THE USE OF ANTIBIOTICS IN BEEF PRODUCTION

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The use of antibiotics in beef production

A thesis

by

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DECLARATION

I declare that this thesis is my own composition and that it is a record of work carried out by myself on an original line of research. All sources of information are indicated in the text and listed in the references and all help received from others is indicated in the acknowledgements. None of the work recorded has been presented in any previous application for a degree.

The experiment reported in section 4 of this thesis has been the subject of a publication in a scientific journal (Wieser, M.F., Preston, T.R., Macdearmid, A. and Rowland, A.C., 1966. Intensive beef production. 8. The effect of chlortetracycline on growth, feed utilization and incidence of liver abscesses in barley-beef cattle. Animal Production 8 : 411-423). A reprint of this publication is included in the appendix.

(Martin F. Wieser)

Contents

1. Summary

In the first section of this thesis, literature is reviewed on low-level feeding of antibiotics to ruminants, on incidence of liver abscesses and rumen lesions in cattle fed high-cereal diets, on possible modes of action of antibiotics in enhancing animal growth and on public health aspects of the use of antibiotics in animal feeds.

In a second section two experiments are described which had the object of investigating possible modes of action of oxytetracycline and bacitracin. These experiments involved 18 calves fed a barley-beef diet and weighing on average 130 kg in expt. 1 and 162 kg in expt. 2. Neither oxytetracycline nor bacitracin influenced dry-matter digestibility, apparent nitrogen digestibility, nitrogen retention, concentration of volatile fatty acids in the rumen or rumen pH. Oxytetracycline significantly increased rumen ammonia and blood urea content, but bacitracin had no such effect. In expt. 1 blood glucose levels were not influenced by the feeding of either antibiotic, in expt. 2 calves on both experimental diets showed a tendency for a greater increase in blood glucose content during the interval from 2 to 10 hrs. after feeding time.

A third section reports an experiment, which was conducted on 14 commercial barley-beef units in Scotland, using a total of 339 early-weaned Friesian male calves. On each unit the trial batch of calves was divided into two groups, which were then allocated to a control diet (85 % barley + 15 % protein supplement) or the same diet supplemented with 20 mg chlortetracycline per kg of feed. The experiment was conducted over the live-weight range

115 to 360 kg. The chlortetracycline significantly ($P<0.01$) improved live-weight gain (+ 4.9 %) and feed utilization (+ 4.8 %). This overall effect was largely due to a high response during the first 12 weeks. From 13 to 28 weeks the chlortetracycline had only a marginal effect, which was not significant. There was no significant difference in the feed intakes of the two groups. There was a significant ($P<0.01$) negative correlation between the effect of the chlortetracycline on live-weight gain at each unit and the growth rate of the control animals at that unit; the response was greatest on farms with poor hygiene. The animals given chlortetracycline showed a significantly ($P<0.05$) lower incidence of liver abscesses (11.8 %) than the controls (28.2 %). Macroscopic examination of the rumen showed that rumenitis is common among intensively fed cattle, but no correlation could be found between incidence of liver abscesses and rumen lesions.

2. Introduction

Genetic potential, environment and type of ration are the three main factors which control the performance of a beef animal. Attempts to improve the efficiency of beef production are therefore directed to create optimal environmental and nutritional conditions in order to allow the animal to exploit its genetic potential as fully as possible. On traditional diets such as roughages, the performance is primarily limited by the energy intake because of the low energy concentration of the ration. On intensive systems on the other hand, when high energy diets are used, this problem can be largely overcome. Hygiene becomes more important, however, since these animals generally live close together and are almost always confined to the same building during their lifetime. Insufficient attention to environmental conditions (e.g. temperature, ventilation) can predispose the animals to diseases and their close proximity facilitates the exchange of pathogens. Several authors (e.g. Johannson, 1956; Taylor, 1957; Coates et al., 1952) have indicated that subclinical disease is more common than is often realised and that it might indeed be the normal state of health in many animal species in intensive units. The symptoms of these subclinical diseases are not always noticeable and in most instances their presence is manifested indirectly by delayed growth and poorer feed utilization. It was in the poultry industry that the first efforts were made to reverse these depressing effects by the low-level administration of antibiotics and from the experiments carried out in the last 15 years it has become evident that certain antibiotics can act as growth promotors in poultry, pigs and young calves (see reviews : by White-Stevens, 1957; Coates, 1962; Braude, Wallace and Cunha, 1953; Lucas, 1957;

Robinson, 1962; Lassiter, 1955; Preston, 1962).

American results (Adams et al., 1955; Flint and Jensen, 1958; Kolari et al., 1960; Heinemann and Fanelli, 1963) indicated that the low-level feeding of antibiotics could also improve the performance of older ruminants. In addition the animals fed antibiotics seemed to show a significantly lower incidence of liver abscesses (Matushima, Dove and Adams, 1954; Bohmann, Wade and Hunter, 1957; Flint and Jensen, 1958).

The purpose of the present study was to evaluate low-level feeding of antibiotics for barley-beef animals (Preston, 1963) from about 3 months of age to slaughter.

3. Review of literature

31. Low-level feeding of antibiotics to ruminants

311. General

The addition of antibiotics to the feed of young animals has today become an established practice. Kampelmacher (1962), who conducted a survey on the non-medical use of antibiotics in various countries for the World Health Organization, mentions e.g. that in the U.S.A. approx. 99 % of all poultry, 90 % of all pigs and 30 % of all beef cattle receive feeds containing antibiotics. Although the U.S.A. is the country where there is the most extensive use of antibiotics in animal feeds, this method of growth promotion is also commonly used in the animal husbandry of most European countries.

Chlortetracycline, oxytetracycline and penicillin are the most widely used antibiotics but others like bacitracin, oleandomycin, tylosin, erythromycin and hygromycin are also being tested or already in use. "Low-level feeding" of antibiotics means the addition to the diet of about 5 to 50 ppm of an antibiotic. The most commonly used level is approx. 10 to 20 ppm. This dosage is about 50 to 100 times smaller than the levels normally used for therapeutic purposes.

The dependance of ruminants upon the microbial fermentation in their rumen first led people to doubt whether the same growth-promoting effect observed in poultry and swine could also be achieved in the bovine. This doubt is still reflected in the

legislation of many countries which forbid the use of antibiotics in rations for ruminants. The experimental evidence on the effect of antibiotic supplementation in feeds for calves and older ruminants is reviewed in the following.

312. Low-level feeding of antibiotics to young calves

The most extensive review on the earlier work on the feeding of antibiotics to calves was done by Lassiter (1955). According to this author, the following effects can be expected as a consequence of this supplementation :

1. an increase in growth-rate ranging from 10 to 30 %
2. an improvement in the efficiency of feed utilization
3. an increase in feed consumption
4. a reduction in the incidence of scours and generally an improvement in the condition and the well-being of the calf.

The same author also states that the antibiotic supplementation is only justified for calves of up to 16 weeks of age and that most of the growth improvement takes place before the calf is 8 weeks old.

Later work has largely confirmed these findings. Preston (1962) in a review of the more recent literature comes to similar conclusions. Both above mentioned authors agree that the most consistent growth improvement in calves is achieved by the addition of either chlortetracycline or oxytetracycline. Preston also mentions that a combination of different antibiotics is no more effective than a single antibiotic and that the oral administration gives the best results. As to the level of supplementation, Lassiter recommends levels of 15 to 20 mg/100 lb body-weight,

Preston, levels of 0.2 to 1.0 mg/kg body-weight (approx. 9 to 45 mg/100 lb body-weight) or approx. 20 to 100 ppm in the diet.

Preston (1962) queries the claims of several authors that growth promotion from antibiotics is confined only to the early weeks of life i.e. to the period when the calves are still in the pre-ruminant state. He tries to classify the various experiments according to the physiological status of the calves involved i.e. whether the calves were still in the neonatal state with only one functional stomach department (abomasum), or whether they were already in the transitional state of becoming functional ruminants. His study reveals that in most experiments the calves were offered hay and concentrates already in the first 4 weeks of life and that hence their rumen was already becoming an important site of digestion and absorption. Preston (1962) also cites experiments carried out at the Rowett Research Institute (Preston, Macleod and Dinda, 1959) with calves that were weaned at 3 weeks of age. In these experiments the inclusion of an antibiotic in the concentrates produced a significant growth promotion both during and after the liquid feeding period.

313. Low-level feeding of antibiotics to beef and dairy cattle

According to a report of the World Health Organization (WHO, 1963) the United States, Canada and Denmark are the only countries which permit the addition of antibiotics to the feed of older ruminants. Most of the work on the effects of antibiotic feeding to beef and dairy cattle was carried out in the United States.

Beef cattle. Most American experiments were done with feedlot cattle of 600 to 800 lb starting live-weight and lasted over a

period of 3 to 4 months. Chlortetracycline (Perry et al., 1954; Hentges et al., 1955; Bohmann, Wade and Hunter, 1957; Chapman et al., 1957; Barrick et al., 1961; Heinemann and Fanelli, 1963) and oxytetracycline (Adams et al., 1955; Dyer, Ensinger and Blue, 1957; Sherman et al., 1959; Kolari et al., 1960) were the only two antibiotics used in these trials with beef animals and were fed at levels ranging between 70 and 100 mg per animal daily. During the first week on the new diet some animals receiving the experimental diet showed a depressed appetite but rapidly regained normal appetite after a few days (e.g. Perry et al., 1954). The effects of chlortetracycline and oxytetracycline on liveweight gain and feed efficiency were very similar. According to Adams et al. (1955), Dyer, Ensinger and Blue (1957) and Sherman et al. (1959) the addition of oxytetracycline significantly enhanced growth and feed efficiency. In a trial reported by Kolari et al. (1960) only the effect on feed efficiency was significant. Perry et al. (1954) and Heinemann and Fanelli (1963) found chlortetracycline to improve significantly both growth and feed efficiency. A similar positive, but not significant effect of chlortetracycline was also observed by Hentges et al. (1955), Bohmann, Wade and Hunter (1957) and Barrick et al. (1961). The only negative effect of chlortetracycline was recorded by Chapman et al. (1957) who reported that the feeding of chlortetracycline depressed growth of steers on pasture.

Dairy cattle. The results of the supplementation of dairy feeds with an antibiotic are more variable. Both Boyd et al. (1960) and Polan et al. (1960) were unable to find any positive effect of the addition of chlortetracycline to the diet either on milk yield or on milk composition. In these studies cows receiving chlortetracycline also showed no obviously improved resistance to mastitis, foot rot or other bacterial disturbances.

Brown and Lassiter (1960) on the other hand reported on experiments involving approx. 1000 cows where the average increase in milk production, due to the addition of chlortetracycline to the diet (0.1 mg CTC/liter milk produced per day), amounted to 0.82 lb milk/day per animal. In these experiments cows receiving chlortetracycline had some trouble with bloat but this was soon overcome.

Similar positive effects are also reported by Shor, Drain and Lamm (1962) in a review of 14 experiments carried out by themselves and a further 33 experiments of the Michigan Institute. In 68 % of the herds involved, the cows on the experimental diet responded positively to the addition of chlortetracycline (0.1 mg CTC/lb body-weight). The average increase in daily milk yield (all experiments) was 0.6 lb milk per day.

To summarize then it seems that the positive effect of low-level antibiotic feeding is not restricted to young calves but that the performance of older ruminants can also be improved. This improvement seems to be more consistent in beef animals but there is evidence that in some instances dairy cattle will also respond positively to antibiotic supplementation.

32. Mode of action

Many authors (Lassiter, 1955; Freerksen, 1956; Johannson, 1956; Taylor, 1957; François, 1961; Preston, 1962) have reviewed and discussed the evidence regarding the possible mode of action in enhancing animal growth. Today, however, the mechanism by which antibiotics bring about their beneficial effect is not yet fully understood. It seems that this effect cannot be explained by one

single mode of action and that the mode of action may also vary depending on the species and the age of the animal concerned. In the following, an attempt is made to discuss briefly some theories on the mode of action that have been put forward by several authors to be the most feasible ones.

Several authors (Freerksen, 1956; Taylor, 1957; François, 1961) agree in their conclusion that the growth promoting effect of antibiotics is mainly due to a removal or a suppression of growth depressing agents rather than to a direct anabolic influence on the metabolism, as is the case with most growth stimulating hormones. Although a direct influence of the antibiotics on the thyroid gland (Calsenick, Harris and Jones, 1954), certain enzyme systems and the adrenal cortex (Schole, 1953; Brüggemann und Schole, 1959) has been suggested, conclusive evidence to prove a true causal relationship between growth effect and changes in the endocrine system has not been forthcoming (Taylor, 1957).

Most authors also agree that the growth promoting properties of the antibiotics are directly related to their common ability to influence bacterial growth. Experiments with inactivated chlortetracycline (i.e. without antibacterial activity) showed that this substance had lost its growth promoting effect (Taylor, 1957). Studies on "germ-free" life, i.e. of animals living in a sterile environment, have also produced information on the dependence of growth promotion upon the antibacterial activity of the antibiotics. Piglets and chicks reared in a sterile environment showed no growth response to chlortetracycline (Coates and Porter, 1955; Whitehair and Johnson, 1956), which seems to prove that the beneficial effect of the antibiotics is dependent on the presence of a certain bacterial flora in the animal.

The question of the possible sites of action of the antibiotic is

also discussed by various authors. Following the dietary administration of an antibiotic supplement to animals the antibiotic is not confined to the digestive tract but can also be found at bacteriostatic levels in the various body fluids (Gordon, 1955; Taylor, 1957). Although this distribution of the antibiotic in the body fluids would justify the assumption of a systemic action of the antibiotic, most authors believe that its main effect takes place in the alimentary tract. Several workers have tried to assess the effects of a dietary antibiotic supplementation on the microflora of the alimentary tract. Freerksen (1956) reviewing these efforts, comes to the conclusion that the influence of the antibiotic on the microflora of the alimentary tract is not an obvious one and does not consist of a simple redistribution of the physiological intestinal flora. According to this author the growth promotion is rather a result of the suppression of a "subclinical infection" of atypical, partly pathogenic populations of the stomach and the small intestines and of organisms in the rectal and colon flora which have been introduced under unsanitary conditions. This "subclinical disease" theory is also held by Taylor (1957). The findings of Radisson, Smith and Ward (1956) and Radisson et al. (1956) furnish also some explanation for the failure to demonstrate any differences in the numbers and types of bacteria isolated from calves treated with antibiotics as compared with controls. According to these authors the presence of an antibiotic in the digestive tract increases the susceptibility of potential pathogenic bacteria to phagocytosis and thus facilitates the function of the normal body defence mechanisms.

Several authors, while not denying that the above mentioned suppression of disease producing organisms might also be important in older ruminants, suggest that the feeding of an antibiotic could also have a specific effect on the rumen fermentation. Vandersall, Hibbs and Conrad (1957) and Dinda (1960) were able to

demonstrate that calves receiving an antibiotic supplemented ration had significantly higher blood glucose contents than the controls. Reviewing these experiments, Preston (1962) suggests that this increase in blood glucose content might be a result of a depression of the starch fermentation in the rumen, thus permitting a large proportion of starch to pass unchanged through the rumen and to be digested posterior to this organ. Since the utilization of glucose derived from the enzymic hydrolization of starch in the intestines is accomplished with less loss than its microbial degradation to fatty acids in the rumen, this greater efficiency could also be partly responsible for a growth promoting effect of an antibiotic.

Both Lassiter (1955) and Preston (1962) mention an increase in feed intake as a further specific effect of antibiotic feeding to ruminants. Although such an increase in feed intake has been repeatedly reported, the experimental evidence available up to now does not supply an adequate explanation of the mechanism by which this is brought about. Furthermore a protein sparing effect of antibiotics in rations where the protein content is limiting either in quality or in total amount has been claimed by Preston (1962).

Thus there is considerable evidence to indicate that the beneficial effect of antibiotic feeding to ruminants is strongly related to the antibacterial activity of these drugs in the digestive tract of these animals. In the young calf the suppression of subclinical infections seems to be of first importance, in the older ruminant an additional direct effect on the rumen fermentation is also feasible.

33. Public health aspects

331. General

The growing use of antibiotics as feed additives for growth promotion has brought about concern among public health officials as well as veterinarians because of the possible immediate and long-term effects on the health of animals as well as man. The standard of arguments brought forward against low-level antibiotic feeding varies greatly. As always when an issue concerning the consumer is at stake there is no lack of exaggerated statements both in the medical and public press. On the other hand, many scientists in the field of human medicine and veterinary science are seriously trying to evaluate the possible hazards.

Unfortunately the discussion on the possible untoward effects does not always make a clear distinction between the use of antibiotics as feed additives on the one hand and the therapeutic use and the use as food preservatives on the other. Thus, as the hazards of uncontrolled and excessive therapeutic use of antibiotics can be substantial (e.g. the presence of antibiotics in milk as a consequence of disregard of the pertinent regulations), this mixing of issues often discredits unjustly the use of antibiotics as feed additives.

Several countries have established special committees to study the possible hazards of the nonmedical use of antibiotics (e.g. Joint ARC and MRC committee, 1962) and an extensive report on this subject has also been published by the World Health Organization (WHO, 1963). In the following, two of the most often mentioned hazards, i.e. the question of antibiotic residues in animal tissues and the emergence of a resistant bacterial flora are discussed.

332. Antibiotic residues in animal tissues

It has been repeatedly suggested that the supplementation of animal feeds with antibiotics might lead to antibiotic residues in animal tissues and that this in turn could be harmful for the consumer. Allergisation of sensitized people, toxic and carcinogenic effects have been mentioned as possible harmful effects of the ingestion of antibiotic containing feedstuffs. To evaluate these hazards the problem has been tackled from two sides. On one side it has been investigated what levels of antibiotic in the feed lead to antibiotic residues in animal tissues and on the other side investigations were conducted to evaluate possible harmful effects of the consumption of antibiotic containing foodstuffs by humans.

The considerable literature on antibiotic residues in animal tissues has been reviewed by Brüggemann und Merkenschlager (1958), Knothe (1964) and Ferrando (1965). The antibiotic assay is generally done microbiologically and the minimum measurable levels of antibiotics in tissues range between 0.01 and 0.1 µg/g tissue. The above mentioned authors agree that at nutritional levels of up to 50 ppm no or only minute traces of antibiotic can be found in the tissues. This is also confirmed by the WHO report (1963) which states that normal low-level feeding of antibiotics (20 ppm) does not result in detectable levels of antibiotic in the meat. There is also evidence (e.g. Luther et al., 1954) that even at levels of over 1000 ppm any antibiotic residue can be avoided by withdrawing the antibiotic 24 hrs. before slaughter. Furthermore several authors (Broquist and Kohler, 1954; Durbin et al., 1954) have demonstrated that cooking, frying or baking of antibiotic containing meat results in completely eliminating the antibiotic activity.

Fortunately most antibiotics have a very low toxicity. Only

chloramphenicol comes into a different category because it is capable of exerting a fatal toxic effect when given in normal therapeutic doses (WHO, 1963). No country, however, allows the use of chloramphenicol as feed additive.

Several workers have investigated the question of whether the consumption of antibiotic containing foodstuffs might lead to allergic reactions in sensitized people. Schuppli (1959) and Weinstein and Welch (1959) reported that oral doses of up to 50 mg oxytetracycline or chlortetracycline were unable to elicit allergic reactions in people who were known to be highly sensitized to these antibiotics. Although several cases have been reported where the consumption of milk containing penicillin as a consequence of intramammary treatment of mastitis had led to allergic reactions (Gounelle et Szakvary, 1966), no such reactions have been observed following the consumption of meat from animals that were fed penicillin.

In summary then it seems reasonable to conclude that the consumption of meat from animals fed antibiotics at nutritional levels does not represent a hazard to the consumer.

333. The emergence of a resistant bacterial flora

The question of bacterial resistance development has been the subject of reviews by Finland (1956), Ross (1957) and Smith (1962) and is also dealt with in the WHO report (1963). From these reviews it is obvious that the experimental evidence available today is not yet sufficient for a definite evaluation of the problem. Public health authorities are mainly concerned with the possibility that a prolongued low-level antibiotic supplementation of livestock feeds might increase the incidence

of resistant pathogenic bacteria and that this in turn could, by way of crossinfection, endanger the health of human attendants.

The mechamism by which resistant bacteria may become dominant varies according to the original composition of the bacterial flora and also according to the concentration and type of the antibiotic employed. Resistance to streptomycin e.g. can develop within as short a time as 24 hrs. whereas the development of resistance to oxytetracycline usually takes place in a slower, stepwise manner.

Generally a distinction is made between natural and acquired resistance. The emergence of resistant bacteria in a certain surrounding might therefore occur in two ways : either by selective multiplication of a naturally resistant strain or by the multiplication of an originally sensitive strain which by a process of spontaneous mutation has become resistant. In the last few years considerable research has been conducted on a new type of infectious resistance i.e. the transference of resistance to several antimicrobial agents among enteric bacteria (Watanabe, 1963; Chabert et Le Minoir, 1966). However, the possible repercussions of this newly described resistance on antibiotic feed supplementation have not yet been fully evaluated.

For the animal husbandry man the most important question is whether the bacteria becoming resistant as a consequence of antibiotic feeding are pathogens or whether they might on the contrary be favourable for the development of the animal. On this point opinions strongly diverge. Smith (1962) e.g. maintains that low-level feeding of antibiotics might further the increase of such pathogenic organisms as Escherichia coli, Salmonella typhimurium and Clostridium welchii. Smith and Crabb (1960) also report that animal attendants looking after pigs and poultry receiving antibiotics in their feed had a distinctly higher percentage of

tetracycline resistant Staphylococci aurei than the personnel looking after animals that received unsupplemented rations. Finland (1956) on the other hand denies the emergence of resistant disease producing organisms as a consequence of low-level antibiotic feeding. On the basis of long-term experiments of antibiotic feeding to pigs and poultry he concludes that the emerging antibiotic resistant microflora must be favourable to the host, since it improves its health and performance.

Most authors, however, agree that low-level antibiotic feeding most probably leads to the development of resistant microflora of some kind in the treated animals. Further experiments will have to show whether this emerging microflora is a danger or a benefit for the animal concerned.

Once the evidence on this question is better documented it will then be possible to decide whether the growth promoting effect achieved by antibiotic supplementation is worth the possible hazards of an emerging resistant microflora or whether the number of antibiotics used and the range of supplemented feeds will have to be substantially reduced.

34. Incidence of liver abscesses and rumen lesions in cattle on high-cereal diets

Records on the incidence of hepatic abscesses in Great Britain are available for a representative sample of 2,043,511 cattle killed during the years 1961, 1962, 1963 (Ministry of Agriculture, Fisheries and Food, 1964). This sample represents approximately

20 % of all cattle killed in Great Britain during this period and the information about the incidence of liver abscesses was collected by the Ministry of Agriculture, Fisheries and Food from various slaughterhouses all over Britain. The average incidence of liver abscesses over this period was 3.33 %. A similar figure, 4.35 % is mentioned by Rubarth (1960) for Sweden and Flint and Jensen (1958) report 5 % as an average figure for the United States. Animals which have been on a high concentrate ration during part or the whole of their life can show a much higher incidence. Among feedlot cattle in the United States (i.e. cattle which spend the first 1-2 years of their life on the range and are then fattened off on a high cereal ration for the last 90-120 days before slaughter) the incidence of liver abscesses in individual feedlots can be as high as 68 % (Flint and Jensen, 1958). The incidence of liver abscesses in barley-beef is also well above the national average.

For example the three main bodies which handle barley-beef in Scotland give the following figures (personal communication) :

	Period	Total animals slaughtered	Abscessed livers	Incidence of liver abscesses %
Border Barley-beef Producers	1. 1.64-31. 8.64	1813	356	19.64
Central Scotland Barley-beef Producers	1.10.63-30. 9.64	4185	819	19.57
Aberdeenshire Barley-beef Producers	1. 1.64-30.10.64	2603	729	28.20
Total		8601	1904	22.14

The condemnation of 1904 livers out of 8601 animals represents a loss of about £ 2850 if one takes the price of a liver at 30 s. If this loss is equally distributed over all 8601 animals the loss per animal is about 6s.6d. per head. Further economic loss can result from death of some animals and from a reduction in the performance of others.

In the literature one can find two different schools of thought about the main causative agent of these liver abscesses. In the American literature the bacterium Spherophorus necrophorus (synonyms : Actinomyces necrophorus, Fusiformis necrophorus) is most frequently mentioned whereas the European literature seems to indicate a predominance of Corynebacterium pyogenes.

Among the American authors both Newsom (1938) and Madin (1949) found Spherophorus necrophorus in the majority of all the abscesses cultured, i.e. in 96 % and 89 % respectively. Jensen, Flint and Griner (1954) were also able to reproduce liver abscesses in healthy cattle by intraportal inoculation of a viable fluid culture of S. necrophorus.

Pellegri (1939) on the other hand, who studied liver abscesses from various adult cattle in Milan, claims C. pyogenes to be the prevailing pathogen. He does not mention, however, that he used anaerobic cultures which could account for his not finding the necrophorus organism. C. pyogenes is also mentioned in a more recent paper by Rubarth (1960). He reported on 56 hepatic abscesses found in autopsies during the years 1934-1959. As a rule most of these animals had died suddenly and unexpectedly and all of them showed a rupture of the abscess into the caudal vena cava. From the bulk of the abscesses he only isolated C. pyogenes and found S. necrophorus in very few cases.

It seems unlikely that these different bacteriological findings indicate a real difference in the bacteriological background of the same disease as between America and Europe. It seems, however, that there is a significant difference in the material studied. Almost all American work has been done on samples of beef livers, mainly from feedlot-fed animals which probably developed this condition during the last 90-120 days of their life. Pellegri (1939) on the other hand studied material which, both in regard to previous management and age, was much more variable than the American material and consisted mainly of mature, aged animals. Rubarth's (1960) sample is also a very specialised one for it includes only liver abscesses which had ruptured into the vena cava. Most animals were from dairy herds and were several years old. The three abscesses that Rubarth (1960) describes in detail are all longstanding ones of about 10 cm diameter and with a fibrous capsule about 1 cm thick.

The difference in the bacteriological findings between the European and American workers can probably be explained by the difference in the material studied. The European sample represented long standing abscesses in mature animals, whereas the American material was from feedlot cattle which had developed this condition during the last 3-4 months of their life.

Various theories have been put forward about the route by which the bacteria reach the liver. Earlier workers considered that S. necrophorus might reach the liver from localized infections in any part of the body by way of the blood stream or the lymphatic system. For example Robinson, Jasper and Guilbert (1951) suggested that S. necrophorus could enter the body from lesions caused by foot rot with which S. necrophorus is often associated. There is, however, no evidence of a positive correlation between liver abscesses and foot rot. Smith (1963) also points out that

this route of infection seems unlikely from anatomical considerations. He indicates that any organism present in the venous system would most probably be filtered out in the passage of the blood through the lungs, where S. necrophorus could produce pulmonary abscesses. If the organisms were not filtered out there they would pass on to all parts of the body by way of the arterial system and would be likely to produce abscesses in other parts as well as in the liver.

Smith (1944) was the first author to produce evidence for a positive correlation between rumen lesions and liver abscesses. He studied the rumens and livers of 1807 cattle and found that 42 % of the cattle with rumen lesions had liver abscesses as well; of those without rumen lesions only 9 % showed liver abscesses. He concluded from these findings that liver abscesses could have their origin in metastasis from infections in the rumen wall. Jensen et al. (1954) who conducted a similar study on 1535 cattle also found a definite relationship between rumen lesions and hepatic abscesses. Further support for the rumen lesions - liver abscess relationship was supplied by Robinson, Jasper and Guilbert (1951) who demonstrated that S. necrophorus was a relatively constant member of the normal rumen microflora. They found that this organism could survive in the rumen under widely different conditions and was unaffected by pH changes varying between pH 5.7 and pH 7.7.

Thus there seems to be strong evidence for the theory postulated by Smith (1944), Jensen et al. (1954) and Smith (1963) that S. necrophorus, a normal member of the rumen microflora, gains entrance into the rumen wall and subsequently into the portal system through foci of rumenitis and that it is carried to the liver in the portal vein. Rumenitis appears to be significantly correlated with the concentrate-roughage ratio in the feed and

the time taken to change from a predominantly roughage ration to a high concentrate ration (Jensen, Connell, Deem, 1954). Cattle on a high concentrate ration generally have a lower rumen pH than cattle given only roughage. In barley-beef cattle the rumen pH averages about 5.2 up to about 180 kg live-weight and thereafter increases slowly to between 5.5 and 6.0 as the animal approaches slaughter weight (Preston, 1964). Cattle given roughage usually have a rumen pH of about 6.5 to 7 (Barnett and Reid, 1961). Several authors, among them Jensen, Connell and Deem (1954) consider the high acid concentration as the main cause of rumenitis. These authors failed, however, to produce rumenitis by forced feeding of straw and acetic acid. They attributed this mainly to the fact, that the low pH obtained by the introduction of the acetic could not be maintained at this level but rapidly reverted to neutrality.

Attempts to prevent liver abscesses have been mainly by vaccination and by incorporation of an antibiotic in the feed. Jensen, Flint and Griner (1954) were unsuccessful in their attempt to immunize sheep against liver abscesses. A series of intraperitoneal injections of a polyvalent culture filtrate of S. necrophorus failed to protect sheep against a challenge dose of viable S. necrophorus. Matushima, Dove and Adams (1954) and Bohmann, Wade and Hunter (1957) were successful in decreasing the incidence of liver abscesses with the inclusion of an antibiotic in the feed. Both authors, however, were using rather small experimental groups, i.e. of 5 and 12 animals respectively. This is too small a sample to study a condition as variable in its incidence as liver abscess. The most extensive study of the use of an antibiotic was by Flint and Jensen (1958). They conducted three experiments with 1895 cattle and fed chlortetracycline at the rate of 70-75 mg per animal daily throughout the whole feedlot period of approximately 120 days. The effect of the antibiotic was significant and on average reduced the incidence of liver abscesses from 46 % to 19 %.

4. Experiments carried out at the Rowett Research Institute

41. General

The two experiments reported in this section were carried out at the Rowett Research Institute during the period from April 1964 to June 1964. Their main object was to get information on possible modes of action of dietary antibiotic supplements in promoting the growth of young ruminants. A similar investigation had earlier been conducted at the same institute by Dinda (1960) who studied the effect of chlortetracycline on the nutrition of early weaned calves. Whereas the calves used by Dinda had ages ranging from 4 to 12 weeks and were still on the early weaning diet, calves used in our experiments were already on the proper barley-beef diet and were studied at ages of approx. 16 weeks (Expt. 1) and 24 weeks (Expt. 2).

42. Experimental

421. Animals

18 Friesian male calves were used. They had been purchased at approx. 3 days of age from local farms and had been reared according to the early weaning system. Their average weight was 130 kg at the start of expt. 1 and 162 kg at the start of expt. 2.

422. Treatment and design

There were 3 treatments. The compositions of the three experimental diets used are given in Tables 1 and 2.

Table 1 : Composition of the three experimental diets.

	Diet C	Diet T	Diet B
Major constituents	85 % barley 15 % protein supplement	85 % barley 15 % protein supplement	85 % barley 15 % protein supplement
Antibiotic supplementation	Nil	1812 g TM5* per 1000 kg final feed	364 g Baciferm** per 1000 kg final feed
Concentration of active antibiotic substance in final diet	Nil	20 mg Terramycin per kg	20 mg Zinc Bacitracin per kg

* containing 5 g oxytetracycline (Terramycin) per lb of TM 5, Pfizer Ltd, Folkestone, Kent

** containing 55 g bacitracin per 1000 g of Baciferm, Apathekernes laboratorium for special praeparater, Oslo.

The protein supplement was the same for all 3 diets and had the composition as shown in Table 2.

Table 2 : Composition of the protein supplement*.

Ingredient	%
Soybean meal	73.50
Molasses	7.50
Barley meal	3.00
Calcium carbonate	8.75
Salt	3.75
Dicalcium phosphate	2.50
Trace mineral/Vitamin mixture**	1.00
	100.00

* prepared as pellets of approx. 0.5 cm (3/16") diameter

** containing per kg : 375 g ferrous sulphate
22 g copper sulphate
3 g cobalt sulphate
42 Mio. I.U. Vit. A
10 Mio. I.U. Vit. E

At the start of expt. 1 the 18 calves were divided into 3 blocks according to their live-weights. Within each of these blocks the six calves were allocated at random to one of the three treatments. Thus each treatment was replicated twice in each block and six times in the whole experiment. Each calf stayed on the same treatment throughout expt. 1 and expt. 2.

423. Management

Expt. 1 : The calves were tied up in individual stalls on slats. After 4 weeks preliminary feeding on the experimental rations the calves were sampled during one day and then transferred to the metabolism cages, where faeces and urine were collected over a period of 6 days. The daily feed intake was restricted to 9 % of the metabolic live-weight for calves under 120 kg and to 10 % of the metabolic live-weight for calves over 120 kg live-weight. The calves were fed four times daily i.e. at 7 a.m., 11 a.m., 3 p.m. and 7 p.m. On the sampling day blood samples were taken from all animals at 6.30 a.m. ($\frac{1}{2}$ hr. before feeding), 8 a.m. (1 hr. after feeding), 11 a.m. (4 hrs. after feeding) and 2 p.m. (3 hrs. after feeding). The samples were obtained from the jugular vein with a syringe. Rumen samples were taken at 8 a.m., 11 a.m. and 2 p.m. by means of a polythene-stomach tube, using a vacuum pump.

Expt. 2 : This experiment involved only blood and rumen sampling but no balance trials. The daily ration was restricted to 10 % of the metabolic live-weight for all calves. The animals were fed only twice daily i.e. at 7.a.m. and 7 p.m. in order to get an uninterrupted sampling period of 12 hours. Blood samples were taken 2, 4, 6, 8, 10 and 12 hrs. after feeding by means of a catheter in the jugular vein as described by Preston and Ndumbe (1960). Rumen samples were taken at 9 a.m. and 11 a.m.

424. Methods

Faeces and urine collection : The faeces were collected daily and stored in polythene bags at 2° C. At the end of the collection period the samples of each animal were thoroughly mixed and two representative samples were taken for the determination of dry matter and N-content. Urine was collected in covered polythene buckets containing 200 ml of glacial acetic acid. At the end of the period a representative sample was taken for the determination of the N-content.

pH of rumen fluid : The pH of the crude rumen samples was determined by the use of a pH-meter with a glass electrode.

Rumen ammonia : After straining the rumen sample through gauze, 5 ml of the clear sample were transferred to a 25 ml volumetric flask containing 5 ml N/10 HCL, made up to the mark with distilled water and filtered. The ammonia present in the filtrate was determined by the method of Conway (1957) using potassium carbonate as the alkaline reagent.

Total steam volatile fatty acids : Clear rumen samples were deproteinized by adding an equal volume of a saturated $MgSO_4$ solution and by centrifuging for 5 mins. at 2000 rpm. The supernatant liquid was filtered and an aliquot of the filtrate distilled in a Markham still. The distillate was titrated with N/50 NaOH under CO_2 free conditions.

Blood glucose : Anticoagulation was achieved with a mixture containing 10 mg sodium fluoride and 30 mg potassium oxalate per 10 ml of blood. The blood was deproteinized with 10 % $ZnSO_4$ and 0.5 N NaOH and filtered through Whatman's No. 42. An aliquot of

the filtrate was mixed with an enzyme-oxygen acceptor according to Huggett and Nixon (1957) and incubated for one hour at 35° - 37° C. A blank determination and a standard were incubated at the same time. The brownish colour which developped was compared in a Unica spectrophotometer at 420 mμ with the colour produced by the standard determination using the blank to zero the instrument.

Blood urea : The determination was made according to the method of Conway (1957).

43. Results and discussion

The main results are presented in Tables 3 and 4.

Table 3*: Digestibility coefficients and nitrogen balance data of calves given diets containing oxytetracycline (O), bacitracin (B) or no antibiotic supplementation (C).

	O	B	C	Standard error of difference
Number of calves	6	6	6	
Dry matter digestibility, %	83.72	83.33	85.27	± 0.74
Apparent nitrogen digestibility, %	79.85	79.57	79.75	± 0.99
Nitrogen retention, g/day	29.92	30.78	27.37	± 2.74
Nitrogen retention, % of dietary N	40.28	40.18	36.02	± 3.45

* For detailed results see Tables 15 - 16 of the appendix.

It is obvious from Table 3 that neither oxytetracycline nor bacitracin had an effect on the digestibility of the ration. This finding is in accordance with the majority of the results of experiments dealing with the effects of antibiotics on the digestibility of rations for ruminants (Dinda, 1960; Barnett and Reid, 1961). Nitrogen retention was slightly improved both by the

addition of oxytetracycline and bacitracin but this effect was not significant. Effects of antibiotic supplementation on nitrogen retention have been variable. Horn, Snapp and Gall (1955) e.g. found chlortetracycline and penicillin to depress nitrogen retention of yearling steers, Hogue et al. (1956) on the other hand reported an improvement of the nitrogen retention of calves fed chlortetracycline. An explanation for this variation is furnished by Preston (1962) who suggests that an improvement in nitrogen retention due to an antibiotic would only be expected on rations that are limited either in the quality or the total amount of protein. The lack of a significant improvement in nitrogen retention in our experiment is probably due to the fact that the protein content of the ration fed was sufficient both in quantity (approx. 14 %) and quality (soybean meal).

Table 4* : Data on rumen ammonia, rumen VFA concentration, rumen pH, blood urea and blood glucose of calves given diets containing oxytetracycline (O), bacitracin (B) or no antibiotic supplementation (C).

	O	B	C	Standard error of difference
Number of calves	6	6	6	
Expt. 1				
Rumen NH_4, meq/l	5.76*	3.91	4.21	± 0.694
Blood urea, mg/100 ml	30.64**	24.13	22.76	± 2.295
Rumen pH	6.60	6.41	6.32	± 0.116
Blood glucose, mg/100 ml	65.95	57.42	64.82	± 3.552
Expt. 2				
VFA concentration, meq/l	89.40	82.73	80.23	± 7.188
Rumen pH	6.46	6.63	6.57	± 0.163
Blood glucose, mg/100 ml	66.44	63.97	64.70	± 3.013
Increase in blood glucose content 2 hrs. to 10 hrs. after feeding time, mg/100 ml	+ 6.58	+ 4.73	+ 2.44	± 3.390

* significant at 5 % level

** significant at 1 % level

* For detailed results see Tables 16 - 22 of the appendix.

It has been suggested that the feeding of an antibiotic to ruminants might depress the microbial fermentation in their rumen. This could have a twofold effect :

- a depression of the microbial protein degradation in the rumen resulting in a decrease in the amount of ammonia produced and a concurrent decrease in the blood urea content (Dinda, 1960);

- a depression of the microbial breakdown of starch in the rumen, leading on one hand to a lower production of volatile fatty acids and a higher pH and on the other hand to an increase in the amount of starch passing unchanged through the rumen and beeing digested by enzymes in the small intestines. An increase in the enzymatic breakdown of starch would be reflected in a higher blood glucose level (Preston, 1962).

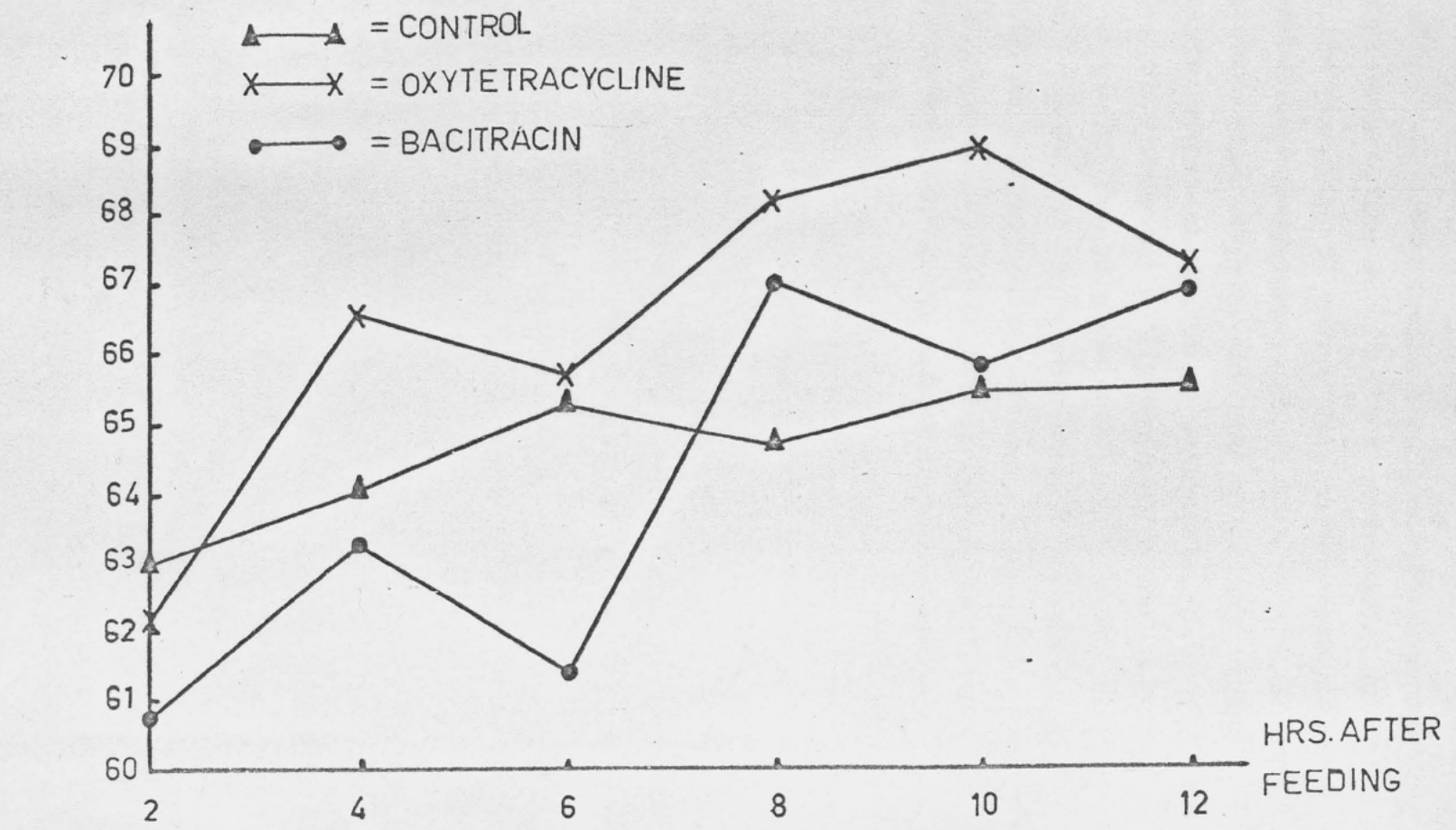
Expt. 1 gave no conclusive evidence on any of these effects (see Table 4). Bacitracin slightly, but not significantly reduced the ammonia concentration in the rumen fluid. There was, however, no concurrent decrease in the blood urea content on this ration. Oxytetracycline, on the other hand, significantly increased both rumen ammonia and blood urea content. There is no explanation for this surprising result which has been contrary to expectations. Dinda (1960) found chlortetracycline to reduce significantly both rumen ammonia and blood urea content.

In both experiments rumen pH was not significantly influenced by the presence of an antibiotic in the diet. In expt. 2, concentrations of volatile fatty acids in the rumen fluid did not differ significantly. This is in contrast to the results of

Dinda (1960) who found a significant effect of chlortetracycline both in decreasing the concentration of volatile fatty acids and in increasing rumen pH.

Blood glucose levels given in Table 4 for expt. 1 are always averages of 4 values recorded at ½ hr. before and 1, 3 and 4 hrs. after feeding time. No significant differences could be found between the three treatments. In expt. 2 the feeding times were changed in order to get an uninterrupted sampling period of 12 hrs. between the meals at 7 a.m. and 7 p.m. It was thought that the study of the course of the blood glucose contents during such a period might perhaps better reveal any differences between the treatments. Preston and Ndumbe (1961), in an investigation on daily variation of blood sugar concentrations of early weaned calves, had demonstrated that the blood sugar levels of calves fed concentrates dropped sharply within the first 2 hrs. after a meal and subsequently increased again to reach a maximum level about 8 to 12 hrs. after feeding time. If an average of the blood glucose contents of the six samples (2, 4, 6, 8, 10, 12 hrs. after feeding) was calculated, no differences could be found between the three diets. However, when the increase in blood glucose content from 2 hrs. to 10 hrs. after feeding was calculated, animals on oxytetracycline and bacitracin supplemented rations showed a slightly but not significantly greater increase in blood glucose content over this period. This is also evident from Figure 1. This was the only indication of a possible effect of these antibiotics on microbial starch fermentation as suggested by Preston (1962). The result is, however, not as clear cut as the findings of Dinda (1961) and Vandersall, Hibbs and Conrad (1957) who found significant higher blood glucose levels in calves fed chlortetracycline than in controls.

FIG.1: AVERAGE BLOOD GLUCOSE CONCENTRATIONS FOR THE TREE TREATMENTS (6 CALVES PER TREATMENT) AT VARIOUS INTERVALS AFTER FEEDING



To summarize then, these experiments have not furnished any definite evidence concerning an effect of oxytetracycline or bacitracin on the digestion of calves on a barley-beef diet. Between the three treatments there were no significant differences in digestion coefficients, nitrogen retention, rumen VFA concentrations and rumen pH. The significant influence of oxytetracycline in increasing both rumen ammonia and blood urea content is not in line with the findings of other authors. Expt. 1 showed no effect of antibiotic supplementation on blood glucose content, the treated calves of expt. 2, on the other hand, showed a slightly but not significantly higher increase in blood glucose content over the period from 2 to 10 hrs. after feeding time.

5. Experiments carried out on 14 commercial barley-beef units

51. Experimental

This experiment was conducted during the period November 1963 - September 1964 on 14 commercial barley-beef units in Scotland. There were 6 units in the Aberdeenshire area, 4 units in Fife and 4 units in East Lothian.

Treatment and design : On each unit the trial batch of calves was divided into two groups, which were then allocated to either a control diet or an experimental diet supplemented with chlortetracycline*. The size of these groups varied from 7 to 19. There was a total of 169 calves on the control ration and 170 calves on the antibiotic ration.

Animals : These were Friesian male calves with an average weight of 115 kg at the start. All were early weaned and had been reared on the trial farm or brought in from special calf rearing units.

Casualities : Casualities during the experiment were as follows : five animals receiving antibiotic died, three from bloat, one from pneumonia and one from an unknown cause. Two others were withdrawn because of chronic bloat or pneumonia. One control animal died from pneumonia and one from a post-castration infection, and five others were withdrawn because of pneumonia (2) injury (2) or bloat.

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* Aurofac 10, containing 10 g aureomycin per 1 lb of Aurofac 10; Cyanamid of Great Britain Ltd.

Diets : On each farm the control diet contained 85 % barley and 15 % of a proprietary protein supplement. The protein supplements were supplied by four different commercial firms. Each was pelleted in the form of a 3/16" pellet and contained approximately 34 % crude protein, 40 million I.U. of vitamin A, 7 million I.U. of vitamin D and the essential minerals as recommended by Preston (1963). On each farm the experimental animals had the same supplement as the control animals but with the addition of 133 mg chlortetracycline per kg of supplement. This was equivalent to 20 mg chlortetracycline per kg of the final ration. This level of antibiotic supplementation resulted in an average daily intake of ca. 75 mg chlortetracycline at the start of the experiment (average daily feed intake 3.9 kg) rising to an average daily intake of ca. 165 mg antibiotic during the final stages of the experiment (average daily feed intake 8.4 kg). On most farms the barley was rolled or crimped but on units 3, 6 and 13 it was ground. The feeding of the concentrate was ad libitum. There was a daily allowance of 0.5 kg hay per animal on units 3 and 13. None was given in the other units.

Management : It was intended that on each farm both groups should be housed under equal conditions. This was achieved on 13 farms where both groups were housed under the same roof and in pens of equal size. On one unit (farm 14), however, the animals were moved during the trial to new quarters, which differed both in size and location. On this farm we continued the experiment but discarded the performance data and analysed only the rumen and liver information. On one farm the animals had been castrated before the start of the experiment. On the others the animals were castrated during the experimental period at weights varying between 140 kg and 230 kg. All animals were implanted with 60 mg hexoestrol at an average weight of 260 kg. Individual weights at

implantation varied from 200 to 275 kg but on each farm control and antibiotic animals were implanted at the same time. The majority of animals (84 %) were slaughtered between 380 kg and 420 kg live-weight, and the remainder at live-weights approaching the above range according to the preference of the individual farmer concerned.

Measurements

Performance data : Live-weights of individual animals and feed intakes of the two groups were recorded at intervals of 4 weeks. On each farm the final measurement on which the performance data were calculated was made when the first animal, control or experimental, was dispatched for slaughter. The overall trial period was 28 weeks for 12 farms and 24 weeks for the remaining farm (farm 2). The average weight of the antibiotic and control animals at the end of this period was 365 kg and 355 kg respectively. Data presented are taken from 13 units for live-weight gain and from only 12 units for feed intake, one unit being omitted because of incomplete feed records. Originally it was intended to record the performance through to slaughter but this could not be achieved because of practical difficulties. Many farmers were cooperating for the first time in such a trial and were not organised to continue the feed records, after the groups were reduced in size.

Rumen and liver condition : At slaughter the livers were checked for abscesses and other abnormalities. Samples of abscessed livers were taken for bacteriological examination. The rumens were opened, washed and examined for abnormalities. The various lesions were classified according to a scale very similar to that of Jensen et al. (1954) (see Table 36 of appendix). Samples of each rumen wall were taken for histopathological examination from the

anterior dorsal, anterior ventral and the posterior dorsal sacs. Practical difficulties due to slaughtering at several different slaughter houses made it impossible to check the carcasses of all animals. Information was obtained on livers for 136 antibiotic and 135 control animals and on rumens for 118 antibiotic and 116 control animals.

52. Results*

521. Performance data

Live-weight gain (Table 5) : The animals fed antibiotic had significantly ($P<0.01$) higher overall live-weight gains over the 28-week period. The average improvement over the controls was 4.9 %. The response seemed, however, to fall off after the first 12 weeks and the positive overall effect of the antibiotic is mainly due to the high response during this first period (+ 8.5 %). From 13 to 28 weeks the chlortetracycline had only a marginal effect which was not significant.

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* For detailed results see Tables 23 - 38 of the appendix.

Table 5 : Effect of chlortetracycline on daily gain

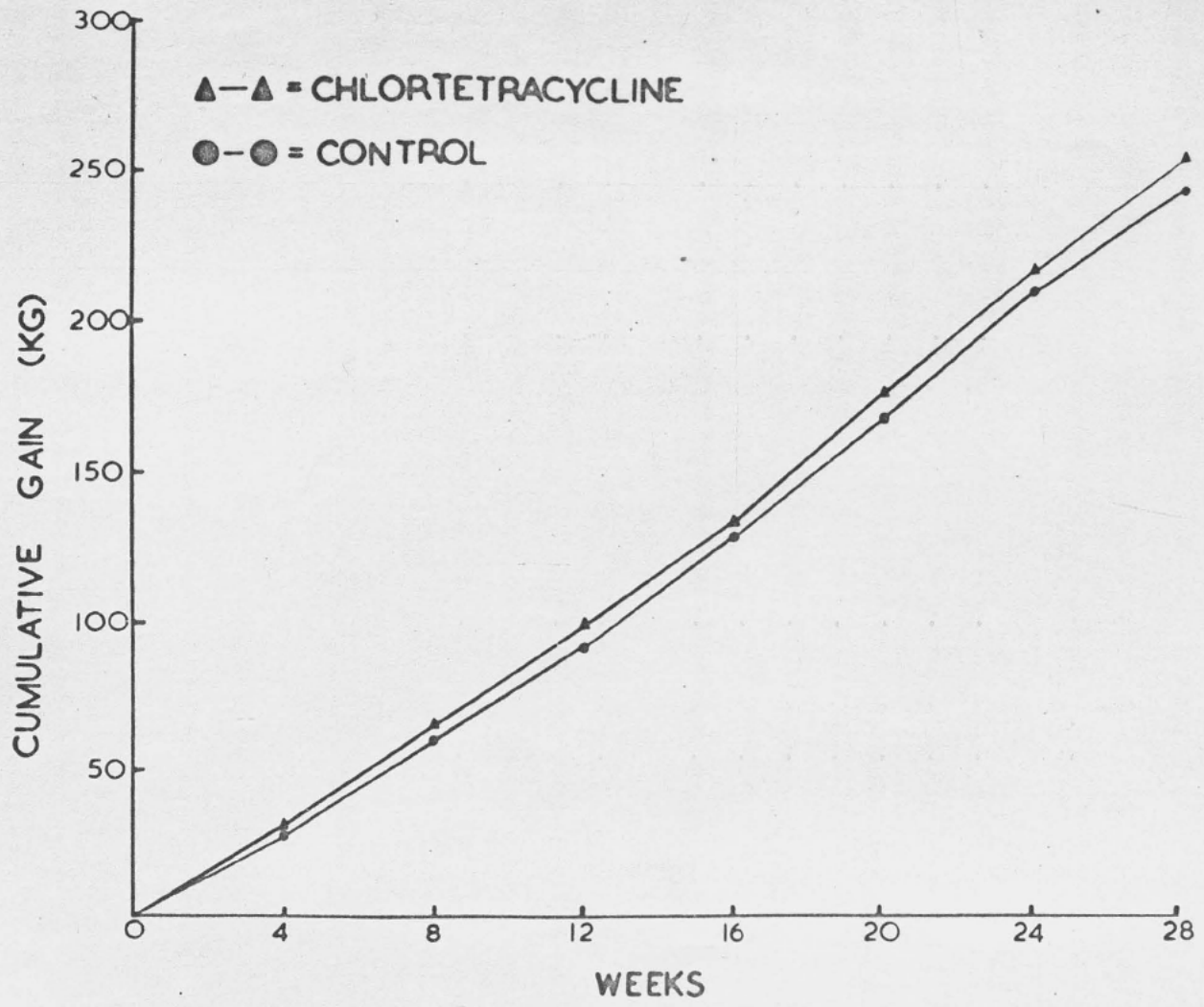
Weeks	Daily gain (kg) CTC	Control	Treatment effect with S.E.
0- 4	1.09	0.97	+ 0.12 ± 0.02**
5- 8	1.20	1.16	+ 0.04 ± 0.04
9-12	1.21	1.09	+ 0.12 ± 0.03**
13-16	1.25	1.31	- 0.06 ± 0.02*
17-20	1.54	1.46	+ 0.08 ± 0.06
21-24	1.44	1.48	- 0.04 ± 0.04
25-28	1.31	1.18	+ 0.13 ± 0.04*
0-12	1.16	1.07	+ 0.09 ± 0.02**
13-28	1.38	1.36	+ 0.02 ± 0.02
0-28	1.29	1.23	+ 0.06 ± 0.02**

* Significant at 5 % level

** Significant at 1 % level

It is, however, interesting to note that the animals fed the antibiotic also grew significantly faster than the controls during the last 4 weeks of the experiment (24-28 weeks).

FIG. 2: EFFECT OF CTC ON LIVEWEIGHT GAIN



Although the effect of the antibiotic on growth rate was falling off from 12 weeks onwards, Figure 2 shows clearly that the experimental animals did maintain their advantage until the end of the experiment. On the majority of farms the implantation with hexoestrol was done after 16 weeks. This is reflected in the graph by the steepening of the slope after this time.

Feed intake (Table 6) : The experimental animals ate slightly less food during the first 12 weeks (- 0.5 %) and slightly more over the whole experimental period (+ 0.5 %) but neither of these differences were significant.

Table 6 : Effect of chlortetracycline (CTC) on daily feed intake

Weeks	Daily feed intake		Treatment effect with S.E.
	CTC kg	Control kg	
0-12	4.64	4.66	- 0.02 ± 0.07
13-28	7.31	7.28	+ 0.03 ± 0.13
0-28	6.11	6.08	+ 0.03 ± 0.10

Feed utilization (Table 7) : To measure feed utilization we have preferred the term conversion efficiency (CE) which is simply the reciprocal of the conversion ratio. It measures the output (gain) as a percentage of the input (feed), thus an improvement in feed utilization is reflected by a rise in conversion efficiency. The effect of chlortetracycline on conversion

efficiency is similar to the effect on live-weight gain. The significant ($P<0.01$) increase of 0.98 % represents an improvement of 4.8 % over the controls. The overall positive effect is again mainly due to a high response during the first 12 weeks (+ 9.2 %).

Table 7 : Effect of chlortetracycline (CTC) on conversion efficiency ($\frac{\text{gain}}{\text{feed}}$ x 100)

Weeks	Conversion efficiency (%)		Treatment effect with S.E.
	CTC	Control	
0- 4	29.4	25.9	+ 3.5 ± 0.80**
5- 8	25.5	24.1	+ 1.4 ± 1.01
9-12	23.7	21.6	+ 2.1 ± 0.52**
13-16	19.9	20.8	- 0.9 ± 0.53
17-20	21.8	20.7	+ 1.1 ± 0.93
21-24	18.9	18.8	+ 0.1 ± 0.14
25-28	15.8	14.4	+ 1.4 ± 0.84
0-12	25.7	23.5	+ 2.2 ± 0.39**
13-28	19.1	18.7	+ 0.4 ± 0.39
0-28	21.3	20.3	+ 1.0 ± 0.21**

* Significant at 5 % level

** Significant at 1 % level

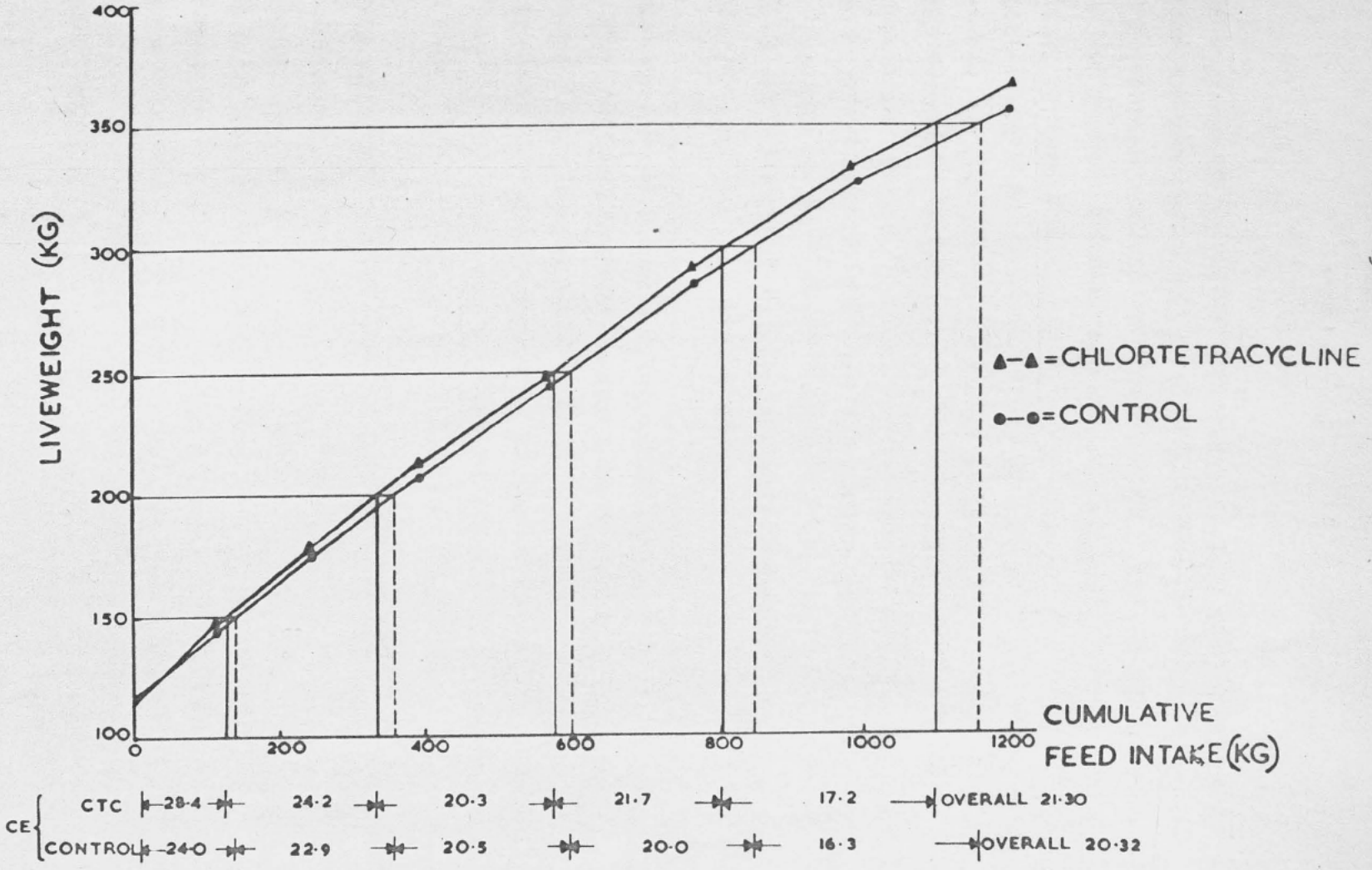
The effect of the antibiotic on conversion efficiency is particularly evident from Figure 3 in which the live-weights of the animals are plotted against their cumulative feed intakes. From this graph one can predict conversion efficiencies for various live-weight ranges between 110 kg and 360 kg. It is interesting to note the decrease in conversion efficiency with the increase in live-weight gain. This is probably due to the higher maintenance requirements of the older animals and to the fact that these lay down increasingly more fat than protein in the later stages. The effect of the antibiotic in retarding this development is obvious from the graph.

Variation in response to the antibiotic between farms

Table 8 : Variation in response to CTC between farms (0-28 weeks for 12 farms, 0-24 weeks for farm 2)

Farm	Effect of CTC on live-weight gain %	Effect of CTC on conversion efficiency %
1	+ 7.0	+ 9.4
2	- 4.7	+ 6.3
3	+ 2.8	+ 2.9
4	+ 15.5	+ 7.8
5	+ 13.2	+ 9.2
6	+ 8.0	+ 3.2
7	+ 0.2	-
8	+ 10.6	+ 5.8
9	- 1.0	+ 10.6
10	+ 0.9	- 0.3
11	+ 5.3	+ 4.0
12	- 2.7	- 0.5
13	+ 2.66	+ 1.1

FIG 3 : EFFECT OF CTC ON CONVERSION – EFFICIENCY (CE)

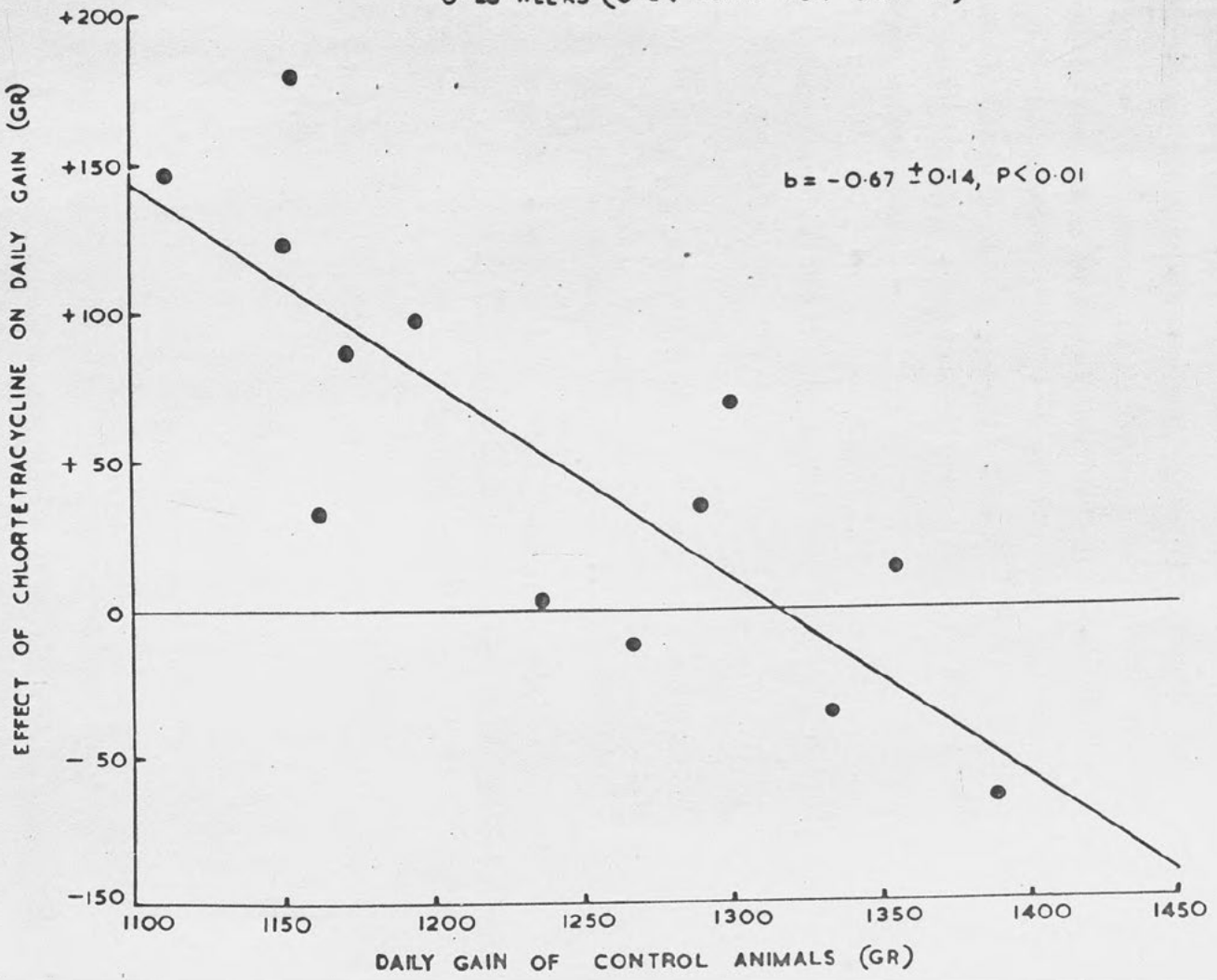


There was a great variation in the effect of the antibiotic as between the various farms (Table 8). The effect on live-weight gain varied between - 4.7 % and+15.5 %, the effect on CE between - 0.5 % and + 10.6 %. We thought that there might be a relationship between the magnitude of the response and the state of management and hygiene on the various farms. From our frequent visits we had our own opinion about the conditions on each place but it was difficult to put these rather subjective judgements into a reasonable scale. We chose therefore the rate of gain of the control animals as an indirect but more objective assessment of the conditions on each farm; for we had experienced in earlier trials that bad housing conditions and poor management were generally reflected by low live-weight gains of the control animals.

The comparison of the average daily gain of the control animals on each farm with the average growth response due to the antibiotic revealed a significant ($P < 0.01$) correlation between these two measurements, i.e. the magnitude of the effect of the antibiotic varied inversely with the rate of growth of the control animals. This relationship is illustrated in Figure 4.

A check was made to confirm that the correlation was meaningful and did not simply arise from random variability in the control results which could affect control results in one direction and the apparent antibiotic response in the other. The relationship between response on each farm and the average rate of gain over both groups of animals was found to be free from any such spurious effect and there was again a significant negative correlation ($P < 0.025$).

FIG.4: CORRELATION BETWEEN EFFECT OF CTC AND PERFORMANCE OF CONTROL ANIMALS 0-28 WEEKS (0-24 WEEKS FOR UNIT 2)



522. Incidence of liver abscesses

Table 9 gives the detailed information about the incidence of liver abscesses in the chlortetracycline-fed groups and the control groups on the various experimental units. On average there were about 5 abscesses per abscessed liver (range 1-15). The majority of the abscesses had a diameter between 1 and 4 cm and were surrounded by a thick fibrous capsule. The capsule contained pus of a creamy viscid consistency (see Figure 5). All abscessed livers were condemned.

Table 9 : Incidence of liver abscesses in 136 chlortetracycline-fed animals and 135 control animals

	CHLORTETRACYCLINE			CONTROL		
Farm	Number of Animals	Animals with abscessed livers	% incidence	Number of Animals	Animals with abscessed livers	% incidence
1	9	1	11.11	8	2	25.00
2	7	-	-	7	1	14.28
3	10	-	-	9	1	11.11
4	8	-	-	6	-	-
5	8	1	12.50	6	4	66.67
6	9	-	-	10	4	40.00
7	9	3	33.33	9	2	22.22
8	9	1	11.11	10	1	10.00
9	-	-	-	-	-	-
10	17	2	11.76	17	6	35.29
11	15	1	6.67	14	2	14.28
12	13	7	53.85	13	4	30.77
13	9	-	-	19	2	22.22
14	13	-	-	17	9	60.00
Total	136	16		135	38	
Average			11.76			28.15

Figure 5. Cut through abscessed liver.

The incidence varied markedly from farm to farm, from nil on some to as high as 67 % in controls and 54 % in those fed antibiotics. For the statistical analysis the percentage figures were transformed by angular transformation. The effect of chlortetracycline in reducing the incidence of liver abscesses was significant at the 5 % level and almost reached the 1 % level of significance.

The bacteriological data are summarized in Table 10.

Table 10 : Bacteriological data of 49 abscessed livers

Organisms	Number of livers	%
Corynebacterium pyogenes only	3	6.1
Corynebacterium pyogenes + *Spherophorus necrophorus*	2	4.1
Spherophorus necrophorus only	10	20.4
Spherophorus necrophorus + other organisms	4	8.2
Other organisms only	9	18.4
No organisms on smears or cultures	21	42.8
Total	49	100

Microscopical examination and aerobic and anaerobic cultures failed to reveal the presence of any organisms in a large percentage (42.8 %) of the material. *S. necrophorus* was isolated most frequently (32.7 % of all lesions) whereas *C. pyogenes* was only found in 10.2 % of the lesions.

Table 11 summarizes the overall incidence of scars in the examined livers. A liver which showed scars but no abscesses was not usually condemned by the meat inspector but was trimmed.

Table 11 : Incidence of scars in control and experimental animals

	CHLORTETRACYCLINE		CONTROL	
	Number of livers	%	Number of livers	%
Total livers examined	136		135	
Livers showing scars	25	18.4	28	20.7

The incidence of liver scars was slightly higher in the control animals but the difference was not significant.

523. Incidence of rumen lesions

Table 12 : Classification and incidence of rumen lesions

	CHLORTETRACYCLINE		CONTROL	
	No. affected	%	No. affected	%
Rumens with no lesions	44	37.3	30	25.9
Rumens showing rumenitis	74	62.7	86	74.1
Acute rumenitis	46	39.0	57	49.1
Chronic rumenitis	9	7.6	8	6.9
Acute + chronic rumenitis	19	16.1	21	18.1
Total rumens examined	118		116	

The incidence of the different degrees of rumen lesions (Table 11) was based on macroscopical examination at the slaughter house. The control animals showed a higher incidence of rumen lesions, but this difference was not significant. Histopathological examination of the sections of the rumen wall will be presented in a separate publication.

Acute Rumenitis : The lesions classified under this heading can be subdivided into three main classes :

Class 1 : Congested, hyperemic areas, varying in size and degree of congestion. Most of the villi in these areas appeared to be normal, although occasional exudative areas were encountered. The size of the affected area varied from about 10-50 cm^2. The affected areas were conspicuous because of their red colour (see Figure 6) and were most commonly encountered in the anterior dorsal sac.

Class 2 : Individual inflamed villi with some obvious deformations, e.g. eroded tops, often capped with exudate, often partly depigmented and necrotic. This kind of lesion was found erratically all over the rumen, but mainly on the floor and the walls of the various compartments. Normally there were only one or two affected villi at one place and they were often found in the middle of a group of villi clumped together by food contents (see Figure 7).

Class 3 : Acute ulcers were found very rarely (only 3.8 % of all lesions). The majority of them were located on the anterior or posterior pillars.

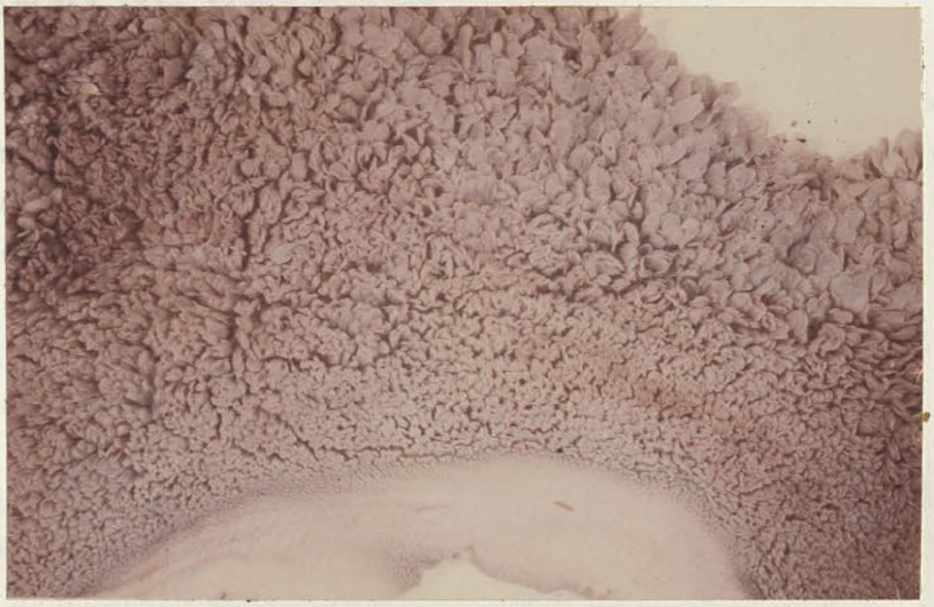


Figure 6. Congested, hyperemic villi, conspicuous because of their pinkish colour (anterior dorsal sac).

Figure 7. Clump of villi that was opened to show inflammed and degenerated villi.

Chronic rumenitis : The various cases of chronic rumenitis can be subdivided into three classes :

Class 1 : Devillated, depigmented areas showing few villi and occasional epithelial nodules (see Figure 8). These lesions were most commonly found on the bottom of the ventral, posterior ventral and posterior dorsal sacs.

Class 2 : Scars-these represented only 16.9 % of all lesions (see Figure 9).

Class 3 : Prominent nodules, almost exclusively found on the anterior and posterior pillars.

Clumped villi : Another conspicuous abnormality which was very commonly found was the adherence of several (10-20) villi together to form a clump (see Figure 10). In some extreme cases the entire villi population of a rumen was thus subdivided into innumerable clumps. These could only be separated by energetic washing and often contained food particles and hairs. The incidence of clumped villi was 61.9 % in the cattle fed antibiotic and 55.2 % in the controls; the difference was not significant statistically. There was no significant difference either in the incidence of clumped villi in normal rumens (52.7 %) and in rumens showing rumenitis (61.25 %). The overall incidence of 58.5 % is much higher than the percentage recorded by Smith (1944) and by Jensen et al. (1954) which were 3.0 % and 3.3 % respectively.

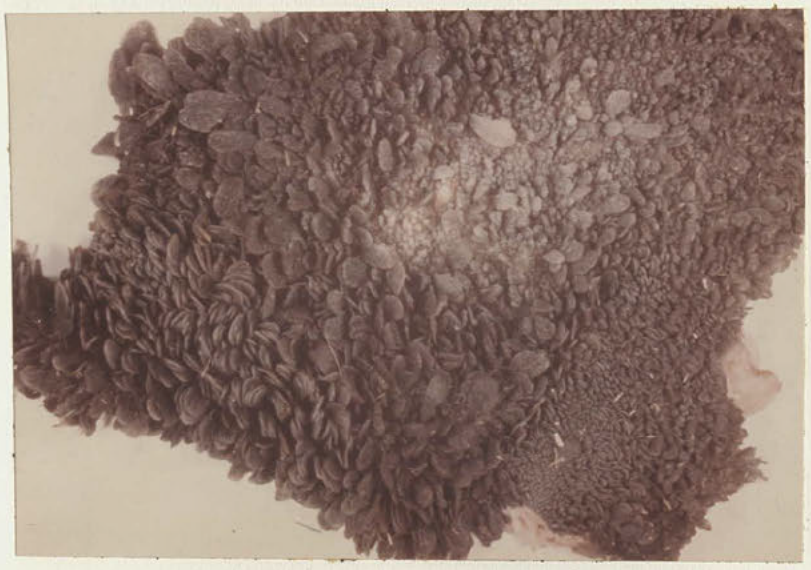


Figure 8. Chronic rumenitis, devillation with epithelial nodule hyperplasia (anterior ventral sac).

Figure 9. Chronic rumenitis, devillation and depigmentation together with well defined scars (ventral sac).

Figure 10 . Sections of the rumen walls (ventral sac) of a conventionally fed (left) and a barley fed animal (right). Note depigmentation, enlarged villi and clumps of villi in the rumen of the barley fed animal.

Correlation between liver abscesses and rumen lesions

Table 13 : Rumen lesions and liver abscesses in 234 cattle

	No. affected	% incidence
Normal rumens	74	
abscessed livers	29	25.7
Injured rumens	160	
abscessed livers	29	18.1

The chi-square test for the association of liver abscesses and rumen lesions was not significant.

53. Discussion

531. Performance data

It is now recognised that certain antibiotics fed at low-levels can improve both the rate of gain and the food utilization of young calves. The magnitude of the growth response varies generally between 10 % and 30 % (Lassiter, 1955). The effect of the antibiotic is less pronounced in older beef cattle; in the average of several experiments with American feedlot cattle (Adams et al., 1955; Flint and Jensen, 1958; Kolari et al., 1960; Heinemann and Fanelli, 1963) the effect was approximately 13 % on live-weight gain and 8 % in food conversion. The results of the present trial confirm this positive effect in older beef cattle, although the average response for both rate of gain and food conversion was only 4-5 %. It has, however, to be noted that this effect was measured over a period of 28 weeks, whereas most of the work with American feedlot cattle was carried out over periods of 12-16 weeks. Our results for the first 12 weeks on experiment (i.e. about 3-6 months of age) which were + 8.5 % for live-weight and + 9.2 % for conversion efficiency are similar to the American findings. Sherman et al. (1959) fed oxytetracycline to 1-year old beef cattle for 24 weeks and recorded a growth response of 4-5 % over this period. The response over the first 12 weeks of the trial was considerably higher (+ 12.7 %) a result which is also in accordance with our own findings.

In the present trial the high response during the first half of the experiment was possibly due to two factors. Most animals had arrived at the fattening unit only shortly before the experiment had started and this change from the calf rearing unit

to the fattening unit is generally a difficult period for the animals. They are often transported over considerable distances and in addition they have to get accustomed to the new environment. Furthermore, the experiment started in late November, i.e. during a season, when because of the varying climatic conditions the animals tend to be more susceptible to respiratory disease. The higher response during the early part of the trial might therefore be related to the generally greater stress conditions of the animals during this period.

The mode of action of the antibiotics in older ruminants is not fully understood. Both Breirem (1956) and Preston (1962) suggested that the higher feed intakes of the antibiotic-fed animals might be one of the causes for their better performance. We failed, however, to show any significant difference between the feed consumption of the two groups. This seems to rule out the feed intake hypothesis for the explanation of the effect in the present trial.

The effect of chlortetracycline on the digestibility of the ration is still a matter of controversy. We ourselves failed to find a positive effect on digestibility and N-retention (see section 43). It does not therefore seem feasible to attribute the positive effect of the antibiotic to an improvement in digestibility. Our ration was adequate both in quantity (approx. 14 % CP in air dry feed) and quality (mainly soya bean meal and fish meal) of the protein supplement. A protein-sparing effect, as described by Whitelaw, Preston and Macleod (1963) seems therefore to be unlikely. A more efficient utilization of the ingested starch by the depression of the starch fermenting rumen bacteria by the antibiotic and an increase in the proportion of starch being digested posterior to the rumen (as suggested by

Preston, 1962) could improve feed utilization since this would increase the metabolizable energy of the ration. This mode of action would lend itself very well to the explanation of the growth effect in barley-beef, since the bulk of the energy of the ration is represented by starch. In our metabolism trials (section 43) we could not, however, confirm the findings of earlier authors (Vandersall, Hibbs and Conrad, 1956; Dinda, 1960) who were able to demonstrate higher blood glucose levels in the animals fed antibiotic. Furthermore, one would expect that such a nutrient sparing effect would lead to more uniform responses on the various units. There is not enough evidence to prove the relevance of this effect in the present trial.

The most striking result of this field trial is the strong negative correlation between the response to the antibiotic and the performance of the control animals. A similar correlation was demonstrated by Braude, Wallace and Cunha (1953) for pigs and by Smith, Taylor and Quenouille (1961) for laying hens. There is also ample evidence that the magnitude of the response both in pigs (Braude, Wallace and Cunha, 1953; Taylor, 1957) and poultry (Coates, Davis and Kon, 1955; White-Stevens, 1957) is largely determined by the "disease-level" or "level of subclinical infections". Many authors therefore concluded that the improved performance of the animals fed antibiotic is at least partly due to the removal of growth depressants rather than to a direct stimulatory effect. It is feasible to assume that a similar mode of action is also responsible for the positive effect of the antibiotic treatment in this experiment. This "disease-level" theory would explain the variation in the responses on the various units and its correlation to the performance of the control animals. The present experiment does not, however, give any indication about the possible nature of these "growth depressing microorganisms". Both in poultry and in pigs these organisms are

thought to be mainly active in the intestines (Coates, 1961; Robinson, 1962).

An effect on the intestinal flora, reflected by a decrease in the incidence of scours has also been claimed for young calves (Lassiter, 1955). In calves over 3 months of age, however, the incidence of scouring is far less important than in the young calf and the site of action of the antibiotic is therefore less obvious. Gordon (1955) presented evidence that the effect of nutritional supplementation with antibiotic does not need to be confined to the digestive tract but that the antibiotic is also distributed throughout the body fluid at detectable bacteriostatic levels. Taylor (1957) reviewing Gordon's work suggested therefore that this systemic distribution could affect micro-organisms in many sites other than the digestive tract. He also reviewed earlier results showing that a number of subclinical and, on occasions, even clinical diseases were actually controlled by nutritional levels of antibiotics. This evidence suggests that the search for growth depressing agents in beef cattle does not necessarily need to be confined to the digestive tract but that one could also expect an effect of the antibiotic on, for example, respiratory diseases or on organisms producing toxins. The effect of an antibiotic in decreasing the incidence of liver abscesses seems to be one example of this systemic action of the antibiotic.

In the light of the above findings the question of the mode of action seems to become more a problem of chemotherapy than nutrition. Further knowledge is thus more likely to be gained by a study of the pathology of these growth depressing organisms.

532. Liver abscesses and rumen lesions

The incidence of liver abscesses in American feedlot cattle is, as already mentioned, directly related to the abrupt introduction of these previously range-fed cattle to a high-cereal diet at about 90-120 days before slaughter. Barley-beef cattle, on the other hand, are gradually changed over to the cereal ration at about 2½ to 3 months of age and there is at first sight no obvious period during which liver abscesses are likely to arise. Although some workers have suggested that the liver abscesses in barley-beef cattle might arise at the time of weaning there is not enough evidence to support this claim. It is perhaps more plausible to use the data of Jensen, Flint and Griner (1954) about the development of abscesses caused by S. necrophorus to estimate the probable age of the abscesses encountered in the present experiment. These authors produced liver abscesses experimentally by intraportal inoculation of S. necrophorus and slaughtered batches of the inoculated animals at varying intervals (1-183 days) after inoculation. From these and earlier results the authors concluded that the average duration of these abscesses was about 115 days and that after this time most abscesses were in the scar stage. If one applies these results to barley-beef conditions and even allowing generously for a cycle of 4-5 months this would mean that most abscesses encountered at slaughter would have originated a long time after weaning, in fact when the cattle were about 6-7 months of age.

The origin of lesions found at the scar stage is even more difficult to date. In the experiment of Jensen, Flint and Griner (1954) liver scars had already appeared 46 days after inoculation and some were still found at 183 days after inoculation which was the longest interval that these authors investigated. The scars,

which we found at slaughter could therefore be the result of abscesses which could have been active both before or during the experimental period. The fact that there was no significant difference in the incidence of scars in the antibiotic and the control group seems to indicate, however, that these lesions had arisen before the start of the antibiotic treatment, i.e. before the animals were 3 to 4 months old.

One could therefore conclude that in barley-beef cattle liver abscesses are likely to arise at almost any age and that any measures to prevent this disease should be applied over the whole period from weaning to slaughter.

The significant decrease in the incidence of liver abscesses from 27.1 % to 10.8 % due to the feeding of chlortetracycline represents a treatment effect of 58 % relative to the incidence in the control animals. Flint and Jensen (1958) working with a total of 1895 animals demonstrated that the feeding of chlortetracycline brought down the incidence from 49 % to 19 %, i.e. a relative reduction of 60 %. The similarity of the two results seems to indicate that the sample of animals used in the present study was sufficiently representative.

There are no data in the literature about the effect of liver abscesses on growth performance. On one farm in the present trial 9 animals out of a control group of 17 animals had abscessed livers (an average of 8 abscesses per liver). The average daily gain for the last 3 months prior to slaughter of the 8 healthy animals was slightly higher (1.54 kg/day) than for the animals with abscessed livers (1.49 kg/day) but this effect was not significant. It is also interesting to relate, in this connection three further cases of spontaneous liver abscesses which occurred

at the Rowett Institute. In one case, a steer of approx. 300 kg live-weight steadily deteriorated in rate of gain and in body condition and had to be prematurely slaughtered. The only abnormality noted at the autopsy was the liver which showed 25-30 abscesses of 1-2 cm diameter. The two other cases were both younger animals which had to be slaughtered at about 250 kg because they had stopped growing. One of them had a huge liver abscess of the size of a football, adhering to the diaphragm; the other had a liver with about 20 abscesses of 2-4 cm diameter. From this rather scarce information one could suggest that the effect of the liver abscesses on growth performance may depend on the extent to which the liver is damaged. The liver tissue has an extraordinary ability to regenerate and can stand a loss of more than half of its functional tissue. If the damage is, however, too extensive or if further complications like adherence to the diaphragm or other organs are involved, the performance of the animal might well be affected.

Some workers (Dinda, 1960; Mann, Masson and Oxford, 1954) report that young calves fed an antibiotic had less acid rumens than control animals. A reasonable hypothesis is that this rise in rumen pH could perhaps alleviate the rumenitis and thereby also reduce the primary cause of the invasion of pathogens into the liver. In older calves, however, we could not reproduce this effect of chlortetracycline on rumen pH (section 43) and the field trial (section 423) showed no significant effect of the antibiotic on the incidence of rumen lesions. It is probably plausible to attribute most of the effect of the chlortetracyclines in decreasing the incidence of liver abscesses to their antimicrobial action on the causative agents of the liver abscesses. Gordon (1956) followed the fate of aureomycin given orally to calves at the rate of 100 mg/day and found detectable bacteriostatic

levels of aureomycin in the blood (0.04 ug - 0.09 ug/ml blood) up to 24 hours after feeding. Although this can not be regarded as a therapeutic level, Gordon (1956) considers that, in a prophylactic sense, this concentration is high enough to aid the normal defence mechanism in preventing the establishment of infections of clinical or subclinical nature.

Examination of the rumens in this experiment showed that rumenitis is a common feature among barley-beef cattle. The range of lesions encountered was very similar to that described for American feedlot cattle although there appear to be differences in the incidence and severity of the individual lesions. The combined incidence of acute and chronic rumenitis in this experiment was considerably higher (68.3 %) than in the experiment of Jensen et al. (1954) (37.6 %). The lesions in the barley-beef cattle seem, however, to be less severe; more than half of the lesions encountered indicated only mild rumenitis, whereas according to the figures and illustrations of Jensen et al. (1954) the lesions in feedlot cattle appeared to be much more severe with a higher incidence of ulcers and scars. This difference possibly reflects the different management of animals under these two systems.

Our failure to confirm a correlation between rumen lesions and liver abscesses as mentioned by Jensen et al. (1954) could be due to two factors. First it could be a consequence of the smaller sample of animals used; secondly it could be due to the fact that the lesions in barley-beef cattle are generally less severe than in feedlot cattle. In trying to establish a rumen lesion - liver abscess correlation we are relating the incidence of rumen lesions at slaughter to the incidence of liver abscesses which have originated 2-4 months earlier. The incidence of smaller

lesions is likely to fluctuate during this time and the original lesions which allowed the invasion of pathogens into the portal system could well have been healed and thus macroscopically unnoticeable at slaughter. The more severe ulcerative lesions in feedlot cattle, on the other hand, would still be easily traceable at slaughter.

The prime cause of liver abscesses, i.e. the inflammation of the rumen wall, is probably a direct consequence of the rapid fermentation of cereals in intensively-fed cattle. This fermentation is, however, one of the basic reasons for the high live-weight gains and good conversion efficiencies in this feeding system. It will therefore be difficult to eliminate this predisposing condition and instead one must probably be resigned to combat the pathogens in the blood and in the liver. Further investigation of possibilities for immunization and of variations in the antibiotic treatment seem therefore to be needed.

533. Financial considerations

From a practical standpoint the main criterion whether or not to feed antibiotics is their economic value. Under barley-beef conditions there are two factors which can determine this value; the saving of feed due to the improved feed utilization and the reduction in the incidence of liver abscesses. Table 14 compares the costs of the antibiotic per animal and the savings achieved by feeding it. Three different calculations are given; one on the basis of the average response over all units on the present trial and one each for both the farm with the highest and the farm with the lowest response. An incidence of liver abscesses of 28.2 % results thus in an average loss of about 8s. 5d. for every animal slaughtered. The significant reduction of this incidence to 11.8 % (see section 522) due to the administration of an antibiotic can therefore be evaluated at about 4s. 10d. a head.

Table 14 : Economics of low-level feeding of antibiotics over the live-weight range from 115 kg to 360 kg (per animal)

	Saving of feed kg	Cost of feed saved*	Saving due to reduction in incidence of liver abscesses	gross saving	Total anti-biotic eaten g	Cost of anti-biotic‡	Net saving
Average (13 units)	52	24s. 6d.	4s. 10d.	29s. 4d.	23.2	23s. 3d.	6s. 1d.
Unit No. 1 (highest response)	129	60s.	4s. 10d.	64s.10d.	19.9	19s.11d.	44s.11d.
Unit No.12 (lowest response)	- 5.5	- 2s. 6d.	4s. 10d.	2s. 4d.	26.0	26s.	- 23s. 8d.

* costing feed at 0.471s./kg
‡ costing antibiotic at 1s./g

Feeding of chlortetracycline gave a net saving on only 7 units.

On farms with an average response the benefit from feeding an antibiotic is marginal. Where conditions are poor and the response correspondingly high, the saving can, however, be as high as 45s. per animal. On the 6 farms with low responses, on the other hand, the cost of the antibiotic was not covered by the saving due to improved performance. It is obvious from these calculations that the feeding of an antibiotic can be of some value on farms where the gains are consistently under the expected average. If poor housing conditions and hygiene are the cause of such results the feeding of antibiotics could be a temporary answer until the main predisposing conditions are corrected. For the average farm, however, the administration of 20 mg chlortetracycline/kg of feed over the live-weight range from 115 to 360 kg does not seem to be an economical proposal.

There are two possible modifications of the administration which could improve the profitability under average conditions. The results of the present trial indicate a high effect of the antibiotic during the first 12 weeks and only a marginal effect during the following 16 weeks. The logical conclusion would therefore be to withdraw the antibiotic after 12 weeks or at least to reduce the level of administration. Jacobson, Kaffetzakis and Hohmeyer, 1952, Ellsworth et al., 1953, Edgerly, 1953, found that the withdrawal of chlortetracycline at 96-116 days of age did affect the growth rate of the previously antibiotic fed animals but their ensuing performance was still at least as good as the performance of their controls. Hibbs, Conrad and Pounden, 1954 and Marshall, Wing and Dix Arnold, 1957, on the other hand demonstrated that following the removal of the antibiotic from the diet the weight gains of the calves were significantly lower than the weight gains of their controls. All the above-mentioned experiments have been done with dairy calves on a predominantly roughage diet with

up to 2 kg of concentrate per calf each day.

An alternative to complete withdrawal would be a reduction of the level of the antibiotic after the animals have reached a live-weight of 200 to 250 kg. In the present experiment the antibiotic was included in the supplement at a standard rate to give a concentration of 20 mg chlortetracycline/kg of feed. Due to the increase in daily feed consumption from approx. 4 to 8 kg over the live-weight range from 115 to 360 kg the antibiotic intake increased proportionally from 80 mg to 160 mg per animal and day. The high intake of chlortetracycline during the later stages represented an unnecessary waste of the expensive material, but the inclusion of the antibiotic in the supplement simplified the handling of the feed by the farmer. American results with feedlot cattle (Flint and Jensen, 1958; Kolari et al., 1960; Heinemann and Fanelli, 1963) demonstrated that a level of 75 mg per animal per day is satisfactory for animals up to 500 kg live-weight. Under the conditions of the present trial, the feeding of a standard rate of 75 mg chlortetracycline per day would have reduced the total antibiotic intake from 23.2 g to 14.7 g per animal. Unfortunately the administration of a uniform daily level of antibiotic does not seem practicable in the present barley-beef system, where the animals are fed ad libitum from self feeding hoppers.

In conclusion it can be said that the low-level feeding of chlortetracycline at 20 mg/kg feed can be of considerable economic value on farms where the performance of animals is consistently below the expected average. Under the conditions encountered on an average barley-beef unit this level of inclusion is only of marginal economic advantage. Experiments to examine the effects of the withdrawal or the reduction of the level of the antibiotic at about 200 to 250 kg live-weight could probably lead to a more satisfactory solution.

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8. Appendix

Table 15 : Digestibility coefficients and nitrogen balance data of calves given diets containing oxytetracycline (O), bacitracin (B) or no antibiotic supplementation (C), (Expt. 1).

Block No.	Calf No.	Diet	Dry matter digestibility %	Apparent nitrogen digestibility %	Nitrogen retention g/day	Nitrogen retention % of dietary N
1	1	C	84.38	80.94	32.26	38.93
	2	C	84.15	80.82	35.05	39.32
	3	O	83.54	80.66	27.98	32.58
	4	O	83.18	80.49	24.55	29.86
	5	B	85.05	82.94	33.30	37.47
	6	B	84.31	81.23	31.18	34.68
2	7	C	84.40	79.80	26.34	43.30
	8	C	83.30	77.58	28.28	44.73
	9	O	82.41	75.43	28.66	48.26
	10	O	83.74	79.15	25.95	42.00
	11	B	83.98	78.76	32.57	52.13
	12	B	83.35	78.04	29.65	47.45
3	13	C	86.44	81.42	22.24	26.15
	14	C	82.94	77.96	20.14	23.69
	15	O	84.32	80.37	34.85	41.90
	16	O	85.21	82.97	37.42	47.00
	17	B	82.07	78.92	28.50	35.36
	18	B	81.23	77.56	29.42	34.03

Table 16 : Analyses of variance for digestibility and nitrogen balance data.

	Source of variation	d.f.	Sum of squares	Mean Square	F-values calculated	Table P=0.05	Table P=0.01
Dry matter digestibility	Treatments	2	3	1.5	0.071	3.8	6.7
	Blocks	2	1	0.5			
	Error	13	21	1.62			
	Total	17	25				
Apparent nitrogen digestibility	Treatment	2	1	0.5	0.17	3.8	6.7
	Blocks	2	27	13.5			
	Error	13	38	2.92			
	Total	17	66				
Nitrogen retention g/day	Treatment	2	38	19	0.84	3.8	6.7
	Blocks	2	17	8.5			
	Error	13	294	22.6			
	Total	17	349				
Nitrogen retention % of dietary N	Treatment	2	70	35.5	0.99	3.8	6.7
	Blocks	2	504	252			
	Error	13	467	35.9			
	Total	17	1041				

Standard error of difference was calculated according to the formula :

$$SE = \frac{\text{mean square of error} \times 2}{6}$$

Table 17 : Rumen ammonia contents (meq/l) of calves given diets containing oxytetracycline (O), bacitracin (B) or no antibiotic supplementation (C), (Expt. 1).

Block No.	Calf No.	Diet	8 a.m.	11 a.m.	2 p.m.	Average
1	1	C	3.89	1.84	5.20	3.64
	2	C	5.46	0.89	1.94	2.76
	3	O	2.78	3.68	8.20	4.89
	4	O	7.67	4.68	6.94	6.76
	5	B	4.57	3.68	4.89	4.38
	6	B	1.94	1.63	6.15	3.24
2	7	C	1.05	3.94	7.36	4.11
	8	C	1.68	1.50	4.89	2.69
	9	O	4.78	5.26	1.09	3.71
	10	O	2.73	4.36	6.62	4.57
	11	B	1.47	3.42	8.20	4.36
	12	B	1.45	2.26	6.36	3.36
3	13	C	5.52	3.36	9.72	6.20
	14	C	8.78	1.68	7.09	5.85
	15	O	12.30	6.83	8.36	9.16
	16	O	7.93	3.68	4.83	5.48
	17	B	3.73	4.68	4.15	4.19
	18	B	5.68	2.31	3.78	3.92

Analysis of variance (pooled average of 3 samples)

Source of variation	d.f.	Sum of squares	Mean square	F - values calculated	Table P=0.05	Table P=0.01
Treatment	2	11.8	5.9	4.1*	3.8	6.7
Blocks	2	13.1	6.6			
Error	13	18.7	1.44			
Total	17	43.6				

* significant at 5 % level

Table 18 : Blood urea contents (mg/100 ml) of calves given diets containing oxytetracycline (O), bacitracin (B) or no antibiotic supplementation (C), (Expt. 1).

Block No.	Calf No.	Diet	6.30 a.m.	8.00 a.m.	11.00 a.m.	2.00 p.m.	Average
1	1	C	21.80	20.84	18.77	20.84	20.56
	2	C	22.91	24.66	22.43	21.80	22.95
	3	O	34.37	36.11	29.59	30.55	32.66
	4	O	36.43	39.14	38.50	39.93	38.50
	5	B	30.07	31.50	27.84	27.52	29.23
	6	B	31.18	31.66	26.41	26.09	28.83
2	7	C	22.27	23.24	20.05	19.25	21.20
	8	C	15.43	16.55	14.32	14.64	15.24
	9	O	25.14	26.41	22.75	23.06	24.34
	10	O	26.09	28.64	25.30	27.68	26.93
	11	B	21.80	23.86	20.68	21.96	22.08
	12	B	21.64	23.39	10.82	22.75	19.65
3	13	C	21.48	24.66	25.30	27.36	24.70
	14	C	29.75	33.57	32.61	31.66	31.90
	15	O	30.55	30.55	31.98	31.34	31.10
	16	O	26.73	30.86	32.46	31.18	30.30
	17	B	17.82	19.25	19.09	19.41	18.89
	18	B	23.86	24.66	28.00	27.84	26.10

Analysis of variance (pooled average of 4 samples)

Source of variation	d.f.	Sum of squares	Mean square	F - values calculated	Table P=0.05	Table P=0.01
Treatment	2	212	106	6.70**	3.8	6.7
Blocks	2	167	84			
Error	13	205	15.8			
Total	17	584				

** significant at 1 % level

Table 19 : Rumen pH values of calves given diets containing oxytetracycline (O), bacitracin (B) or no antibiotic supplementation (C), (Expt. 1).

Block No.	Calf No.	Diet	8 a.m.	11 a.m.	2 p.m.	Average
1	1	C	6.90	6.35	6.55	6.60
	2	C	6.60	6.00	6.95	6.52
	3	O	5.90	6.20	6.80	6.30
	4	O	6.30	6.35	7.10	6.58
	5	B	7.00	6.90	7.00	7.00
	6	B	6.20	5.90	6.80	6.30
2	7	C	5.65	6.20	6.70	6.18
	8	C	5.25	5.60	6.40	5.75
	9	O	5.60	6.60	6.95	6.38
	10	O	6.60	6.85	7.15	6.87
	11	B	5.80	5.70	6.95	6.15
	12	B	5.90	5.80	6.95	6.21
3	13	C	6.50	6.55	6.85	6.63
	14	C	5.70	6.20	6.80	6.23
	15	O	6.40	6.75	7.20	6.78
	16	O	6.40	6.75	7.05	6.73
	17	B	5.95	6.80	6.60	6.45
	18	B	6.00	6.60	6.50	6.37

Analysis of variance (pooled average of 3 samples)

Source of variation	d.f.	Sum of squares	Mean square	F - values calculated	Table P=0.05	Table P=0.01
Treatment	2	0.2	0.1	2.17	3.8	6.7
Blocks	2	0.9	0.45			
Error	13	0.6	0.046			
Total	17	1.7				

Table 20 : Blood glucose contents (mg/100 ml) of calves given diets containing oxytetracycline (O), bacitracin (B) or no antibiotic supplementation (C), (Expt. 1).

Block No.	Calf No.	Diet	6.30 a.m.	8.00 a.m.	11.00 a.m.	2.00 p.m.	Average 6.30a.m. 11.00a.m. 2.00p.m.
1	1	C	56.2	-	67.2	65.3	62.9
	2	C	56.9	-	59.0	56.9	57.6
	3	O	56.7	-	57.9	54.2	56.3
	4	O	74.6	-	60.6	63.1	66.1
	5	B	52.3	-	57.4	54.8	54.8
	6	B	52.6	-	54.2	53.2	53.3
2	7	C	65.8	60.3	58.6	65.6	63.3
	8	C	71.5	55.3	57.3	66.2	65.0
	9	O	60.6	46.2	51.0	52.5	54.7
	10	O	64.8	57.2	55.4	61.8	60.7
	11	B	64.0	50.5	61.8	71.3	65.7
	12	B	56.0	44.7	37.6	41.1	44.9
3	13	C	72.5	68.7	71.1	63.5	69.0
	14	C	74.3	73.7	74.0	66.8	71.7
	15	O	81.3	83.9	81.9	82.0	81.7
	16	O	77.2	73.1	75.4	75.9	76.2
	17	B	58.8	56.1	61.7	57.4	58.9
	18	B	71.9	69.6	66.4	61.9	66.7

Analysis of variance (pooled average of 3 samples)

Source of variation	d.f.	Sum of squares	Mean square	F - values calculated	Table P=0.05	Table P=0.01
Treatment	2	257	126	3.3	3.8	6.7
Blocks	2	563	281			
Error	13	494	38			
Total	17	1314				

Table 21 : Rumen pH values and volatile fatty acid concentrations in the rumen of calves given diets containing oxytetracycline (O), bacitracin (B) or no antibiotic supplementation (C), (Expt. 2).

Block No.	Calf No.	Diet	Rumen pH			VFA concentrations (meq/l)		
			9 a.m.	11 a.m.	Average	9 a.m.	11 a.m.	Average
1	1	C	6.30	6.40	6.35	86.8	74.8	80.8
	2	C	6.60	6.55	6.57	83.6	75.8	79.7
	3	O	6.60	6.45	6.52	89.6	86.2	87.9
	4	O	5.45	5.45	5.45	125.8	120.7	123.3
	5	B	6.45	6.65	6.55	89.2	85.8	87.5
	6	B	5.85	6.20	6.02	108.0	94.0	101.0
2	7	C	6.25	6.80	6.53	92.9	87.6	90.3
	8	C	6.90	6.80	6.85	58.4	80.0	69.2
	9	O	6.55	6.65	6.60	89.2	91.6	90.4
	10	O	6.85	6.95	6.90	71.4	79.0	75.2
	11	B	6.75	6.90	6.82	73.6	92.0	82.6
	12	B	6.75	7.20	6.97	77.8	60.8	69.3
3	13	C	6.20	6.60	6.40	103.6	78.6	91.1
	14	C	6.60	6.85	6.72	86.6	73.8	70.3
	15	O	6.80	6.95	6.87	66.6	71.6	69.1
	16	O	6.45	6.45	6.45	88.56	92.86	90.6
	17	B	6.70	6.70	6.70	72.40	84.0	76.2
	18	B	6.80	6.60	6.70	72.80	86.8	79.8

Analyses of variance

	Source of variation	d.f.	Sum of squares	Mean square	F - values calculated	Table P=0.05	Table P=0.01
Rumen pH (pooled average of 2 samples)	Treatment	2	0.30	0.15	1.87	3.8	6.7
	Blocks	2	1.00	0.50			
	Error	13	1.05	0.08			
	Total	17	2.35				
VFA (pooled average of 2 samples)	Treatment	2	270	135	0.87	3.8	6.7
	Blocks	2	768	384			
	Error	13	2027	155			
	Total	17	3065				

Table 22 : Blood glucose concentrations (mg/100 ml) of calves given diets containing oxytetracycline (O), bacitracin (B) or no antibiotic supplementation (C), (Expt. 2).

Block No.	Calf No.	Diet	9 a.m.	11 a.m.	1 p.m.	3 p.m.	5 p.m.	7 p.m.	Average	Increase 9a.m.-5p.m.
1	1	C	69.59	66.67	69.59	62.43	72.21	70.80	68.55	+ 2.62
	2	C	55.34	55.54	59.73	59.25	63.22	58.72	58.63	+ 7.88
	3	O	68.77	69.89	66.58	64.74	73.02	77.11	70.02	+ 4.25
	4	O	53.70	56.47	65.48	60.10	67.44	56.69	59.98	+ 13.74
	5	B	68.22	63.64	59.18	61.05	59.13	64.03	62.54	- 9.09
	6	B	60.27	55.50	55.30	(61.12)	62.67	69.75	60.70	+ 2.40
2	7	C	67.84	76.74	69.61	71.24	74.51	78.43	73.06	+ 6.67
	8	C	(59.03)	60.46	63.37	58.82	62.42	(67.29)	60.82	+ 3.39
	9	O	55.85	66.28	61.92	66.34	64.05	64.05	63.08	+ 8.20
	10	O	63.07	63.37	63.08	76.47	66.67	65.68	66.39	+ 3.60
	11	B	76.02	77.33	70.93	62.74	78.43	78.43	73.98	+ 2.41
	12	B	42.48	57.27	53.78	74.18	62.09	56.14	57.66	+ 19.61
3	13	C	63.73	61.27	63.03	64.39	61.15	59.35	63.15	- 2.58
	14	C	63.03	64.00	67.25	71.94	59.71	57.91	63.97	- 3.32
	15	O	65.14	73.94	67.96	70.14	69.78	72.30	69.88	+ 4.46
	16	O	67.25	69.37	68.66	71.58	72.30	66.55	69.28	+ 5.05
	17	B	56.29	63.38	65.14	70.14	64.75	67.62	64.55	+ 8.46
	18	B	61.62	62.32	64.08	66.55	66.19	65.47	64.37	+ 4.57

( ) = missing values in original data (clotted blood) were calculated according to the formula $x = \bar{x} + (\frac{B+x}{nB} - \bar{x}) + (\frac{T+x}{nT} - \bar{x})$

(B=Sum of other values of the same block, T=Sum of other values of the same treatment).

Analysis of variance

	Source of variation	d.f.	Sum of squares	Mean square	F - values calculated	Table P=0.05	Table P=0.01
Pooled average of 6 samples	Treatment	2	20	10	0.37	3.8	6.7
	Blocks	2	24	12			
	Error	13	354	27.23			
	Total	17	398				
Increase 9a.m.-5p.m.	Treatment	2	52	26	1.31	3.8	6.7
	Blocks	2	69	34.5			
	Error	13	257	19.8			
	Total	17	378				

Table 23 : Number of animals on the two treatments and average weight of the animals at the start of the experiment.

CTC - groups			Control - groups		
Farm	Number of animals	Live-weight lb	Farm	Number of animals	Live-weight lb
1	10	247.1	1	10	257.6
2	8	329.0	2	7	314.0
3	11	255.2	3	11	264.7
4	9	258.2	4	9	257.4
5	9	218.4	5	9	217.3
6	10	262.8	6	10	264.6
7	10	243.0	7	10	250.4
8	12	193.7	8	12	197.8
9	11	265.4	9	9	274.4
10	17	257.4	10	17	267.6
11	15	245.0	11	15	249.2
12	13	269.7	12	13	284.3
13	9	231.0	13	9	238.8
Total (Farms 1-13 excl. casualities and withdrawals)	144			141	
Average		252.0			256.8
		114.5 kg			116.7 kg
Farm 14 (performance data discarded)	19			19	
Casualities and withdrawals during expt. (all farms)	7			9	
Total number of calves at start of experiment	170			169	

Table 24 : Performance data 0 - 4 weeks.

Farm	CTC - group				Control - group			
	Live-weight* lb	Gain lb	Feed-intake lb	Conv. eff.	Live-weight* lb	Gain lb	Feed-intake lb	Conv. eff.
1	326.9	79.8	215.6	37.01	321.3	63.7	219.0	29.09
2	396.4	67.4	304.5	22.14	389.0	75.0	311.5	24.08
3	328.4	73.2	249.0	29.39	326.4	61.7	249.0	24.78
4	308.7	50.6	261.0	19.37	303.3	45.9	243.0	18.88
5	273.0	54.8	222.0	24.68	266.0	48.7	205.0	23.76
6	333.9	71.1	160.4	44.33	326.9	62.3	163.8	38.03
7	298.0	55.0	-	-	298.2	47.8	-	-
8	263.7	70.0	191.3	36.59	260.8	63.0	196.0	32.14
9	326.8	61.4	269.3	22.78	326.1	51.7	293.4	17.61
10	340.1	82.8	260.8	31.73	342.2	74.6	258.7	28.81
11	319.7	74.7	261.3	28.59	318.3	69.1	268.8	25.70
12	331.7	61.9	264.7	23.39	333.7	52.8	258.0	20.46
13	299.4	68.4	209.2	32.72	296.3	57.6	208.0	27.67
Total	4146.7	871.1	2869.1	352.72	4108.5	773.9	2874.2	311.01
Average	319.0	67.0	239.1	29.39	316.0	59.53	239.5	25.92
Kg per day and animal		1.09	3.88			0.97	3.89	

* Live-weights given in Tables 24 to 30 are always live-weights recorded at the end of the mentioned period, in this table e.g. after the calves had been 4 weeks on the experiment.

Table 25 : Performance data 5 - 8 weeks.

Farm	CTC - group Live-weight lb	Gain lb	Feed-intake lb	Conv. eff. %	Control - group Live-weight lb	Gain lb	Feed-intake lb	Conv. eff. %
1	392.0	65.1	232.8	27.96	394.8	73.5	229.0	32.10
2	472.1	76.1	399.0	19.07	473.1	84.0	436.6	19.24
3	396.4	68.1	316.0	21.55	390.0	63.6	327.0	19.45
4	395.8	87.1	249.0	34.98	365.5	62.2	240.0	25.92
5	331.3	58.3	184.0	31.68	311.1	45.1	174.0	25.91
6	423.5	89.6	298.1	30.06	404.6	77.7	292.6	26.56
7	386.4	88.4	-	-	389.2	91.0	-	-
8	330.2	66.5	252.0	26.39	329.6	68.8	252.0	27.33
9	397.7	70.9	292.6	24.23	402.2	76.1	307.1	24.78
10	410.1	70.0	339.1	20.64	416.3	74.1	332.9	22.26
11	394.3	74.7	321.1	23.26	393.9	75.6	343.5	22.01
12	407.1	75.4	319.4	23.60	405.5	68.4	323.0	21.18
13	366.3	66.9	288.9	23.15	364.8	68.4	303.4	22.56
Total	5103.2	957.1	3492.0	306.57	5040.6	928.5	3561.1	289.30
Average	392.6	73.62	291.0	25.55	387.7	71.42	296.8	24.11
Kg per day and animal		1.20	4.72			1.16	4.82	

Table 26 : Performance data 9 - 12 weeks.

Farm	CTC - group Live-weight lb	Gain lb	Feed-intake lb	Conv. eff. %	Control - group Live-weight lb	Gain lb	Feed-intake lb	Conv. eff. %
1	453.6	61.6	261.2	23.58	454.3	59.5	251.8	23.63
2	547.8	75.3	420.0	17.92	545.0	72.0	480.1	15.00
3	472.2	75.7	326.0	23.22	460.1	70.0	321.0	21.81
4	485.3	89.4	299.0	29.90	439.4	73.9	280.0	26.39
5	420.0	88.7	256.0	34.65	381.1	70.0	243.0	28.80
6	480.2	56.7	345.8	16.40	451.5	46.9	324.1	14.47
7	438.2	51.8	-	-	441.0	51.8	-	-
8	418.8	88.7	336.0	26.39	401.9	72.3	308.0	23.48
9	468.6	70.9	343.1	20.67	473.9	71.7	394.8	18.15
10	490.4	80.3	317.4	25.30	486.3	70.0	320.0	21.88
11	464.8	70.5	365.9	19.26	460.6	66.7	350.9	19.02
12	493.2	86.2	365.0	23.60	493.2	87.8	362.0	24.25
13	437.9	71.6	294.7	24.28	426.2	61.4	269.9	22.76
Total	6071.0	967.4	3930.1	285.17	5914.5	874.0	3905.6	259.64
Average	467.0	74.41	327.5	23.76	455.0	67.23	325.5	21.64
Kg per day and animal		1.21	5.32			1.09	5.28	

Table 27 : Performance data 13 - 16 weeks.

Farm	CTC - group Live-weight lb	Gain lb	Feed-intake lb	Conv. eff. %	Control - group Live-weight lb	Gain lb	Feed-intake lb	Conv. eff. %
1	527.1	73.5	321.5	22.86	526.4	72.1	336.0	21.46
2	638.8	91.0	448.0	20.31	647.0	102.0	500.0	20.40
3	538.4	66.2	377.0	17.56	526.3	66.2	377.0	17.56
4	558.4	73.1	398.0	18.37	521.9	82.4	380.0	21.68
5	470.6	50.6	355.0	14.24	437.9	56.8	338.0	16.80
6	581.0	100.8	399.7	25.22	548.1	96.6	395.5	24.42
7	508.9	70.7	-	-	515.2	74.2	-	-
8	474.8	56.0	340.7	16.44	463.8	61.8	294.0	21.03
9	527.2	58.6	359.0	16.33	536.7	62.8	420.4	14.93
10	591.3	100.9	392.0	25.73	583.5	97.2	363.6	26.73
11	544.1	79.3	425.6	18.64	540.9	80.3	425.6	18.86
12	585.3	92.1	430.0	21.41	597.7	104.4	460.8	22.66
13	524.2	86.3	390.4	22.11	514.9	88.7	383.1	23.14
Total	7070.1	999.1	4636.9	239.22	6960.3	1045.5	4674.0	249.67
Average	543.8	76.85	386.4	19.94	535.4	80.42	389.5	20.80
Kg per day and animal		1.25	6.27			1.31	6.32	

Table 28 : Performance data 17 - 20 weeks.

	CTC - group				Control - group			
Farm	Live-weight lb	Gain lb	Feed-intake lb	Conv. eff. %	Live-weight lb	Gain lb	Feed-intake lb	Conv. eff. %
1	625.8	98.7	362.7	27.21	613.2	86.8	366.8	23.66
2	738.6	99.8	528.5	18.88	745.0	98.0	548.0	17.88
3	633.2	94.8	422.0	22.46	623.6	97.4	413.0	23.58
4	666.6	108.1	459.0	23.55	620.7	98.8	435.0	22.71
5	577.9	107.3	407.8	26.31	525.8	87.9	388.9	22.60
6	660.8	79.8	476.0	16.76	624.4	76.3	448.0	17.03
7	599.9	91.0	-	-	607.6	92.4	-	-
8	558.2	83.4	373.3	22.35	527.3	63.6	359.3	17.70
9	636.4	109.1	421.8	25.86	630.6	93.9	484.4	19.38
10	674.9	83.6	431.5	19.37	682.7	99.2	431.5	23.00
11	658.0	113.9	500.3	22.77	638.0	97.1	477.8	20.32
12	655.8	70.5	465.2	15.16	688.2	90.5	465.2	19.44
13	619.9	95.7	444.4	21.53	607.4	92.6	435.6	21.25
Total	8306.0	1235.7	5292.5	262.21	8134.5	1174.5	5253.5	248.55
Average	638.9	95.05	441.0	21.84	625.7	90.35	437.8	20.71
Kg per day and animal		1.54	7.16			1.46	7.11	

Table 29 : Performance data 21 - 24 weeks.

	CTC - group				Control - group			
Farm	Live-weight lb	Gain lb	Feed-intake lb	Conv. eff. %	Live-weight lb	Gain lb	Feed-intake lb	Conv. eff. %
1	701.4	75.6	356.5	21.21	704.2	91.0	372.9	24.40
2	818.1	79.6	493.5	16.13	827.0	82.0	616.0	13.31
3	710.8	77.6	448.0	17.33	700.0	76.4	468.0	16.32
4	766.1	99.6	507.0	19.64	703.1	82.4	457.0	18.04
5	665.0	87.1	433.8	20.08	608.2	82.5	441.6	18.67
6	742.7	81.9	502.7	16.29	704.2	79.8	462.4	17.26
7	685.3	85.4	-	-	699.3	91.7	-	-
8	656.8	98.6	448.0	22.00	624.2	96.8	443.3	21.84
9	715.6	79.3	509.7	15.56	731.1	100.6	648.9	15.50
10	766.3	91.4	443.1	20.63	766.7	84.0	434.4	19.34
11	751.3	93.3	560.0	16.66	734.5	96.6	552.5	17.48
12	752.2	96.4	482.5	19.98	793.7	105.5	509.3	20.71
13	735.7	105.8	485.3	21.80	724.9	117.4	497.8	23.59
Total	9467.3	1151.6	5670.1	227.31	9321.1	1186.7	5904.1	226.46
Average	728.2	88.58	472.5	18.94	717.0	91.28	492.0	18.87
Kg per day and animal		1.44	7.67			1.48	7.99	

Table 30 : Performance data 25 - 28 weeks.

Farm	CTC - group Live-weight lb	Gain lb	Feed-intake lb	Conv. eff. %	Control - group Live-weight lb	Gain lb	Feed-intake lb	Conv. eff. %
1	788.9	87.5	362.5	24.14	762.3	58.1	379.0	15.33
2								
3	770.0	59.2	489.0	12.10	765.5	65.5	473.0	13.86
4	832.2	66.1	466.0	14.18	754.4	51.3	429.0	12.00
5	760.0	94.9	516.1	18.40	696.1	87.9	502.7	17.48
6	819.0	76.3	518.5	14.72	779.1	74.9	492.4	15.21
7	777.0	91.7	-	-	783.3	84.0	-	-
8	742.0	85.2	532.0	16.01	693.6	69.4	513.3	13.52
9	806.2	90.5	668.5	13.54	820.5	89.4	650.0	13.76
10	847.4	81.1	416.5	19.48	851.9	85.2	426.3	20.00
11	835.3	84.0	604.0	13.91	809.7	75.1	580.1	12.95
12	828.7	76.5	582.6	13.12	858.0	65.2	597.7	10.90
13	801.9	76.2	535.1	14.24	794.9	70.00	510.2	13.72
Total	9608.6	969.2	5690.8	173.84	9369.3	876.0	5553.7	158.73
Average	800.7	80.77	517.3	15.80	780.8	73.0	504.9	14.43
Kg per day and animal		1.31	8.40			1.18	8.20	

Table 31 : Performance data 0 - 12 weeks.

	CTC - group			Control - group		
Farm	Gain lb	Feed-intake lb	Conv. eff. %	Gain lb	Feed-intake lb	Conv. eff. %
1	206.5	709.6	29.10	196.7	699.8	28.10
2	218.8	1123.5	19.47	231.0	1228.0	18.81
3	217.0	891.0	24.35	195.4	898.0	21.76
4	227.1	809.0	28.07	182.0	762.0	23.88
5	201.9	663.0	30.45	163.8	622.0	26.33
6	217.4	804.3	27.03	186.9	780.5	23.95
7	195.2	-	-	190.6	-	-
8	225.1	779.3	28.88	204.2	756.0	27.01
9	203.2	905.0	22.45	199.4	995.3	20.04
10	233.0	917.2	25.41	218.6	911.6	23.98
11	219.8	948.2	23.18	211.4	963.2	21.95
12	223.5	949.1	23.54	208.9	943.0	22.15
13	206.9	792.8	26.10	187.4	781.3	23.99
Total	2795.4	10292.0	308.03	2576.3	10340.7	281.95
Average	215.0	857.7	25.67	198.2	861.7	23.50
Kg per day and animal	1.16	4.64		1.07	4.66	

Table 32 : Performance data 13 - 28 weeks.

	CTC - group			Control - group		
Farm	Gain lb	Feed-intake lb	Conv. eff. %	Gain lb	Feed-intake lb	Conv. eff. %
1	335.3	1403.0	23.90	308.0	1454.2	21.18
2						
3	297.8	1736.0	17.15	305.4	1731.0	17.64
4	346.9	1831.0	18.94	315.0	1702.0	18.51
5	340.0	1713.0	19.85	315.0	1672.0	18.84
6	338.8	1896.9	17.86	327.6	1798.3	18.22
7	338.8	-	-	342.3	-	-
8	323.2	1693.7	19.08	291.6	1610.0	18.11
9	337.5	1959.0	17.23	346.7	2203.7	15.73
10	357.0	1683.1	21.21	365.7	1655.5	22.90
11	370.5	2089.8	17.73	349.1	2035.8	17.15
12	335.4	1959.9	17.11	365.7	2032.0	18.00
13	364.0	1855.2	19.62	368.7	1826.7	20.18
Total	4085.2	19820.6	209.68	4000.8	19721.2	206.46
Average	340.4	1801.9	19.06	333.4	1792.8	18.76
Kg per day and animal	1.38	7.31		1.36	7.28	

Table 33 : Performance data 0 - 28 weeks.

	CTC - animals			Control - animals		
Farm	Gain lb	Feed-intake lb	Conv. eff. %	Gain lb	Feed-intake lb	Conv. eff. %
1	541.8	2112.8	25.64	504.7	2154.0	23.43
2						
3	514.8	2627.0	19.60	500.8	2629.0	19.05
4	574.0	2640.0	21.74	497.0	2464.0	20.17
5	541.6	2376.0	22.80	478.8	2294.0	20.87
6	556.2	2701.2	20.59	514.5	2578.8	19.95
7	534.0	-	-	532.9	-	-
8	548.3	2473.0	22.17	495.8	2366.0	20.96
9	540.8	2864.0	18.88	546.1	3199.0	17.07
10	590.1	2600.4	22.69	584.3	2567.4	22.76
11	590.3	3038.0	19.43	560.5	2999.0	18.69
12	559.0	2909.0	19.21	574.6	2975.0	19.31
13	570.9	2648.0	21.56	556.1	2608.0	21.32
Total	6661.8	28989.4	234.31	6346.1	28834.2	223.58
Average	555.2	2635.4	21.30	528.9	2621.3	20.32
Kg per day and animal	1.29	6.11		1.23	6.08	

Table 34 : Tests for significance of treatment differences.

Period (weeks)	Gain d.f.	Gain F - value	Feed-intake d.f.	Feed-intake F - value	Conversion efficiency d.f.	Conversion efficiency F - value
0- 4	1,12	24.73**	1,11	0.39	1,11	19.70**
5- 8	1,12	0.64	1,11	3.48	1,11	2.00
9-12	1,12	13.66**	1,11	0.01	1,11	16.59**
13-16	1,12	5.94*	1,11	0.04	1,11	2.63
17-20	1,12	1.74	1,11	0.64	1,11	1.49
21-24	1,12	0.98	1,11	1,15	1,11	0.26
25-28	1,11	7.75*	1,10	2.92	1,10	2.64
0-12	1,12	16.62**	1,11	0.08	1,11	30.76**
13-28	1,11	1.44	1,10	0.09	1,10	0.91
0-28	1,11	10.20**	1,10	0.12	1,10	22.00**

$F_{1,10}$ (P=0.05) = 4.96 $F_{1,11}$ (P=0.05) = 4.84 $F_{1,12}$(P=0.05) = 4.75

$F_{1,10}$ (P=0.01) = 10.04 $F_{1,11}$ (P=0.01) = 9.65 $F_{1,12}$(P=0.01) = 9.33

* significant at 5 % level

** significant at 1 % level

Table 35 : Correlation between effect of CTC on daily live-weight gain and daily live-weight gain of control animals for the period of 0-28 weeks (0-24 weeks for farm 2).

Farm	Daily live-weight gain(g) of CTC-animals($=gain_{CTC}$)	Daily live-weight gain(g) of control animals($=gain_{C}$) x	Effect of CTC ($=gain_{CTC}-gain_{C}$) y
1	1255	1170	+ 85
2	1320	1385	- 65
3	1193	1160	+ 33
4	1329	1151	+ 178
5	1255	1109	+ 146
6	1288	1193	+ 95
7	1237	1234	+ 3
8	1269	1149	+ 120
9	1253	1264	- 11
10	1366	1352	+ 14
11	1366	1297	+ 69
12	1295	1332	- 37
13	1322	1288	+ 34

Calculation of regression coefficient b and test of significance

	d.f.	yy	xy	xx
Sum of squares or products	13	96 576	758 349	19 994 590
Correction factor	1	33 915	-821 521	19 899 620
Corrected sum of squares or products	12	62 661	- 63 172	94 970
Regression	1	$\frac{3\ 990\ 701\ 584}{94\ 970}$ = 42 020		
Residue	11	62 661-42 020 = 20 641		

$F_{1,11}(P=0.05)=4.84$

$F_{1,11}(P=0.01)=9.65$

$b = \frac{-63\ 172}{94\ 970} = -0.6652$

mean square $= \frac{20\ 641}{11} = 1876$

$F = \frac{42\ 020}{1876} = 22.4^{**}$

** significant at 1 % level

Table 36 : Classification scale for macroscopic examination of rumens and livers at slaughter.

Macroscopic Examination of Rumen

Site of Lesions :

a) Anterior Pillar
b) Posterior Pillar
c) Dorsal Sac
d) Anterior Dorsal Sac
e) Posterior Dorsal Sac
f) Ventral Sac
g) Anterior Ventral Sac
h) Posterior Ventral Sac

Description :

1. Traditional rearing
2. Traditional under 3 years (3 teeth)
3. Traditional over 3 years (full mouth)
4. Barley-Beef
5. Content mainly roughage
6. Content mixed
7. Content mainly barley
8. Content entirely barley
9. Pigmentation - green
10. Pigmentation - black
11. Normal epithelium
12. Moderate hyperkeratosis
13. Marked hyperkeratosis
14. Adherent content
15. Congestion of tips of villi
16. Acute inflammation of individual villi (capping with exudate)
17. Acute ulceration with loss of villi and diphteritic membrane (2-4 cm)

18. Acute ulceration with loss of villi and diphteritic membrane (4-6 cm)
19. Acute ulceration with loss of villi and diphteritic membrane (6-8 cm)
20. Clean healing ulcers (2-4 cm)
21. Clean healing ulcers (4-6 cm)
22. Clean healing ulcers (6-8 cm)
23. Gross scars with loss of pigment and villi (2-4 cm)
24. Gross scars with loss of pigment and villi (4-6 cm)
25. Gross scars with loss of pigment and villi (6-8cm)
26. Reduced numbers of villi and development of secondary villi with depigmentation
27. Clumping of villi
28. Prominent granulomatous nodules

Macroscopic Examination of Liver

Description :

1. Normal
2. Congested
3. Pale
4. Diffuse lesions
5. Focal lesions
6. Early coagulative necrosis
7. Yellow coagulative necrosis - thin capsule
8. Yellow coagulative necrosis - thick capsule (1-2 cm)
9. Yellow coagulative necrosis - thick capsule (2-4 cm)
10. Abscess with frank pus
11. Healed scars
12. Number of Lesions - Dorsal
13. Number of Lesions - Ventral

Table 37 : Angular transformation‡ of percentage of abscessed livers on the various farms and test for significance.

Farm	CHLORTETRACYCLINE				CONTROL					
	Number of animals	Animals with abscessed livers Number	%	Angular transfrom. x	Number of animals	Animals with abscessed livers Number	%	Angular transform. y	y-x	$(y-x)^2$
1	9	1	11.11	19.5	8	2	25.00	30.0	10.5	110.25
2	7	-	-	-	7	1	14.28	22.2	22.2	492.84
3	10	-	-	-	9	1	11.11	19.5	19.5	380.25
4	8	-	-	-	6	-	-	-	-	-
5	8	1	12.50	20.5	6	4	66.67	34.5	14.0	196.00
6	9	-	-	-	10	4	40.00	39.2	39.2	1536.64
7	9	3	33.33	35.3	9	2	22.22	28.1	-7.2	51.84
8	9	1	11.11	19.5	10	1	10.00	18.4	-1.1	1.21
9*	-	-	-	-	-	-	-	-	-	-
10	17	2	11.76	20.1	17	6	35.29	36.5	16.4	268.96
11	15	1	6.67	14.9	14	2	14.28	22.2	7.3	53.29
12	13	7	53.85	47.2	13	4	30.77	33.7	-13.5	182.25
13	9	-	-	-	9	2	22.22	28.1	28.1	789.61
14	13	-	-	-	17	9	60.00	50.8	50.8	2580.64
Tot.	136	16			135	38			186.2	6643.78
Av.			11.76				28.15			

$F_{calculated} = 8.05$

$F_{1,12}\,table(P=0.05) = 4.75$

$F_{1,12}\,table(P=0.01) = 9.33$

* For farm 9 no slaughter data could be collected.

‡ According to Snedecor (1957)

Table 38* : Chi-square test to test difference in incidence of abscessed livers between animals with healthy rumens and animals showing rumenitis.

		Livers		
		healthy	abscessed	Total
Rumens	healthy	55	19	74
	showing rumenitis	131	29	160
	Total	186	48	234

x^2 calculated = 1.336 (not significant)
x^2 table (P=0.05) = 3.84
x^2 table (P=0.01) = 6.64

* Taking into account those 234 animals of which both rumen and liver data were available.