincomycin treated heifers had only a slightly lower quality grade (12.46) than those of the control heifers (12.52).

Carcasses from lincomycin plus diethylstilbestrol treated heifers had the least amount of marbling (4.90) of any group, although it was not significantly less than those treated with diethylstilbestrol alone. Considering the fact that the combination treatment and treatment of lincomycin separately resulted in the largest amount of external covering and the combination treatment heifers had the least amount of estimated kidney fat (table 12) and the least amount of marbling (table 13), it might be suggested that when lincomycin is fed with diethylstilbestrol, there is a tendency for the carcasses to deposit fat externally rather than intramuscularly or internally.

The means for texture of marbling for treatment groups were not significantly different. While the texture of the marbling for all groups was medium to fine, the groups with the lesser amounts of marbling, i.e. diethylstilbestrol and lincomycin plus diethylstilbestrol, also had marbling with
less fine texture than the other two groups.

The lean of the 1. dorsi cross-section for diethylstilbestrol treated heifers tended (P < .10) to be less firm and less finely textured than either the control or the lincomycin treated heifers. The lincomycin plus diethylstilbestrol treated heifers approached the firmness and texture of the heifers treated with diethylstilbestrol separately, but were not significantly different. This may be due to the effect of diethylstilbestrol upon firmness and texture of lean. The control heifers had the firmest and finest textured lean. The color of lean was the least desirable and darkest for heifers treated with lincomycin and diethylstilbestrol separately (2.49 for both groups). The light color of the lean for the control heifers might have been a reflection of the amount of marbling present, however, this was not true for lincomycin plus diethylstilbestrol treated heifers. The latter group had the least amount of marbling, but had a lighter muscle color than the diethylstilbestrol or lincomycin treated heifers. There were no dark cutting carcasses in any group.

With the exception of the effect of diethylstilbestrol on firmness and texture of the exposed cross-sectional surface of the 1. dorsi, it appears that lincomycin, diethylstilbestrol, and the combination of the two treatments had little effect on the carcass quality factors in this study.
Partial correlation coefficients between measures of carcass composition and final feedlot weight, average daily gain and carcass weight are shown in table 14. As was expected, when initial weight was held constant, final feedlot weight was highly significantly ($P < .01$) correlated with carcass weight and when carcass weight was held constant, final feedlot weight was highly associated ($P < .01$) with carcass weight and average daily gain. When the variation in initial weight was removed, final feedlot weight was significantly correlated ($P < .05$) with methods of estimating carcass yield, i.e. U.S.D.A. yield grade, computed yield grade and calculated percent yield, and was highly significantly correlated ($P < .01$) with l. dorsi area and l. dorsi area/cwt. carcass. When adjustment was made for the variation in initial weight, final feedlot weight was not significantly related to measures of fatness.

When the variation in initial weight was considered but the variation in carcass weight adjusted, final feedlot weight was significantly ($P < .05$) negatively correlated with conformation grade, fat thickness and fat thickness/cwt. carcass. There was a non-significant negative correlation between final feedlot weight and the two yield grades (U.S.D.A. yield grade and computed yield grade) and a significant ($P < .05$) positive correlation with calculated percent yield. It should again be pointed out that the
Table 14. PARTIAL CORRELATION COEFFICIENTS BETWEEN MEASURES OF CARCASS COMPOSITION AND FINAL FEEDLOT WEIGHT, AVERAGE DAILY GAIN AND CARCASS WEIGHT 1/

<table>
<thead>
<tr>
<th>Items</th>
<th>Covariant</th>
<th>Measures of carcass composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final feedlot wt.</td>
<td>Initial 0.74** 0.99** 0.10 0.22* 0.22* -0.22* 0.27* -0.45** 0.10 -0.12 0.12</td>
<td></td>
</tr>
<tr>
<td>Carcass wt.</td>
<td>Carcass ---- 0.66** -0.25* -0.17 -0.17 0.21* 0.07 0.10 -0.21* -0.20* -0.12</td>
<td></td>
</tr>
<tr>
<td>Average daily wt. gain</td>
<td>Carcass ---- -0.23* -0.09 -0.11 0.13 -0.06 -0.04 -0.21* -0.19 -0.10</td>
<td></td>
</tr>
<tr>
<td>Carcass wt.</td>
<td>Initial ---- 0.36** 0.42** 0.43** -0.45** 0.35** -0.64** 0.33** 0.03 0.27**</td>
<td></td>
</tr>
</tbody>
</table>

1/ Computed within treatment, year and replication subclasses.

* P < .05.

** P < .01.
yield grades are numerically inverse of the yield of the carcass.

Because of the very high relationship between final feedlot weight and average daily gain ($r_{12.3} = 0.99$), similar degrees of relationship and levels of significance were found for average daily gain and the measures of carcass composition as were found for final feedlot weight.

When initial weight was held constant, carcass weight was highly significantly correlated ($P < .01$) with every measure of carcass composition except fat thickness/cwt. carcass. This high degree of relationship is expected because carcass weight is a consideration for arriving at the measures of carcass composition except for conformation grade, $L_{dorsi}$ area and fat thickness. Assuming that $L_{dorsi}$ area and fat thickness are reliable indicators of carcass composition, it seems reasonable that variations in these two factors would be related to carcass weight.

Except for carcass grade, the partial correlation coefficients between measures of carcass quality and final feedlot weight, average daily gain and carcass weight were low and non-significant (table 15). Final feedlot weight and average daily gain were significantly ($P < .05$) negatively correlated with carcass grade when carcass weight was adjusted. When initial weight was adjusted, carcass weight was significantly ($P < .05$) correlated with carcass
grade.

All possible partial correlation coefficients among carcass traits adjusted for carcass weight are shown in table 16. There appeared to be little association between the measures of carcass composition and the aforementioned measures of carcass quality. However, conformation grade was highly significantly correlated ($P < .01$) with carcass grade and marbling score and was significantly ($P < .05$) correlated with color of lean. The relationship between conformation grade and texture of marbling approached significance. Since conformation grade is a factor considered in determining carcass grade, the high relationship between these two variables is expected. Also as expected, fat thickness was highly correlated ($P < .01$) with carcass grade.

With few exceptions, there appeared to be a high degree of relationship among the measures of carcass composition. Conformation grade was highly significantly ($P < .01$) related to $1. dorsi$ area, $1. dorsi$ area/cwt. carcass, fat thickness and fat thickness/cwt. carcass. The U.S.D.A. yield grade was positively and highly significantly ($P < .01$) associated with the computed yield grade and both measures of fat thickness. The U.S.D.A. yield grade was negatively and highly significantly ($P < .01$) correlated with calculated percent yield and both measures of $1. dorsi$ area. The high degrees of association among these variables suggest that the
Table 15. PARTIAL CORRELATION COEFFICIENTS BETWEEN MEASURES OF CARCASS QUALITY AND FINAL FEEDLOT WEIGHT, AVERAGE DAILY GAIN AND CARCASS WEIGHT 1/

<table>
<thead>
<tr>
<th>Items</th>
<th>Covariant</th>
<th>Measures of carcass quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Carcass grade</td>
</tr>
<tr>
<td>Final feedlot wt.</td>
<td>Initial wt.</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Carcass wt.</td>
<td>-0.23*</td>
</tr>
<tr>
<td>Average daily gain</td>
<td>Initial wt.</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Carcass wt.</td>
<td>-0.22*</td>
</tr>
<tr>
<td>Carcass wt.</td>
<td>Initial wt.</td>
<td>0.25*</td>
</tr>
</tbody>
</table>

1/ Computed within treatment, year and replication subclasses.
* P < .05.
Federal grader was conscientiously evaluating the carcasses for cutability.

There was a highly significant ($P < .01$) association between measures of carcass composition and computed yield grade as well as calculated percent yield except for the correlation between calculated percent yield and estimated percent of kidney fat. There was essentially no correlation between both measures of $l.$ dorsi area and both measures of fat thickness.

Carcass grade was highly significantly ($P < .01$) related to marbling score, as expected, and negatively ($P < .01$) associated with firmness and color of lean. The latter association suggests that coarser, darker lean tends to lower carcass grade. Since there was little relationship between carcass grade and texture of marbling and lean, apparently the texture within the $l.$ dorsi cross-sectional area did not influence carcass grade. Marbling score was somewhat, but non-significantly, related to texture of marbling, and firmness, texture and color of lean. Except for the correlation between texture of marbling and color of lean which approached significance, there were highly significant ($P < .01$) relationships among texture of marbling, and firmness, texture and color of lean.

With few exceptions, the correlations among measures of carcass merit are in accord with those reported in the literature (Hedrick, 1968; Bray, 1963).
<table>
<thead>
<tr>
<th>Carcass traits</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Conf. grade</td>
<td>0.01</td>
<td>0.06</td>
<td>-0.11</td>
<td>0.26**</td>
<td>0.25*</td>
<td>0.34**</td>
<td>0.32**</td>
<td>-0.07</td>
<td>0.69**</td>
<td>0.43**</td>
<td>0.19</td>
<td>-0.05</td>
<td>0.05</td>
<td>-0.21*</td>
</tr>
<tr>
<td>2 U.S.D.A. yld. gr. 2/</td>
<td>0.59**</td>
<td>-0.64**</td>
<td>-0.40**</td>
<td>-0.40**</td>
<td>0.50**</td>
<td>0.50**</td>
<td>0.19</td>
<td>0.09</td>
<td>0.01</td>
<td>0.03</td>
<td>-0.01</td>
<td>0.02</td>
<td>-0.02</td>
<td></td>
</tr>
<tr>
<td>3 Computed yld. gr. 3/</td>
<td>-0.93**</td>
<td>-0.56**</td>
<td>-0.54**</td>
<td>0.74**</td>
<td>0.74**</td>
<td>0.35**</td>
<td>0.09</td>
<td>0.01</td>
<td>0.03</td>
<td>-0.01</td>
<td>0.02</td>
<td>-0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Calculated % yield</td>
<td>0.62**</td>
<td>0.62**</td>
<td>-0.78**</td>
<td>-0.78**</td>
<td>-0.14</td>
<td>0.17</td>
<td>-0.07</td>
<td>-0.10</td>
<td>-0.02</td>
<td>-0.01</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 l. dorsi area</td>
<td>0.98**</td>
<td>0.00</td>
<td>-0.02</td>
<td>0.00</td>
<td>0.12</td>
<td>0.04</td>
<td>0.08</td>
<td>0.05</td>
<td>-0.09</td>
<td>-0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 l. dorsi area/ cwt. car.</td>
<td>0.00</td>
<td>-0.02</td>
<td>0.01</td>
<td>0.12</td>
<td>0.05</td>
<td>0.12</td>
<td>0.08</td>
<td>-0.07</td>
<td>-0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Fat thickness</td>
<td>0.99**</td>
<td>0.17</td>
<td>0.31**</td>
<td>0.13</td>
<td>0.18</td>
<td>0.06</td>
<td>-0.07</td>
<td>-0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Fat thickness/ cwt. car.</td>
<td>0.18</td>
<td>0.31**</td>
<td>0.13</td>
<td>0.17</td>
<td>0.06</td>
<td>-0.08</td>
<td>-0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Est. % kidney fat</td>
<td>0.10</td>
<td>0.15</td>
<td>-0.07</td>
<td>-0.19</td>
<td>-0.06</td>
<td>-0.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Carcass grade</td>
<td>0.67**</td>
<td>-0.05</td>
<td>-0.30**</td>
<td>-0.03</td>
<td>-0.37**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 Marbling score</td>
<td>0.04</td>
<td>-0.16</td>
<td>0.10</td>
<td>-0.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 Texture of marbling</td>
<td>0.51**</td>
<td>0.47**</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 Firmness of lean</td>
<td>0.41</td>
<td>0.29**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 Texture of lean</td>
<td>0.47**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Color of lean</td>
<td>0.47**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

* P < .05.  **P < .01.  **P < .01.  
1/ Computed within treatment, year and replication subclasses.  
2/ Grade determined by Federal grader.  
The presence of liver abscesses in cattle has been conclusively shown to suppress feedlot performance (Wise et al., 1968; Powell, Durham and Gann, 1968). Table 17 shows the incidence of liver parasitism and liver condemnation by treatment groups. Some degree of parasitism was observed in 13.3% of the heifers treated with lincomycin plus diethylstilbestrol, 24.1% of the heifers treated with lincomycin and 27.6% of the control heifers. However, parasitism was observed in nearly half (43.3%) of the heifers treated with diethylstilbestrol.

Table 17. PERCENT OF HEIFERS IN TREATMENT GROUPS WITH SOME DEGREE OF LIVER PARASITISM AND LIVER CONDEMNATION

<table>
<thead>
<tr>
<th>Treatment groups</th>
<th>Control</th>
<th>Lincomycin</th>
<th>DES 1/ plus DES 1/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
<td></td>
<td>Lincomycin plus DES 1/</td>
<td></td>
</tr>
<tr>
<td>Number of heifers</td>
<td>29</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>Liver parasitism,%</td>
<td>27.6</td>
<td>24.1</td>
<td>43.3</td>
</tr>
<tr>
<td>Liver condemnation,%</td>
<td>3.5</td>
<td>0.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Diethylstilbestrol

The number of condemned livers was extremely low in all groups except that group treated with diethylstilbestrol. For heifers treated with only lincomycin, there were no livers condemned. There were 3.3% of the livers condemned in the lincomycin plus diethylstilbestrol treated heifers.
and 3.5% condemned in the control heifers. However, apparently due to the high incidence of liver parasitism, there were 20.0% of the livers condemned in the diethylstilbestrol treated heifers.

It was evident that under conditions present in this study, the treatment of diethylstilbestrol without the presence of the antibiotic lincomycin, resulted in an increased susceptibility of the liver to parasites. Only a small amount of work is found concerning the effect of diethylstilbestrol on liver tissue. Voelker and Dracy (1956) demonstrated that diethylstilbestrol had no effect on the size or weight of the liver in cattle. However, Wilkinson et al. (1954) reported an increase in liver size, but no change in the glycogen content.

Ten hepatic tissue slides were selected at random from each of the treatment groups for a detailed study. With the assistance of M. Y. Andres (Professor of Veterinary Anatomy, The Ohio State University, Columbus, Ohio) and M. W. Glenn (Pathologist, Upjohn Co., Kalamazoo, Michigan), there were some observations made of the hepatic tissues which were found in all treatment groups and were not necessarily an effect of treatments. There appeared to be an increase in sinusoidal spaces and a decrease in hepatic cord cell size in localized areas of all treatment groups.
This observation was found near the hepatic trinity and away from the central vein of the lobules. There appeared to be some perivascular leakage of proteinaceous materials into the extracellular spaces and an increase in cord cell size accompanied by a crowding of cord cells near the central vein. These observations may have been due to (1) phagocytosis of tissues other than the liver proper, (2) increased blood supply in the portal system or (3) the tissue fixation process.

The hepatic cells adjacent to Glisson's capsules contained larger numbers of vacuoles than the deeper hepatic cells. The presence of larger vacuoles in this area of the liver was indicative of glycogen storage and was expected in cattle with adequate nutrition. Within the deeper cells, the presence of glycogen vacuoles did not appear to vary appreciably among the treatment groups and there was no evidence of alterations in nuclear structure among treatment groups.

There was a mild degree of cholangitis present in tissues of all treatment groups. This was characterized by small bile ducts with inflammed cells infiltrating the periductal tissues.

Since the aforementioned conditions were observed in tissues of all treatment groups, it appears unlikely that lincomycin, diethylstilbestrol or the combination of
lincomycin and diethylstilbestrol caused any significant alterations in structure or function of hepatic tissues.
SUMMARY

One hundred and twenty beef heifers were allotted by weight stratification to 8 lots of 15 heifers each and placed on a basal ration of corn silage ad libitum, 1.0% body wt. of ground shelled corn and 2.00 lb. supplement containing 32% crude protein/head daily. Treatments of 45 mg. lincomycin/head daily, 10 mg. diethylstilbestrol/head daily and a combination of 45 mg. lincomycin and 10 mg. diethylstilbestrol/head daily were each fed to two replicated lots. Two replicated lots received no antibiotic or hormone treatment and served as non-treated controls. The data were analyzed by the least-squares analysis of covariance method. The study was conducted over a two-year period with treatment of diethylstilbestrol for one year only. The comparisons made were (1) lincomycin and no lincomycin (2) diethylstilbestrol and lincomycin with diethylstilbestrol and (3) the two aforementioned comparisons with any true year effect.

The mean initial weight of the heifers was 438 lb. but there was a large amount of variation in initial weight. Therefore, the data relative to efficiency and rate of
growth were analyzed with initial weight as a covariant, except for one of the analyses for the rate of growth during the first 112 days of the trial. Lincomycin alone improved the growth rate 4.3% during the first 28 days but diethylstilbestrol alone depressed the growth rate 3.9% during the same period when adjustment for variation in initial weight was not considered. The addition of lincomycin to treatments of diethylstilbestrol appeared to produce an added response to growth and improved the rate of growth 8.2% over the non-treated control heifers irrespective of any true year effect. When adjustment was made for initial weight, lincomycin treated heifers showed a considerable improvement (52.2%) in growth rate over the non-treated control heifers during the first 28 days, but it was not statistically significant at the 5% level. The growth rate improvement for the same period for heifers treated with diethylstilbestrol and lincomycin plus diethylstilbestrol, respectively, was 18.6% and 33.6%. Similar trends occurred at 56, 84 and 112 days, however, the efficacy of lincomycin alone diminished with time, but the response to the combination improved ($P < .10$) with time.

The average daily gain for the entire trial (274 days) for the non-treated group was 1.57 lb., for the lincomycin group 1.63 lb., for the diethylstilbestrol group 1.64 lb., and for the lincomycin with diethylstilbestrol group 1.85 lb.
Diethylstilbestrol treated heifers had an increased average daily gain (P < .10) over those not treated with diethylstilbestrol. When lincomycin was fed with diethylstilbestrol, there was an additional growth response (P < .10). Feed conversion was improved 7.3% by lincomycin, 9.3% by diethylstilbestrol and 17.1% by the combination, but the differences were not significant. The same trend existed for cost/unit gain which suggests a synergistic effect of the combination of lincomycin and diethylstilbestrol on rate and cost/unit of growth.

The treatments of lincomycin, diethylstilbestrol or the combination of the two did not significantly affect the size of L. dorsi or the calculated yield in percent of boneless, trimmed retail cuts. However, the combination treatment resulted in a significantly (P < .05) higher U.S.D.A. yield grade than did diethylstilbestrol alone. Carcass quality and conformation grades, marbling score, texture of marbling and color of lean were not significantly affected by treatment. However, the lean in the L. dorsi cross-section of diethylstilbestrol treated heifers tended (P < .10) to be softer and coarser than the lean of heifers treated with the combination of lincomycin and diethylstilbestrol, although there was no significant difference for this trait between lincomycin treated and non-treated control heifers.

Average daily gain was highly significantly correlated
(P < .01) with 1. dorsi area and significantly related (P < .05) to calculated yield. There was a highly significant association (P < .01) among measures of carcass yield, 1. dorsi area and fat thickness.

After 30 hr. of in vitro fermentation, the pH of rumen contents was significantly (P < .05) higher when diethylstilbestrol or lincomycin were added to the ration. There was a highly significant (P < .01) linear effect on rumen pH when the lincomycin concentration was increased from zero to 42.5 mg./lb. feed.

Liver parasitism was found in 13.3% of the heifers treated with the combination of lincomycin and diethylstilbestrol, 24.1% of the heifers treated with only lincomycin and 27.6% of the non-treated control heifers. Parasitism was observed in nearly half (43.3%) of the heifers treated with diethylstilbestrol only. There were no livers condemned in the lincomycin group. There were 3.3% and 3.5% of the heifers which had livers condemned for the lincomycin and diethylstilbestrol combination treatment group and control group, respectively. The group treated with diethylstilbestrol alone had a 20.0% liver condemnation rate.

This study indicates that lincomycin, when fed separately or in combination with diethylstilbestrol does increase the rate of growth in early stages of the feeding period while diethylstilbestrol alone suppressed early growth,
although these effects were not significantly different at the 5% level. Lincomycin, diethylstilbestrol and their combination increased growth rate for the entire length of the feeding period (P < .10) but these treatments did not appreciably affect the efficiency or composition of growth. Lincomycin and diethylstilbestrol alone or in combination significantly reduced the in vitro acid concentration of the rumen contents. Lincomycin was effective for preventing liver abscesses, however a relatively low incidence of liver abscesses was found in all treatment groups, except those receiving diethylstilbestrol only. Lincomycin, diethylstilbestrol and their combination did not significantly influence the structure of hepatic tissue cells.
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