# COMPARISON OF FEEDING MEAT-STRAIN CHICKS A NITROFURAN, SINGLE SOURCES AND COMBINATIONS OF ANTIBIOTICS, AND NITROFURAN-ANTIBIOTIC COMBINATION

by

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## TABLE OF CONTENTS

| | |
|---|---|
| INTRODUCTION | 1 |
| REVIEW OF LITERATURE | 4 |
| MATERIALS AND METHODS | 10 |
| RESULTS | 12 |
| DISCUSSION | 13 |
| SUMMARY AND CONCLUSIONS | 18 |
| ACKNOWLEDGMENT | 20 |
| LITERATURE CITED | 21 |
| APPENDIX | 26 |

# INTRODUCTION

The discovery that antibiotics have growth-stimulating properties was a spectacular development in animal nutrition, and marked the beginning of a new era in livestock feeding. During the short span of a little over a decade, these agents have come into wide use as growth promotants. With the popularity and greater application of these agents, more and more new products are being continuously added to the ever-increasing list of antibiotics. The level of antibiotic employed varies within wide limits, ranging from as little as two to as high as 200 grams or more per ton of feed, depending upon the purpose for which they are fed, but generally 10 grams per ton of feed are used for continuous low-level feeding.

Notwithstanding their great popularity and wide acceptance as feed supplements, the exact mechanism of the action of antibiotics still remains to be fully understood. Although the growth-promoting action of antibiotics is ascribed to their influence on the intestinal microflora, suppression of sub-clinical diseases, a sparing action on food nutrients, a better utilization of nutritional factors etc., the mode of their action is still a debatable issue.

The discovery of growth-promoting action of furazolidone, a member of the nitrofuran series of antibacterial compounds introduced originally for its effectiveness against Salmonella infections and infectious enterohepatitis, is perhaps an outcome of the research conducted on the mode of action of antibiotics-influence upon the microflora.

Although the arsonic acid compounds, antibiotics and nitrofurans are unrelated chemically, they seemingly have a similar action upon the microflora of the gut, which apparently explains their mode of action. The value of these agents as feed supplements is best noted in increased weight gains and better feed efficiency; however, the results achieved differ considerably. Responses have been shown to vary with environment, the type of diet, level of antibiotic used, combinations of growth promotants employed, the stage of growth, and even with species and sexes.

Under normal conditions of large commercial operations where successive flocks of birds are maintained on the same premises it is highly impractical, even with the best effort, to maintain a "clean" environment conducive for the chicks to grow to their maximum growth potential. The solution to the problem was the low-level feeding of antibiotics or other growth promotants. This accounts for the wide acceptance and great popularity of these agents as supplements to poultry feeds.

Voluminous work has been done on various growth promotants to determine both their efficacy and mode of action. However, several inconsistencies are present. There appears to be poor agreement among workers regarding the level of these agents to be employed and the effectiveness of single sources versus combinations of antibiotics, or a combination of antibiotics with other growth promotants. Besides, evidence is accumulating that some of these agents are losing their effect. Antibiotics which had shown consistent growth stimulation in the past are now giving only slight responses. While it is very premature to draw any positive inferences from such reports, nevertheless, the possibility of a decreasing response cannot be completely overlooked. Maybe, the newer products or combinations of some of the growth promotants may have a broader application in the future. This calls for a greater scrutiny and further studies in order to understand them better.

In view of the conflicting reports in the literature and the great differences among the antibiotics in their combining ability or synergistic value, it was considered desirable to determine the comparative value of some of the more recent, commercially available products and especially to study complementary effects, if any, from their combined use.

Accordingly, two experiments were conducted, one on litter in floor pens and the other on wire in batteries to test the performance of meat-strain chicks fed a nitrofuran, single sources and combination of antibiotics, and a nitrofuran-antibiotic combination. The following were studied: (1) effect of antibiotics or a nitrofuran on growth of broiler strain chicks, (2) comparison of single sources and combinations of antibiotics, (3) comparison of feeding a nitrofuran, single sources and combinations of antibiotics, and a nitrofuran-antibiotic combination, (4) pounds of feed per pound of gain or feed conversion as influenced by each diet, and (5) response to various treatments under floor pen and battery conditions of management.

# REVIEW OF LITERATURE

The initial discovery by Moore *et al.* (1946) that antibiotics stimulate chick growth, followed by the observations of Stokstad *et al.* (1949) that supplements primarily produced as $B_{12}$ concentrates contained some factor in addition to $B_{12}$, which was later identified as an antibiotic, opened a new field for investigations. Since then, increasing interest has centered around these agents, and numerous experiments were conducted with different antibiotics in poultry feeds.

Following the work of Stokstad and Jukes (1950), who showed that feeding of aureomycin had a stimulating effect on the growth of chicks, a number of other reports have appeared showing increased growth of chicks from different antibiotic supplements (McGinnis *et al.*, 1950; Whitehill *et al.*, 1950; Groschke and Evans, 1950; and Peppler and Oberg, 1950). However, Scott and Glista (1950), using highly fortified diets, reported a slight growth stimulation of chicks with aureomycin hydrochloride when the ration was fed *ad libitum*, but found no response when the feed intake was equated.

The role of antibiotics as growth stimulants in poultry rations has been reviewed by Braude *et al.* (1953), Jukes and Williams (1953), Branion *et al.* (1953), Stokstad (1953, 1954), and Stutz (1961). No attempt has been made in this presentation to review the literature any more extensively than is needed to cite references relevant to this work.

Coates (1953) indicated that early growth of chickens is influenced by the kind of quarters used, as there was evidence to show that undesirable bacterial types became prevalent in quarters used continuously for rearing poultry, which markedly depressed growth. Contrarily, the growth of chicks reared under germ-free conditions was more rapid than that of controls reared in normal environment (Reyniers et al., 1950). Further, Coates et al. (1951), Bird et al. (1952), Hill et al. (1953), and Lillie et al. (1953) observed no growth responses from the use of antibiotics in a "new" environment, but chicks showed increased growth over controls when antibiotics were fed in an "old" environment.

Reports have appeared during the past few years indicating a decline or disappearance of the growth response of chicks to dietary antibiotics. Waibel et al. (1954) reported that addition of penicillin or aureomycin consistently increased growth of chicks during the period August, 1950 to May, 1952, but these antibiotics no longer increased the growth from June, 1952 to July, 1953. It was observed that a decrease in growth-promoting effect of the antibiotics occurred in an environment continuously occupied by chicks. This disappearance of growth stimulation was associated to the possibility that harmful bacteria had been eliminated through the long-continued use of antibiotics.

The work of Libby and Schaible (1955c) adds further evidence to the progressive decrease in response to antibiotics when used over a considerable period of time on the same premises. Their explanation was that the long-term use of antibiotics created an environment with a lower germ load or disease potential in which birds without an antibiotic in their feed (controls) also were benefited to some extent. This may have been responsible for the apparent decrease in response and should not be interpreted to mean a proliferation of resistant strains.

McGinnis et al. (1958) and Wiese and Petersen (1959) have indicated a marked decline in the response to penicillin, where erythromycin still gave good results under the same conditions. Monson et al. (1959) failed to obtain a response with procaine penicillin, bacitracin, oleandomycin, or atterinin at low levels of supplementation.

A loss of antibiotic response on premises where antibiotics have been fed over an extended period has been reported by Matterson et al. (1959). Experimental data by Anderson (1960) showed that penicillin and chlortetracycline are no longer as effective as they were some years ago. The newer antibiotics bacitracin, erythromycin, or oleandomycin, however, produced significant increases in growth, even though addition of penicillin or chlortetracycline did not.

The reports of Scott and Glista (1950) and Tarver et al. (1954) indicated little or no beneficial effect upon broilers fed 3-nitro-4-hydroxyphenyl arsonic acid, singly or in combination with an antibiotic, while Combs and Laurent (1952), and Milligan et al. (1955) reported that arsonic acid derivatives increased growth in the presence of an antibiotic. Similar results have been obtained by West (1956) with "low" levels of antibiotics; however, the greatest stimulating effect upon growth and feed conversion was obtained when the arsonic acid compound was added alone to the diet.

Davis and Briggs (1951) observed that a mixture of aureomycin hydrochloride and streptomycin gave no greater and possibly less growth stimulation than when either antibiotic was added alone. Similar results were obtained when procaine penicillin G and bacitracin were combined in the feed. It was suggested that superior results may not be obtained by certain mixtures of antibiotics and that additive effects may not result.

Working with Broad Breasted Bronze turkey poults, McGinnis et al. (1951) found that a mixture of terramycin and penicillin, or a combination of terramycin, streptomycin, and penicillin was no more effective than penicillin alone. The combined use of penicillin and terramycin did not result in a statistically significant growth-promoting effect in broilers (Reynolds et al., 1951). Combinations of penicillin and terramycin at various levels gave no greater growth response than the comparable level of penicillin alone (Saxena et al., 1952). However, Couch and coworkers (1952), cited by Heywang (1957), reported that best and most consistent results have been obtained when a combination of antibiotics is fed to broilers.

It was observed by Sanford (1952) that combining two antibiotic-$B_{12}$ feeding supplements resulted in growth superior to combining four.

Wisman et al. (1954) conducted experiments to determine the effect on growth up to 10 weeks of age by combining and interchanging antibiotics. Terramycin and penicillin produced comparable growth to 10 weeks of age when fed either singly or as a mixture, or when one replaced the other at three weeks of age at the same level. Streptomycin produced less growth when it was fed singly or when it was used as a replacement for either terramycin or penicillin at three weeks of age. However, streptomycin along with penicillin resulted in growth greater than from streptomycin alone. It was suggested that penicillin apparently was able to compensate for the ineffectiveness of streptomycin.

Matterson _et al_. (1952) fed aureomycin, penicillin, terramycin, and bacitracin in all possible combinations of pairs. No combination of antibiotics gave a growth response significantly greater than that obtained by the better of the two antibiotics when fed alone.

Lewis and Sanford (1953) reported that Aurofac and bacitracin proved a very effective combination for supplementing a ration containing cottonseed meal.

Stephenson and Sullivan (1955) did not obtain any significant benefits by adding high levels of a single source or combinations of antibiotics to a basal diet that already contained four grams per ton of penicillin.

According to Heywang (1957), the average increase in weight and feed efficiency of meat-type chicks during hot weather were about the same when their diet contained a combination of one gram procaine penicillin G and three and three-fourths grams of either chlortetracycline or oxytetracycline per ton, as when it contained 50 or 100 grams of either alone.

Menge and Lillie (1960), using a combination of three antibiotics, observed that a significant growth response to such a supplementation was present in only three of the six experiments conducted.

According to Stutz (1961), a combination of zinc bacitracin and erythromycin significantly increased growth as compared to the controls or any other antibiotic supplements used in the experiment.

March et al. (1954) supplemented rations by combining antibiotic penicillin with surface active agents, which are also believed to promote growth. The results, however, have been inconsistent.

In a series of experiments, extensive studies were conducted on nf-180 by Libby and Schaible (1955a). Experiments were conducted in batteries to study the effect on growth and feed efficiency with nf-180 singly and in combination with penicillin and/or arsanilic acid, using wire floor, clean litter, and/or contaminated litter. Growth stimulation occurred in many instances. Similar results have been reported in another study with nf-180 in the presence of penicillin or arsanilic acid (Libby and Schaible, 1955b).

Feeding trials by Pope and Schaible (1958) with low-levels of furazolidone, penicillin, arsanilic acid, 3-nitro-4-hydroxyphenyl arsonic acid, and their combinations, revealed no significant growth improvement when furazolidone, penicillin, or arsanilic acid was fed singly. However, significant growth responses were obtained with combinations of furazolidone and penicillin or when furazolidone, penicillin, and 3-nitro-4-hydroxyphenyl arsonic acid were combined for supplementation.

## MATERIALS AND METHODS

Two separate experiments were conducted at the Nutrition Laboratory at the Kansas State University Poultry Farm. A total of 660 birds, involving both experiments, were used in this study. Cobb Strain-Cross, White Rock, straight-run broiler chicks were used in each experiment. The chicks had free access to all-mash feed and water.

Experiment 1, consisting of 480 chicks, was initiated on November 17, 1961 and ran until January 11, 1962, for a period of eight weeks. The chicks were randomized into 12 lots of 40 chicks each, vaccinated intranasally for Newcastle disease and infectious bronchitis, wingbanded, individually weighed, and randomly assigned to 12 floor pens in a brooder house with deep litter (Pinewood shavings). Individual electric brooders were used.

The 1960-61 Kansas State University chick broiler ration containing 21 per cent protein was used as the control diet (hereafter referred to as K.S.U. broiler basal). The composition of this ration is given in Table 1 (Appendix).* The experimental diets consisted of the K.S.U. broiler basal supplemented with the nitrofuran, furazolidone, or the antibiotic zinc bacitracin or erythromycin, or their combinations as shown in Table 2, and fed

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* All tables appear in the Appendix.

at levels indicated in the same. The supplements were blended homogeneously by running through appropriate mixers. Feed and water were provided ad libitum. Each diet was fed to two replicate lots.

Individual body weights were recorded for each two-week period. Sex of each bird was determined, and weights adjusted for sex at the time of terminating the experiment. The adjusted eight-week weight gains for all lots appear in Table 3. Records of feed consumption were maintained, and pounds of feed required per pound of gain or feed conversion is reported in Table 7 for each lot of chicks at the end of eight weeks.

Experiment II, consisting of 180 chicks, initiated March 6, 1962, was terminated May 1, 1962, after a period of eight weeks. The chicks were randomized into 12 lots of 15 chicks each and randomly assigned to lot positions in the six-deck starting batteries, with raised wire floor. The chicks were reared with heat until the fourth week and then transferred to growing batteries and kept there until the end of the eight-week experimental period. In all other respects, Experiment II was identical to Experiment I.

Mortality was low during both experiments and amounted to less than 2.5 per cent of all chicks involved.

Analysis of variance of the data pooled from both experiments was run on adjusted eight-week weight gains and feed conversion according to the method of Snedecor (1956). The pooled analysis of variance for eight-week weight gains is given in Table 4, and for feed conversion in Table 8.

# RESULTS

The analysis of variance of the data pooled from both experiments revealed that the diets were significantly different at the .01 level. A further analysis (L.S.D. method) was run to locate the differences in the diets and to rank them according to the eight-week weight gains. The ranked diets are presented in Table 5.

It was observed that Diet 6, containing zinc bacitracin, erythromycin, and furazolidone as supplements, gave the highest weight gains and was significantly better than Diets 3, 2, 4, and 1. However, the difference was statistically nonsignificant from Diet 5, which ranked next best. Diet 5, which was a combination of two antibiotics (zinc bacitracin and erythromycin), resulted in better growth than all other diets except Diet 6. It gave significantly better growth over Diets 4 and 1. This combination of two antibiotics resulted in better growth than a single antibiotic supplement or furazolidone alone in feed.

Any supplementation was found to be better than no supplementation in promoting growth. Diets 3, 2, and 4 which included either single sources of an antibiotic or a nitrofuran gave increased weight gains when compared to Diet 1, which had no supplement. Diet 1 (negative control) gave the least growth response. However, Diets 3, 2, 4, and 1 were statistically nonsignificant in improving growth. The per cent increase in weight gains for all diets is shown in Table 6.

The analysis of variance further indicated a significant difference between housing at the .001 level. Chicks raised on litter in floor pens grew significantly better than those in batteries. The interaction between sexes and housing showed that the floor pen environment was more favorable for growth of male chicks compared to batteries. This was significant at the .05 level. Other interactions were nonsignificant. The differences between the replicates were also nonsignificant.

Feed conversion varied between the different supplements, and in some cases between the lots receiving the same diet. An analysis of variance, however, showed no significant differences in feed conversion among diets (Table 8). However, housing markedly influenced feed conversion. Chicks on litter floor needed less feed per pound of gain. This was significant at the .001 level.

## DISCUSSION

Results of two experiments indicate that a combination of two antibiotics (zinc bacitracin and erythromycin) and a nitrofuran (furazolidone) gave the highest weight gains as compared to other supplements or no supplement. It was observed that zinc bacitracin, erythromycin, or furazolidone singly was not so effective as a combination of all three. Pope and Schaible (1958) have reported a similar ineffectiveness of furazolidone, penicillin, or arsanilic acid when added singly, while significant growth responses were obtained from a mixture of furazolidone and penicillin. This suggests that antibiotics could be combined with other growth promotants with beneficial results. These results compare favorably with earlier reports from Libby and Schaible (1955a, b), where growth responses were obtained from furazolidone in the presence of penicillin or arsanilic acid. Antibiotics have also been shown to give increased growth responses along with arsonic acid derivatives, according to Combs and Laurent (1952) and Milligan et al. (1955). However, Scott and Glista (1950) and Tarver et al. (1954) indicated little or beneficial effect upon broilers fed 3-nitro-4-hydroxyphenyl arsonic acid singly or in combination with an antibiotic. West (1956) reported that arsonic acid compounds gave best results in the absence of antibiotics.

Under the conditions of this study, it was further observed that combinations of two antibiotics proved better than single sources of antibiotics or furazolidone alone in feed, in stimulating growth. These results are in agreement with the work of Sanford (1952), Lewis and Sanford (1953), Wisman et al. (1954), Heywang (1957), and Stutz (1961), insofar as the efficacy of an antibiotic combination is concerned. Contrary results have, however, been reported by Davis and Briggs (1951), McGinnis et al. (1951), Reynolds et al. (1951), Matterson et al. (1952), Saxena et al. (1952), and Stephenson and Sullivan (1955). Inconsistent results were obtained by Menge and Lillie (1960).

The addition of single sources of an antibiotic or a nitrofuran resulted in increased growth in comparison with the nonsupplemented basal diet (control); however, this was not significantly greater than controls. This further indicates that certain combinations may prove more valuable than feeding a single supplement. Rather, there is reason to believe that certain supplements may be of value only in combinations rather than when fed singly. Wisman et al. (1954) observed that streptomycin produced less growth to 10 weeks of age when fed singly, but a mixture of penicillin and streptomycin resulted in growth greater than streptomycin alone. They contended that penicillin apparently was able to compensate for the ineffectiveness of streptomycin.

The results of this study also indicate that the usefulness of zinc bacitracin, erythromycin, and furazolidone can be greatly enhanced by combining all three for supplementation.

Significant differences in the housing were observed, as seen from the analysis of variance. The chicks raised in floor pens showed considerably higher weight gains than those reared in batteries. A possible explanation for this difference may be the degree of contamination present under each of these conditions. Coprophagy may yet be another factor influencing the response to supplementation.

According to Coates et al. (1952), antibiotics can stimulate growth only in the presence of an infectious agent, since chicks raised in a clean environment did not respond to dietary antibiotics. The work of Anderson et al. (1956) also lends support to this view, as feeding chlortetracycline was shown to overcome the growth depression of chicks fed enterococci. Coates (1953) further reported that chicks which did not respond to added antibiotics could be made to do so if their environment was contaminated with intestinal contents obtained from chicks that responded to antibiotics.

Consistent growth responses were obtained with oxytetracycline when the diet contained raw hen feces (Mameesh _et al._, 1959). Barnes _et al._ (1959) showed that rats fed penicillin exhibited an increased growth rate only if they had access to their feces.

Moreover it has been suggested that availability of certain fresh fecal contamination to chicks may play an important part in their ability to respond to antibiotic feeding (Warden and Schaible, 1961).

In this study it was experienced that the feed and water were more often contaminated considerably with the feces of chicks raised in floor pens; besides, they also had a ready access to their droppings in the litter, which possibly could have altered their response more favorably to the supplements than in the batteries.

This may also appear meaningful in the light of earlier reports by Anderson _et al._ (1953) who showed that bacterial cultures originally obtained from cecal contents of birds fed antibiotics stimulated growth.

Saxena _et al._ (1952) achieved better responses from antibiotic supplementation in chicks raised in floor pens compared to chicks raised in batteries with wire floors. However, similar results were obtained in batteries when the wire floors were simply removed and replaced with litter floor. The same explanation also may sound logical in this instance. Possibly for the same reason Ackerson et al. (1952) failed to obtain a response with vitamin $B_{12}$ and aureomycin on raised wire screens, while the same ration increased the growth of chicks raised on built-up litter.

Yet another conclusion can be made from these observations; that is, antibiotics or other growth promotants seem to vary considerably in their ability to stimulate growth of chicks in the presence of contamination. Mameesh et al. (1959) have reported that oxytetracycline consistently improved the growth of chicks fed raw hen feces while growth response to penicillin was present in only one of the four experiments. Similarly, Warden and Schaible (1961) found that the addition of zinc bacitracin to feed contaminated with fresh feces only partially restored growth while terramycin or aureomycin significantly improved weight gains. This may possibly explain, to some extent, the variations in response obtained with feed additives used for growth stimulation.

The feed conversion was significantly better for chicks on the litter floor than those in batteries in this study. This may have been in all probability due to feed wastage in batteries, as feed worked out from feeders was lost forever to chicks, which may not be so in the floor pens.

## SUMMARY AND CONCLUSIONS

Two separate experiments were conducted, one in floor pens and the other in batteries to study the effect of a nitrofuran, single sources and combinations of antibiotics, and a nitrofuran-antibiotic combination on the growth and feed conversion of meat-strain chicks. A total of 660 Cobb Strain-Cross White Rock straight-run chicks were used in the two experiments. The 1960-61 Kansas State University chick broiler ration (all-mash) containing 21 per cent protein was used as the control diet.

Zinc bacitracin and erythromycin, singly or in combination, and furazolidone singly and combined with the two antibiotics were used for supplementation in this study. A level of 10 grams of antibiotic(s) either as single sources or by equal parts in combination per ton of feed were added to the K.S.U. broiler basal. Furazolidone, when present, was supplemented at a level of 50 grams per ton of feed.

Body weights and feed consumption records were maintained for each two-week period until the end of eight weeks, when the experiments were concluded. The following conclusions were made from this study:

1. A combination of zinc bacitracin, erythromycin, and furazolidone significantly increased growth and ranked superior to all other diets.

2. The combination of two antibiotics (zinc bacitracin and erythromycin) proved better than these agents singly or furazolidone alone in feed, in promoting growth.

3. All supplements resulted in weight gains higher than the negative controls.

4. Chicks raised on litter in floor pens grew significantly better than those in batteries. Presumably, chicks show a greater growth response to such supplementation if they have access to their droppings.

5. Chicks raised on the litter in floor pens required less feed per pound of gain.

6. Mortality and abnormalities were found to be minimum.

7. No significant differences in feed conversion were observed between the various diets.

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# LITERATURE CITED

Ackerson, C. W., R. L. Borchers, and F. E. Mussehl.
The utilization of food elements by growing chicks. XIV. Effect of the addition of vitamin $B_{12}$ and antibiotics. Poultry Sci. 31:1023-1026. 1952.

Anderson, G. W., S. J. Slinger, and W. F. Pepper.
Bacterial cultures in the nutrition of poultry. I. Effect of dietary bacterial cultures on the growth and cecal flora of chicks. J. Nutrition 50:35-46. 1953.

Anderson, G. W., M. M. Heuser, M. L. Wright, and J. R. Couch.
The effect of dietary enterococci and chlortetracycline hydrochloride on the intestinal flora and growth of chicks. Can. J. Micro. 2:733-739. 1956.

Anderson, J. O.
Changing effectiveness of antibiotics. Utah Agr. Exp. Farm & Home Sci. 21:74-75. 1960.

Barnes, R. G., G. Fala, K. Delancy, and E. Caplan.
Coprophagy, refection and the influence of antibiotics in the rat. Fed. Proc. 18(1):1,516,2032.

Bird, H. R., R. J. Lillie, and J. R. Sizemore.
Environment and stimulation of chick growth by antibiotics. Poultry Sci. 31:907. 1952.

Branion, H. D., G. W. Anderson, and D. C. Hill.
Antibiotics and the growth of ducks (with a review of possible mechanisms by which antibiotics stimulate growth). Poultry Sci. 32:335-347. 1953.

Braude, R., S. K. Kon, and J. W. G. Porter.
Antibiotics in nutrition. Nut. Abst. Rev. 23:473-495. 1953.

Coates, M. E.
The mode of action of antibiotics in animal nutrition. Chem. Ind. 1333-1335. 1953.

Coates, M. E., C. D. Dickinson, S. M. Cummings, and W. F. J. Cuthbertson. Mode of action of antibiotics in stimulating growth of chicks. Nature 168:332. 1951.

Coates, M. E., C. D. Dickinson, G. F. Harrison, S. K. Kon, J. W. G. Porter, S. H. Cummins, and W. F. J. Cuthbertson.
A mode of action of antibiotics in chick nutrition. J. Sci. Food Agric. 1:43-48. 1952.

Combs, G. F., and C. K. Laurent.
The value of aureomycin HCl and 3-nitro-4-hydroxyphenyl arsonic acid in broiler rations. Miscellaneous publication No. 151, University of Maryland. 1952.

Davis, R. L., and G. M. Briggs.
Studies with antibiotics in chick and poult starting rations. Poultry Sci. 30:767-771. 1951.

Groschke, A. C., and R. J. Evans.
Effect of antibiotics, synthetic vitamins, vitamin $B_{12}$ and an APF supplement on chick growth. Poultry Sci. 29:616-618. 1950.

Heywang, B. W.
The effect of high levels of antibiotics on the growth of chickens during hot weather. Poultry Sci. 36:335-337. 1957.

Hill, D. C., H. D. Branion, S. J. Slinger, and G. W. Anderson.
Influence of environment on the growth response of chicks to penicillin. Poultry Sci. 32:462-466. 1953.

Jukes, T. H., and W. L. Williams.
Nutritional effects of antibiotics. Pharm. Rev. 5:381-420. 1953.

Lewis, R. W., and P. E. Sanford.
Use of equivalent levels of antibiotics and vitamin $B_{12}$ supplements with cottonseed and soybean oil meals in chick diets. Poultry Sci. 32:268-275. 1953.

Libby, D. A., and P. J. Schaible.
Effect of low levels of furazolidone in poultry feeds upon early growth of chickens. Mich. Agr. Exp. Q. Bul. 38:241-251. 1955a.

__________.
The effect of furazolidone (nf-180) in poultry feeds upon early growth of chickens. Poultry Sci. 34:1207. 1955b.

__________.
Observations on growth responses to antibiotics and arsonic acids in poultry feeds. Science 121:733-734. 1955c.

Lillie, R. J., J. R. Sizemore, and H. R. Bird.
Environment and stimulation of growth of chicks by antibiotics. Poultry Sci. 32:466-475. 1953.

Mameesh, M. S., B. Sass, and B. C. Johnson.
The assessment of the antibiotic growth response in the chick. Poultry Sci. 38:512-515. 1959.

March, B. E., M. Burdett, and J. Biely.
Antibiotics and surface active agents in chick nutrition. Poultry Sci. 33:300-304. 1954.

Matterson, L. D., E. P. Singsen, L. Decker, and A. Kozeff.
Combinations of antibiotics as growth stimulants in chick starting and growing rations. Poultry Sci. 31:926. 1952.

Matterson, L. D., L. M. Potter, and J. Tulstohowicz.
Studies on the apparent loss of antibiotic response in chicks. Poultry Sci. 38:1225. 1959.

McGinnis, J., L. R. Berg, J. R. Stern, R. A. Wilcox, and G. E. Bearse.
The effect of aureomycin and streptomycin on growth of chicks and turkey poults. Poultry Sci. 29:771. 1950.

McGinnis, J., J. R. Stern, R. A. Wilcox, and J. S. Carver.
The effect of different antibiotics on growth of turkey poults. Poultry Sci. 30:492-496. 1951.

McGinnis, J., L. H. Merrill, R. E. Fry, and L. S. Jensen.
Use-history of antibiotics as related to their efficacy in promoting growth of turkeys. Poultry Sci. 37:810-813. 1958.

Menge, H., and R. J. Lillie.
Ineffectiveness of antibiotic combination on response of chicks fed fish solubles. Poultry Sci. 39:1188-1190. 1960.

Milligan, J. L., H. L. Wilcke, J. E. Marr, and R. M. Bethke.
Arsonic acid in commercial broiler rations. Poultry Sci. 34: 794-799. 1955.

Monson, W. J., L. D. Christian, B. R. Krengel, and H. W. Howard.
The lack of effect of low levels of certain antibiotics in improving growth and feed efficiency of chicks. Poultry Sci. 38: 1230. 1959.

Moore, P. R., A. Evenson, T. D. Luckey, E. McCoy, C. A. Elvehjem, and E. B. Hart.
Use of sulfasuxidine, streptothricin and streptomycin in nutritional studies with the chick. J. Biol. Chem. 165:437-441. 1946.

Peppler, H. J., and E. B. Oberg.
The effect of feeding crude polymyxin D on the intestinal bacteria of chickens. Poultry Sci. 29:520-526. 1950.

Pope, C. W., and P. J. Schaible.
Interrelationships of furazolidone and other feed additives on the growth of poultry. Mich. Agr. Exp. Q. Bul. 40:857-860. 1958.

Reyniers, J. A., P. C. Trexler, R. F. Ervin, M. Wagner, H. A. Gordon, T. D. Luckey, R. A. Brown, G. J. Mannering, and C. J. Campbell.
Germ free chicken nutrition. J. Nutrition 41:31. 1950.

Reynolds, J. W., T. D. Runnels, and E. F. Waller.
A comparison of terramycin and penicillin at various levels on rate of growth and feed efficiency in broiler diets. Poultry Sci. 30:928. 1951.

Sanford, P. E.
Effect of feeding chicks combinations of vitamin $B_{12}$ and various antibiotic feeding supplements. Poultry Sci. 31:933-934. 1952.

Saxena, H. C., L. R. Berg, and J. McGinnis.
Factors affecting the growth response of chicks and turkey poults to antibiotics. Poultry Sci. 31:1070-1074. 1952.

Scott, H. M., and W. A. Glista.
The effect of aureomycin and arsonic acid on chick growth. Poultry Sci. 29:921-923. 1950.

Snedecor, G. W.
Statistical methods. Fifth edition. Ames, Iowa: The Iowa State College Press, 1956.

Stephenson, E. L., and T. W. Sullivan.
Proper antibiotic level in broiler feeds confused. Flour and Feed 56:23-24. 1955.

Stokstad, E. L. R.
Antibiotics in animal nutrition. Antibiotics and Chemotherapy 3:434-441. 1953.

__________.
Antibiotics in animal nutrition. Physiol. Rev. 34:25-51. 1954.

Stokstad, E. L. R., T. H. Jukes, J. V. Pierce, A. C. Paige, Jr., and A. L. Franklin.
The multiple nature of animal protein factor. J. Biol. Chem. 180:647. 1949.

Stokstad, E. L. R., and T. H. Jukes.
Further observations on the "animal protein factor." Proc. Soc. Exp. Biol. Med. 73:523-528. 1950.

Stutz, M. W.
A comparison of the performance of broiler strain chicks fed single source and combination of antibiotics. Unpublished Master's thesis, Kansas State Univ., Manhattan, 1961.

Tarver, F. R., Jr., H. Patrick, and O. E. Goff.
Influence of arsenic and penicillin on dressing grades and quality of poultry. Poultry Sci. 33:1085. 1954.

Waibel, P. E., O. J. Abbott, C. A. Baumann, and H. R. Bird.
Disappearance of the growth response of chicks to dietary antibiotics in an "old" environment. Poultry Sci. 33:1141-1146. 1954.

Warden, W. K., and P. J. Schaible.
The effect of feeding antibiotics to chicks in the presence of fresh, dried, and autoclaved hen feces. Poultry Sci. 40:363-367. 1961.

West, J. W.
Effects of 3-nitro-4-hydroxyphenyl arsonic acid and certain antibiotics in broiler rations. Poultry Sci. 35:835-842. 1956.

Whitehill, A. R., J. J. Oleson, and B. L. Hutchings.
Stimulatory effect of aureomycin on growth of chicks. Proc. Soc. Exp. Biol. Med. 74:11-13. 1950.

Wiese, A. C., and C. F. Petersen.
Comparison of several antibiotics for chick growth. Poultry Sci. 38:1259. 1959.

Wisman, E. L., R. V. Boucher, and E. W. Callenbach.
The influence of combining and interchanging antibiotics in chick diets. Poultry Sci. 33:290-293. 1954.

APPENDIX

Table 1. Composition of the 1960-61 K.S.U. 21 per cent protein chick broiler ration used as the basal diet in both experiments.

| Ingredients | Quantity used per 100 lbs. (lbs.) |
|---|---|
| Corn, ground, yellow | 30.00 |
| Sorghum grain, ground | 35.00 |
| Alfalfa meal, dehydrated, 17% protein | 2.00 |
| Soybean oil meal, solvent extracted, 44% protein | 25.00 |
| Fish meal, 60% protein | 4.00 |
| Soluferm-500 (R) (Fermentation residue) | 1.50 |
| Calcium carbonate (Limestone)* | 1.00 |
| Dicalcium rock phosphate* | 1.00 |
| Salt (Sodium chloride)* | 0.50 |
| Total | 100.00 |
| Added per 100 lbs. of ration | (grams) |
| CCC-244 with Zinc (R) (Trace mineral mix)* | 23 |
| Vitamin A (10,000 USP units/gram)+ | 10 |
| Vitamin $D_3$ (15,000 ICU/gram)+ | 5 |
| Merck 58-A (R) (B-complex vitamin mix)+ | 46 |
| D-L Methionine (Feeding grade)+ | 23 |
| Proferm-12 (R) (Vitamin $B_{12}$ mix)+ | 10 |
| Choline chloride - 25% mix+ | 40 |
| Amprol (R) (Coccidiostat)+ | 23 |

(R) Registered trademark.

* Mineral premix.

\+ Vitamin and additives premix.

Table 2. The levels and kinds of supplements used in both experiments.

| Diet | Lots | | Supplement(s) | Level (gms/ton) |
|---|---|---|---|---|
| 1 | 1 & 2 K.S.U. Broiler basal | + | 0 Suppl. | - |
| 2 | 3 & 4 K.S.U. Broiler basal | + | Zinc bacitracin[1] | 10 |
| 3 | 5 & 6 K.S.U. Broiler basal | + | Erythromycin[2] | 10 |
| 4 | 7 & 8 K.S.U. Broiler basal | + | Furazolidone[3] | 50 |
| 5 | 9 & 10 K.S.U. Broiler basal | + | Zinc bacitracin<br>Erythromycin | 5<br>5 |
| 6 | 11 & 12 K.S.U. Broiler basal | + | Zinc bacitracin<br>Erythromycin<br>Furazolidone | 5<br>5<br>50 |

[1] Baciferm-10$^{(R)}$, a product of Commercial Solvents Corporation, Terre Haute, Indiana, supplying 10 grams of drug per pound of supplement.

[2] Gallimycin-10$^{(R)}$, a product of Abbott Laboratories, North Chicago, Illinois, supplying 10 grams of drug per pound of supplement.

[3] nf-180$^{(R)}$, a product of Hess and Clark, a division of Richardson Merrill Co., Ashland, Ohio, supplying 50 grams of drug per pound of supplement.

Table 3. Average eight-week weight gains[1] for all lots in the two experiments (adjusted for sex[2]).

| Diet | Lot No. | Experiment I[3] | Experiment II[4] |
|---|---|---|---|
| | | Weight in grams | |
| 1 | 1 | 1379 | 1247 |
| | 2 | 1375 | 1283 |
| 2 | 3 | 1375 | 1266 |
| | 4 | 1389 | 1284 |
| 3 | 5 | 1395 | 1346 |
| | 6 | 1394 | 1286 |
| 4 | 7 | 1380 | 1316 |
| | 8 | 1353 | 1244 |
| 5 | 9 | 1390 | 1340 |
| | 10 | 1354 | 1386 |
| 6 | 11 | 1460 | 1360 |
| | 12 | 1431 | 1342 |

[1] Final eight-week weight minus the initial zero-week weight.

[2] Average male weight plus average female weight divided by two.

[3] Floor pen experiment.

[4] Battery experiment.

Table 4. Analysis of variance of eight-week weight gains on the data pooled from both experiments (adjusted for sex).

| Source of variation | Degrees of freedom | Sum of squares | Mean square | F-ratio |
|---|---|---|---|---|
| Housing | 1 | 80,197 | 80,197 | 60.76*** |
| Diets | 5 | 37,209 | 7,442 | 5.64** |
| Housing x diets | 5 | 14,344 | 2,869 | 2.17 ns |
| Reps: Housing and diets | 12 | 15,841 | 1,320 | 2.03 ns |
| Sexes | 1 | 869,408 | 869,408 | 1,339.61*** |
| Sexes x housing | 1 | 3,267 | 3,267 | 5.03* |
| Sexes x diets | 5 | 5,030 | 1,006 | 1.55 ns |
| Error B | 17 | 11,038 | 649 | |
| Total | 47 | 1,036,334 | | |

ns Nonsignificant.

*** Significant $P < .001$.

** Significant $P < .01$.

* Significant $P < .05$.

Table 5. Ranked diets based on LSD method,[1] showing diets ranked from high to low from pooled eight-week weight gains in grams (adjusted for sex).

| Diets | | | | | |
|---|---|---|---|---|---|
| 6 | 5 | 3 | 2 | 4 | 1 |
| 1398 | 1367 | 1355 | 1330 | 1323 | 1321 |

[1] Any two diets not underscored by the same line are significantly different, and any two diets underscored by the same line are not significantly different.

LSD = 40 grams.

Table 6. Response to supplementation as per cent increase in growth, for both experiments combined (adjusted for sex).

| Diet | Mean chick weight in grams | Per cent increase in weight |
|---|---|---|
| 1 | 1357 | -- |
| 2 | 1368 | 0.81 |
| 3 | 1392 | 2.58 |
| 4 | 1361 | 0.29 |
| 5 | 1396 | 2.87 |
| 6 | 1438 | 5.97 |

Table 7. Feed conversion for all lots in both experiments at the end of the eight-week experimental period.

| Diet | Lot No. | Experiment I | Experiment II |
|---|---|---|---|
| | | Lbs. feed per lb. gain | |
| 1 | 1 | 2.27 | 2.38 |
| | 2 | 2.30 | 2.34 |
| 2 | 3 | 2.24 | 2.55 |
| | 4 | 2.21 | 2.39 |
| 3 | 5 | 2.27 | 2.31 |
| | 6 | 2.25 | 2.46 |
| 4 | 7 | 2.25 | 2.40 |
| | 8 | 2.29 | 2.33 |
| 5 | 9 | 2.30 | 2.42 |
| | 10 | 2.24 | 2.39 |
| 6 | 11 | 2.13 | 2.29 |
| | 12 | 2.20 | 2.34 |

Table 8. Analysis of variance of feed conversion on pooled data of both experiments.

| Source of variation | Degrees of freedom | Sum of squares | Mean square | F-ratio |
|---|---|---|---|---|
| Housing | 1 | .1134 | .1134 | 39.10*** |
| Diets | 5 | .0292 | .0058 | 2.00 ns |
| Housing x diets | 5 | .0177 | .0035 | 1.21 ns |
| Reps: Housing and diets | 12 | .0351 | .0029 | |
| Total | 23 | .1954 | | |

ns Nonsignificant.

*** Significant $P < .001$.

COMPARISON OF FEEDING MEAT-STRAIN CHICKS A NITROFURAN, SINGLE SOURCES AND COMBINATIONS OF ANTIBIOTICS, AND NITROFURAN-ANTIBIOTIC COMBINATION

by

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AN ABSTRACT OF A MASTER'S THESIS

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MASTER OF SCIENCE

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Two separate experiments were conducted, one on litter in floor pens and the other on wire in batteries at the Kansas State University Poultry Farm to test the performance of broiler chicks fed a nitrofuran, single sources and combinations of antibiotics, and a nitrofuran-antibiotic combination.

A total of 660 Cobb Strain-Cross White Rock straight-run chicks were used in the two experiments. The 1960-61 Kansas State University chick broiler ration (all mash) containing 21 per cent protein was used as the control diet. Zinc bacitracin and erythromycin singly or in combination, and furazolidone singly and combined with the two antibiotics, were used for supplementation in this study. A level of 10 grams of antibiotic(s) either as single sources or by equal parts in combination per ton of feed were added to the K.S.U. broiler basal. Furazolidone, when present, was supplemented at a level of 50 grams per ton of feed. Thus, five supplemented diets and one without any supplement (negative control) were fed to two replicate lots in each of the experiments.

Body weights and feed consumption records were maintained for each two-week period until the end of eight weeks at which time the experiments were concluded.

An analysis of variance of the data pooled from both the experiments was run for eight-week weight gains (adjusted for sex) and feed conversion. The following conclusions were made from this study:

A combination of zinc bacitracin, erythromycin, and furazolidone significantly increased growth and gave best results.

For promoting growth, a combination of two antibiotics (zinc bacitracin and erythromycin) proved better than these agents singly or furazolidone alone in feed.

All supplements resulted in weight gains higher than the negative controls.

Chicks raised on litter in floor pens grew significantly better than those on wire in batteries, and required less feed per pound of gain.

No significant differences in feed conversion were observed among the different diets.