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EFFECT OF FEEDING ANTIBIOTICS
TO DAIRY CALVES

Thesis for the Degree of M. S.
MICHIGAN STATE COLLEGE
Stanley Arthur Ellsworth
1952

This is to certify that the

thesis entitled

Effect of Feeding Antibiotics to Dairy Calves

presented by

Stanley Arthur Ellsworth

has been accepted towards fulfillment
of the requirements for

MS degree in Dairy

C. F. Huffman
Major professor

Date Aug. 8, 1952



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EFFECT OF FEEDING ANTIBIOTICS
TO DAIRY CALVES

by
Stanley Arthur Ellsworth

A THESIS

Submitted to the School of Graduate Studies of Michigan
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INTRODUCTION

The raising of good replacement heifers is usually essential for the maintenance of a profitable dairy herd. The efficient and rapid growth potential of young animals often is not realized in dairy calves because of calf scours and other rearing problems. Slow growth during early life may be reflected in delayed maturity which would shorten the profitable life span of the dairy cow.

Recent reports have indicated that the addition of antibiotics to the ration of dairy calves and other young animals will stimulate growth and prevent digestive disturbances. Antibiotics have given particularly good results when the dairy calves were raised under unfavorable environmental conditions or on milk substitute rations.

This study was undertaken to determine the effect of adding antibiotic feed supplements to the ration of dairy calves reared under very favorable feeding and management practices.

REVIEW OF LITERATURE

Introduction

The term antibiotic as currently used in the pharmaceutical and medical practice connotes a metabolic product of one microorganism that is detrimental or adverse to the life activities of other microorganisms. Although antagonism between microorganisms had been noted for years, the present rapidly expanding field of antibiotics probably stemmed from the observation of Fleming (1929) that Penicillium sp. caused the clearing of Staphylococcus aureus cultures. Extensive studies by microbiologists and cooperating chemists, with their rapidly improving extraction methods, finally enabled the isolation of the nearly pure antibiotic compounds desired for medical use. The need for such valuable chemotherapeutic agents for bacterial infections during and after World War II stimulated research in the field of antibiotics so that many antibiotics were discovered and the most desirable ones were produced commercially for clinical use.

Antibiotics are rather unique in being able to exert a selective action in inhibiting microorganisms at relatively low concentrations, usually 10 micrograms or less per milliliter. Recent investigations indicate that the more desirable antibiotics for clinical use accomplish inhibition by exerting a biochemical action in the cell. A review by Peck and Lyons (1951) shows that several workers in the field of antibiotics have found that various enzyme systems, particularly those involved in respiration, are affected. The enzyme system affected varies

with different antibiotics; for example, Loomis (1950) observed that aureomycin depressed phosphorylation while penicillin, chloromycetin, and sulfadiazine did not. The same antibiotic may also indirectly, if not directly, affect more than one enzyme system. Lichstein and Gilfillan (1951) found S. fragilis unable to use B-alanine as a precursor of pantothenic acid in the presence of streptomycin, and these results suggested that antibiotics may prevent the synthesis of some essential metabolite required by the bacterial cell. The antibiotic might also substitute for some essential nutrient or metabolite because of stereochemical similarities and interfere with normal metabolic processes. The modes of action for antibiotics given above are believed to account for a certain antibiotic at a given concentration inhibiting some microorganisms, depending on their metabolic systems and essential nutrients, while not markedly affecting other microorganisms or the host.

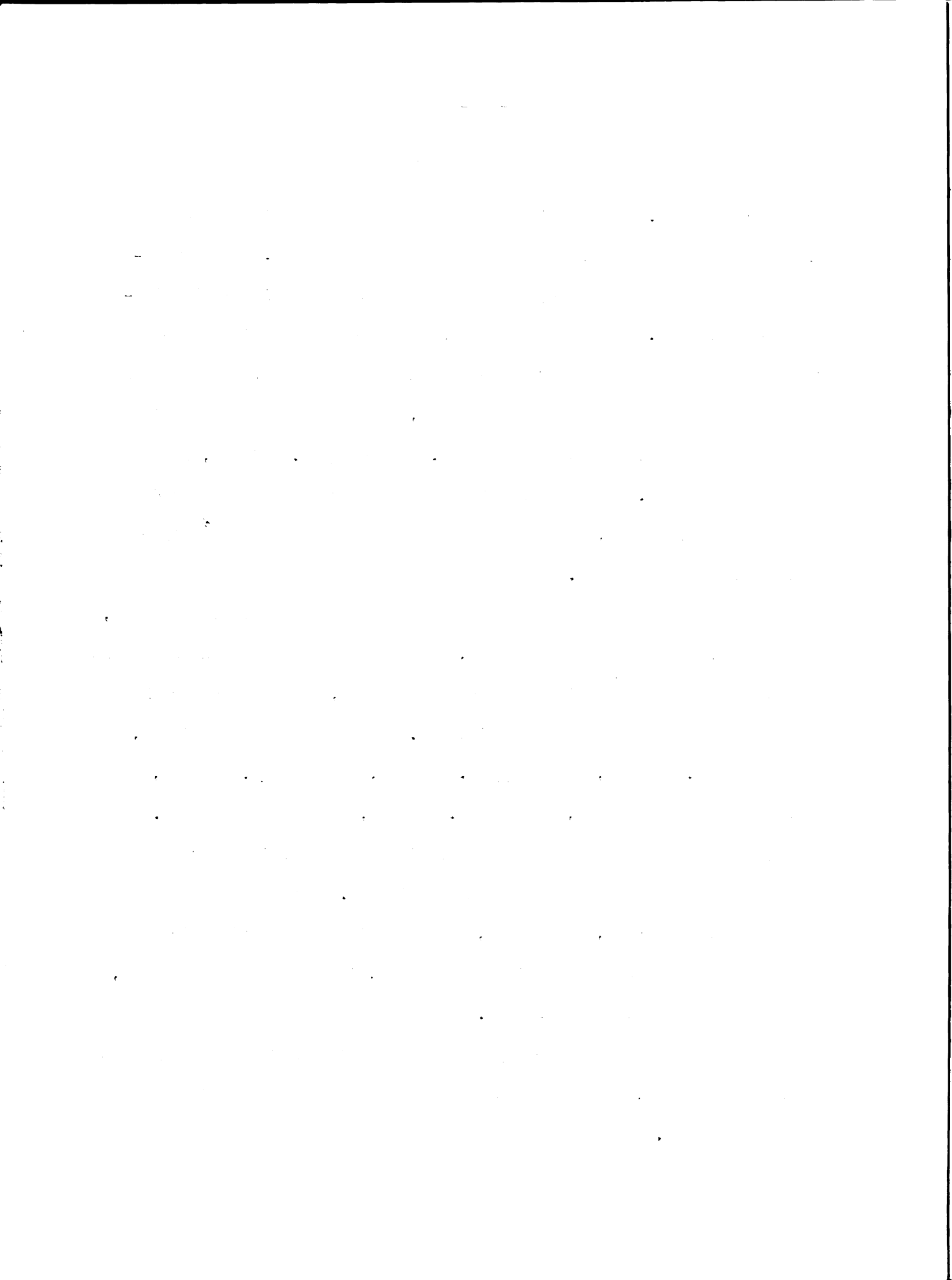
Although all antibiotics may exert some surface action on the bacterial cell, it is not believed to be the primary mode of action except in some cases such as tyrothricin. These highly surface active antibiotics are limited to topical use, and they are generally not used in livestock feeds.

The sulfa drugs and arsonic acid derivatives exert a similar bacteriostatic action to that of antibiotics although they do not fit the strict definition of an antibiotic. Usually these products cause more undesirable effects than antibiotics when used clinically. However, the sulfa drugs and arsonic acid derivatives are mentioned occasionally in comparisons of various growth promoting compounds.

Discovery of Growth Promoting Effect of Antibiotics

Rickes et al. (1948) discovered that the fermentation residues from the production of antibiotics contained vitamin B₁₂. Many nutritionists soon used these by-products as sources of vitamin B₁₂ in live-stock experiments. Because these products seemed to contain some other unidentified growth factor(s) which seemed to exert a sparing action on the need for animal protein in the ration, they were commonly termed animal protein factor (APF) supplements. Cunha et al. (1949a, 1949b) and Burnside et al. (1949) found that these APF supplements improved growth in growing pigs, and Stokstad and Jukes (1950) noted a similar growth response in chicks.

Because crystalline vitamin B₁₂ supplementation and APF supplements, containing no appreciable antibiotic, stimulated growth to a lesser extent than the products containing residual antibiotics, some of the growth response was attributed to the antibiotic. Stokstad and Jukes (1950), Edwards et al. (1950), Luecke et al. (1950), Cunha et al. (1950b), Groschke and Evans (1950), Dyer et al. (1950), and Carpenter et al. (1950) confirmed the growth promoting action of antibiotics by using the purified compounds in subsequent experiments. Although the results were somewhat variable, in general, the inclusion of an antibiotic in the ration increased weight gain and appetite, improved feed efficiency, and reduced digestive disturbances. Since a large part of the growth response seemed to be due largely to the residual antibiotics in the fermentation residues, these products are now commonly called antibiotic feed supplements.



Moore et al. (1946) previously had obtained increased growth in chicks on apparently adequate diets when streptomycin or sulfasuxidine were added. Apparently the growth stimulating potential of these compounds was overlooked because they did not accomplish their objective, sterilization of the intestinal tract.

Comparison of Various Antibiotics

Assuming a bacterial mode of action of antibiotics in promoting growth, different antibiotics would be expected to vary in effectiveness since each antibiotic has a particular group of microorganisms which it inhibits most effectively; for example, penicillin is effective mainly against the Gram-positive staining bacteria, streptomycin against the Gram-negative and acid fast bacteria, and aureomycin is effective against a much broader range including some of the rickettsia and viruses. If the mode of action is systemic, antibiotics should also vary in their growth promoting ability.

Swine. Cunha et al. (1951) found that growing pigs fed five or 15 milligrams of penicillin per pound of ration were slightly less thrifty than those fed the vitamin and mineral supplemented corn-peanut meal basal ration. Streptomycin, 100 milligrams per pound of ration, produced a slight increase in weight gain while 45.4 milligrams of aureomycin produced the largest growth response. Luecke et al. (1951) compared 10 milligrams of streptomycin, aureomycin, or neomycin and one milligram of penicillin per pound of a basically corn-soybean oil meal ration. At these levels penicillin and aureomycin gave equally significant growth responses. Neither neomycin nor streptomycin increased

the daily gain or feed consumption but neomycin did improve feed efficiency. A higher level of penicillin gave no greater growth response.

Cuff et al. (1951) tested several antibiotics at a level of 10 milligrams per pound of ration for weanling pigs to 135 pounds of body weight. Aureomycin, terramycin, and penicillin increased the average daily gain over the basal ration and also controlled scours which resulted from an enteritis, while streptomycin, bacitracin and polymixin neither controlled scours nor increased growth rate. Wallace et al. (1951a) found a significant increase in weight gain when two grams of terramycin or aureomycin were added per pound of a fortified corn-peanut meal ration. At the same level chloromycetin, bacitracin, or 3-nitro-4-hydroxyphenyl arsonic acid failed to increase the growth rate. The arsonic acid derivative, however, gave the best feed efficiency. Only aureomycin or terramycin stimulated appetite and controlled an intermittent diarrhea. Becker et al. (1952) found that five milligrams of aureomycin or procaine penicillin per pound of feed were equally effective in significantly stimulating the rate of gain. Neomycin and chloramphenicol at the same level produced only slight increases in daily gain.

Carpenter (1951) compared several antibiotics at a level of 1.25 grams per 100 pounds of feed with penicillin at a level of 0.88 grams per 100 pounds of feed. Aureomycin, terramycin, penicillin, streptomycin, and chloromycetin all stimulated growth of pigs under the imposed environmental conditions. Chloromycetin did not control diarrhea. Brown and Luther (1950) noted no appreciable differences in the effectiveness of terramycin, streptomycin, penicillin or aureomycin in

promoting growth and these antibiotics produced a 40 per cent increase in weight gain over the controls after four weeks on an all vegetable protein ration containing vitamin B₁₂. A level of three parts per million of antibiotic in the ration was sufficient to give the growth response. The antibiotic supplemented vegetable protein ration showed comparable superiority over unsupplemented practical rations containing animal protein. Graded levels of antibiotic activity in fermentation residues gave similar growth results to those obtained with the purified antibiotics.

Contrary to these results, Luecke et al. (1951) and Speer et al. (1950) obtained considerably more growth response with a feeding supplement derived from aureomycin fermentation residues than with a combination of pure aureomycin and pure vitamin B₁₂. These workers suggested that the APF (Lederle) supplements might contain an additional unrecognized growth factor(s).

Miller et al. (1951) noted increased growth in pigs fed a basically corn-soybean oil meal ration when 0.5 per cent sulphathalidine or streptomycin and vitamin B₁₂ were added to the feed. Briggs and Beeson (1951b) added 15 milligrams of streptomycin or 10 milligrams of aureomycin per pound of an all-plant protein ration and found both antibiotics increased the average daily gain from 11 to 13 per cent and increased feed efficiency 14 to 16 per cent. The unsupplemented ration produced average daily gains of 1.62 pounds and required 392 pounds of feed per 100 pounds of gain.

Nesheim et al. (1950a, 1950b), Wahlstrom et al. (1950), Wahlstrom and Johnson (1951), and Noland et al. (1951) added various levels of

different antibiotics to "synthetic milk" for baby pigs. The results obtained with several of the antibiotics seemed to be somewhat variable, as has been noted in the experiments given above, but aureomycin or terramycin appeared to give a positive growth response most consistently. In connection with this similarity of growth response between these two antibiotics, Pepinsky and Watonabe (1952) recently found the chemical structure and formulas to be very similar. Analytical data indicated that aureomycin contains a chlorine atom in place of a hydroxyl group in terramycin.

Shefchik et al. (1950) found that aureomycin produced a greater growth response than streptomycin in a "synthetic milk" for baby pigs, but a combination of the two antibiotics produced the largest growth response. However, Brides et al. (1951) found that a combination of penicillin and streptomycin did not give as significant a growth response as did either antibiotic when added alone to the basal ration. In connection with combinations of different antibiotics Gunnison et al. (1950) found that aureomycin and terramycin interfered with the antibiotic action of penicillin against two test organisms used in an in vitro study.

Terrill et al. (1951) added five milligrams of aureomycin or bacitracin per pound of a fortified corn-soybean ration. Bacitracin gave a significant increase, 16 per cent, in weight gain while aureomycin gave a highly significant increase, 27 per cent, over the basal group. Results with purified bacitracin and a bacitracin feed supplement were similar. In another trial the addition of several different protein supplements to the basal ration containing seven supplemental B vitamins did not affect the growth response obtained from dietary terramycin. Briggs et al.

(1951c) found the growth responses from dietary penicillin were similar whether the ration contained animal and plant proteins or all-plant protein. Burnside et al. (1949) found that the addition of an APF supplement containing aureomycin increased the average daily gain of pigs on a basically corn-peanut meal ration from 0.62 to 1.40 pounds; on a corn-soybean oil meal ration from 1.01 to 1.31 pounds; and on a corn-fish meal ration from 1.29 to 1.45 pounds.

Baker et al. (1951) found that several levels of Aurofac A (Lederle) produced similar positive growth responses in weanling pigs in concrete dry-lot, on soil, behind cattle or on pasture. Brinegar et al. (1951) also found comparable results from several antibiotics added to the rations of pigs on dry-lot or pasture.

Chickens. Stokstad and Jukes (1950) found favorable growth responses in vitamin B₁₂-deficient chicks by supplementing a basal diet containing B₁₂ with aureomycin, an aureomycin fermentation by-product or aureomycin cultures in which the antibiotic activity had been destroyed by alkaline hydrolysis. Smaller responses were also noted with vinylsulfathiazole, streptomycin and 3-nitro-4-hydroxyphenyl arsonic acid. Dornbush et al. (1951) noted that very drastic conditions were necessary to completely inactivate aureomycin by alkali treatment of the crude cultures and they concluded that the antibiotic activity of the compound was still causing the growth stimulation. They found that alkali-treated, crystalline aureomycin was inactive for promoting growth in chicks.

Whitehall et al. (1950) observed that aureomycin stimulated growth in normal hatchery-run chicks or vitamin B₁₂-depleted chicks when vitamin B₁₂ was included in the ration. The antibiotic produced favorable results

in a corn-soybean oil meal ration, synthetic diet or commercial chick starter. One hundred milligrams of streptomycin or penicillin per kilogram of ration yielded comparable results to 25 milligrams of aureomycin in the same amount of ration. Chloromycetin and sulfasuxidine produced no significant increases in weight gain. Reynolds et al. (1951) obtained nearly the same body weight increase from the addition of either penicillin or terramycin to a practical-type broiler ration. A level of two grams per ton of feed appeared optimum under their test conditions. Elam et al. (1951b) found that both penicillin and bacitracin stimulated growth obtained from a normal chick ration. Peppler et al. (1950) obtained an increased growth rate from dietary carbon-absorbed polymixin. A 2.5 per cent level of the antibiotic supplement temporarily depressed growth and then stimulated it.

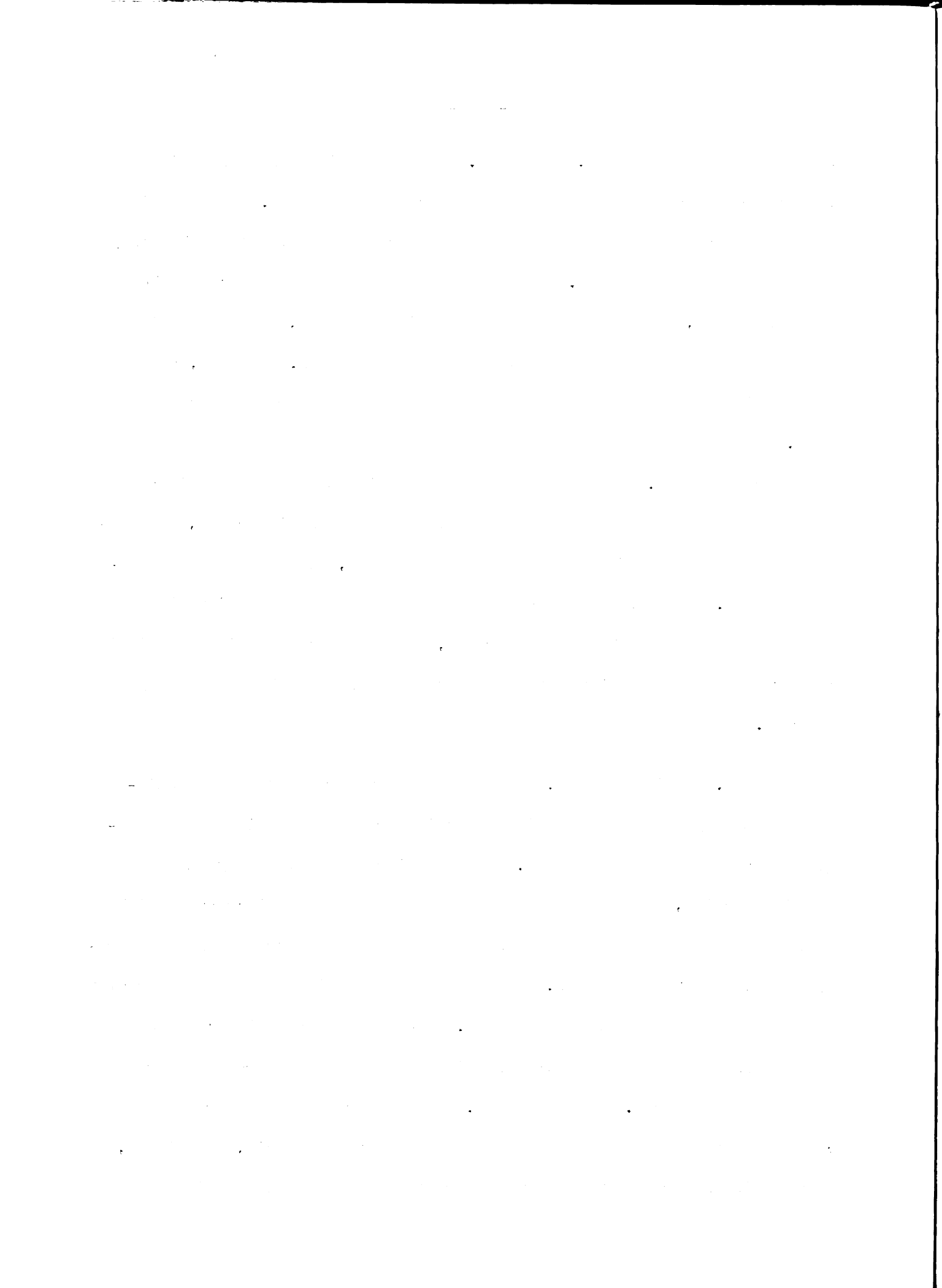
Scott et al. (1951) tested the effect of adding various supplements to a fortified corn-soybean oil meal chick ration with or without aureomycin (15 milligrams per kilogram). Aureomycin alone did not yield any growth response, and only corn distillers solubles and defatted liver meal increased weight gains without the antibiotic. However, corn distillers solubles, condensed fish solubles and butyl fermentation solubles at a five per cent level, and two per cent of a grass juice concentrate produced favorable growth responses with the antibiotic in the ration. Dehydrated alfalfa meal, dried brewers yeast and dried cereal grass did not increase growth with or without the dietary antibiotic.

Matterson and Singsen (1951) added several different antibiotics to an all-vegetable chick ration containing butyl solubles with or without fish meal. The fish meal increased growth 7.7 per cent, and the antibiotics

alone increased growth 10.1 per cent. When both fish meal and antibiotics were added the antibiotics produced an increase of only 3.3 per cent in growth rate and the increase was not significantly greater than when only the antibiotics were added. Results indicated that penicillin was the most effective, aureomycin and terramycin intermediary, and bacitracin the least effective as supplements to the basal ration. However, all the antibiotics gave similar growth responses on the basal ration plus fish meal.

Burgess et al. (1951) noted that a significant response to dietary antibiotics was more consistently observed in their fast-growing, broiler-type New Hampshire chicks than in their open-bred, Single Comb White Leg-horn strain. Singen and Matterson (1952) report that a complete lack of growth response from feeding bacitracin, aureomycin or procaine penicillin appeared to occur more frequently in floor experiments than in battery rearing.

Turkeys. McGinnis et al. (1951) obtained the greatest growth stimulus in turkey poults from adding five milligrams of penicillin per kilogram of a practical type ration. Five milligrams of streptomycin was the least effective, but 10 and 25 milligram levels produced increased weight gains equal to those obtained with five milligrams of aureomycin and terramycin per kilogram of ration. A combination of antibiotics gave no greater growth response than penicillin alone. The greatest antibiotic stimulus was obtained on a ration containing fish meal and similar results were also noted in chicks. Branion et al. (1951) also obtained a growth response in turkeys from the addition of 25 milligrams of aureomycin, penicillin, terramycin or streptomycin to rations containing 15 per cent animal protein



supplements or all-plant protein with vitamin B₁₂ added. The relative ability of each antibiotic to stimulate growth was not the same for the first four weeks as for the second four weeks of the experiment. The antibiotics improved feed efficiency on the all-plant protein diet but not on the animal protein supplemented diet. Chloromycetin produced no beneficial response. Stern et al. (1952) tested the possible growth promoting properties of several antibiotics which are active against an extensive range of microorganisms and are less commonly used clinically because of producing adverse effects in the host. Neomycin, polyvinyl pyrrolidone iodine, tyrocidin, tyrothricin, acriflavin, crystal violet and gramacidin produced slight increases in weight gain of poults, but the response was much smaller than that which penicillin produced. Actidione, an antifungicide, decreased the rate of growth considerably.

Scott (1951) found that aureomycin increased the daily weight gain of poults 54.9 per cent over that produced on the basal ration alone. However, when dried brewers' yeast, dried skim milk or grass juice concentrate were added to the ration, the growth responses from the antibiotic were reduced to 28, 33.4, and 10.1 per cent, respectively.

Laboratory animals. Stern and McGinnis (1950) found that the weight gains of young rats were increased by adding aureomycin, terramycin or streptomycin to a semipurified diet. The Long-Evans strain gave an increased growth rate from the addition of vitamin B₁₂ but another strain required both vitamin B₁₂ and antibiotics.

Vijayaraghavan et al. (1952) fed mice various diets with and without supplemental aureomycin. A marked stimulation of growth was observed in

the mice fed the antibiotic supplemented diets based on soybean meal and cottonseed meal but the antibiotic produced no growth response in the natural food rations, purified-casein diets or peanut-meal rations.

Lawrence and McGinnis (1952) did not obtain any increase in rate of gain in rabbits fed various levels of terramycin in a practical type of rabbit ration.

Effect of Removing Antibiotics from Ration

Catron (1952a) reports that antibiotics produce the maximum growth response in young growing pigs but pigs fed antibiotics continuously reached market weight sooner than when the antibiotic was removed from the ration at 125 pounds of weight. Luther and Brown (1951) found that pigs maintained their initial increase in weight gain even when the antibiotic was withdrawn from the ration as early as six weeks after weaning. Wallace et al. (1951b) observed that the average daily gain of pigs was markedly reduced if aureomycin was removed from the ration during the period from 100 to 200 pounds of body weight.

Berg et al. (1950) found that the removal of an antibiotic feed supplement from the ration of 4.5-week old chicks resulted in a cessation of the growth stimulus previously obtained. An immediate growth response was obtained when the antibiotic was added to the ration of chicks of this age.

Stern and McGinnis (1950) found that rats that previously had shown a growth response from aureomycin supplementation fell behind their litter mates in average daily gain when the antibiotic feeding was discontinued.

Antibiotics for Dairy Calves

Rusoff and Haq (1950) found an APF supplement (Merck) was of no value for dairy calves weaned from milk at an early age and fed a plant protein calf starter. Hibbs and Pounden (1950) noted no growth response from the same APF supplement fed to rumen inoculated calves on a high roughage ration at an early age. Williams and Knodt (1951) also fed an APF supplement containing no appreciable amount of antibiotic to healthy calves with a similar lack of growth stimulation.

Loosli and Wallace (1950) found that the addition of 10 grams of crystalline aureomycin or 56 pounds of aureomycin feeding supplement per ton of milk substitute significantly increased the average daily gain. During the eight-week trial period after the calves were removed from their dams, the antibiotic supplemented calves gained at an average daily rate of 1.11 pounds as compared to 0.92 pound for the controls. The antibiotic appeared to reduce the incidence and severity of scours. Loosli et al. (1951) obtained similar results when two per cent of Aurofac (Lederle aureomycin feed supplement) was included in the milk replacement. The calves receiving Aurofac consumed 40 per cent more grain, but they required less total digestible nutrients per pound of gain. No significant difference was noted in the amount of hay consumed. Preliminary studies indicated no marked difference in total count or morphological types of bacteria in the rumens of calves fed the antibiotic.

Bartley et al. (1950) gave three grams of Aurofac containing five milligrams of aureomycin daily by capsule to calves on a normal diet and they obtained an increase of 70 per cent in average daily gain from birth

to 42 days of age. A very high incidence of scours had been found previously in this calf barn, and the lowered incidence of scours in the antibiotic supplemented calves was believed to account for a large part of the increased weight gain. The rate of growth of the supplemented calves did not exceed that of the Ragsdale standard. Bartley et al. (1951) found that three or nine grams of aureomycin feed supplement daily increased the rate of gain during a 22-week period from birth. The difference between the two levels was not significant. The supplemented calves consumed 22 per cent more grain than did the controls but the amount of total digestible nutrients and digestible protein per pound of gain were similar for all groups. Large doses, 200 to 800 milligrams of crystalline aureomycin per 100 pounds of body weight, were fed to a few 12 to 16-week old calves without producing any visible detrimental effects.

Rusoff and Davis (1951b) found that 75 to 150 milligrams of aureomycin daily by capsule or the feeding of a calf starter containing two per cent of an aureomycin feed supplement increased the average daily gain approximately 20 per cent during a 16-week feeding trial. The calves were weaned from milk at 30 days of age. The crystalline aureomycin prevented scours while the antibiotic feed supplement did not reduce scours until the calves were consuming sufficient aureomycin in the grain.

Morrison and Deal (1951) observed no beneficial response from feeding an aureomycin feed supplement in the milk for two weeks after the calves were removed from their dams.

Bloom and Knodt (1951) found that 10 parts per million of penicillin in a milk replacement significantly lowered the growth rate of dairy calves. In a second trial various levels of crystalline aureomycin or Aurofac gave

significant increases in weight gain and starter consumption. One gram of aureomycin per 100 pounds of milk replacement gave nearly the same growth response as did two grams but gave a significantly larger response than 0.5 gram.

Cason and Voelker (1951) obtained no significant growth response from giving 15 or 30 milligrams of terramycin by capsule each day. Daily observations indicated that the feces of the calves given terramycin were firmer but both supplemented and control groups had mild cases of scours of two or three days duration. Voelker and Cason (1951) gave calves 30 milligrams of terramycin per 100 pounds of body weight daily and the supplemented calves gained 63 pounds as compared to 52 pounds for the controls during the trial period. A higher level of 100 milligrams of terramycin produced a statistically significant response of 28 per cent increase in weight gain over the controls. In a subsequent eight-week trial a grain mixture containing 2.5 per cent Aurofac was fed to 4.8-month old dairy calves on pasture and produced a significant increase, 17 per cent, in daily gain over the control ration. A series of eight body measurements showed greater structural growth in the Aurofac fed calves.

Murley and coworkers (1951a) found that 80 milligrams of aureomycin fed daily in the milk to calves from four to 60 days of age resulted in increased weight gain, better physical appearance and increased feed efficiency. Murley et al. (1951b) found that the same level of aureomycin produced a much smaller growth response in a restricted diet of reconstituted skim milk. Analysis of the urine at two, five and eight weeks of age showed no differences in reducing sugars and nitrogen attributable to

aureomycin feeding. Analysis of the feces also showed no significant differences in dry matter, reducing sugars, nitrogen, ether extract, or ash.

MacKay et al. (1952) found a significant increase in the daily gains of heifer calves fed a normal ration supplemented with nine grams of Aurofac A. No difference was noted in starter consumption or general appearance and thriftiness. No cases of scours were observed in either the control or supplemented lots.

Jacobson et al. (1951, 1952a and 1952b) obtained a 30 per cent increase in growth from the addition of 80 milligrams of crystalline aureomycin to the milk of dairy calves from four to 116 days of age. Aureomycin was removed from the ration at 116 days of age and Aurofac A was introduced into the grain mixture of half of the calves in both groups. No apparent adverse effects were noted from the addition or deletion of dietary aureomycin. The calves which had the aureomycin removed from their ration had an average daily gain similar to that of the controls during the period from 116 to 200 days of age, but the initial advantage was maintained. The addition of Aurofac to the ration of the control group caused an increased rate of weight gain.

Rusoff (1951a) fed an all-plant protein starter with and without two per cent of an aureomycin feed supplement to 14-week old Jersey calves. The antibiotic supplement increased daily gains 60, 36 and 30 per cent for the first three, two-week periods of the trial, respectively. After these periods the difference in daily gain between the groups decreased until both groups had the same growth rate during the final two-week period of the 20-week trial.

Murdock et al. (1951) obtained a growth response from 25 milligrams of aureomycin or terramycin per kilogram of dry matter intake over a six-week period from birth. During the following six weeks the calves received no antibiotic supplement, and at the end of 12 weeks the average daily gain for the entire experimental period was not significantly higher for the aureomycin groups. There was a significant difference in favor of the controls instead of the terramycin supplemented calves over the entire period. These results indicated that the antibiotic supplemented calves grew much slower than the controls after the antibiotic was removed from the ration.

Graf and Holdway (1952) have recently reported that preliminary results with the feeding of an arsonic acid derivative to dairy calves had indicated a lowered incidence of scours and increased weight gains. Levels of 60 and 120 grams per ton of milk replacement and calf starter gave slightly better results than the 240-gram level for increasing weight gains.

Antibiotics for Other Ruminant Animals

Colby et al. (1950a) found that 100 milligrams of crystalline aureomycin given by capsule daily to fattening lambs caused a marked reduction in feed consumption, rapid loss of weight, and diarrhea. Bacterial counts of the rumen contents were higher in the antibiotic supplemented group. Colby et al. (1950b) found similar adverse effects from an aureomycin feed supplement. Colby et al. (1950c) found that neither penicillin nor streptomycin produced quite as severe undesirable effects in young lambs. Using a lower level of aureomycin supplementation (five milligrams daily), Jordan and Bell (1951) obtained an increase in average daily gain when suckling

lambs were drenched with the antibiotic. Fattening lambs receiving six milligrams of aureomycin daily also showed a growth response and better feed efficiency than the controls. No abnormalities were noted among the antibiotic supplemented lambs.

Neuman et al. (1951) found that the growth rate of beef heifers was essentially unchanged when two milligrams of crystalline aureomycin or in the form of a crude aureomycin feed supplement were added per pound of feed. A severe reduction in feed consumption was noted for a few days, but appetite was soon returned to normal. No diarrhea or other adverse effects were observed. Bell et al. (1951) noted a marked loss of appetite and severe diarrhea when 0.6 of a gram of aureomycin was added daily to the ration of 620-pound steers. A reduction in the digestibility of crude fiber, dry matter, nitrogen-free extract was found in a digestion trial with 0.2 of a gram of aureomycin fed daily. Milder digestive upsets were still noted. Chance (1952) observed no signs of anorexia or diarrhea when 0.5 or 1.0 gram of aureomycin was fed daily to two rumen fistula steers on a high roughage ration. The rate of removal from the rumen of dry matter, crude fiber, crude protein, nitrogen-free extract, non-protein nitrogen, the 10 essential amino acids and riboflavin was faster with 0.5 gram of aureomycin in the ration than with none or one gram. There was an accumulation of ether extract, nicotinic acid and pantothenic acid in the rumen during the same period.

Haq and coworkers (1952) observed no loss of appetite or evidence of diarrhea from feeding 130 milligrams of aureomycin or tyrothricin daily to dairy cows.

Mode of Action of Antibiotics in Promoting Growth

Theories have been proposed by Sieburth et al. (1951), Peppler et al. (1950), Elam et al. (1951b) and others in an attempt to explain the mode of action of antibiotics in stimulating growth. These theories can be summarized as follows: (1) inhibition or elimination of toxin-producing bacteria, (2) reduction of known or unidentified mildly infectious organisms, (3) selective inhibition of microorganisms in the intestinal tract allowing the beneficial groups, which synthesize known or unidentified essential nutrients, to grow more abundantly, (4) restriction of microorganisms competing with the host for essential nutrients and (5) act systemically in the animal body.

As noted previously many workers have obtained an increased growth rate from the feeding of antibiotics in conjunction with a decreased incidence of diarrhea, enteritis, scours or other digestive disturbances which could be caused by bacteria. From these observations some investigators including Speer et al. (1950) and Lawrence and McGinnis (1952) have explained the failure of antibiotics to promote growth in some experiments by a "disease level" theory. They theorize that healthy, well-fed animals not exposed to disease may not respond to antibiotic feeding as would unthrifty animals reared in a contaminated environment.

Coates and coworkers (1952) obtained some very interesting results on this possible mode of action. Chicks from the same hatch and fed the same diet showed no significant growth response from antibiotics in two new laboratories where poultry had not been kept previously, but the growth rate in an old poultry laboratory was depressed below the rate of gain in

the new laboratories when penicillin was not fed. These results indicated that the antibiotic had controlled some unsuspected and unidentified infectious organism present in the old poultry laboratory.

Sieburth et al. (1951) and Jacob et al. (1951) found that antibiotics reduced the count of the clostridium type of anaerobes in the feces. Since Merchant (1950) stated that Clostridium perfringens caused an enterotoxemia in sheep, these investigators postulated that the antibiotic might promote growth by reducing an enterotoxemia caused by Clostridia sp. Williams et al. (1951a) also found a 10 to 150-fold decrease in clostridia anaerobes and almost complete elimination of hemolytic clostridia. However, the inoculation of aureomycin-supplemented or control chicks with live cells of various Clostridia sp. or the sterile toxins from these bacteria produced no significant effect on the growth rate of either group.

Cuff et al. (1951) were not able to correlate total anaerobe counts with scouring or rate of gain in pigs even though the three most effective growth promoting antibiotics controlled scouring caused by an enteritis. Noland et al. (1951) found that several antibiotics reduced the fecal anaerobic count to a similar extent in pigs, but the growth response to the different antibiotics varied a great deal. Larson and Carpenter (1952a) also found no correlation between rate of gain in pigs and fecal clostridia counts.

Schneider et al. (1951) found that 15 milligrams of aureomycin or terramycin in the ration were of little help in preventing experimentally produced swine erysipelas.

Todd and Stone (1952) found that dietary penicillin increased growth and reduced the size and number of roundworms, Ascaridia Galli, in chicks

after experimental contamination with the organism.

Although reports vary on the effect of dietary antibiotics on the total bacteria count, several recent reports have indicated that there is an alteration in the relative numbers of various types of intestinal microorganisms which might affect the nutrient requirements of the animal. Romoser et al. (1952) found an increase in the coliform group, Aerobacter aerogenes most consistently, in the ceca of chicks showing a growth response from dietary penicillin. The addition of lactose to the ration also increased the coliform count, and a combination of lactose and penicillin produced a greater growth response than either one alone. Penicillin decreased the number of Gram-positive, non-sporulating rods which were found in large numbers in the ceca of slow growing chicks. These investigators suggested that the coliform group, particularly the A. aerogenes, might synthesize some growth factor(s) for the chick while the unidentified rods might have competed with the host for critical nutrients. Examination of the ceca showed them to be larger in the antibiotic fed chicks, and the contents were foamy.

Ely and Schott (1952) found that surface active, growth promoting compounds inhibited cultures of bacteria, except the coli-aerogenes type, which were isolated from fresh chick droppings. Since the degree of growth response or relative lack of response obtained in chicks from dietary antibiotics or surface active agents was similar in side-by-side comparisons, these investigators believed that the mode of action was similar for both types of compounds. Because highly bactericidal, quaternary ammonium salts did not give any larger, if as large, growth

response as other surfactants, these workers suggested that a selective instead of general inhibition of microorganisms may be involved in stimulating growth. Luecke et al. (1952) obtained nearly the same growth response in pigs from the feeding of aureomycin or a surface active agent, and a combination of the two growth promotants gave no larger response than either one alone.

Anderson et al. (1952) found that dietary penicillin enhanced the coliform and lactobacilli counts in chicks. Aciduric and proteolytic counts were reduced. Williams et al. (1951a) noted no significant change in the number of coliform or lactic acid bacteria in the intestine of chicks fed aureomycin. Wahlstrom and Johnson (1951), Sieburth et al. (1951) and Moore et al. (1946) noted a reduction in coliform counts, and the pigs and chickens showed a growth response from antibiotic feeding.

March and Biely (1952) found a marked depression of lactobacilli in aureomycin fed chicks, and they postulated that the lactic acid bacteria might compete with the host for nutrients because these bacteria are known to have specific requirements for many vitamins.

Couch et al. (1951) and Elam et al. (1951a) noted an increase in enterococci and penicillin resistant bacteria in the feces of chicks fed penicillin.

Elam et al. (1951c) noted a significant increase in yeast counts during penicillin feeding of chicks. Kratzer et al. (1951) found a five to 10-fold increase in the number of intestinal yeast cells in streptomycin fed poults. One strain of yeasts isolated from the feces even produced a slight growth response in some feeding trials. However, Luther and Brown (1951) obtained a 51 per cent increase in the weight gain of

pigs fed rimocidin, a new antibiotic which inhibits yeasts and molds but is inactive against bacteria.

Various changes have been noted in the nutrient requirements of animals receiving dietary antibiotics but no direct correlation has been made between changes in specific groups of bacteria and nutrient requirements. Stokstad and Jukes (1951a) and Cravioto-Munoz and Poncher (1951) reported that aureomycin exerted a "sparing effect" upon the vitamin B₁₂ requirement in some, but not all, experiments with chicks and rats, and in some cases the antibiotic replaced the vitamin in the ration. Olesen et al. (1950) and Wahlstrom and Johnson (1951) found that aureomycin could not replace vitamin B₁₂ in the ration of chicks and baby pigs. Carlson et al. (1951) noted an accentuated B₁₂ deficiency in breeding turkey hens fed a diet containing aureomycin but deficient in vitamin B₁₂. Davis and Chow (1951) found increased fecal excretion of vitamin B₁₂ from rats fed ⁶⁰Co and aureomycin.

Biely and March (1951), Lih and Baumann (1951) and Sauberlich (1952) reported that dietary antibiotics had little effect on the growth rate of chicks or rats on diets containing the recommended allowance of the B vitamins. However, a marked increase in growth rate was noted on diets containing suboptimal levels of nicotinic acid, folic acid, riboflavin, thiamine, pantothenic acid or pyridoxine, and the average daily gain approximated that on the diets containing optimal levels of these B vitamins. The growth response observed from different antibiotics varied with the vitamin deficiency of the ration. Linkswiler et al. (1951) found pyridoxal or pyridoxamine gave as good growth results in rats as pyridoxine when aureomycin was added to the diet. Briggs and Beeson (1951a), and Luecke

et al. (1951) found that the addition of several B vitamins to pig rations containing antibiotics increased the average daily gain. Stokstad et al. (1951b) reported that large differences in the requirement for water soluble vitamins were not found as a result of adding aureomycin to the diet of chicks.

Waisman et al. (1951) found that aureomycin counteracted the effect of certain drugs which caused a "folic acid" deficiency in rats but that the antibiotic was without effect on previously produced deficiencies. Schwarz (1951) found more, active citrovorum factor in the ceca and livers of rats receiving aureomycin than in the controls. Scott (1951) found that dietary antibiotics for turkeys reduced the incidence of the enlarged hock disorder which is believed to be caused by a deficiency of some unidentified factor. Pepper et al. (1951) found that aureomycin lowered the manganese requirement for growth and the prevention of perosis in chicks.

Cunha et al. (1950a), Burnside et al. (1951) and Catron et al. (1952b) found that the addition of antibiotics to pig rations lowered the protein requirement and Machlin et al. (1952) found similar results in chickens. However, Slinger et al. (1951b) reported that antibiotics did not influence the protein requirement in their chick experiments. Slinger et al. (1951a) found that antibiotic supplementation of a basal diet containing sunflower seed oil meal as a protein source increased the incidence of white feathering which is caused by a deficiency of lysine in turkey rations.

Whitehill et al. (1950) and Groshke and Evans (1950) obtained no growth response from the intravenous or intramuscular injection of antibiotics into chicks. Elam et al. (1951a, 1951b, and 1951c) and Couch et al. (1951) obtained a growth response from injected antibiotics in

chicks, and Carpenter (1951) noted a similar response in pigs. Since Elam et al. (1951b) noted no significant change in the fecal microflora from parenterally administered antibiotics, they suggested that the antibiotic molecule or a fragment of it might act as a body metabolite. However, Coates et al. (1952) pointed out that the possibility of antibiotics acting similar to vitamins or hormones probably should be discounted because of the varied chemical structures of the different antibiotics which stimulate growth.

In other studies, Elam et al. (1951a, 1951c) found an alteration of the intestinal flora coincident with the injection of antibiotics. Larson and Carpenter (1952b) found that both oral and injected aureomycin were excreted in the feces of pigs so that the antibiotic still might exert its action in the intestinal tract. Herrill and Heilman (1949) reported that injected antibiotics were excreted from the liver in the bile by man and Kraus et al. (1951) reported the excretion of aureomycin and terramycin in human saliva.

Noland and coworkers (1952) believed in a systemic action of antibiotics in promoting growth and thought the lack of response in some experiments might be due to poor absorption from the digestive tract. These investigators found that the implantation of a 1000-unit pellet of bacitracin in suckling pigs produced a significant increase in weight gain.

Reynier, Luckey and Gordon (1952) reported no growth response from dietary antibiotics in preliminary trials with germ-free chicks and poults at the Lobund Institute and antibiotic-supplemented, naturally-reared birds approximated the weight gain of the germ-free birds. Chicks from

the same hatch and fed the same diets as the germ-free birds showed a significant growth response from dietary antibiotics in one laboratory and not in another. These results indicated to these investigators that the microbial flora of the animal was directly or indirectly involved in the growth promoting effect of antibiotics. However, these workers did not exclude the possibility of a systemic action. Reynier pointed out that the toxicity to the host of higher concentrations of antibiotics than are used clinically or in livestock feeds has usually been overlooked. Some antibiotics have appeared to stimulate growth of bacterial cells at a concentration just below the toxic level for the microorganisms, so a stimulatory effect of sub-toxic levels in the animal body tissues or organs is not an unreasonable hypothesis. These investigators noted from autopsies that there was a striking similarity between some of the changes in organ size in the germ-free birds and the conventionally reared birds receiving antibiotics. These results were rather unexpected because no marked reduction in the number of microorganisms in the intestinal tract of animals receiving antibiotics has been found by most workers. Some of the most significant changes noted were a reduced size and weight of the small intestine, depression of weight and lymphocyte concentration in the lymphatic organs, and enlarged thymus. The extent of these changes seemed to be greatest or least in the maximum-minimum growth response birds within the conventionally-reared groups receiving antibiotics. Histological examination of the intestinal wall in the antibiotic fed chicks indicated that some of the protective cells had been stripped off and those tissues concerned with absorption were left.

In connection with the rate of nutrient absorption, Catron et al. (1951) found that the blood glucose level rose faster after feeding a test meal of glucose to aureomycin fed pigs than to the controls. Blood glucose levels were also highest when aureomycin was added to the basal ration. Murley et al. (1951b) found that blood-reducing sugar levels rose faster and higher after feeding when aureomycin was fed to dairy calves than when it was not fed.

Burgess et al. (1951) noted significantly higher liver vitamin A and serum carotenoid levels when chicks were fed penicillin, but found these results were not correlated with the growth response or feed consumption.

Burnside et al. (1951) found that aureomycin and vitamin B₁₂ increased the hemoglobin and total plasma protein level more than either one added alone. Cunha et al. (1950a) noted an increase in hemoglobin levels in conjunction with an increased growth rate in pigs fed antibiotics. Shefchik et al. (1950) found no difference in hemoglobin level between control and antibiotic supplemented groups of pigs.

Brown et al. (1951) found no difference in the rate of food passage through the digestive tract in control and antibiotic supplemented pigs. These investigators believed that increased feed consumption was the major cause of increased daily gains from aureomycin supplementation of their healthy pigs.

Bratzler and Black (1951) reported that dietary streptomycin or aureomycin did not significantly influence the energy metabolism of the rat.

Summary of Review of Literature

Many investigators have found that the inclusion of antibiotics in the ration of young, growing farm livestock has usually increased average daily gain, increased grain consumption, improved feed efficiency and reduced digestive disturbances. Some antibiotics have produced one or more of these beneficial effects while not influencing all of them. The degree of growth response obtained from dietary antibiotics in general, or from different antibiotics, has depended on the environmental conditions and the composition of the ration. While some antibiotics have apparently produced an increase in weight gain more consistently than others, higher concentrations of some of the seemingly less desirable antibiotics than of the "antibiotics of choice" have produced equally beneficial results in some cases. Species and even strains within a species have been noted to vary in their response to antibiotic feeding.

Although growth stimulation has stopped when the antibiotic was removed from the ration, animals have usually maintained their initial weight advantage over controls which did not receive the antibiotic.

Dairy calves have usually shown a 10 to 30 per cent increase in average daily gain if aureomycin has been included in the ration during a period of about two to four months after birth. The antibiotic has, in most cases, produced a better physical appearance, increased appetite for concentrates and reduced the incidence and severity of scours.

Adverse effects from dietary antibiotics have been noted in some experiments with lambs and fattening beef animals.

Recent reports on the effect of antibiotic feeding have indicated that an alteration in the microflora, particularly in the digestive tract of the animal, is probably involved in the growth promoting effect of antibiotics. The results from several experiments have suggested that the antibiotic may control some infectious organisms or organisms which cause digestive upsets. Although various changes in the nutrient requirements have been noted by several workers, no direct correlation has been made with the increase or decrease in numbers of certain groups of microorganisms noted by several other investigators. The theories suggested are that the antibiotic may reduce the competition for critical nutrients required by the host or that the antibiotic may allow more abundant growth of certain groups of microorganisms that synthesize essential nutrients. Several investigators have suggested a systemic mode of action and have noted physiological and anatomical changes which could have been caused by a direct systemic action of the antibiotic. The many varied and divergent results reported by the workers in the field of antibiotic feeding have indicated that more than one specific mode of action is probably involved in the growth promoting effect of antibiotics and that the mode of action may be somewhat dependent on the conditions imposed on the animal.

EXPERIMENTAL PROCEDURE

Animals Used

The heifer calves used in this experiment were being raised for replacement stock in the Michigan State College dairy herd. Eight Holstein, six Jersey, four Guernsey and three Brown Swiss calves suitable for the experiment were born from October 1, 1951 to March 10, 1952. Only calves that appeared healthy were used. The random assignment system within each breed was as follows: the first calf born served as a control, the second calf born received supplemental Aurofac A¹ and if a third calf was born within a month or six weeks the calf received supplemental Bacifirm 5². The calves were placed on experiment when they were removed from their dams at three days of age. A pair of comparable, two-month old Brown Swiss calves was also available for a preliminary trial and one of these calves received Aurofac A for 11 weeks.

¹ Aurofac A is an antibiotic feed supplement derived from the fermentation residues of aureomycin production by the Lederle Laboratories who have a patent on this antibiotic. It is guaranteed to contain at least 1.8 grams of aureomycin per pound and appreciable amounts of vitamin B₁₂. The Aurofac A was furnished by the Lederle Laboratories, Pearl River, New York.

² Bacifirm 5 is an antibiotic feed supplement derived from the fermentation residues of bacitracin production by the Commercial Solvents Corporation, who have a patent on this antibiotic. It is guaranteed to contain at least 5 grams of bacitracin per pound. The Bacifirm 5 was furnished by the Commercial Solvents Corporation, Terre Haute, Indiana.

Feeding and Management

Because the experiment was carried out under practical conditions in the main dairy barn of Michigan State College the experimental procedures were fitted into the usual feeding and management practices. Colostrum milk was fed for two days and then whole Holstein milk was fed for about two months depending somewhat on the size of the animal. At that age the calves were gradually shifted to reconstituted skim milk mixed at a ratio of one pound of skim milk powder to nine pounds of water. Skim milk feeding was continued for two or three months again depending on the size of the animal. The whole or skim milk was fed at a level of approximately one pound of milk per 10 pounds of body weight until a maximum of 14 pounds of skim was reached daily. A nipple pail was used until the calves were about one month of age and then the calves were taught to drink from a pail. The amount of the antibiotic feed supplements required to furnish one milligram of active aureomycin or bacitracin daily per pound of body weight was adjusted and weighed out weekly. The supplements were stirred into the milk at each feeding and usually were dispersed in the milk very well. Only a slight residue of the larger particles remained in the bottom of the pail after feeding. Bacifirm appeared to be left in smaller quantities than was the Aurofac.

A simple grain mixture composed of 125 pounds whole oats, 50 pounds whole corn and 25 pounds soybean oil meal was fed free choice after the calves were about two weeks of age. A sufficient daily allowance was weighed out for each calf so that a small amount was left in the manger and weighed back weekly. A medium quality alfalfa-mixed grass hay was

fed ad libitum in suspended racks. During the last part of the experiment individual racks were available so that hay consumption could be measured. The amount wasted by each calf was assumed to be the same.

The calves were kept in individual steel pipe pens until about 100 days of age depending on the need for the pens for newborn calves. During the first two months of age the calves were kept in pens with raised steel mesh floors lightly bedded with straw and then they were moved into pens with built-up shaving litter. At 100 days of age the antibiotic feed supplements were discontinued and at about that age the calves were moved into group pens holding five calves. They were also changed to a ground grain concentrate. Although no measurement of hay or grain consumption was possible in the group pens it seemed desirable to continue weekly body weight measurement for a period of 60 days. All the calves were allowed the same quality of grain and hay, ad libitum, and the same amount of skim milk so it was believed that the weight measurement would give a general indication of the growth rate of the control calves in comparison with the growth rate of the calves which had previously received antibiotic feed supplements. The heart girth was also measured weekly as another index of growth rate during the period from three to 100 days of age.

Bacteriological Methods

Fecal samples for bacteriological studies were obtained by stimulation of the rectum. Samples were obtained at the same time on two successive days each week and the results for the two days were averaged. The fecal samples were collected in sterile Petri dishes and immediately taken to the Dairy Bacteriology laboratory where the bacteriological studies were made.

A 10-gram sample of the feces was added to a 90-milliliter water blank and the volume made up to 100 milliliters giving a 1:10 dilution. The contents were thoroughly shaken and a 10-milliliter sample preserved in five milliliters of a 40 per cent formalin solution for total bacteria count. This gave a 1:15 dilution. For the cultural studies 10 and one-milliliter samples from the 1:10 dilution were added to 90 and 99-milliliter water blanks, respectively, which gave 1:100 and 1:1000 dilutions. Successive logarithmic dilutions were made from these two dilutions and the other successive dilutions by putting one milliliter in a 99-milliliter water blank. This serial dilution method gave successive dilutions from $1:10^2$ to $1:10^9$. One milliliter of each serial dilution was placed in a test tube containing the cultural test media.

Lauryl tryptose broth prepared according to the formula of Mallmann and Darby (1941) was used to determine the coliform group and the highest dilution showing gas formation was recorded as a logarithm to indicate the number of coliform organisms present per gram of feces. Dextrose-azide broth was used mainly as an enrichment media for the streptococci group although it has been used directly for determining the streptococcic organisms (Mallmann and Seligmann, 1950). After 24 hours of incubation at 37 degrees Centigrade four loopfuls (diameter of four millimeters) were transferred from all the dextrose azide broth tubes showing growth to tubes containing ethyl violet azide broth (Mallmann et al. (1952). The highest dilution in which turbidity could be observed in 48 hours was recorded as a logarithm to indicate the number of streptococci, or more specifically enteric streptococci, per gram of feces.

The microscopic method developed by Bortree et al. (1948) was used for the total count. The stain was prepared by saturating 10 milliliters of 95 per cent ethyl alcohol with crystal violet. One milliliter of the ethanol solution was added to 49 milliliters of distilled water, heated to 60 degrees Centigrade, mixed thoroughly and filtered. One milliliter of the 1:15 formalin solution of fecal material was placed in seven milliliters of sterile distilled water to produce a 1:120 dilution. One milliliter of the 1:120 dilution of fecal material and one milliliter of the stain were transferred to a test tube containing eight milliliters of sterile distilled water and shaken thoroughly. This resulted in a final dilution of 1:1200 of the fecal samples. The test tube was heated over a low flame until the solution bumped gently. A blood pipette was filled with the bacterial suspension and a drop was placed in a clean Petroff-Hausser counting chamber. The bacteria in 200 small squares of the counting chamber were counted for each sample. The number of bacteria per gram of feces was computed by the following formula:

$$\text{Number of bacteria per gram} = \frac{\text{Bacterial count} \times \text{dilution} \times 20 \text{ million}^*}{\text{no. squares counted}}$$

* 20 million -- factor which converts the size of the counting chamber which is in millimeters to a milliliter or gram in the case of the fecal samples. (The size of the counting chamber is 1/20 millimeter on each side and 1/50 millimeter deep.)

RESULTS

Preliminary Trial

In the preliminary trial with the pair of two-month old Brown Swiss calves, the one receiving Aurofac averaged 1.83 pounds daily gain during the 11-week trial period while the control calf averaged 1.55 pounds daily. The rate of gain was similar for both calves during the first seven weeks of the trial and the faster rate of gain of the Aurofac calf during the last part of the trial appeared to be due partially to an outbreak of pneumonia amongst the older calves in the barn. Both calves had very high temperatures, but the temperature of the Aurofac supplemented calf did not rise quite as high and the disease was not as severe as that of the control calf. Sulfamerazine was used for treatment. The Aurofac supplemented calf did not consume as much grain as the control calf during the first six weeks of the trial. An attempt was made to introduce the Aurofac into the grain mixture but the calf would not consume the grain readily with the Aurofac in it.

Growth Rate

The average daily gain for various periods and the increase in heart girth during the period of antibiotic supplementation are presented in Table I according to treatment. The average growth curves of the Aurofac, Bacifirm and control groups are presented in Figure 1 and the average growth curves of the Holstein and Jersey groups with and without supplemental Aurofac are presented in Figure 2.

TABLE I

GROWTH RATES OF CONTROL AND ANTIBIOTIC SUPPLEMENTED CALVES
FROM THREE TO 100 DAYS OF AGE

Treatment Calf No.	Body wt. at 3d.	Average daily gain				Ht. girth increase 3-100d.
		3-30d.	30-65d.	65-100d.	3-100d.	
	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)	(in.)
<u>Brown Swiss</u>						
Control						
395	90'	1.11	1.71	1.51	1.47	11.5
Aurofac						
396	91	1.00	1.91	1.91	1.66	12.0
Bacifirm						
397	111	1.00	1.91	1.40	1.47	10.0
<u>Guernsey</u>						
Control						
2002	66	0.33	0.80	1.57	0.94	9.5
2005	77	0.19	0.89	1.28	0.84	7.5
<u>Ave.</u>	<u>66.5</u>	<u>0.26</u>	<u>0.85</u>	<u>1.43</u>	<u>0.89</u>	<u>8.5</u>
Aurofac						
2003	87	0.81	1.46	2.06	1.49	10.5
Bacifirm						
2004	65	0.26	1.51	1.37	1.11	9.0
<u>Jersey</u>						
Control						
1120	50	0.59	1.34	1.34	1.13	10.0
1122	63	0.37	1.17	1.49	1.06	9.5
1123 T	41	0.44	0.97	1.11	0.88	10.0
<u>Ave.</u>	<u>51.3</u>	<u>0.47</u>	<u>1.16</u>	<u>1.31</u>	<u>1.02</u>	<u>9.8</u>
Aurofac						
1121	45	0.81	1.26	1.43	1.20	11.5
1125	50	0.52	1.06	1.66	1.12	9.0
1124 T	39	0.37	1.40	1.54	1.16	11.5
<u>Ave.</u>	<u>44.7</u>	<u>0.57</u>	<u>1.24</u>	<u>1.54</u>	<u>1.16</u>	<u>10.7</u>

TABLE I (concluded)

Treatment Calf No.	Body wt. at 3d.	Average daily gain				Ht. girth increase 3-100d.
		3-30d.	30-65d.	65-100d.	3-100d.	
	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)
<u>Holstein</u>						
Control						
554	88'	1.04	1.54	1.71	1.46	11.5
556	102	0.93	1.54	1.88	1.49	10.0
559	77	0.56	1.51	1.83	1.36	11.0
<u>Ave.</u>	<u>89.0</u>	<u>0.84</u>	<u>1.53</u>	<u>1.81</u>	<u>1.44</u>	<u>10.8</u>
Aurofac						
555	95	1.07	1.91	2.11	1.75	12.5
558	86	0.81	1.94	2.26	1.74	11.5
560	103	1.11	2.20	2.09	1.86	12.0
<u>Ave.</u>	<u>94.7</u>	<u>1.00</u>	<u>2.02</u>	<u>2.15</u>	<u>1.78</u>	<u>12.0</u>
Bacifirm						
557	97'	1.07	2.23	2.23	1.91	11.5
561	86	0.81	1.57	1.80	1.44	11.0
<u>Ave.</u>	<u>91.5</u>	<u>0.94</u>	<u>1.90</u>	<u>2.02</u>	<u>1.68</u>	<u>11.3</u>
Averages (All Breeds)						
Control (8)	72.9	0.66	1.33	1.54	1.22	10.4
Aurofac (8)	74.5	0.81	1.68	1.88	1.50	11.3
Control (4)	85.3	0.72	1.40	1.66	1.30	10.3
Bacifirm(4)	85.8	0.79	1.81	1.70	1.48	10.4

T non-identical Jersey twins
' estimated

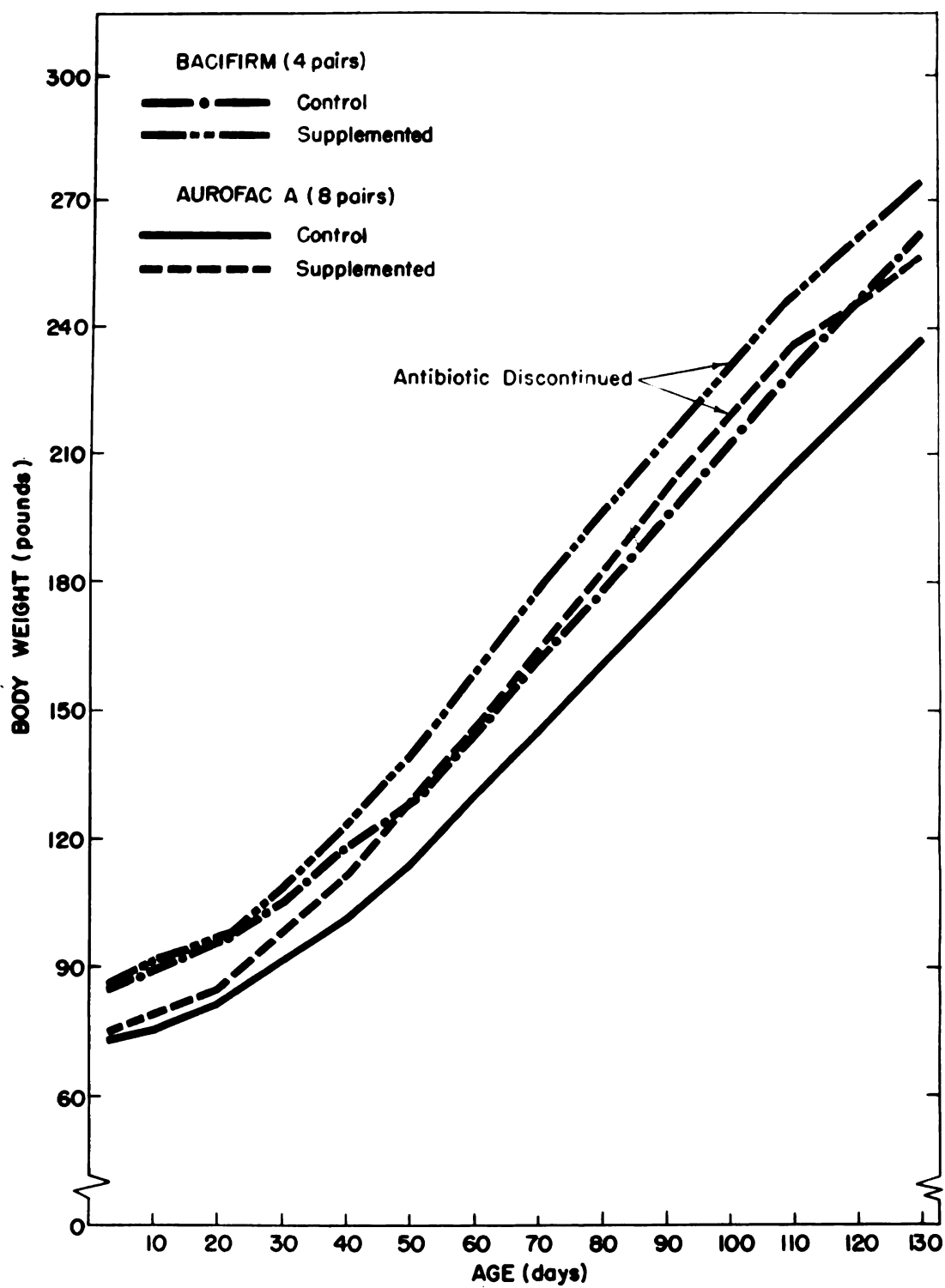


Figure 1. Summary growth curves of calves by treatments.

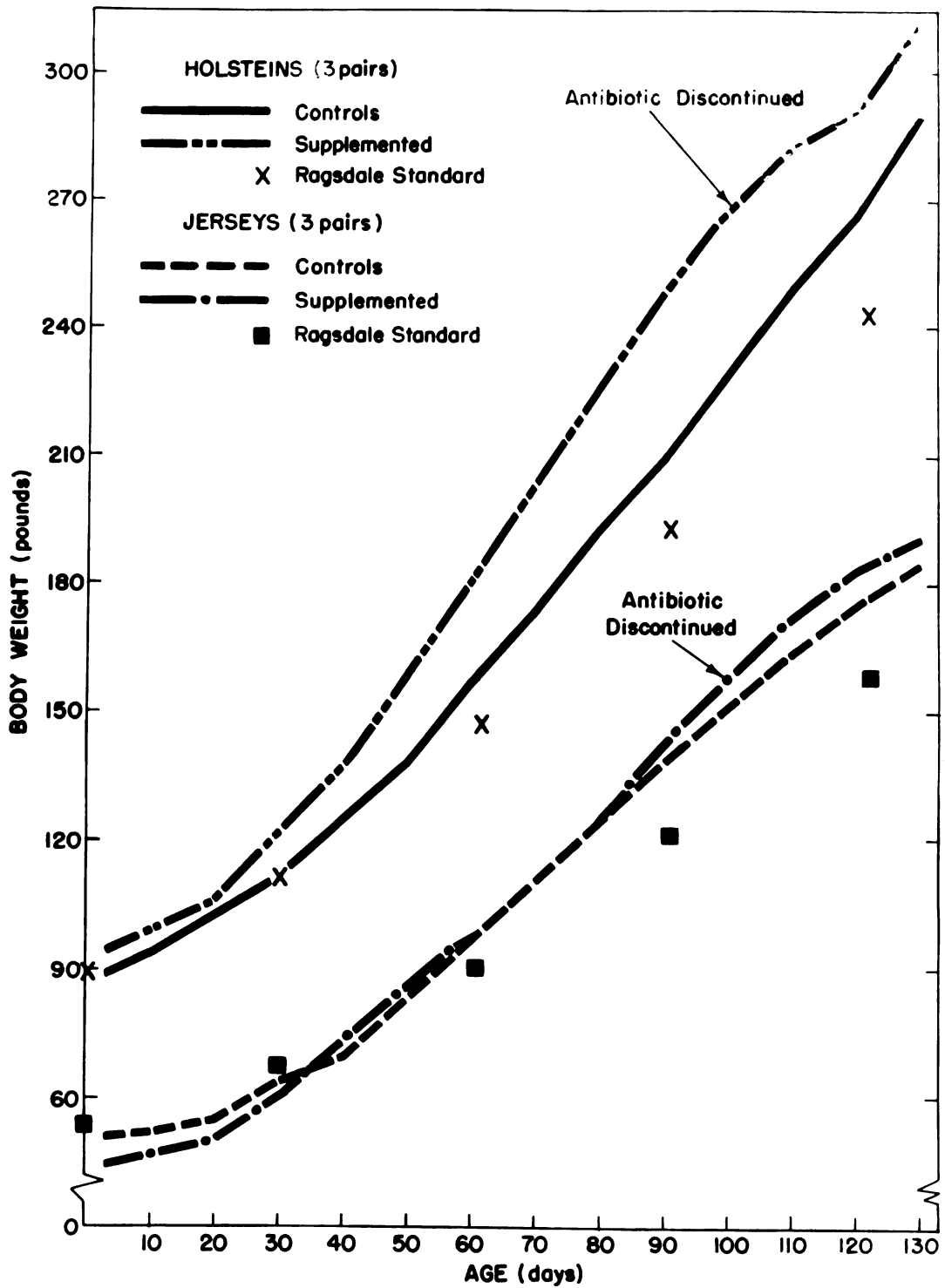


Figure 2. Summary growth curves of Holsteins and Jerseys with and without Aureofac A.

During the period from three to 100 days of age the Aurofac supplemented calves gained 23 per cent more than their controls. The Baciform supplemented calves gained 14 per cent more than their controls. The average daily gains of the Holstein control, Aurofac supplemented and Baciform supplemented groups exceeded the Ragsdale standard (Ragsdale, 1934) by 22, 51 and 42 per cent, respectively. The Jersey groups averaged 29 and 47 per cent above the Ragsdale standard for the control and Aurofac supplemented groups, respectively. The two Guernsey controls averaged 12 per cent above the Ragsdale standard while the Aurofac and Baciform supplemented calves were 86 and 39 per cent above, respectively.

During the period from three to 100 days the average daily gain was at least 0.20 of a pound greater for the three Holstein, the Brown Swiss and the Guernsey calves receiving Aurofac than for their controls. Two of the Jerseys receiving Aurofac gained only slightly more than their controls but the Aurofac supplemented Jersey twin gained markedly more than her twin control. However, the increased average daily gain in the Baciform supplemented group of four calves was due to that of only two calves, Holstein number 557 which had the largest increase in body weight of any calf in the experiment and Guernsey number 2004 which also gained faster than her controls. The other Holstein and Brown Swiss calves receiving Baciform had the same average daily gain as did the controls.

Because the average daily gain naturally varies among the different breeds, a statistical analysis of this data, using the Student's t-test, did not show any significant differences between the antibiotic supplemented groups and their control groups. However, since the variation was small in the Holstein control and Aurofac supplemented groups, the increase

in average daily gain was significant at the five per cent level of probability for that breed. The increase in weight gain of the entire Aurofac supplemented group over the control group was also statistically significant at the five per cent level of probability when the percentage increase over birth weight was used as the basis for the analysis. Using the same method the increased weight gain was not significant in the Bacifirm group.

In general the increases in heart girth coincided with the increases in weight gain although the per cent increases were not as large.

The increase in average daily gain in the Aurofac supplemented group over that of the controls was 23, 26 and 22 per cent for the three to 30-day, 30 to 65-day and 65 to 100-day periods, respectively. However, the increase in pounds was greatest during the periods from 30 to 65 days of age and 65 to 100 days of age. The greatest increase in the Bacifirm supplemented group occurred during the period from 30 to 65 days of age. The growth curves for the Holsteins and for all breeds supplemented with Aurofac indicate that the increase in daily gain over that of the controls was gradual after about 20 days of age. However, the increase in daily gain of the Aurofac supplemented Jerseys occurred during the first and last periods of Aurofac supplementation.

Feed Consumption and Efficiency

The data for feed consumption and feed efficiency are presented in Table II. Because a few of the calves had to be moved from the individual pens before 100 days of age, these data could only be grouped for the first

TABLE II

WEIGHT GAIN, FEED CONSUMPTION AND FEED EFFICIENCY
FROM 3 TO 90 DAYS OF AGE

Treatment Calf No.	Wt. gain 3-90d.	Grain 3-90d.	Hay 3-90d.	Whole milk	Skim milk	TDN/ lb. gain
	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)
<u>Brown Swiss</u>						
Control						
395	129	73		580	406	
Aurofac						
396	143	67		580	406	
Bacifirm						
397	128	40		560	434	
<u>Guernsey</u>						
Control						
2002	71	29		689	98	
2005	67	41	42	469	288	2.24
<u>Ave.</u>	<u>69</u>	<u>35</u>		<u>579</u>	<u>193</u>	
Aurofac						
2003	126	90		629	294	
Bacifirm						
2004	99	57	70	637	112	1.91
<u>Jersey</u>						
Control						
1120	99	76		354	350	
1122	89	70	47	546	204	2.02
1123 T	72	41	63	585	---	2.17
<u>Ave.</u>	<u>87</u>	<u>62</u>	<u>55</u>	<u>495</u>	<u>188</u>	<u>2.10</u>
Aurofac						
1121	103	67		378	322	
1125	92	44	76	532	120	1.81
1124 T	97	94	72	592	---	2.07
<u>Ave.</u>	<u>97</u>	<u>68</u>	<u>74</u>	<u>501</u>	<u>147</u>	<u>1.94</u>

TABLE II (concluded)

Treatment Calf No.	Wt. gain 3-90d.	Grain 3-90d.	Hay 3-90d.	Whole milk	Skim milk	TDN/ lb. gain
	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)
<u>Holstein</u>						
Control						
554	120	64		680	266	
556	123	96	98	560	434	2.00
559	116	102	70	574	336	1.98
<u>Ave.</u>	<u>120</u>	<u>87</u>	<u>84</u>	<u>605</u>	<u>345</u>	<u>1.99</u>
Aurofac						
555	147	103		620	350	
558	153	111	88	595	336	1.62
560	158	173	130	550	448	2.01
<u>Ave.</u>	<u>153</u>	<u>129</u>	<u>109</u>	<u>588</u>	<u>378</u>	<u>1.82</u>
Bacifirm						
557	158	142	123	450	588	1.81
561	120	60	80	602	238	1.67
<u>Ave.</u>	<u>139</u>	<u>101</u>	<u>102</u>	<u>526</u>	<u>413</u>	<u>1.74</u>
Averages (All Breeds)						
Control (8)	102	69.6	70*	557	274	2.04*
Aurofac (8)	127	93.6	91*	560	285	1.88*
Control (4)	109	76.5	70**	573	342	2.07**
Bacifirm(4)	127	75.0	88**	562	343	1.80**

T = non-identical
Jersey twins

* average 4 pairs
** average 3 pairs

90 days of the trial. During that period the Aurofac supplemented group averaged to consume 34 per cent more grain than their control group while the Bacifirm supplemented group averaged to consume the same amount as their control group. Five of the six calves which showed pronounced increases in weight gain from Aurofac feeding also consumed more grain than their control pair-mates. The two Jerseys which showed only slight increases in weight gain from Aurofac feeding consumed less grain than their pair-mate controls. Holstein number 561 and Brown Swiss number 397 which received Bacifirm consumed considerably less grain than did their control pair-mates and yet they gained weight at essentially the same rate. The other two Bacifirm supplemented calves did consume more grain and gained more than their control pair-mates.

The amount of grain per pound of gain was 0.68 pound for the control animals as compared to 0.74 pound for the Aurofac supplemented calves.

None of the calves consumed an appreciable amount of grain until after 30 to 40 days of age. However, the amount of grain consumed daily by the Aurofac supplemented calves, which consumed more grain during the entire period, increased much faster after that period than did the amount consumed daily by the control animals. Two or three of the Aurofac calves did start to eat grain at an earlier age than did their control pair-mates after it was placed in their manger at about two weeks of age.

The limited amount of data available on hay consumption indicates that the Aurofac and Bacifirm supplemented groups averaged to eat more hay than the control groups. However, the Jersey twins received the same quality of hay at the same age and the increase in hay consumption by the Aurofac supplemented twin was not appreciable.

The calculated data for pounds of total digestible nutrients per pound of gain indicated that nearly all calves receiving Aurofac or Bacifirm used their feed more efficiently than did their control pair-mates. The values for calculating this data were 73, 50, 16.3 and 8 pounds of total digestible nutrients per 100 pounds of grain, hay, whole milk and skim milk, respectively.

General Observations

Several of the calves in all groups had mild cases of scours at about 10 days to two weeks of age and the incidence did not appear to vary markedly among the control and Aurofac or Bacifirm supplemented groups. All cases of scours responded quite well to treatment with bismuth subnitrate. However, the cases of scours in the calves fed Aurofac usually did not affect the rate of gain as much as in the control calves. In general, the individual growth curves for the calves fed Aurofac were smoother than those of the control calves. A few of the control calves had digestive upsets after two weeks of age which slowed growth but these digestive upsets were not noted in the Aurofac or Bacifirm supplemented calves.

The outbreak of pneumonia, previously mentioned in connection with the pair of calves in the preliminary trial, also affected two control calves in these groups. Brown Swiss number 395 had a high temperature and did not gain any weight during the week that she was infected. The increase in weight gain in Aurofac supplemented calf number 396 over 395 appeared to be partially explainable by the fact that she did not have pneumonia. Holstein number 554 was the only other calf which had pneumonia but it did not seriously affect her rate of gain.

No marked differences were noted in the general appearance of the calves in the various groups at the end of the period of Aurofac or Bacifirm supplementation. Holsteins numbers 555, 558 and 560 on Aurofac and 557 on Bacifirm did appear to have a little smoother and more glossy hair coat than their control group pair-mates.

Observations indicated that Holstein calves numbers 555, 558 and 560 and Jersey twin number 1124, which showed a significant response to Aurofac feeding, were slightly more irritable and active in their pens than were the control calves. These calves were more difficult to make stand on the scales during weighing than the other calves.

Growth Rate after Antibiotic Feed Supplements Discontinued

The average daily gains for the period after Aurofac and Bacifirm feeding was discontinued are indicated in Table III. The average daily gain was smaller for the calves which had previously received Aurofac than for the control calves during the period from 100 to 130 days of age and the reverse of this occurred during the 130 to 160-day period. However, the average daily gain was similar for both groups during the entire period from 100 to 160 days of age. In general, a similar trend was noted in the control and previously Bacifirm supplemented groups.

Bacteriological Data

The grouped bacteriological data are presented in graphic form in Figure 3. No definite trends or differences were noted among the different treatments in the number of bacteria in the streptococci or coliform

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TABLE III

GROWTH RATES OF CONTROL AND PREVIOUSLY ANTIBIOTIC SUPPLEMENTED
CALVES FROM 100 TO 160 DAYS OF AGE

Previous treatment Calf No.	Average daily gain			
	3-100d.	100-130d.	130-160d.	100-160d.
	(lb.)	(lb.)	(lb.)	(lb.)
		<u>Brown Swiss</u>		
Control 395	1.47	1.50	1.53	1.51
Aurofac 396	1.66	.93	2.13	1.54
Bacifirm 397	1.47	1.70	1.93	1.81
		<u>Guernsey</u>		
Control 2002	.94	1.43	1.07	1.25
2005	.84	.80	----	----
<u>Ave.</u>	<u>.89</u>	<u>1.12</u>	<u>----</u>	<u>----</u>
Aurofac 2003	1.49	1.37	1.07	1.22
Bacifirm 2004	1.37	.87	1.10	.99
		<u>Jersey</u>		
Control 1120	1.13	1.33	1.23	1.28
1122	1.06	1.13	----	----
1123 T	.88	.90	.77	.84
<u>Ave.</u>	<u>1.02</u>	<u>1.12</u>	<u>1.00</u>	<u>1.06</u>
Aurofac 1121	1.20	1.13	1.30	1.22
1125	1.16	1.17	----	----
1124 T	1.12	.97	1.30	1.14
<u>Ave.</u>	<u>1.16</u>	<u>1.09</u>	<u>1.30</u>	<u>1.18</u>

TABLE III (concluded)

Previous treatment Calf No.	Average daily gain			
	3-100d.	100-130d.	130-160d.	100-160d.
	(lb.)	(lb.)	(lb.)	(lb.)
	<u>Holstein</u>			
Control 554	1.46	2.00	1.83	1.91
556	1.49	1.93	1.63	1.78
559	1.36	2.13	1.57	1.85
<u>Ave.</u>	<u>1.44</u>	<u>2.02</u>	<u>1.68</u>	<u>1.85</u>
Aurofac 555	1.75	1.63	1.73	1.68
558	1.74	1.30	2.20	1.75
560	1.86	1.43	2.10	1.77
<u>Ave.</u>	<u>1.78</u>	<u>1.45</u>	<u>2.01</u>	<u>1.73</u>
Bacifirm 557	1.91	1.80	1.93	1.87
561	1.44	1.57	1.20	1.39
<u>Ave.</u>	<u>1.68</u>	<u>1.69</u>	<u>1.57</u>	<u>1.63</u>
Averages (All Breeds)				
Control (8)	1.22	1.51	1.38*	1.49*
Aurofac (8)	1.50	1.24	1.69*	1.47*
Control (4)	1.30	1.67	1.45	1.60
Bacifirm (4)	1.48	1.49	1.54	1.52

T = non-identical
Jersey twins

* average 7 pairs

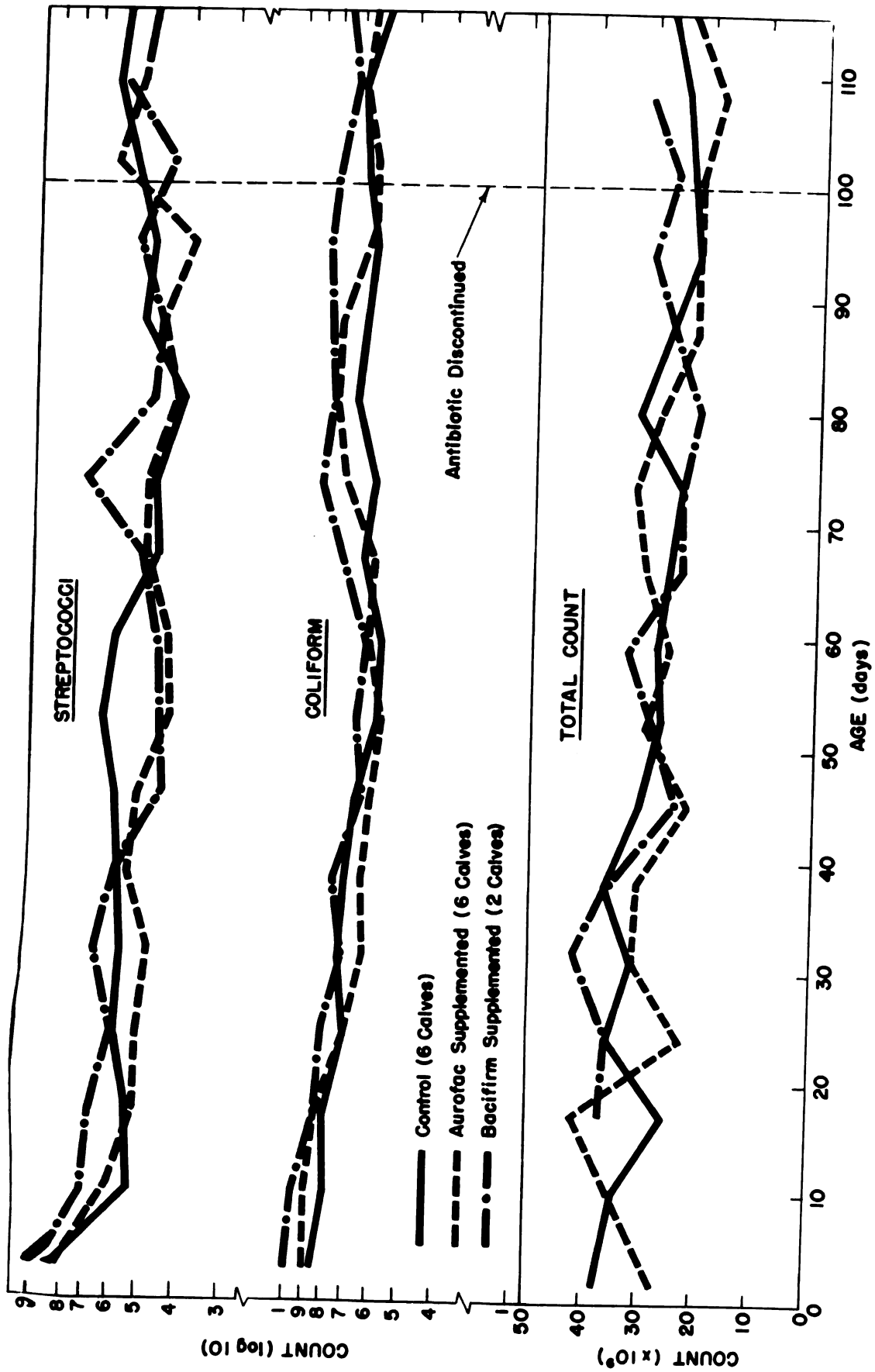


Figure 3. Summary of the number of bacteria per gram of feces.

groups or in the total bacteria count. The numbers of streptococci did appear to be slightly lower for the Aurofac supplemented calves than for the control animals during the period from 20 to 60 days of age. The individual weekly data for each calf is presented in the Appendix.

DISCUSSION

The increase in average daily gain obtained with the Aurofac supplemented group in comparison with the control group agrees quite well with the results obtained by such investigators as Bartley et al. (1951), Bloom and Knodt (1951), Jacobson et al. (1951), MacKay et al. (1952), Murley et al. (1951a), Loosli et al. (1951) and Rusoff and Davis (1951b) who also supplemented the ration of young dairy calves with Lederle aureomycin feeding supplements or crystalline aureomycin. Some of these investigators did not feed as high a level of aureomycin either in crystalline form or as a feed supplement as was fed in this experiment and they obtained similar increases in weight gain. Of course the amount of an antibiotic required to produce a growth response appears to depend on the ration and environment as has been pointed out in the review of literature. Knodt and Ross (1952) recently reported on the feeding of several levels of aureomycin to dairy calves and they found that the higher levels did not produce any harmful effects. The higher levels of aureomycin did appear to slightly increase the beneficial effect of aureomycin feeding in their calves. The principle of diminishing response for each added increment does appear to be borne out in the addition of antibiotics to the rations of animals.

Because the variation was quite large among breeds in average daily gain and among calves within each breed in increase over birth weight, the increased weight gain in the Aurofac supplemented calves was not highly significant on statistical analysis. However, since the increase over

the Ragsdale standard was quite uniform between breeds and individuals in the control and Aurofac supplemented groups, the increased weight gain was highly significant at the one per cent level of probability when these data were used for analysis. The Brown Swiss pair had to be omitted from this analysis since Ragsdale established no standard for this breed.

Although only half as many calves received Bacifirm as Aurofac, the results obtained with these groups indicated that Bacifirm did not produce as large or consistent increase in weight gain as Aurofac did in dairy calves. Of course a higher level of Bacifirm supplementation than the selected level of one milligram of bacitracin in Bacifirm per pound of body weight might have produced an equally significant increase in weight gain as the aureomycin in the Aurofac did at the same level. Although the mode of action of antibiotics in promoting growth is generally believed to be connected with their effect on the intestinal microflora, it should probably be pointed out that bacitracin is poorly absorbed, if at all, from the intestinal tract after oral administration (Pratt and Dufrenoy, 1949). These same authors also stated that oral aureomycin has proved successful for the treatment of systemic clinical infections. The Bacifirm appeared to be quite hygroscopic and it became quite damp at times in the bulk container and in the paper bags into which the individual daily feeding requirement was weighed out weekly. Bacitracin loses some of its antibiotic activity in aqueous solutions (Pratt and Dufrenoy, 1949) so that possibly some of the stated antibiotic potency in the Bacifirm might have been lost. However, the first and last calves fed Bacifirm were the ones which did not respond to the supplementation and about three months had elapsed between the time when Bacifirm

supplementation was started in these two calves. The Aurofac was not as hygroscopic as the Bacifirm. Apparently the length of time the Aurofac was stored had little effect on its growth promoting effect as the first and last Jerseys placed on the supplement only responded with a slight increase in weight gain. Although Terrill et al. (1951) were working with pigs, the relative increase in body weight of 16 and 27 per cent for bacitracin and aureomycin respectively agrees very well with the 14 and 23 per cent increase from Bacifirm and Aurofac in this experiment.

The fairly uniform growth response from Aurofac in the three Holstein calves and the variable growth response in the Jerseys indicated that the effect of antibiotics varies with different breeds and particularly with individual calves. The results obtained with these two breeds are contrary to the results obtained by Rusoff and Davis (1951b) who found a larger per cent increase in weight gain in their Jerseys than in their Holsteins fed aureomycin.

The experimental results indicated that the antibiotic feed supplements exerted two general effects in producing beneficial results in the calves. Three Aurofac supplemented calves and two Bacifirm supplemented calves did not consume as much grain as their controls while they gained as much as their control pair-mates and had better feed efficiency. In most of these cases this beneficial effect seemed to be due partially to the fact that the calves got a better start during the first month of age. However, the five Aurofac supplemented and two Bacifirm supplemented calves which had the largest weight increase consumed more grain and showed the largest weight increase over their controls during the grain feeding period. Probably the two effects were additive in those calves showing the largest

increase in weight. Most of the fastest growing calves also had an improved feed efficiency as might naturally be expected since fewer nutrients would be required for maintenance.

The data for hay consumption indicated that the calves receiving Aurofac and Bacifirm consumed more hay than their control groups. The quality of the hay did vary considerably from week to week and no attempt was made to account for the variation in the amount wasted by each calf. Most investigators including Loosli et al. (1951) and Bartley et al. (1951) have reported similar hay consumption in control and aureomycin supplemented calves. Of course calves which consumed more grain as the Aurofac supplemented animals did in this experiment might be expected to also have a greater appetite for hay. The relative increase in hay and grain consumption was similar in the Aurofac supplemented group. Jacobson et al. (1952b) reported that Aurofac supplemented calves did consume more hay than the control calves from 16 to 28 weeks of age when the grain was limited to four pounds daily.

Several investigators, Loosli and Wallace (1950), Loosli et al. (1951), Rusoff and Davis (1951b) and Bartley et al. (1950, 1951), have reported reductions in the incidence and severity of scours in aureomycin supplemented calves which they believed to be partially responsible for the increased growth rate. However, no distinct difference was noted in the occurrence of scouring in the various groups in this experiment, particularly during the first few weeks of age. Apparently the type of scours is involved in the degree of benefit obtained from dietary aureomycin in this respect. Bartley et al. (1950) noted that Aurofac was more effective in controlling acute scours than mild scours which was apparently the type

of scours observed in this experiment. MacKay et al. (1952) and Bloom and Knodt (1951) reported an increase in weight gain from dietary aureomycin even when no cases of scours were observed.

The results indicated that possibly some of the aureomycin in the Aurofac was absorbed into the system of the calves and helped in reducing the severity and occurrence of pneumonia. Only one of the four cases of pneumonia noted in the outbreak was in an Aurofac supplemented calf and this animal recovered faster than its control pair-mate.

The slight hyperirritability noted in four Aurofac supplemented calves might indicate some mineral deficiency due to the increased rate of gain. No studies on the mineral requirements of antibiotic supplemented animals have been reported. The increased activity in these calves might have been due to an increased metabolic rate but Bratzler and Black (1951) reported no significant effect of antibiotics on the metabolic rate in rats.

Rusoff (1951b), Murley et al. (1951a) and others have reported better physical appearance and sleeker hair coat in aureomycin supplemented calves than in the controls. Somewhat similar results were noted in four of the antibiotic supplemented calves in this experiment. These observations tend to bring out the question of whether the antibiotics are actually increasing the structural growth in the calves or are fattening the calves with the increased amount of concentrates usually consumed. Although vigorous and healthy calves are desired, excess conditioning during this period of growth in the dairy herd replacement heifer would not be particularly desirable or beneficial. Body weight has usually been used as the only index of growth in the experiments conducted on antibiotic feeding. Jacobson et al. (1952b) recently reported that the feeding of Aurofac to

dairy calves significantly ($P = 0.01$) increased the body weight and chest circumference. However, they noted that the increase in height at withers and chest depth were not significant even at the five per cent level of probability. These measurements might be considered better indices of structural growth than either body weight or chest circumference. An increase in heart girth has been noted in this experiment but the per cent increase was not as large as the increase in body weight. Heart girth is usually quite closely correlated with body weight. Voelker and Cason (1951) did report increases in structural growth from the measurement of eight different body parts in the Aurofac supplemented and control groups.

The data indicated that the calves which had previously received Aurofac or Bacifirm had a slower growth rate than the control animals during the period from 100 to 130 days of age. In this connection, McGillard et al. (1952) noted that calves utilized their feed less efficiently after aureomycin administration was discontinued than did the control animals. They believed that these results might be due to a lag in the establishment of a normal rumen flora and found that cud inoculations were somewhat beneficial after aureomycin feeding was stopped at 35 days of age. However, their calves showed periods of accelerated growth after periods of slow growth so that growth in all groups was similar at the end of 16 weeks of age. Apparently the period of slow growth after the antibiotic was discontinued in this experiment was also followed by accelerated growth so that the growth rate from 100 to 160 days was similar for control and previously supplemented calves. The similar growth rate of previously antibiotic supplemented calves and the maintenance of the original increase in body weight in the antibiotic supplemented group agrees with the results obtained by Jacobson et al. (1952a, 1952b).

Rusoff et al. (1952) and Loosli et al. (1951) noted no marked difference in total bacteria count or the numbers of bacteria in various groups present in the feces or rumen of the calf. Neither has any distinct difference been noted in this experiment from the bacteriological studies made on the feces. These results indicate that the antibiotics may alter the relative numbers of specific species within the groups if a bacterial mode of action is involved in promoting growth. Of course the antibiotic might alter the nutrient requirements of the microorganisms without markedly affecting the relative number of bacteria present. This may be accomplished indirectly since some experimental results from studies on the effect of antibiotics on bacteria indicated that the antibiotic resistant organisms which survived exposure to the antibiotics had a lower metabolic rate than that of the normal population (Pratt and Dufrenoy, 1949).

SUMMARY

Twenty-one heifer calves from the Jersey, Holstein, Gurnsey and Brown Swiss herds were placed on experiment at three days of age. Nine representative calves were allotted to the control group, eight received supplemental Aurofac and four received supplemental Bacifirm. The calves were reared under rather common feeding and management practices except that more milk and skim milk were fed than is normally considered practical. The antibiotic feed supplements, Aurofac and Bacifirm, were fed in the milk at a level of one milligram of active antibiotic per pound of body weight.

During the period from three to 100 days of age the Aurofac supplemented calves gained an average of 1.50 pounds daily compared to 1.22 pounds for their controls. The Bacifirm supplemented calves and their controls averaged 1.48 and 1.30 pounds daily gain, respectively, during the same period. The data indicated that the Bacifirm was not as effective as the Aurofac in stimulating weight gain in dairy calves at the same level of antibiotic supplementation and under the experimental conditions of this study.

The calves which showed the largest increases in weight gain from the antibiotic feed supplements also consumed more grain than their control pair-mates. The antibiotic supplemented calves tended to utilize feed more efficiently than their control pair-mates.

The antibiotic feed supplements were deleted from the ration at 100 days of age and the growth rate of the previously supplemented calves was

first slowed and then accelerated over that of the controls. The growth rate for the entire period from 100 to 160 days of age was similar for the control and previously antibiotic supplemented groups.

Bacteriological studies did not reveal any distinct difference between the control and antibiotic supplemented groups in the numbers of bacteria either in the coliform or streptococci groups or total numbers of bacteria present in the feces of the calves.

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The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry, no matter how small, should be recorded to ensure the integrity of the financial data. This includes not only sales and purchases but also expenses and income. The document further states that regular audits are necessary to verify the accuracy of these records and to identify any discrepancies.

In addition to record-keeping, the document highlights the need for transparency in financial reporting. It suggests that all stakeholders should have access to the relevant financial information to make informed decisions. This transparency is crucial for building trust and ensuring the long-term success of the organization. The document also mentions that clear communication is essential for explaining the financial results and the reasons behind any variances.

Another key point discussed is the importance of budgeting and financial planning. The document advises that a well-defined budget should be established at the beginning of each fiscal year. This budget should serve as a guide for all financial activities and help in monitoring the organization's performance against its financial goals. The document also notes that regular reviews of the budget are necessary to adjust to changing circumstances and to ensure that the organization remains on track.

Finally, the document stresses the importance of maintaining accurate and up-to-date financial statements. It states that these statements are a critical tool for assessing the financial health of the organization and for providing a clear picture of its performance to external stakeholders. The document recommends that these statements be prepared on a regular basis and that they be subject to external audits to ensure their reliability.

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A P P E N D I X

TABLE IV

WEEKLY BACTERIOLOGICAL DATA - NUMBER BACTERIA PER GRAM OF FECES
BROWN SWISS CALVES 393 & 394

Date	Control 394 (Born 8/25/51)			Aurofac 393 (Born 8/20/51)		
	Coli- form	Strepto- cocci	Total count	Coli- form	Strepto- cocci	Total count
	$\log_{10}$	$\log_{10}$	10^9	$\log_{10}$	$\log_{10}$	10^9
10/22,23/51	6.5	7.5	38	6.0	6.0	76
10/25,26	7.0	4.5	71	6.5	3.5	49
11/1,2	6.5	3.0	38	8.0	---	75
11/8,9	6.5	6.5	128	7.0	6.0	70
11/14,15	8.0	7.5	36	6.0	4.0	40
11/20,21	7.5	9.0	53	7.0	3.0	119
11/28,29	7.0	6.0	25	6.5	5.5	28

(Aurofac started 10/29/51)

TABLE V

WEEKLY BACTERIOLOGICAL DATA - NO. BACTERIA PER GRAM OF FECES
BROWN SWISS 395, 396 & 397

Date	Control 395 (Born 10/1/51)			Aurofac 396 (Born 10/23/51)		
	Coli- form	Strepto- cocci	Total count	Coli- form	Strepto- cocci	Total count
	Log ₁₀	Log ₁₀	10 ⁹	Log ₁₀	Log ₁₀	10 ⁹
10/24,26/51	8.0	6.0	76	9.0	7.5	55
11/1,2	6.0	1.5	44	9.0	8.5	70
11/8,9	7.0'	6.0'	66'	8.0	7.0	97
11/14,15	7.5	5.0	26	7.5	6.0	46
11/20,21	6.0	6.0	42	7.5	4.0	100
11/28,29	5.0	6.0	20	7.5	4.5	29
12/5,6	7.0	6.0	14	6.5	7.0	27
12/12,13	5.0	4.0	24	7.0	6.0	58
12/19,20	6.5	2.5	27	6.0	4.0	35
12/26,27	8.0	6.0	49	5.5	5.5	34
1/2,3/52	6.5	5.5	34	8.0	6.5	63
1/9,10	7.0	6.5	36	8.0	6.0	38
1/16,17	6.5	7.5	26	8.0	6.5	19
1/23,24	5.0'	4.0'	26'	6.0'	4.5'	20'
1/30,31				5.0	6.0	23
2/6,7	7.0	7.5	24	6.0	5.0	22
2/13,14	5.0'	6.0'	27'	6.0	6.0	22

(Aurofac started 10/29/51)
(" stopped 2/2/52)

TABLE V (concluded)

Date	Bacifirm 397 (Born 10/30/51)		
	Coli- form	Strepto- cocci	Total count
	Log ₁₀	Log ₁₀	10 ⁹
11/1,2/51	10.0'	9.0'	101'
11/8,9	9.5	7.0	100
11/14,15	9.0'	6.0'	51'
11/20,21	8.5	4.5	48
11/28,29	6.5	5.5	41
12/5,6	7.0	5.0	54
12/12,13	5.5	4.0	25
12/19,20	7.5	3.5	33
12/26,27	7.0	6.5	51
1/2,3/52	7.0	4.0	32
1/9,10	8.5	8.0	35
1/16,17	7.5	6.0	24
1/23,24	8.0	5.5	28
1/30,31	8.0'	6.0'	28'
2/6,7	7.5	4.0	20
2/13,14	7.0	7.0	22
' = one day only			(Bacifirm started 11/3/51) (" stopped 2/2/52)

TABLE VI

WEEKLY BACTERIOLOGICAL DATA - NO. BACTERIA PER GRAM OF FECS
HOLSTEIN CALVES 554 & 555

Date	Control 554 (Born 10/12/51)			Aurofac 555 (Born 10/25/51)		
	Coli- form	Strepto- cocci	Total count	Coli- form	Strepto- cocci	Total count
	Log ₁₀	Log ₁₀	10 ⁹	Log ₁₀	Log ₁₀	10 ⁹
10/29,30/51	8.5	6.0	49	9.0	8.5	38
11/1,2	8.0	3.0'	56'	9.5	8.0	70
11/8,9	8.0'	8.0'	102'	8.5	8.5	83
11/14,15	6.0'	7.0'	52'	8.5	4.0	42
11/20,21	5.0	6.5	51	6.5	5.5	43
11/28,29	6.0	7.0	23	5.0	7.0	31
12/5,6	5.0	6.5	25	5.5	4.0	17
12/12,13	6.0'	4.0'	35'	5.5	2.5	33
12/19,20	6.5	5.0	24	6.0	4.0	31
12/26,27	9.0'	6.0'	56'	5.5	4.5	43
1/2,3/52	6.5	7.0	39	7.0	7.5	35
1/9,10	7.0	7.5	32	7.5	5.5	42
1/16,17	7.0	6.0	--	8.0	6.0	24
1/23,24	7.0	5.0	--	7.0	4.5	31
1/30,31	---	---	--	6.0	4.0	19
2/6,7	7.0'	6.0'	23'	6.0'	3.0'	10'
2/13,14	7.0'	4.0'	19'	6.5	4.0	20
2/20,21	6.0'	6.0'	18'	6.5	2.0	20

' = one day only

{Aurofac started 10/31/51
" stopped 2/9/52}

TABLE VII

WEEKLY BACTERIOLOGICAL DATA - NO. BACTERIA PER GRAM OF FECES
HOLSTEIN CALVES 556, 557 & 558

Date	Control 556 (Born 11/29/51)		
	Coli- form	Strepto- cocci	Total count
	Log ₁₀	Log ₁₀	10 ⁹
12/5,6/51	8.5	8.5	18
12/12,13	8.0	4.5	23
12/19,20	8.0	4.5	27
12/26,27	7.0	7.0	44
1/2,3/52	8.0	8.0	29
1/9,10	5.0	8.5	37
1/16,17	8.0	6.5	24
1/23,24	5.0	7.5	28
1/30,31	7.5	6.5	20
2/6,7	7.5	4.0	21
2/13,14	6.0	4.5	25
2/20,21	7.5	3.0	28
2/27,28	6.0	5.5	20
3/5,6	7.0	4.5	14
3/12,13	7.5	5.5	20
3/19,20	6.0	5.5	29
3/26,27	6.0	7.0	42
4/2,4	6.5	5.5	24
4/9	5.0	4.0	39
4/16,18	6.0	3.5	34

TABLE VII (concluded)

Date	Bacifirm 557 (Born 12/23/51)			Aurofac 558 (Born 1/3/52)		
	Coli- form	Strepto- cocci	Total count	Coli- form	Strepto- cocci	Total count
	Log ₁₀	Log ₁₀	10 ⁹	Log ₁₀	Log ₁₀	10 ⁹
1/9,10/52	7.5	7.5	28	8.0	7.5	35
1/16,17	7.5	7.5	27	9.0	5.0	19
1/23,24	8.0	8.0	44	8.0	4.0	27
1/30,31	8.0	7.0	25	7.5	5.5	23
2/6,7	7.5	5.0	23	6.5	5.0	28
2/13,14	6.0	5.5	24	6.5	4.5	20
2/20,21	5.5	3.0	20	7.5	5.5	20
2/27,28	7.5	6.5	18	6.0	3.5	18
3/5,6	8.5	7.0	17	7.5	5.0	11
3/12,13	8.0	4.0	18	6.0	5.0	22
3/19,20	8.0	4.0	24	7.5	4.5	22
3/26,27	8.5	5.0	32	7.5	5.5	31
4/2,4	8.0	5.0	34	7.5	5.0	21
4/9	7.0	5.0	44	6.0	4.0	35
4/16,18	7.5	3.5	31	7.5	4.0	21

(Bacifirm started 1/5/52)
(" stopped 4/5/52)

(Aurofac started 1/6/52)
(" stopped 4/12/52)

TABLE VIII

WEEKLY BACTERIOLOGICAL DATA - NO. BACTERIA PER GRAM OF FECES
JERSEY CALVES 1120 & 1121

Date	Control 1120 (Born 11/4/51)			Aurofac 1121 (Born 11/18/51)		
	Coli- form Log ₁₀	Strepto- cocci Log ₁₀	Total count 10 ⁹	Coli- form Log ₁₀	Strepto- cocci Log ₁₀	Total count 10 ⁹
11/8,9/51	9.0	9.0	98			
11/14,15	8.5	6.0	76			
11/20,21	8.0	5.0	32	8.0'	9.0'	29'
11/28,29	7.0	7.5	33	9.5	7.0	26'
12/5,6	8.0	4.0	17	9.0	6.5	36
12/12,13	7.5	4.0	35	8.0'	3.0'	18'
12/19,20	7.0	6.0	29	7.0	3.0	21
12/26,27	6.5	6.0	62	6.0	5.5	39
1/2,3/52	6.0	7.0	35	6.0	6.0	29
1/9,10	6.5	7.5	29	6.0	3.5	32
1/16,17	6.5	6.5	27	6.0	6.0	18
1/23,24	6.5	7.0	25	6.0	6.5	34
1/30,31	6.0'	3.0'	27'	9.0	6.0	30
2/6,7	5.0	3.0	19	8.0	3.0	13
2/13,14	6.0'	7.0'	22'	8.5	5.5	17
2/20,21	7.5	6.5	22'	7.0	2.5	20
2/27,28	5.5	4.0	27	7.5	6.0	24
3/5,6	5.5	4.0	14	7.5	6.0	14
3/12,13	6.0	5.5	21	6.0	5.0	20

' = one day only

(Aurofac started 11/21/51)
(" stopped 3/1/52)

TABLE IX

WEEKLY BACTERIOLOGICAL DATA - NO. BACTERIA PER GRAM OF FECES
JERSEY TWIN CALVES 1123 & 1124

Date	Control 1123 (Born 2/3/52)			Aurofac 1124 (Born 2/3/52)		
	Coli- form	Strepto- cocci	Total count	Coli- form	Strepto- cocci	Total count
	Log ₁₀	Log ₁₀	10 ⁹	Log ₁₀	Log ₁₀	10 ⁹
2/6/52	8.0	8.0	33	9.0	8.0	9
2/13,14	7.0'	7.0'	20'	7.0	4.5	27
2/20,21	9.0	7.5	21	9.0	6.0	25
2/27,28	6.5	6.0	14	8.0	5.0	14
3/5,6	7.5	6.5	16	6.5	4.0	17
3/13	8.0	4.0	22	7.0'	7.0'	47
3/19,20	6.0'	5.0'	24'	5.0	4.5	19
3/26,27	6.5	5.5	27	4.5	2.5	22
4/2,4	5.5	4.5	36	6.5	5.0	39
4/9	6.0	3.0	35	7.0'	3.0'	40
4/16,18	6.0	5.0	25	6.0	3.5	30
4/23,25	7.0	3.5	42	7.0	2.0	38
4/30,25	6.0	4.0	--	7.0	3.5	--
5/7,9	6.0'	4.5'	--	6.0'	5.5'	--
5/14,16	6.5	5.0	--	6.5	7.0	--
5/23	7.0	7.0	--	7.0'	7.0'	--

' = one day only

(Aurofac started 2/7/52)
(" stopped 5/17/52)

TABLE X

WEEKLY BACTERIOLOGICAL DATA - NO. BACTERIA PER GRAM OF FECES
GUERNSEY CALVES 2002 & 2003

Date	Control 2002 (Born 11/21/51)			Aurofac 2003 (Born 12/3/51)		
	Coli- form	Strepto- cocci	Total count	Coli- form	Strepto- cocci	Total count
	Log ₁₀	Log ₁₀	10 ⁹	Log ₁₀	Log ₁₀	10 ⁹
12/5,6/51	8.5	8.0	43	9.5	9.0	13
12/12,13	8.0'	4.0'	14'	10.0	2.5	28
12/19,20	6.5	4.0	24	8.0	3.5	28
12/26,27	6.0	6.0	30	5.0	5.5	21
1/2,3/52	7.0	6.0	26	5.5	6.0	27'
1/9,10	9.0'	5.0'	38'	6.0	7.5	27
1/16,17	6.5	7.0	24	6.0	6.0	23
1/23,24	5.5	7.0	41	5.0	6.5	31
1/30,31	5.5	-	24	6.0	-	37
2/6,7	6.0	3.5	18	5.0	3.0	18
2/13,14	6.5	4.5	25	6.0	4.0	24
2/20,21	5.0	2.5	16	8.0'	3.0'	22
2/27,28	6.5	6.0	17	8.0	3.5	37
3/5,6	5.5	5.0	17	7.0	2.5	12
3/12,13	6.0	4.0	28	5.0	6.5	22
3/19,20	6.5	7.0	22	7.5	5.5	22
3/26,27	6.0	2.5	20	7.0'	7.0'	32'

' = one day only

(Aurofac started 12/6/51)
(" stopped 3/15/52)

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