THE EFFECT OF ANTIBIOTIC GROWTH STIMULANTS ON BLOOD AND CARCASS CONSTITUENTS IN SWINE

by

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A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1959

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Date thesis is presented November 6, 1958

Typed by Verna Anglemier

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ACKNOWLEDGEMENTS

The author gives his most sincere appreciation to Dr. James E. Oldfield to whom he is deeply indebted for continuous help in carrying out the experiments and for subsequent advice and encouragement in the preparation of the thesis.

Special thanks are extended to Dr. Allen F. Anglemier for his cooperation and technical assistance in the study presented.

For aid in setting up the physical facilities, management of the animals, and for sound advice, much credit is due Thomas K. Johnson.

Dr. W. W. Ellis, Mrs. Phyllis Touchie, and John Kaufmes are gratefully acknowledged for their assistance with the blood chemistry.

The penicillin used as an antibiotic feed supplement was supplied as "Pro Pen 4" through the courtesy of Merck and Company Inc., Rahway, N. J. Lederle Laboratories Division, American Cyanamid Company, Pearl River, N. Y. made available the aureomycin as "Aurofac 2A" and in addition carried out the antibiotic potency assays reported in Experiment I. The 3-nitro 4-hydroxy phenylarsonic acid was donated by Dr. Salsbury's Laboratories, Charles City, Iowa.

I wish to thank my wife, Mimi, for her considerable help, unfailing interest and patience during the preparation of this thesis.

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THE EFFECT OF ANTIBIOTIC GROWTH STIMULANTS ON BLOOD AND CARCASS CONSTITUENTS IN SWINE

INTRODUCTION

The use of antibiotics in animal diets has been hailed by Welch and Tennison (75, p. 191) as "perhaps the most significant advance in the science of nutrition of this century". Among those animals to which antibiotics are normally fed, swine are prominent in their response to addition of "nutritional" levels (5 to 15 milligrams per pound of ration). The practical importance of supplementing swine rations with antibiotics is evident in that about 64 cents worth of antibiotic (6.19 grams) is adequate to meet the requirements of an average pig growing from 35 to 200 pounds. This pig grows about 12 per cent faster on 5 per cent less feed enabling him to be marketed 12 days earlier than his nonantibiotic-supplemented litter mate. The saving from feed and labor alone is apparent. In addition, pigs fed antibiotics are noticeably more uniform in appearance and therefore command higher prices. Even the "runt" pig is eliminated. This is illustrated by an experiment carried out by Catron and Cuff (18, p. 120) with four groups, each containing 8 runt pigs averaging 20 pounds at 76 days. The control group made average daily gains of 0.46 pounds during the 62 day feeding period, the second group supplemented with skim milk gained 0.60 pounds per day, the third supplemented with B vitamins made gains of 0.70 pounds per day, and the fourth group supplemented with both B vitamins and an additive containing aureomycin gained 1.16 pounds per day. This is typical of the magnitude of response noted in other experiments of this type. Another widely observed and extremely important practical result is the reduction of scours in swine which accompanies antibiotic feeding.

Turning now from what is relatively well known, the practical effects of antibiotics on animal production, one encounters that which is not so well known, the mechanism of antibiotic action. This is a problem still to receive a wholly satisfactory explanation. The aim of the present investigation, employing three antibacterial agents: penicillin, a narrow spectrum antibiotic; aureomycin, a broad spectrum antibiotic; and 3-nitro, 4-hydroxy phenylarsonic acid, a "chemobiotic", was to make a slightly different approach to the problem--that of determining how the growth response effected by these compounds influenced certain blood and carcass constituents in the animal--thus reflecting the effect of this growth response on the fat, protein, carbohydrate, and mineral metabolism of the body. A change noted in any of these might easily offer a clue needed to clarify some phase of antibiotic action.

REVIEW OF LITERATURE

Mechanism of Antibiotic Growth Stimulation

It has been widely demonstrated and is now generally accepted that various substances possessing antibacterial activity are capable of causing a stimulation in the growth of swine as well as the majority of other domestic animals. In swine this stimulus to growth rate appears to be fairly consistent in occurrence but is quite variable in magnitude. It has been shown that some of the more important factors accounting for this variability are: kind of antibacterial supplement, composition of diet, animal health, degree of sanitation, animal age, level of supplementation, breed, sex, and so forth. Evidence that antibiotics are effective growth stimulants for swine is presented by Braude et al. (3, p. 272-273) who have summarized the majority of research accomplished prior to 1953. The data given below, extracted from their review, are index values from 245 growth comparisons, showing an advantage of from 9 to 17 per cent for the antibiotics listed.

Antibiotic	Growth Index (Unsupplemented = 100)
Aureomycin	115.1
Penicillin	110.4
Streptomycin	109.0
Terramycin	117.6
Bacitracin	110.9

These data represent fairly typical conditions and do not include results of investigators whose data show either severe digestive disorders of control animals or a nutritionally inadequate control ration.

The means by which antibiotics accomplish this growth increase has received much attention and many experiments have been carried out designed to clarify their mechanism of action. Indeed, some works have cast considerable light in this direction, but still, in general there is no single simple explanation of antibiotic action which holds true for all conditions and it seems probable that they can act in several different ways depending on environmental conditions.

Moore _et al_. (53, p. 438-440), the first experimenters recording a growth response due to antibiotics (1946, in chicks fed a purified diet supplemented with sulfasuxidine and streptomycin), suggested that these agents could be inhibiting intestinal bacteria that were either producing toxic substances or that were competing with the animal for certain dietary vitamins, or they could be acting systemically. The latter suggestion, that antibiotics may have a vitamin-like catalytic effect, is still recognized as a possibility, but as antibiotics differ so widely in chemical structure and because they have been shown to spare a number of unrelated nutrients, this explanation is not considered a probable one. Another group of investigators, Harned et al. (36, p. 193), in 1948 working with antibiotics attributed the growth response to aureomycin seen in chicks to the elimination of an infection. Numerous investigators have since attacked the problem and have obtained much information which directly supports these original suggestions.

Most of the evidence indicates that the effect of antibiotics is on the intestinal microflora, and because antibacterial action is the only property all antibiotics possess in common this is deemed a probable explanation. Their growth promoting powers in general seem to be directly related to the degree of their antibacterial potency; thus the wide spectrum antibiotics, aureomycin (chlortetracycline) and terramycin (oxytetracycline), seem to be more effective in eliciting growth responses than the narrow spectrum antibiotics, such as penicillin and bacitracin. It is recognized that the possible effects of antibiotics on intestinal microflora are: (1) suppression of harmful organisms, including known pathogens and those which produce toxins causing subclinical infections, (2) suppression of organisms competing with the host for nutrients, or (3) enhancement of the growth of organisms which synthesize various essential nutrients. In strong support of items (1) and (2) are observations that chicks hatched and grown under aseptic conditions, thus having no intestinal microflora, were found to approach weight gains made by antibiotic-supplemented chicks, and did not make further gains when supplemented with antibiotics (47, p. 10-11). Along this same line, Coates (23, p. 44-47) has reported that antibiotics have no additional effect when given to chicks reared in new, previously uncontaminated quarters or in old quarters thoroughly cleaned and disinfected. But when birds from the regularly used poultry houses were mixed with birds in the new houses a growth depression was apparent. From these observations they postulated that bacteria which have an inhibitory effect on animal growth are normally present in the intestinal tract and that chicks raised under conditions free from these bacteria grow at a maximal rate. In 1949 before aureomycin had been identified as a growth stimulant in hog rations, Catron (16, p. 217) advanced the concept that growth differences in similar pigs under similar feeding and management conditions were due to differences in disease level. Later in 1950, after Jukes (43, p. 324-325) and Carpenter (14, p. 469-470) reported weight gain increases in swine supplemented with aureomycin, Catron's group (64, p. 452-453) reported that in their experiment with healthy swine they had noted no growth benefit from aureomycin supplementation and suggested that healthy, previously well-fed pigs may not respond to aureomycin feeding as would unthrifty pigs in unsanitary surroundings. Jukes and Williams (42, p. 386) have shown that baby pigs grown in new quarters with or without aureomycin weighed 21 kilograms at 8 weeks of age. Thereafter in these same quarters the control pigs reached only a weight of about 16 kilograms in the course of time it took aureomycin-fed pigs to reach 21 kilograms. The observation made by many workers that antibiotics are effective in alleviating or reducing the severity of scours in pigs is evidence of the therapeutic action of antibiotics. This action is thought to differ only in degree from antibiotic action in promoting growth in apparently healthy animals.

Changes in the microbial population in the gut were thought a profitable line of approach to obtain direct evidence that the antibiotic growth effect was due to antibacterial action. Results from this type of investigation revealed that changes in numbers and types of micro-organisms were small and results of different laboratories were generally inconsistent. It is possible that although presence and morphology remain largely unchanged, bacterial metabolism has undergone alteration which is only evident from nutritional studies. Much of the experimentation carried out in this regard has been summarized by Jukes and Williams (42, p. 381-420).

Administration of antibiotics parenterally should produce no growth reaction if antibiotics act solely on the micro-organisms of the digestive tract. It has been reported, however, that increased growth rates have occurred both in swine (4, p. 262-263; 55, p. 772) and chicks (29, p. 834-835) injected with antibiotics. As an explanation to this one finds cited the findings of Larson and Carpenter (45, p. 240) who recovered aureomycin in the feces of swine, and suggested that injected aureomycin is secreted into the intestine by way of the bile. Recently, in 1957, Dick and Johansson (26, p. 350-357) have compared the effects of oral versus injected antibiotics in rats. Penicillin and aureomycin were equally effective in promoting growth when administered either orally or parenterally, yet the intestinal concentration of aureomycin given parenterally was only 10 per cent of the amount found when it was given orally. Bacitracin only stimulated growth when injected, however, there were no detectable quantities of it found in the intestinal contents. These results indicate no correlation between antibiotic growth effect and intestinal concentration. Others have observed a growth response in chicks when bacitracin was fed (49, p. 8) but not when it was implanted subcutaneously (7, p. 1097-1098). After examination of material from several hundreds of pigs, Gordon et al. (33, p. 747) reported that aureomycin and penicillin are not confined to the digestive tract even when fed at the low levels of 4 parts per million, but are excreted in significant amounts in the urine.

Another possible means of accounting for the antibiotic growth effect is to suppose that antibiotics stimulate the appetite in some manner. Thus it has been reported by several workers (11, p. 380-382; 46, p. 46-47; 56, p. 311-312; 71, p. 6) that antibiotic-supplemented animals consume significantly larger amounts of feed than control animals. This increased feed consumption may be a direct result of the antibiotic supplementation, or one of the manifestations of a resulting improved state of health, or yet merely the consequence of the animal growing larger so that its capacity for food is larger. A good evidence that antibiotics directly cause an increase in feed consumption by virtue of increasing ration palatability is shown by Tomlin et al. (70, p. 44-46) who state that the aureomycin-supplemented ration was much preferred by swine to the basal ration or any of three other antibiotics tested. Notwithstanding it has been shown earlier by Brown (11, p. 380-382) and more recently by Wallace (74, p. 1101) that the antibiotic growth effect is dependent in the healthy pig on an increase in feed intake.

Gordon (32, p. 11) has shown that the weights of the small intestine of either penicillin-fed or "germ-free" chicks was significantly lower than those of control chicks. Taylor and Harrington (68, p. 643) have extended this observation to hogs and found the weight of the small intestine to be very significantly ($P < .001$) lower than that of the controls. Coates _et al_. (22, p. 1334) have shown that the gut of chicks receiving penicillin or aureomycin is distinctly lighter in weight than untreated controls due to a thinner wall. They (24, p. 149) also noted that body weight was increased and liver stores of vitamin A, both in untreated birds reared in sterile conditions and in penicillin-treated birds reared under ordinary conditions, were higher than in controls reared under ordinary conditions. These observations suggest that either antibiotic supplementation or "germ-free" conditions may enhance intestinal absorption of nutrients by the elimination of an infection which theoretically attacks the intestine directly, causing a thickened intestine and a resulting decrease in intestinal efficiency.

Antibiotics and Nutrient Requirements

In addition to their established effects on nutritionally adequate diets, there are many reports that antibiotics have the ability to spare certain of the B vitamins--an evidence of the probability of their multiple mode of action. Synthesis by intestinal micro-organisms is the only property that these vitamins, which are structurally different and which possess varied biochemical function, hold in common. Just how antibiotics are able to spare these vitamins is not known, but it has been hypothesized that (1) antibiotics may favor certain organisms which synthesize an abundance of these vitamins, possibly by suppression of other organisms, or that (2) the intestinal absorption is improved by decreasing a supposed bacterial infection. One of the fairly consistent results of antibiotic feeding is the improvement in efficiency of feed utilization which on the average amounts to 3 to 5 per cent in hogs depending on the type of antibiotic used (8, p. 273, 276). This may be directly attributable to an increased intestinal absorption and hence an increased utilization of available feed.

No sparing action on vitamin B_{12} has been attributed to aureomycin in swine rations by Catron and co-workers (19, p. 35-40). An excerpt of their data shows that aureomycin addition gave a consistent 16 per cent increase in growth rate, whether or not vitamin B_{12} was added to the ration.

Treatment	Rate of gain (lbs/day)
None	1.35
Aureomycin (20 mg/lb ration)	1.57
Vitamin B_{12} (10 mg/lb ration)	1.53
Aureomycin plus Vitamin B_{12}	1.77

On the other hand when Sheffy *et al*. (61, p. 99-101) supplied either aureomycin alone or in combination with vitamin B_{12} to baby pigs, they obtained equal growth response on a ration shown to respond to B_{12} addition. They implied that aureomycin was able to spare vitamin B_{12}. These discordant results are in keeping with the majority of the experimental observations on vitamin replacement and in general there seems to be no consistent effect of antibiotics on the requirements for any of the known vitamins. The great majority of research in this regard has been carried out with chicks and is well summarized in the monograph, *Antibiotics in Nutrition*, by Jukes (41, p. 44-49) or in the review article by Stokstad (65, p. 31-37).

The effects of antibiotics on vitamin A and carotene have been somewhat more reproducible than those with B vitamins. Increased liver storage of vitamin A during the administration of antibiotics has been shown in rats (38, p. 437), chicks (24, p. 149), and swine (3, p. 713).

Type of protein concentrate has been studied by various investigators as it affects the growth response produced by antibiotics. Workers (58, p. 450-453) in the British Isles showed that addition of penicillin to a vegetable protein diet caused pigs to gain 16 per cent faster, while addition of penicillin to an animal protein (fishmeal) diet resulted only in a 9 per cent increase in gains. Even though this indicates that penicillin may have some sparing action on protein quality, maximal gains were only obtained on the latter ration. In his review article, Braude (8, p. 278) lists the average response of pigs fed a mixed vegetable protein ration supplemented with aureomycin as 26 per cent and the response to a mixed animal-vegetable protein ration at 14 per cent. Likewise the average response of aureomycin-supplemented pigs receiving a fishmeal containing ration was 3 per cent while average response to a soybean oil meal containing ration was 14 per cent. Some workers (10, p. 650) have reported no growth response to antibiotic additions when pigs were fed very high quality rations containing such ingredients as fishmeal, meat scraps, livermeal, fish solubles, tankage, and whey. In contrast Briggs and co-workers (9, p. 1041) obtained a better growth response to the antibiotic supplementation of a meat scraps containing ration than to a similar ration containing only vegetable protein. Catron et al. (17, p. 1043) studied the effects of aureomycin on growth of swine fed corn-soybean oil meal rations at four protein levels (14, 16, 18, and 20 per cent). Those pigs receiving the aureomycin showed no significant difference in rates of gain due to level of protein as compared to a marked variation in unsupplemented pigs on different protein levels. These results are similar to those obtained by Sewell and Keen (60, p. 354-356). In two experiments involving 288 pigs, Jensen et al. (39, p. 80) summarized the effects of both aureomycin and terramycin on swine growth rate in response to protein levels varying from 10 to 20 per cent. In general, average daily gains reached a maximum in unsupplemented hogs at 16 and 18 per cent protein levels, whereas antibiotic-supplemented pigs made maximum daily gains at 14 per cent protein (a nonsignificant difference). Meade (52, p. 304-305) concluded that aureomycin exerted no sparing effect on protein requirement in swine, but suggested the possibility that an antibiotic may spare protein indirectly by increasing the feed consumption of pigs fed diets containing lower protein levels.

Evidence is available that antibiotics may have a positive or negative effect on requirements for certain essential amino acids. Jones and Combs (40, p. 920) reported a sparing effect of aureomycin on the tryptophan requirement but not on the lysine requirement in chicks. In fact, Slinger _et al_. (62, p. 353-354) observed that the lysine requirement of turkeys was increased by feeding either aureomycin or penicillin as indicated by the increased incidence of white feathers; lysine deficiency in poultry is manifest in an achromotrichia of the feathers. Cunha _et al_. (25, p. 617) believed aureomycin to spare methionine in swine on corn-peanut meal rations. However, Hale (34, p. 88) using a barley-peanut meal ration showed no sparing effect of penicillin on methionine in swine, and this finding has been recently confirmed by others (60, p. 355-356).

Carcass Composition as Affected by Antibiotics

An important facet of the action of antibiotics is the controversy caused from numerous conflicting observations as to their effect on carcass fat deposition. Concern has been indicated by some workers who have recorded fatter, hence less desirable carcasses, produced by feeding antibiotics. Additional weight increases consisting primarily of extra fat would surely be of limited value in view of the present depressed market for lard. Among those reporting additional fat is Vestal (71, p. 8) who in 1950 reported 10 per cent thicker backfat in hogs fed on alfalfa pasture plus corn and soybean oil meal and supplemented with Animal Protein Factor (a product of Lederle Laboratories containing both vitamin B_{12} and aureomycin) as compared to hogs not so supplemented. The supplemented hogs also gained faster and ate more than the control hogs. His later work (72, p. 2-3) indicated that pigs removed at 125 pounds from B_{12}-antibiotic supplemented rations showed only slightly increased dorsal fat when slaughtered at market weight, but if continued on the supplement until market weight the carcass fat depth was greatly increased.

Bowland *et al.* (6, p. 635) supplementing small grain rations for Yorkshire swine with Animal Protein Factor including residual aureomycin stated that there was a statistically nonsignificant trend toward increased dressing percentage and lowered carcass grades in conjunction with increased fat deposition and decreased carcass lengths in these hogs. He suggested that the deleterious effect of A.P.F. and aureomycin on carcass composition may be due to the very rapid gains made during fattening (24 per cent faster than controls). In contrast to this Wilson (78, p. 295) has presented data from 96 pigs demonstrating that fat deposition was not increased even though the addition of vitamin B_{12} and aureomycin significantly accelerated weight gains ($P < .01$). In a like manner levels of streptomycin, varying from 10 to 40 mg. per pound of feed, produced no significant difference in thickness of backfat although they did increase weight gains significantly (11 to 19 per cent greater than controls) as reported by Terrill _et al_. (69, p. 833-835). An instance where 200 mg. aureomycin per pound of ration did not improve rate of gain at any of three protein levels, but did increase backfat thickness of hogs on both low and high levels of protein is reported in the work of Wallace (73, p. 179-182).

Catron _et al_. (20, p. 52-60) using Durocs and Landrace-Duroc crossbred pigs, set up an experiment involving a mixture of antibiotics (aureomycin, terramycin, streptomycin and penicillin at 10 mg. each per pound). Antibiotic-fed pigs gained 0.25 pounds per day more than nonantibiotic-fed pigs. Averages of four measures of backfat (taken at 1st, 7th, last rib and last lumbar vertebra) in Durocs were 1.92 and 1.82 inches for antibiotic and nonantibiotic-supplemented hogs respectively. Landrace-Duroc crossbreds showed slightly more backfat when not antibiotic supplemented. Neither difference was statistically significant.

In two experiments involving 102 carcasses from pigs fed corn-soybean oil meal rations, Ashton and co-workers (1, p. 88-92) found no indication of important alterations in carcass quality due to inclusion of antibiotics (5 mg. of either aureomycin or terramycin per pound ration) as evidenced from measurement of backfat depth directly and by "live probing", percentage lean cuts, or weight of leaf fat. Others (2, p. 309-310, 313) had previously come to similar conclusions after measuring carcass lengths and fat depth at inner and outer shoulder, and determining percentage of water, per cent fat, fat free residue, and iodine values of fat from 5 depots on pigs fed plant protein-supplemented rations containing aureomycin and penicillin as compared to controls. These pigs did make significant ($P < .05$) increases in daily gains over those of the controls and were more efficient in utilization of feed.

In contrast, Perry _et al_. (56, p. 311-314) present data showing that aureomycin-supplemented crossbred pigs gained highly significantly faster (1.60 pounds per day as compared to 1.30 pounds per day) slightly less efficiently (3.84 as to 3.44 pounds feed per pound gain), but ate significantly more (6.15 pounds feed as to 4.51 pounds feed) and had highly significantly more backfat (61.9 mm as to 54.1 mm) than basal-fed pigs. Chemical analysis of the carcasses verified that the aureomycin group was definitely the fatter group containing more total fat, less protein, and less water. Another group determining carcass composition chemically was that of Hanson (35, p. 37-41), which in a comprehensive experiment involving 77 swine, reported no significant differences in carcass moisture, crude protein, or total carcass fat between controls and pigs supplemented with either aureomycin, terramycin, or penicillin to either 125 or 200 pounds. The aureomycin group fed to 200 pounds showed a trend towards greater depth of backfat; however, chemical analysis of a representative sample taken from half of the ground carcass revealed them to have actually less fat than the unsupplemented pigs. They conclude that antibiotics <u>per se</u> do not affect carcass quality, but that the trend toward additional subcutaneous fat noted in aureomycin supplemented swine was a result of increased rates of gain.

One of the most recent studies concerning aureomycin effects on fat quality and quantity and blood fat levels in relation to fat metabolism is that of Kelly et al. (44, p. 79-83). Carcass data were collected on hogs slaughtered at differing predetermined weights (85, 125, 165, and 205 pounds). No significant differences due to aureomycin were noted on dressing percentages, carcass length, or per cent lean cuts. An interesting point in this study was a significant difference of backfat deposition and average daily weight gains recorded between males and females fed aureomycin supplements. It would appear that aureomycin exerts a more stimulatory effect on males, as barrows gained significantly faster ($P < .05$) and laid down a significantly greater amount ($P < .05$) of backfat than aureomycin-supplemented females.

It is evident from the inconsistency of the data reviewed that numerous factors, such as breed differences, stage of maturity, sex, type of ration, state of animal health, and many others, play some role in determining whether an antibiotic supplement will cause a fatter swine carcass. It is not unreasonable to assume as various investigators have pointed out, that when antibiotic-supplemented swine are driven to consume larger quantities of feed and make rapid weight gains, this excess nutrition is metabolized and deposited in the form of carcass fat.

EXPERIMENTAL

Experiment I

By far the majority of swine feeding trials involving antibiotic supplementation have included corn as the main nutrient source. To this reviewer's knowledge, Bowland et al. (6, p. 630-631) are the only workers using fibrous grain, that is, barley and oat, type rations for antibiotic experimentation. As barley and oats are the chief energy sources (because of availability and economy) in Oregon swine rations, it was desirable to further test the effects of antibiotics on growth, feed efficiency, and certain carcass and blood elements using this type ration.

In 1953 when this work was started, and even now, the mechanism by which antibiotics stimulate growth rate has not been clearly demonstrated. When listing possible modes of action, the possibility that antibiotics may stimulate the appetite in some manner, is often overlooked. Brown (12, p. 1042) suggests that increased feed consumption is the primary effect of dietary aureomycin in the healthy pig. In 201 comparisons compiled by Braude et al. (8, p. 274) from the majority of data published before 1953, efficiency of feed use was not improved in 45 cases or about 22.5 per cent, suggesting that the advantage of antibiotics in producing increased rate of gain is not universally accompanied by increased feed efficiency. To examine this question further, individual feeding methods were employed to eliminate many of the inaccuracies involved with measurement of feed intake of group fed hogs.

Dinusson (27, p. 327-328) reported that beef heifers gaining more rapidly than controls showed a significantly higher per cent of blood lipids. Since blood lipid content represents fat in transport, and hence may indicate an increased rate of fat metabolism, it was deemed possible to form an idea of type of growth being produced in antibiotic supplemented hogs by measuring blood lipid levels.

Several organic arsenic containing compounds, notably 3-nitro, 4-hydroxy phenylarsonic acid, have been implicated in producing rapid weight gains in chickens and swine. In an earlier experiment by Oldfield (54, p. 5) at Oregon State College, the supplying of 3-nitro, 4-hydroxy phenylarsonic acid to swine fed a nutritionally adequate diet resulted in slightly higher but statistically non-significant growth rates as compared to the control groups. In view of this slight but positive tendency further investigation was warranted.

<u>Methods</u> <u>and</u> <u>Materials</u>.

Eight feeder barrows and eight feeder gilts, of reasonably equal weights and ranging in age from 97 to 108 days, were selected from three litters of purebred Berkshire swine from the Oregon State College herd. Animals were further stratified into heavy and light pigs, one heavy and one light pig of each sex were randomly assigned to the following treatments:

Lot 1 Basal Ration (Control)

Lot 2 Basal Ration plus Penicillin

Lot 3 Basal Ration plus Aureomycin

Lot 4 Basal Ration plus 3-nitro, 4-hydroxy phenylarsonic acid

Pens allowing approximately twenty square feet of concrete floor space were constructed for individual penning and feeding. Table 1 lists the rations that were fed twice daily; these were carefully compounded, thoroughly mixed, and then pelleted by a commercial feed concern. Sufficient feed to last throughout the experimental period was prepared and stored in multi-thickness paper bags. Samples of these pelleted feeds were sent to Lederle Laboratories Division, American Cyanamid Company, Pearl River, New York, for assay of antibiotic potency. Water was supplied ad libitum, one water trough supplying two pigs on the same treatment.

Daily feed consumption was restricted to the amount the pig ate readily; any feed remaining resulted in a lowering of the amount given. However, as quickly as the pig indicated readiness for more feed, it was made available. By not allowing excess feed, wastage was kept to a minimum. Amounts given at each feeding were recorded.

Pigs were weighed individually at exact weekly intervals through the 76-day feeding period. These weights were recorded as were the final and carcass weights at the time of slaughter. Blood for hemoglobin determinations and lipid phosphorus levels was collected by cardiac puncture nine days after the pigs were put on test, again in 28 days, and finally at slaughter. Samples of 10 cc. were drawn into tubes containing a solution of saturated sodium citrate to prevent clotting. Grams hemoglobin per 100 ml. of blood were determined by reading the hemolyzed blood in a Spencer Hemoglobinometer (American Optical Company). Blood phospholipid was determined by the method of Youngberg as modified by Hawk, Oser, and Summerson (37, p. 541-542).

Weight gain, feed consumption, efficiency of feed utilization, and dressing percentage data were analyzed statistically as a 4 x 2 factorial experiment, enabling the extraction of treatment effects, sex effects, and a treatment-sex interaction effect. Blood data, namely, hemoglobin and lipid phosphorus levels, were treated statistically as a 4 x 2 x 3 factorial experiment with a

TABLE 1

Composition of rations used in Experiment I

Lot 1	Basal Ration	
	Ground Barley	1100 lbs.
	Ground Oats	550
	Ground Alfalfa (sun cured)	100
	Peanut Oil Meal	150
	Tankage	75
	Oyster Shell Flour	10
	Steamed Bonemeal	10
	Iodized Salt	5
		2000 lbs.
Lot 2	Basal Ration + 10 mg. Procaine Penicillin G per pound total feed.	
Lot 3	Basal Ration + 10 mg. Aureomycin per pound total feed.	
Lot 4	Basal Ration + 0.00375 per cent 3-nitro, 4-hydroxy phenylarsonic acid.	
	B Vitamin Supplement (added to all rations)	
	Riboflavin	0.8 mg./1 lb.
	Calcium Pantothenate	4.5 mg./1 lb.
	Niacin	5.0 mg./1 lb.
	Choline Chloride	0.1 per cent

split plot design, treatment and sex being main effects, period a sub-effect (63, p. 309-313). All analyses are located in Appendix A.

Results

Individual feed and performance records of the sixteen pigs are presented in Table 2.

Weight gain data revealed some rather unexpected results in certain respects. Pigs receiving the control diet had an average daily gain of 1.54 pounds; those receiving the arsonic acid supplemented ration, closely approached this rate of gain (1.53 pounds per day). Animals on either antibiotic supplemented ration exceeded the controls. The penicillin-fed lot exhibited a very slight 3 per cent increase; aureomycin supplemented pigs, however, gained 14 per cent more than did the controls. This result with aureomycin was not unexpected, but the relatively small increase from the penicillin supplemented ration was entirely unforeseen in the light of the literature review.

Antibiotic assay revealed, however, that the pelleted, penicillin-containing ration had lost 95 per cent of the original potency of 10 mg. penicillin per pound, probably accounting for the only very slight advantage of the penicillin over the basal. Aureomycin potency was also

TABLE 2

Individual Feed and Performance Records of Swine Fed Rations Supplemented with Antibiotics and Phenylarsonic Acid (Experiment I)

Lot Number	Animal Number	Sex	Initial Weight (Lbs.)	Final Weight (Lbs.)	Weight Gain (Lbs.)	Average Daily Weight Gain (Lbs.)	Total Feed Consumption (Lbs.)	Feed[1] Efficiency	Cold Carcass Wt. (Lbs.)	Dressing[2] Percentage
1 (Basal)	112	Barrow	77	212	135	1.78	472	349	147	69.3
	138	Barrow	71	183	112	1.47	429	383	136	74.3
	109	Gilt	73	193	120	1.58	434	361	137	71.0
	144	Gilt	65	165	100	1.32	336	336	117	70.9
Lot Average			71	188	117	1.54	418	358	134	71.4
2 (Penicillin)	115	Barrow	79	203	124	1.63	493	397	145	71.4
	140	Barrow	66	190	124	1.63	433	349	137	71.4
	105	Gilt	80	209	129	1.70	468	363	149	71.3
	146	Gilt	70	174	104	1.36	370	357	124	70.9
Lot Average			74	194	120	1.58	441	367	139	71.2
3 (Aureomycin)	116	Barrow	85	224	139	1.83	523	376	159	71.0
	117	Barrow	67	237	170	2.24	607	357	171	72.2
	106	Gilt	86	212	126	1.66	445	353	159	75.0
	149	Gilt	54	163	109	1.43	377	347	117	71.3
Lot Average			73	209	136	1.79	488	358	152	72.4
4 (Phenylarsonic Acid)	137	Barrow	73	194	121	1.59	427	353	140	72.2
	114	Barrow	67	183	116	1.52	379	328	130	70.7
	118	Gilt	87	201	114	1.50	461	404	143	71.1
	110	Gilt	62	177	115	1.51	392	342	130	73.0
Lot Average			72	189	116	1.53	415	357	136	71.7

1 Expressed as pounds feed per 100 pounds weight gain.

2 Calculated as $\frac{\text{cold carcass weight}}{\text{end weight}}$ (The end weight was taken immediately prior to slaughter and is not necessarily equal to final "off test" weight.

reduced, to a lesser extent, showing a 6 mg. per pound activity, a 40 per cent loss.

An observation made on pig number 117 (pen 10) of the aureomycin-fed group was of interest. This pig was the smallest (birth weight 2.1 pounds) of a litter of seven (average birth weight of the other six was 2.8 pounds) and remained the runt of the litter until the time he was placed on the experiment. Almost immediately he began to consume large quantities of feed and make rapid gains and at the finish had made the fastest gains and was the heaviest pig on the experiment.

As all hogs were on the experiment for an equal time period, total weight gains were used for statistical analysis. In a preliminary covariance analysis, the effect due to initial weight was extracted; it was noted that initial weight had no apparent effect on total weight gain, so the data were set up as a factorial design, separating the effects of treatment, sex, and their interaction.

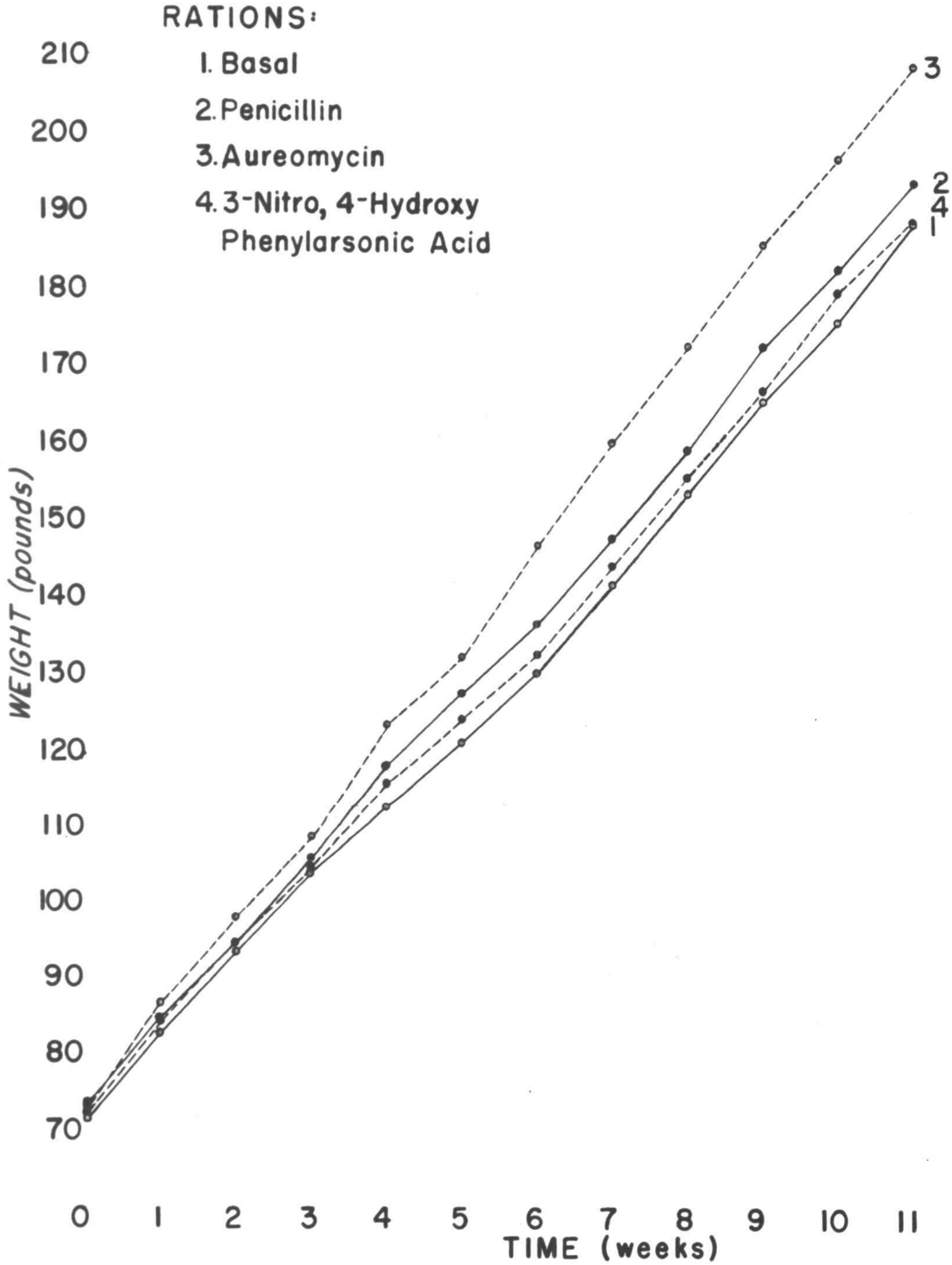
There was no significant difference of weight gains among rations when tested by the F test. The specific hypothesis, that the aureomycin-fed hogs gained faster than the control group approached, but did not reach statistical significance at the 5 per cent level. Barrows on all rations gained an average of 1.71 pounds per day as compared to 1.51 pounds per day for gilts; this is a 13.2 per cent difference and is statistically significant ($P < .05$). Individuals in the aureomycin group were primarily responsible for this variation in gain due to sex. The difference between sexes in this group, although not statistically significant at the 5% level of significance, was approximately 180% greater than differences between sexes in any other ration group. Results such as this would lead one to suspect that perhaps aureomycin supplementation exerted a greater stimulus on males. Growth curves (Figure 1), plotted on the basis of average weekly group weights, illustrate a small but steady advance of the aureomycin group over the control group during the first two weeks on experiment. However, the largest growth increase over the control group is noted during the fifth and sixth weeks of feeding when animals weighed between 130 and 160 pounds.

All ration groups were quite similar with regard to feed efficiency, the over-all average being approximately 3.6 pounds feed per pound gain. Braude _et al._ (8, p. 274) report that in 109 comparisons of hogs fed aureomycin versus those fed a control ration, the average feed utilization index for aureomycin was approximately 5 per cent

FIGURE I

Average Weekly Weights of Animals by Ration Group

(Experiment I)



less than the basal, and in 19 comparisons of aureomycin to the basal where a mixed animal-vegetable protein was used, the feed utilization was 96.6 per cent. This indicates that if an efficiency of feed utilization is to be expected, the magnitude will probably be less than 5 per cent.

As individual feed records were kept and wastage kept to a minimum, quite an accurate determination of actual feed consumption was possible. Average daily feed intake of the basal group was 5.5 pounds per day. The penicillin-fed group consumed 5.8 pounds per day, a 5.5 per cent increase over the control; the aureomycin lot showed a 16.8 per cent increase over the control group (6.4 pounds feed per day); and the arsonic acid supplemented hogs ate 1 per cent less feed than did the control lot. Castrate males in general ate 14.6 per cent more feed than females. The magnitude of these differences, both ration and sex, seems quite large but individual variation rendered them nonsignificant statistically.

Dressing percentages were very close together, with the aureomycin group dressing out on the average 1 per cent greater than the other three groups. Analysis showed no statistical difference due to ration, sex, or ration-sex interaction.

Average hemoglobin values for ration groups are as follows: Basal Ration, 11.65 grams per 100 mls. blood; Penicillin supplemented ration, 11.48 grams; Aureomycin supplemented ration, 11.25 grams; and Arsonic Acid supplemented ration, 11.63 grams. It is evident that ration had no great effect on hemoglobin levels. The effect of sex was even more negligible, whereas the effect due to period when the pigs were sampled had quite a significant effect ($P < .005$). Hemoglobin levels increased throughout the feeding period from an average of 10.19 grams per 100 mls. initially to 11.69 grams at mid-trial to 12.62 grams at the trial end. Table 3 contains individual blood data.

Lipid phosphorus content of the pigs' blood did not vary as a result of supplementing the ration with antibiotics, as a result of sex, or as a result of the interaction of ration and sex. Statistically significant ($P < .025$) only was the effect of time of blood withdrawal. These values showed no definite trend, but went from an initial average concentration of 11.22 mg. per cent to 9.77 mg. per cent at mid-trial, then up to 10.99 mg. per cent at slaughter. These observations would not seem consistent with the expected trend during the growing-fattening period.

TABLE 3

Individual hemoglobin and blood lipid phosphorus values of swine fed rations supplemented with antibiotics and phenylarsonic acid (Experiment I)

Lot Number	Animal Number	Hemoglobin gms./100 ml. Blood			Blood Lipid Phosphorus mg./100 ml. plasma		
		Initial Concentration	Mid-trial Concentration	Final Concentration	Initial Concentration	Mid-trial Concentration	Final Concentration
1 (Basal)	112	10.9	10.5	12.6	12.15	9.03	10.59
	138	11.2	13.9	13.0	12.15	12.41	9.53
	109	8.5	10.6	12.2	10.62	10.56	9.41
	144	10.7	12.5	13.2	10.20	7.78	10.55
Lot Average		10.3	11.9	12.8	11.28	9.95	10.02
2 (Penicillin)	115	11.6	11.2	12.5	11.30	10.32	12.70
	140	11.4	11.0	12.3	10.88	10.18	11.26
	105	10.0	11.8	12.7	11.48	10.56	12.37
	146	9.5	11.4	12.3	12.08	9.72	10.71
Lot Average		10.6	11.4	12.5	11.44	10.20	11.76
3 (Aureomycin)	116	9.5	10.0	12.1	9.85	8.47	12.30
	117	9.0	11.0	13.1	12.08	6.94	13.78
	106	9.7	12.5	13.9	12.33	10.56	10.92
	149	10.3	11.6	12.3	10.95	11.39	10.79
Lot Average		9.6	11.3	12.9	11.30	9.34	11.95
4 (Phenylarsonic Acid)	137	11.7	12.4	13.3	10.88	10.00	12.76
	114	10.3	11.0	11.9	10.70	7.82	8.29
	118	10.0	13.5	13.1	12.75	10.93	11.65
	110	8.7	12.2	11.4	9.08	9.60	8.16
Lot Average		10.2	12.3	12.4	10.85	9.59	10.22
Period Average		10.2	11.7	12.6	11.22	9.87	10.99

Discussion

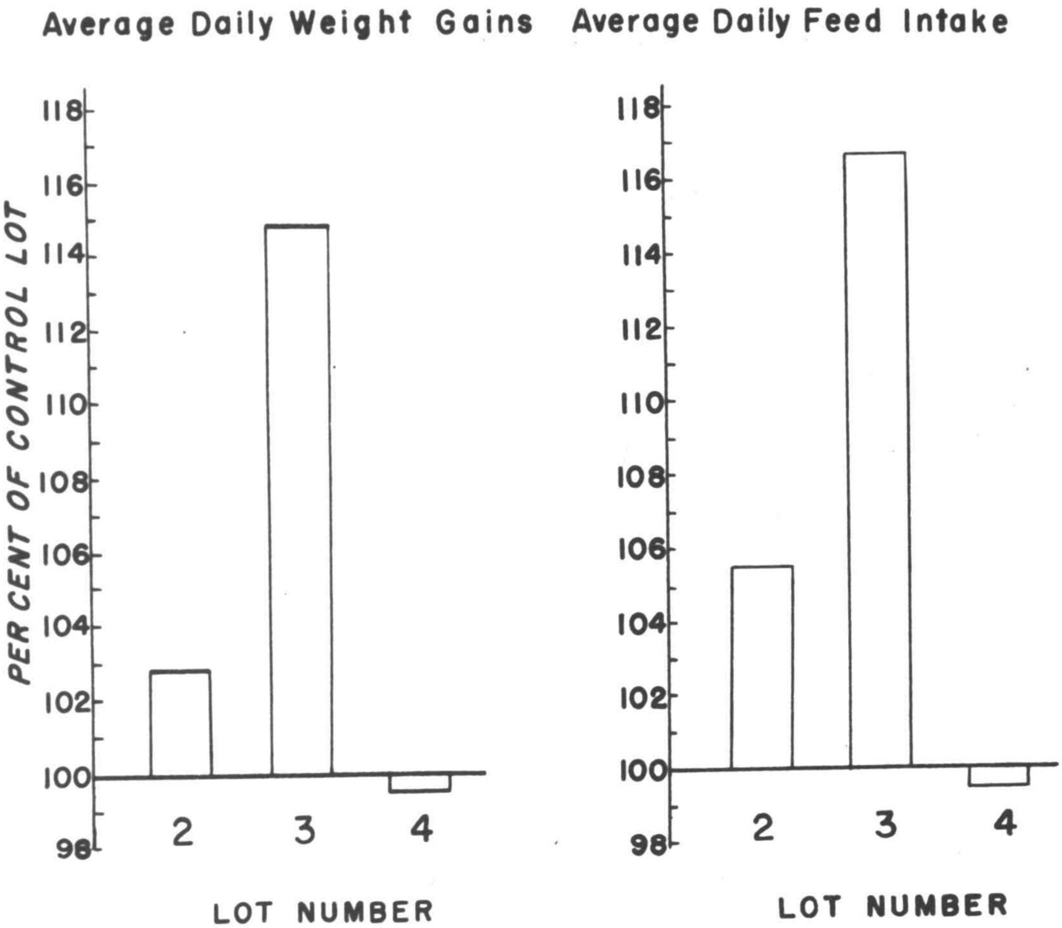
In five feed trials listed by Braude *et al.* (8, p. 275) where the average daily weight gain of the basal groups was 1.5 pounds, penicillin-supplemented pigs gained an average of 8 per cent more than basal-fed pigs. Controls in the experiment reported herein gained 1.54 pounds per day and the penicillin-fed group only 3 per cent more than this. This lack of response to penicillin may be due to the almost total destruction of the penicillin as seen by potency assay. It is quite possible that the reduction in activity occurred due to the combined effects of pelleting and storage. Williams and Esposito (77, p. 2) have shown that procaine penicillin, though in 1953 the most stable of the penicillin salts, undergoes an average destruction of 50 per cent when feeds are pelleted and 70 per cent destruction after storage at about 90 degrees F. No doubt the susceptibility of this penicillin salt to destruction in feed pelleting and storage modifies its usefulness as a growth stimulant in animal rations.

In 118 comparisons of average daily gain between basal and aureomycin-fed pigs, the modal increase due to aureomycin feeding was 11 to 20 per cent, as reported by Braude and co-workers (8, p. 274). Therefore, the local results of 14 per cent increase in the aureomycin-fed group is representative of the bulk of previous work. Scrutiny of this over-all gain reveals that the actual response of individual sexes has been obscured by the average, and that the increase is due largely to the males. Barrows on the control ration have gained 12 per cent more than control gilts, whereas aureomycin-fed barrows gained 31 per cent more than gilts on the same ration. It appears that ration and sex are not exerting their effects independently. Kelly, Bray, and Phillips (44, p. 77-79) have observed this same phenomenon and suggest that castration and the accompanying alteration of hormone balance may make barrows respond differently to antibiotic treatment than gilts. A more important factor, it would seem, is the gross sex difference and the greater potential of the male to respond to a growth stimulus.

The correlation between feed consumption and average daily gains is apparent from Figure 2, indicating that daily gains were proportional to daily feed consumption and not associated with greater feed efficiency. This observation closely parallels those reported by certain other workers. Brown *et al.* (12, p. 1042), using individual feeding methods and by restricting the feed intake of an aureomycin supplemented lot to that of the control, report that there was no statistically significant difference in rate of gain or feed efficiency due to aureomycin

FIGURE 2

Relation between Rate of Gain and Feed Consumption (Experiment 1)



2-Penicillin Supplemented

3-Aureomycin Supplemented

4-Phenylarsonic Acid Supplemented

supplementation, but when aureomycin-fed hogs were full fed they gained .35 pounds per day more than the controls and ate 1.28 pounds more feed per day, which led them to the conclusion that the predominant influence of dietary aureomycin in the healthy pig is mediated through an increased feed consumption. Lasley _et al._ (46, p. 46-47) likewise report increases in feed consumption accompanying increases in rate of gain of hogs supplemented with aureomycin or penicillin. However, they suggest that although the antibiotic has seemingly increased the pigs appetite, this increased feed consumption may be a direct result of the pig growing larger and thus increasing his capacity to consume more feed. In one experiment they compared aureomycin-supplemented hogs to hogs fed the basal ration and found that on the same weight basis aureomycin-supplemented hogs actually consumed less feed per 10 pounds increase in body weight. A third possible explanation of greater feed intake by antibiotic-fed hogs is based on the disease level concept of antibiotic action. According to this, antibiotic-fed hogs are elevated to an improved level of health which is accompanied by an appetite increase.

Growth improvement in chickens has been recorded by Bird _et al._ (5, p. 223-225) as a result of supplementing with .005 per cent 3-nitro, 4-hydroxy phenylarsonic acid.

Carpenter (15, p. 651), having conducted three tests with weaned pigs, reported that inclusion of phenylarsonic acid at either 0.005, 0.01, or 0.02 per cent levels produced growth stimuli. In contrast, .00375 per cent 3-nitro, 4-hydroxy phenylarsonic acid had absolutely no effect on growth rate, feed consumption, feed efficiency, dressing percentage, hemoglobin levels, or blood lipid phosphorus levels, under the conditions imposed by the experiment reported here. In fact, this ration approximated the control ration more closely than any other treatment for all quantities measured.

Bowland _et al_. (6, p. 633-634), using small grain rations, have reported a 24 per cent improvement in growth rate of pigs supplemented with APF and residual aureomycin. While results obtained with antibiotic supplements in this experiment are not as convincing as those of Bowland, they indicate that rations of barley and oats are useful in promoting antibiotic growth effects.

Observations on hemoglobin formation were similar to those obtained by Brown (11, p. 380-381), who reported no significant difference due to antibiotic supplementation. Erratic results in hemoglobin formation due to added aureomycin, however, were listed by Burnside _et al_. (13, p. 192-192) using rations with three protein levels. Pigs on medium protein rations supplemented with aureomycin showed significantly higher ($P < .05$) hemoglobin levels than controls; pigs on high protein rations showed no difference from controls; and pigs on low protein rations had significantly lower ($P < .05$) hemoglobin levels than controls. In the experiment reported herein the mean hemoglobin value increased approximately 24 per cent as pigs aged from 100 to 176 days. That this is the usual condition for hogs grown in confinement is shown by Schwarte (59, p. 301), who presents data on 82 individuals from 10 litters. Hemoglobin levels of the blood increased 23 per cent in these pigs during the period from 100 to 168 days of age.

Recently, Kelly and co-workers (44, p. 77) using the method of Allen found that absorptive blood fat levels of swine were apparently lowered, however, not significantly, when they were fed rations supplemented with aureomycin. Conversely, Perry et al. (56, p. 312-313) comparing blood lipid content of basal-fed pigs and antibiotic-fed pigs observed a higher, although nonsignificant, increase in the latter group. Blood lipid phosphorus levels, an indirect measure of the blood lipid content, were used in this experiment. While this method of measurement is not strictly comparable with the above, observations showed the penicillin-fed group to have about 7 per cent (nonsignificant at $P = 0.05$) more lipids in blood and the aureomycin-fed group to have 4 per cent higher blood lipid levels than the basal-fed group. These results suggest that faster gaining groups (aureomycin and penicillin supplemented) may have slightly higher lipid phosphorus levels than more slowly gaining animals. This relationship ceases to exist, however, when extended to the comparison between the penicillin and aureomycin groups.

Experiment II

It has been widely established that certain antibiotics are capable of stimulating growth rate of swine on presumably nutritionally complete rations. Why this occurs is not entirely clear and much research has been devoted recently to elucidation of the mode of antibiotic action. The additional growth resulting from antibiotic supplementation may affect all tissues more or less indiscriminately or may be largely of one type such as fat, protein, or mineral. As an indication of an altered metabolism of any of these, blood analyses in this second experiment were extended to include levels of glucose, amino acid nitrogen, inorganic calcium and phosphorus in addition to lipid phosphorus and hemoglobin levels previously determined. As a further indication of fat metabolism, backfat measurements were made on the carcasses.

Moorehouse[1] has shown .00375 per cent to be the optimal level for supplementing with 3-nitro, 4-hydroxy phenylarsonic acid. Others (15, p. 651; 5, p. 223-225) have indicated higher levels (.005 per cent) to be very effective in promoting growth increases. As .00375 per cent 3-nitro, 4-hydroxy phenylarsonic acid was ineffective in stimulating growth in Experiment I, the level was raised to .005 per cent in this experiment.

Another incentive for a second experiment was to test the observation of Experiment I, that antibiotic-supplemented swine consumed larger quantities of feed and that the amount of feed was in almost direct relation to gains made.

Methods and Materials

Sixteen purebred Berkshire swine from three litters were allotted to four treatments in a manner similar to Experiment I. The over-all average "on test" weight was 60 pounds, about 12 pounds lighter than the average initial weight of pigs on the previous experiment. Treatments also were similar to those of Experiment I, namely:

Lot 1 Basal Ration (Control)

Lot 2 Basal Ration + Penicillin

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[1] Communication with Dr. James E. Oldfield.

Lot 3 Basal Ration + Aureomycin

Lot 4 Basal Ration + 3-nitro, 4-hydroxy Phenylarsonic Acid

Pigs were individually penned and management practices adopted in Experiment I were continued. Rations used varied somewhat and are listed in Table 4, together with proximate analyses. Main differences include substitution of soybean oil meal for peanut oil meal as a plant protein source and exclusion of steamed bone meal from all rations.

Daily feed records were kept and weekly weights taken. To insure that comparisons of weight and blood data were made at equal stages of growth, pigs were removed from experiment as they reached 190 pounds, taken to a commercial packing plant and slaughtered. The cold carcass was weighed and the depth of back fat measured at the first rib, tenth rib, and last lumbar vertebrae.

Blood samples were taken twice during the experiment by the technique of cardiac puncture. The first sample of 25 ml. was taken seven days after the hogs were placed on the experiment, the mid-trial sampling, 20 ml., was 43 days thereafter, and the final sampling, 40 ml., was taken at the time of slaughter. Blood was drawn into tubes containing .0125 ml. of saturated sodium citrate per ml. of

TABLE 4

Composition and proximate analysis of rations used in Experiment II

Lot 1	Basal Ration	
	Ground Barley	1100 lbs.
	Ground Oats	555 lbs.
	Alfalfa Meal	150 lbs.
	Soybean Oil Meal	100 lbs.
	Tankage	75 lbs.
	Oyster Shell Flour	10 lbs.
	Iodized Salt	10 lbs.
	Total	2000 lbs.
Lot 2	Basal Ration + 10 mg. Procaine Penicillin per pound total feed.	
Lot 3	Basal Ration + 10 mg. Aureomycin per pound total feed.	
Lot 4	Basal Ration + 0.005 per cent 3-nitro, 4-hydroxy Phenylarsonic Acid.	
	B Vitamin Supplement (added to all rations)	
	Riboflavin	0.8 mg./1 lb.
	Calcium Pantothenate	4.5 mg./1 lb.
	Niacin	5.0 mg./1 lb.
	Choline Chloride	0.1 per cent

Lot No.	Per Cent Crude Protein	Per Cent Fat	Per Cent Crude Fiber	Per Cent Ash
1	14.10	3.50	7.22	3.88
2	14.07	3.66	7.38	3.98
3	14.10	3.61	7.37	3.62
4	13.33	3.64	7.68	3.89

blood as an anticoagulant. Blood withdrawals were made about midway between daily feeding periods to minimize effects of feed.

The following blood determinations were made:

<u>Hemoglobin</u>

0.5 ml. of well mixed blood was placed in a spot plate, hemolyzed with saponin and read with a Spencer Hemoglobinometer.

<u>Blood Calcium</u>

As an indication of the relative metabolism of a major mineral, serum calcium was determined by the Clark-Collip modification of the Kramer-Tisdall method (21, p. 462-464).

<u>Blood Inorganic Phosphate</u>

Another criterion of mineral metabolism, inorganic phosphate was determined by the method of Fiske and Subbarow (30, p. 375-400).

<u>Blood Glucose</u>

As an indication of carbohydrate metabolism, glucose levels were determined by the Sunderman and Fuller modification of the Benedict Method (67, p. 1077-1084; 66, p. 193-195).

<u>Blood Lipid Phosphorus</u>

As phospholipids have been implicated in fat transport, these were used as a relative measure of fat metabolism.

Youngberg's method, as modified, listed in Hawk, Oser and Summerson (37, p. 541-542), was used for determination.

Blood Amino Acid Nitrogen

Indicative of protein metabolism, total amino nitrogen was run by the method of Folin as modified by Danielson; Sahyun; and Frame, Russell, and Wilhelmi (37, p. 517-519).

Average daily gains, feed consumption, feed efficiency, and dressing percentage data were analyzed as a 4 x 2 factorial design considering ration as one variable and sex as the other. As in Experiment I, all blood data and carcass fat data were analyzed as a 4 x 2 x 3 factorial experiment with a split plot design (63, p. 309-313). Ration and sex were the two main effects; a further division was into three subclasses, periods for blood, and location for fat depths.

Results

Table 5 contains individual feed and performance records of swine on the second experiment. Those on the control ration made average daily gains of 1.48 pounds, which is remarkably close to gains made by the control group of Experiment I, even though these groups are not strictly comparable. Average daily gains for Lot 2 (supplemented with 10 mg. penicillin per pound of feed) were

TABLE 5

Individual feed and performance records of swine fed rations supplemented with antibiotics and phenylarsonic acid (Experiment II)

Lot Number / Animal Number	Sex	Initial Weight (Lbs.)	Final Weight (Lbs.)	Weight Gain (Lbs.)	No. of Days	Average Daily Gain (Lbs.)	Average Daily Feed Cons. (Lbs.)	Feed[1] Efficiency	Cold Carcass Weight (Lbs.)	Dressing Per Cent[2]	Back Fat (Inches) 1st Rib	Back Fat (Inches) 10th Rib	Back Fat (Inches) Last Lumbar
1 (Basal)													
101	Barrow	68	194	126	84	1.50	5.58	373	135	69.6	1.8	1.0	1.4
112	Barrow	47	179	132	84	1.57	5.23	333	126	70.1	1.6	0.7	1.3
96	Gilt	63	170	107	84	1.27	5.19	407	117	68.8	1.6	0.8	1.2
108	Gilt	67	198	131	84	1.56	6.02	386	133	67.2	1.9	0.9	1.4
Lot Average		61	185	124	84	1.48	5.51	375	128	68.9	1.7	0.9	1.3
2 (Penicillin)													
95	Barrow	79	189	110	56	1.96	8.50	432	141	74.6	1.0	0.9	2.3
113	Barrow	41	149	108	84	1.29	4.29	333	115	77.2	1.8	0.8	1.3
109	Gilt	60	190	130	77	1.69	5.68	332	132	69.5	1.1	0.9	2.3
110	Gilt	62	198	136	77	1.77	6.21	351	139	70.2	1.0	0.9	1.6
Lot Average		61	182	121	74	1.68	6.15	362	132	72.9	1.2	0.9	1.9
3 (Aureomycin)													
93	Barrow	72	188	116	56	2.07	7.96	385	145	77.1	1.3	1.0	2.4
103	Barrow	59	194	135	63	2.14	8.21	383	138	70.9	1.3	1.0	2.1
107	Gilt	64	194	130	63	2.06	8.35	405	135	69.6	1.3	1.0	2.0
115	Gilt	43	187	144	84	1.71	5.85	341	129	68.7	1.8	1.1	1.5
Lot Average		60	191	131	67	2.00	7.59	378	137	71.6	1.4	1.0	2.0
4 (Phenylarsonic Acid)													
102	Barrow	58	175	117	84	1.39	5.55	399	1121	69.1	2.0	0.8	1.3
105	Barrow	61	190	129	84	1.54	5.69	371	137	72.1	2.0	1.1	1.5
99	Gilt	66	190	124	84	1.48	5.32	360	137	71.8	1.6	0.9	1.4
116	Gilt	53	185	132	84	1.57	5.18	330	133	71.6	1.6	0.8	1.4
Lot Average		60	185	126	84	1.49	5.44	365	132	71.2	1.8	0.9	1.4

[1] Expressed as pounds feed per 100 pounds weight gain. [2] Calculated as $\frac{\text{cold carcass weight}}{\text{final weight}}$

1.68 pounds. This is a 13.5 per cent increase over the control group and a considerable increase over the penicillin group results of the first experiment. This increase, however, was not statistically significant. Unfortunately, antibiotic assay data are not available on the pelleted feeds used in Experiment II.

The average number of days to slaughter for pigs on aureomycin was 66 as compared to 84 days for the basal group. This represents a very highly significant difference ($P < .005$) in rate of gain over the controls. This group averaged a daily weight gain of 2.00 pounds per day, an advantage of 0.52 pounds per day over the basal. Within this average gain there was a nonsignificant difference of 11 per cent between barrows and gilts of the group.

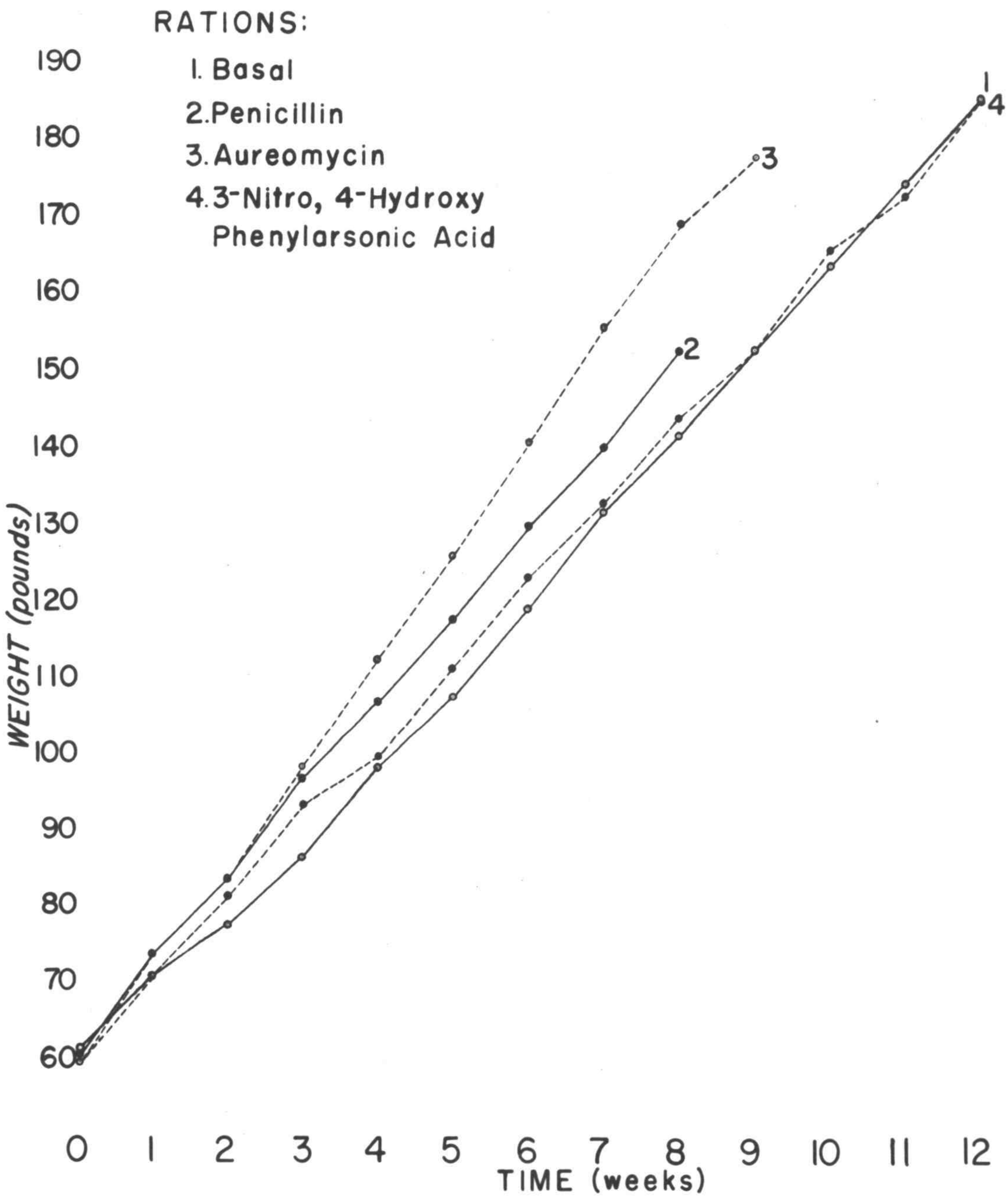
Even at a higher level (.005 per cent) 3-nitro, 4-hydroxy phenylarsonic acid supplemented hogs exhibited an average daily gain of only 1.49 pounds per day. For the second year this supplement showed no tendencies toward increasing the rate of gain in growing-fattening swine.

Contrary to results of the previous year the effects of sex on rate of gain were not significant, in fact, there was good uniformity noticed. Average feed efficiencies of the four groups were as follows:

FIGURE 3

Average Weekly Weights of Animals by Ration Group

(Experiment 2)



	Ration	Pounds Feed/Pound Gain
Lot 1	Basal	3.75
Lot 2	Basal + Penicillin	3.62
Lot 3	Basal + Aureomycin	3.78
Lot 4	Basal + Phenylarsonic Acid	3.64

These values showed the penicillin-fed lot to have a 3.4 per cent, nonsignificant trend toward greater efficiency than the basal lot. The phenylarsonic acid-fed group showed similar tendencies, whereas aureomycin-fed pigs were 1 per cent less efficient than those on the basal ration. These results are in direct agreement with results of the previous experiment. Over-all sex differences in feed efficiency were considerably less than difference due to individual variation.

A marked variability in feed intake was evident as the aureomycin-fed group far exceeded the basal-fed group by consuming 37.8 per cent (2.08 pounds) more feed per day, which is significant at the 2.5 per cent probability level. The penicillin-fed group likewise showed an increase over the basal-fed group, amounting to 11.1 per cent. There was no stimulation in feed intake due to addition of phenylarsonic acid to the ration. It is extremely interesting to note that the weight gain data vary almost directly with the feed intake data. This point is illustrated in Figure 4.

Average dressing percentage data are as indicated:

Ration		Average Dressing Per Cent	Percentage of Basal
Lot 1	Basal	68.9	100
Lot 2	Basal + Penicillin	72.9	105.9
Lot 3	Basal + Aureomycin	71.6	103.8
Lot 4	Basal + Phenylarsonic Acid	71.2	103.2

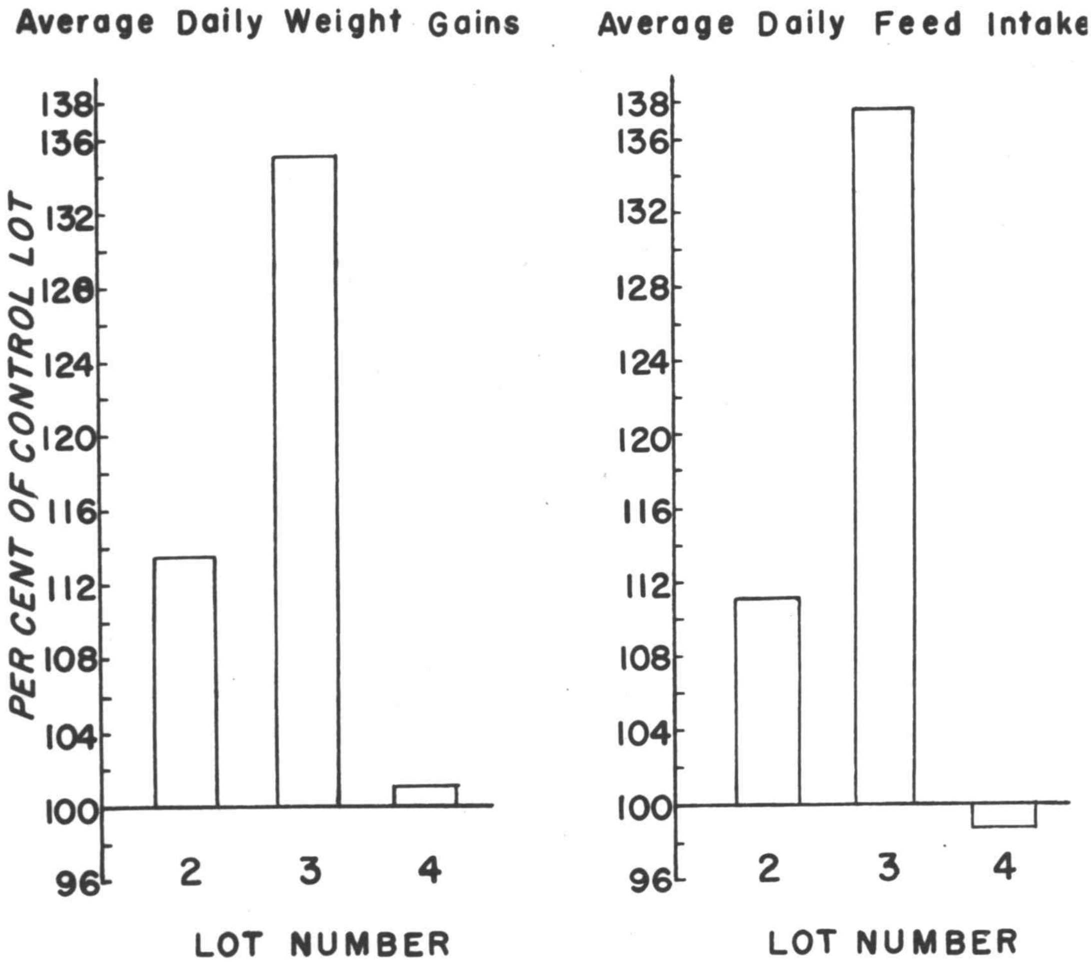
As all three antibacterial treatments exceeded the control ration in dressing percentage, the specific hypothesis that they were significantly higher than the controls was tested. This showed that there was a significant difference ($P < .10$) in this respect. There was also a significant difference ($P < .05$) in carcass dressing percentage due to the effect of sex, barrows dressing out 4.2 per cent more than gilts.

The results of this experiment indicate that antibiotic supplementation had a rather important effect on carcass fatness. The data analyzed as a factorial, split plot design, showed a statistically significant difference ($P < .05$) in the amount of back fat between the basal and

FIGURE 4

Relation between Rate of Gain and Feed Consumption

(Experiment 2)



2 - Penicillin Supplemented

3 - Aureomycin Supplemented

4 - Phenylarsonic Acid Supplemented

aureomycin-fed groups. As compared to the control group the aureomycin group had 14 per cent more backfat, the penicillin group 2 per cent more, and the arsonic acid group 5 per cent more.

Also interesting was the relationship between ration and location of fat deposition; which proved to be very highly significant ($P < .005$). Thus it appears that ration influenced not only depth but also location of fat deposits. It will be shown that this is probably an indirect result arising through a greater growth stimulus. Average fat depths (in inches) with regard to ration and location are listed below:

	Basal	Penicillin	Aureomycin	Arsonic Acid
First Rib	1.7	1.2	1.4	1.8
Tenth Rib	.9	.9	1.0	.9
Last Lumbar	1.3	1.9	2.0	1.4

Both antibiotic-fed groups have lowered fat deposits over the shoulders as compared with the basal and arsonic acid-fed groups, and increased fat over the loin area. Fat deposition in the arsonic acid-fed group is very similar to the basal group.

Individual concentrations of the several blood constituents measured are tabulated in Tables 6 and 7.

TABLE 6

Individual hemoglobin, blood calcium, and blood inorganic phosphorus levels in swine supplemented with antibiotics and phenylarsonic acid (Experiment II)

		Hemoglobin, gms/100 ml. blood			Blood Calcium, mg/100 ml. plasma			Inorganic Phosphorus, mg/100 ml. plasma		
Lot Number	Animal Number	Initial Concentration	Mid-trial Concentration	Final Concentration	Initial Concentration	Mid-trial Concentration	Final Concentration	Initial Concentration	Mid-Trial Concentration	Final Concentration
1 (Basal)	101	12.0	12.2	12.6	8.71	8.40	11.65	3.24	7.85	8.81
	112	11.4	11.7	12.1	10.18	9.03	12.49	5.59	7.22	10.78
	96	12.3	12.0	12.5	9.66	7.77	11.65	7.22	8.02	10.44
	108	12.2	13.2	15.2	7.77	7.98	11.65	3.24	7.32	8.25
Lot Average		12.0	12.3	13.1	9.08	8.30	11.86	4.82	7.60	9.57
2 (Penicillin)	95	11.0	12.6	13.4	6.30	6.93	11.44	3.64	8.21	8.78
	113	10.0	11.9	12.2	10.18	5.98	10.50	6.69	7.15	8.51
	109	11.5	12.1	12.0	9.66	7.56	11.65	6.53	8.39	9.93
	110	11.7	13.1	14.2	9.24	6.82	11.13	6.85	8.13	10.57
Lot Average		11.1	12.4	13.0	8.85	6.82	11.18	5.93	7.97	9.45
3 (Aureomycin)	93	12.4	13.3	14.2	7.40	8.82	12.18	3.29	6.52	8.43
	103	10.2	13.2	13.2	10.39	7.98	11.02	5.45	7.74	8.64
	107	10.8	12.2	12.5	8.82	7.45	11.23	4.71	7.42	8.90
	115	10.8	11.3	12.7	9.13	8.08	11.70	5.29	7.53	8.87
Lot Average		11.1	12.5	13.2	8.94	8.08	11.53	4.69	6.05	8.71
4 (Phenylarsonic Acid)	102	11.7	13.5	13.5	9.87	7.45	11.70	6.85	7.29	8.54
	105	11.2	11.7	12.8	10.29	7.14	11.44	6.10	7.95	8.27
	99	11.5	12.6	13.2	9.34	8.92	11.02	7.43	8.02	8.35
	116	11.7	12.5	12.5	10.50	6.51	11.97	7.65	7.22	9.56
Lot Average		11.5	12.6	13.0	10.00	7.51	11.53	7.01	7.62	8.68
Period Average		11.4	12.4	13.1	9.22	7.68	11.53	5.61	7.31	9.10

TABLE 7

Individual blood glucose, blood lipid phosphorus, and blood amino acid nitrogen levels in swine supplemented with antibiotics and phenylarsonic acid (Experiment II)

Lot Number	Animal Number	Blood Glucose, mg/100 ml. plasma			Lipid Phosphorus, mg/100 ml. plasma			Amino Acid Nitrogen, mg/100 ml. plasma		
		Initial Concentration	Mid-Trial Concentration	Final Concentration	Initial Concentration	Mid-Trial Concentration	Final Concentration	Initial Concentration	Mid-Trial Concentration	Final Concentration
1 (Basal)	101	126.90	61.25	41.70	7.75	11.41	14.70	8.98	12.29	9.54
	112	101.77	77.85	72.97	6.02	9.09	26.40	8.87	12.24	9.39
	96	70.95	54.22	55.87	8.75	9.59	24.20	8.67	11.47	9.76
	108	60.90	58.27	41.47	9.33	11.50	23.50	9.69	11.28	9.42
Lot Average		90.13	62.90	53.00	7.96	10.40	22.20	9.05	11.82	9.50
2 (Penicillin)	95	64.65	60.00	83.77	9.07	12.86	14.95	9.40	11.07	9.27
	113	76.12	56.32	65.17	9.86	11.50	29.91	8.84	13.44	9.02
	109	72.90	55.34	39.90	9.07	11.00	24.40	9.64	10.81	9.12
	110	68.02	55.27	39.37	9.33	11.18	20.82	8.80	12.38	9.32
Lot Average		70.42	56.73	57.05	9.33	11.64	22.52	9.17	11.93	9.14
3 (Aureomycin)	93	74.85	38.63	77.02	9.86	11.34	16.76	9.99	15.46	8.60
	103	61.57	42.22	69.67	11.45	13.87	17.10	9.28	12.52	9.17
	107	65.25	43.05	48.22	9.40	11.41	14.05	9.72	12.20	9.17
	115	86.70	40.75	64.65	9.66	12.36	23.45	10.04	11.37	8.49
Lot Average		72.09	41.16	64.89	10.09	12.25	17.84	9.76	12.89	8.86
4 (Phenylarsonic Acid)	102	53.40	58.20	60.82	9.40	10.84	27.25	7.85	11.30	10.56
	105	88.57	38.17	50.32	9.94	12.60	28.10	9.05	11.56	9.76
	99	54.60	42.60	62.02	9.07	12.60	24.70	8.67	11.28	9.50
	116	67.80	33.52	72.97	9.33	9.09	21.92	8.80	12.01	11.63
Lot Average		66.09	43.12	61.53	9.44	11.28	25.49	8.59	11.54	10.36
Period average		74.68	50.98	59.12	9.21	11.39	22.01	9.14	12.05	9.48

Hemoglobin levels due to differences in ration and sex were not significantly different, the over-all level being 12.3 grams hemoglobin per 100 ml. blood, a slightly higher figure than that (11.95) listed by Dukes (28, p. 36). The sex by treatment interaction term was significant ($P < .025$), as barrows fed aureomycin had 1.1 grams hemoglobin more than gilts of the same ration, whereas, in the basal and penicillin rations the reverse situation was true, gilts having on the average 0.7 grams more hemoglobin than barrows. There was a highly significant ($P < .005$) difference in hemoglobin levels due to the time they were taken. Initially the over-all concentrations were 11.4 grams hemoglobin per 100 mls. blood, mid-trial concentrations were 12.4 grams, and final samples were 13.1 grams hemoglobin.

Calcium levels of blood plasma showed no significant trends due to antibiotic supplementation. Values, averaging 9.46, were within the range of 9-15 mg. per cent in serum as listed by Dukes (28, p. 49). Again, period differences were highly significant ($P < .005$); the mid-trial concentration of 7.68 mg. calcium per 100 ml. plasma was lower than either the initial concentration of 9.22 mg. per 100 ml. or the final concentration of 11.53 mg. per 100 ml. The sexes were essentially equal in this respect.

Over-all blood phosphorus levels fell well within the normal range listed by Dukes (28, p. 49), although certain individual animals either exceeded or fell below this range. Treatment groups were quite similar with the exception of the aureomycin-fed group, which had a lower average blood phosphorus level than did the controls. This difference approaches but does not reach a statistical significance at the 5 per cent level of significance. Sampling period differences were again highly significant and show a steady increase from weaning to slaughter. Generally, gilts had a higher blood phosphorus level (7.54) than did barrows (7.15) on this experiment. This difference is not a significant one.

Normal blood glucose levels of swine are listed as ranging from 45-75 mg. per 100 ml. whole blood (28, p. 49). Glycemic levels for the four treatments were: Basal, 68.68 mg. per cent; Penicillin, 61.40 mg. per cent; Aureomycin, 59.38 mg. per cent; and Arsonic Acid, 56.92 mg. per cent. The basal group has a higher blood glucose level than any one of the antibacterial additives, however, this observation is not statistically significant. By period, average glucose levels were: Period I, 74.68 mg. per cent; Period II, 50.98 mg. per cent; Period III, 59.12 mg. per cent, reflecting a highly significant variability. A noticeable but nonsignificant difference was between barrows (average 66.75 mg. per 100 ml.) and gilts (average

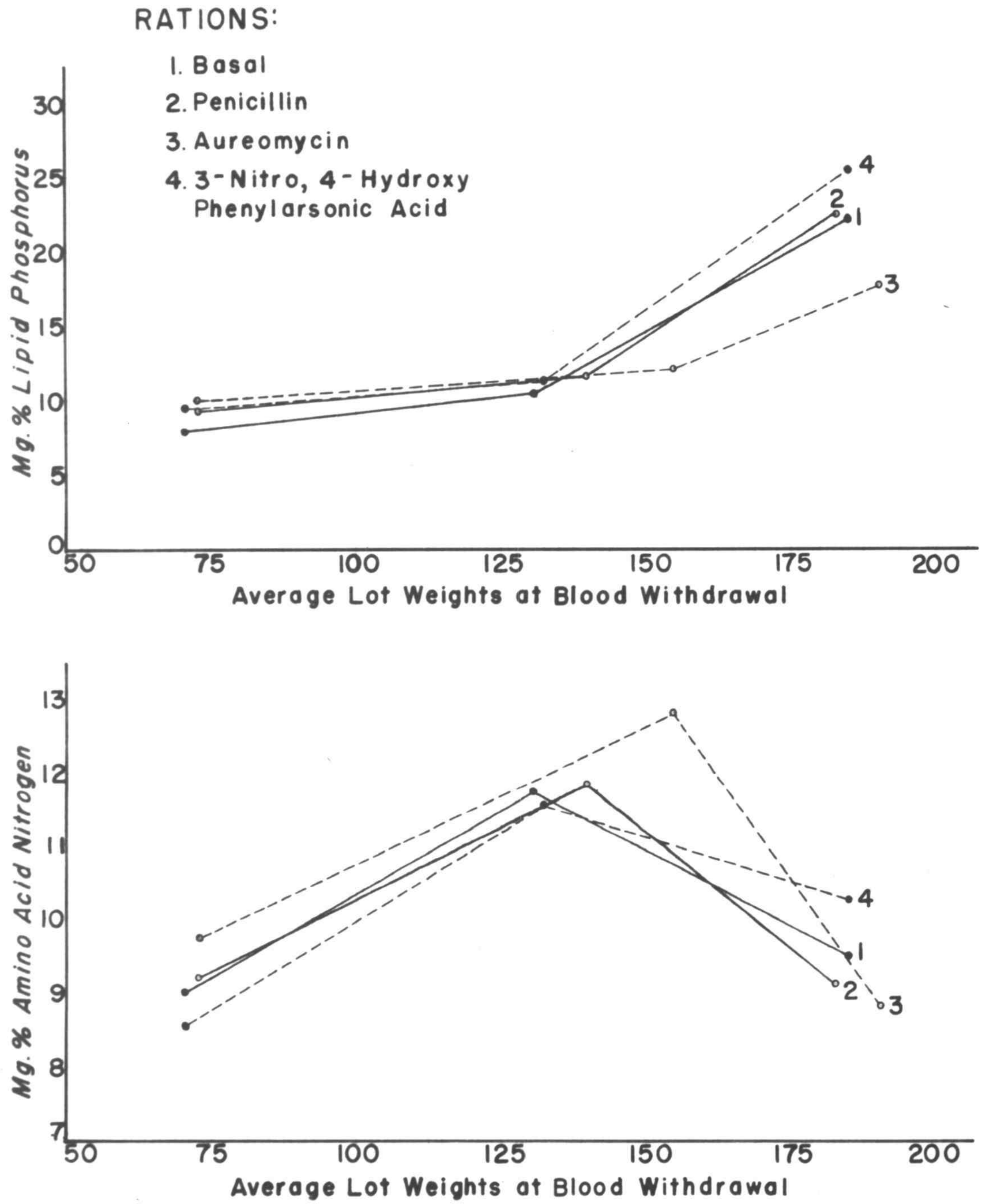
56.44 mg. per 100 ml.).

Plasma lipid phosphorus levels are plotted against weight at time of blood sampling in Figure 5. Aureomycin-fed pigs which reached slaughter weight earlier show lower lipid phosphorus levels, however this difference is not significant statistically. Differences due to periods were quite variable and were highly significant ($P < .005$). Initially, sampling values were lower although not greatly diverse from the mid-trial samples. Final samples were 139 per cent higher than initial samples and 104 per cent higher than mid-trial concentrations. The sex effect and various interaction effects were not significant.

Levels of blood amino acid nitrogen are illustrated in Figure 5, showing milligrams per cent amino acid nitrogen as related to the average ration group weight at the time of blood withdrawal. Overall values are approximately 2 mg. per cent higher than the "normal" value, 8 mg. per cent, listed by Dukes (28, p. 49). A statistically highly significant difference ($P < .005$) is the high levels observed at mid-trial as compared with the two other sampling periods. No statistically significant difference was evidenced due to the ration fed. Correlations between average rate of gain and the final amino acid nitrogen concentration showed a nonsignificant trend toward lower values for faster gaining hogs (-42.15).

FIGURE 5

Blood Metabolite Levels in Relation to Weight at Time of Sampling



Discussion

In this second trial both penicillin and aureomycin stimulated a greater growth response over the basal diet than was evident in the previous experiment. A probable explanation of this is the relatively lighter weight at which pigs on this experiment were started. Growth indices compounded from 215 experiments demonstrate that the lighter the animal at the beginning of the test, the greater the response elicited from antibiotic supplementation (8, p. 280). Another possibility is that the antibiotic growth response in Experiment I may have been lessened by the fact that the pigs were in newly-constructed pens. This agrees with Coates' observation (23, p. 44-47) that chicks in newly cleaned and disinfected quarters showed no response to antibiotics, whereas chicks reared in these same pens after the rearing of several groups showed an antibiotic growth response. The 13.5 per cent increase in daily weight gain by penicillin-fed pigs over the basal-fed group was 5.5 per cent higher than the average response obtained in 5 other trials where basal-fed hogs gained 1.5 pounds daily (8, p. 275). The average daily gain of 2.0 pounds made by aureomycin-supplemented swine was exceptional. Braude (8, p. 275) lists 11 per cent as an average response to aureomycin over a basal group gaining 1.5 pounds per day. The obvious sex differences in rate of weight gain present in the aureomycin group of Experiment I (males 31 per cent higher than females) has been reduced to a less obvious but still apparent 11 per cent, still suggesting a greater male potential.

Even more striking in this second experiment than in the previous one is the extreme parallelism between feed consumption and rate of gain. This relationship necessitates that feed efficiency values be similar; however, comparisons of efficiency of feed utilization perhaps cannot be directly made as the aureomycin-fed animals were shown to have significantly more backfat than the basal-fed animals. In the course of growing to equal weights, the animal laying down more fat is penalized as equally efficient, since energywise the cost of fat deposition is relatively more expensive. A gross stimulation of appetite amounting to an intake of 38 per cent more feed was evident in the aureomycin lot. Stimulation of the appetite control mechanism as a possible mode of action for antibiotics cannot be ignored, as based on the two experiments presented as well as many others, some of which have been reviewed. Yet as shown in the discussion of Experiment I, it cannot be assumed that appetite stimulation is positively a direct effect of antibiotic supplementation as the possibility also exists that it may be an indirect effect apparent only because of increased growth.

In this study, depth of backfat was significantly increased in aureomycin-supplemented swine, confirming similar reports by Bowland *et al.* (6, p. 635), Vestal (71, p. 8), and Perry *et al.* (56, p. 311-313), previously reviewed. Interesting to note, these experimenters also reported greatly increased daily weight gains and feed consumption. The results listed herein are in exact agreement. Kelly *et al.* (44, p. 81-82) report a statistically significant ($P < .05$) increase in backfat in aureomycin-supplemented barrows, accompanying a significantly increased ($P < .01$) weight gain. Gilts on the same ration neither gained more nor had greater backfat than did the control group. Hanson and co-workers (35, p. 40) state that in most research in which increased fat deposition has been reported due to the feeding of an antibiotic there has been increased feed consumption and increased rate of gain associated with fatter carcasses. They present data showing that vitamin B_{12} and aureomycin supplements when fed to pigs to 200 pounds produced 14 per cent more backfat which was associated with 12 per cent greater daily weight gain than pigs supplemented with vitamin B_{12} alone. Chemical determination of total carcass fat, however, revealed the latter group actually to be fatter. All of this information suggests rather strongly that aureomycin-supplemented hogs which are stimulated to greater feed consumption and therefore a higher nutritional plane quantitatively, have in general a greater deposition of subcutaneous fat over the dorsal area. This follows McMeekan's reasoning (50, p. 335-336) that fat deposition is dependent on the surplus nutrition available after prior claim by the more active tissues and is only restricted by feed consumption, and that subcutaneous fat is influenced to a greater degree than is intramuscular fat.

That rate of gain apparently influences site of fat deposit is shown by correlating the former with subcutaneous fat depth at the shoulder region and again at the loin region. Highly significant correlation coefficients ($P < .01$) obtained show that as rate of gain increases, anterior subcutaneous fat deposition is forfeited ($r = -.67$) and development of posterior subcutaneous fat is greatly favored ($r = .84$). Therefore, as both penicillin and aureomycin-fed pigs were better gainers than control and phenylarsonic acid-fed pigs, location of greatest fat depth was shifted. In short, the effect of antibiotics on fat deposition pattern in this study was probably an indirect one mediated through greater growth rates. It is possible that the antibiotic-fed hog, receiving an early growth stimulation, quickly passes through the initial anterior developmental period (resulting in lowered subcutaneous fat thickness anteriorly) and therefore reaches earlier the developmental stage favoring posterior development, hence greater fat depth posteriorly. This of course hinges on McMeekan's growth gradient theory of differential rates of growth in body parts at different times (50, p. 342-344).

Pigs receiving any one of the antibacterial supplements showed higher dressing percentages than pigs on the control ration. Others (6, p. 635; 56, p. 313-314; 35, p. 38; 44, p. 82-83) have reported a trend toward increased dressing percentage associated with higher daily gains and deeper backfat in swine fed aureomycin. Fatter carcasses are generally associated with higher dressing percentages by those in the meat trade.

The interpretation of the blood analysis data from this study has been hampered by the dearth of information on the subject available in the literature. In most of the various blood constituents examined there were no significant differences recorded due to the effect of antibiotic supplementation. This was due in a few instances to rather large individual variation rendering ration deviations unimportant, but mainly because individual uniformity was maintained throughout all experimental groups.

Hemoglobin content of the blood was similar to that noted during the previous experiment. There was an interaction of sex and treatment, males in the aureomycin group having higher hemoglobin levels than females, whereas in gilts on other groups the reverse situation was true. No definite conclusion can be drawn from these relationships, however, since they were not consistent in the two experiments. The overall average hemoglobin value increased 15 per cent during this experiment. This was a statistically significant gain, although somewhat lower than the 24 per cent gain recorded in Experiment I.

Plasma calcium levels reflect only minor variation and display no apparent trends, indicating that metabolism of this mineral is not altered due to the growth stimulus produced by aureomycin. These findings substantiate the statement of White, Handler, Smith, and Stetten (76, p. 816) that plasma calcium levels are under the control of a rigorous homeostatic mechanism. Gabuten and Shaffner (31, p. 52), however, noted that the blood calcium levels of chicks increased with increasing concentration of supplemented penicillin.

Inorganic phosphorus, likewise subject to homeostatic regulation, was not apparently altered by antibiotic supplementation nor growth increases. This suggests that growth stimulation is manifested in the soft tissues rather than in deposition of inorganic phosphates in the skeleton.

Average blood glucose levels of the three supplemented groups were noticeably lower than the average of the control group. Individual variation was marked and caused ration differences to be nonsignificant. Accounting for a portion of the individual variation in blood glucose levels would be the pig's reaction to the bleeding process. The release of epinephrine in those pigs that were highly excited would produce a prompt hyperglycemia, consequently affecting the results. As blood glucose levels have been implicated in the past as exerting some effect on appetite regulation, it was interesting to note that both groups exhibiting increased feed consumption and therefore increased appetites had lower blood glucose levels than did the control group. However the phenylarsonic acid-supplemented group had the lowest blood glucose level and ate slightly less than the control group.

Analysis of variance of lipid phosphorus data revealed no significant differences due to ration groups, though when values for the final period were correlated with average daily rate of gain a highly significant ($P < .01$) negative correlation was demonstrated ($r = -74.8$). This relationship signifies that faster gaining hogs had lower plasma lipid phosphorus levels. White, Handler, Smith and Stetten (76, p. 650) state that concentrations of various components of blood plasma represent at any given time a resultant of a number of physiological processes and that the nature and amount of a particular blood constituent is determined by (1) the rate at which the substance is being synthesized at its site of production, (2) the rate at which addition of the component to the blood takes place, and (3) the rate of utilization or removal of the substance from the blood by various tissues. It has been shown previously that faster gaining hogs consumed more feed than more slowly gaining animals. This greater feed consumption would allow for a more rapid addition of lipids to the blood stream and consequently higher blood levels. However, as blood phospholipid values were actually lower it must be assumed that removal of lipids from the blood is taking place at an even faster rate, indicating a greater rate of fat deposition. It will be noted that these observations are not in good agreement with the lipid phosphorus data of Experiment I, where the trend, although not significant, is towards higher blood phospholipid levels in faster gaining groups. Nor is it in accord with Dinusson (27, p. 327-328) who has reported higher blood lipid levels in faster gaining beef heifers. The extremely large average increase in blood lipid phosphorus levels at the final sampling period (139 per cent higher than initially) would appear to illustrate a point made by McMeekan (51, p. 548), namely that fattening occurs only after the nutrient demands by other tissues, e.g., bone and muscle, have been satisfied and therefore is a later occurring phenomenon.

Richardson _et al_. (57, p. 375) determined total nitrogen in the blood of male pigs weighing 75 pounds and found no difference due to supplementation with antibiotics, which is in good accord with observations of the experiment presented here. MacDonald (48, p. 111-112) reported that more slowly gaining beef cattle had higher blood amino acid nitrogen levels than faster gaining animals at either 500 or 800 pound weights. In the swine experiment reported herein, a correlation of average daily gain with final concentration of blood amino acid nitrogen resulted in a trend in this same direction, which was statistically nonsignificant. When rate of gain was correlated with mid-trial amino acid nitrogen concentrations the reverse situation was noted. Why this relationship should exist is not readily apparent.

SUMMARY

1. The effect of supplementing nutritionally adequate small grain rations with the proclaimed antibacterial growth stimulants: aureomycin, penicillin, and 3-nitro, 4-hydroxy phenylarsonic acid on growth, feed consumption, feed conversion, carcass measurements, and blood constituents has been investigated in two experiments involving 32 swine.

2. Growth rates of ration groups as measured by average daily gain (pounds) were as follows:

	Basal	Penicillin	Aureomycin	Phenylarsonic Acid
Experiment I	1.54	1.58	1.79	1.53
Experiment II	1.48	1.68	2.00*	1.49

*statistically significant at $P < .005$

A similar trend, although much more marked in Experiment II, is manifest in both experiments.

3. The greatest increase in rate of gain by the aureomycin-fed group over the basal-fed group occurred during the fourth week after the beginning of the experiment as based on growth curves.

4. Barrows gained significantly more than did gilts on Experiment I, a difference due largely to the

aureomycin-fed group (31 per cent difference). In Experiment II aureomycin-supplemented barrows exceeded gilts in rate of gain by 11 per cent, a nonsignificant difference.

5. Destruction of the added penicillin by pelleting and storage was 95 per cent and of the added aureomycin 40 per cent in Experiment I.

6. Efficiency of feed utilization was similar for all groups during both trials. Faster gaining groups consumed greater amounts of feed in direct proportion to their weight gain increases.

7. Backfat as measured at three locations showed aureomycin-fed hogs to have 14 per cent more backfat (statistically significant, $P < .05$) than basal-fed hogs.

8. Faster gaining groups (aureomycin and penicillin groups) showed highly statistically significantly ($P < .005$) less fat over the shoulder region and more fat over the loin region than animals on the control ration.

9. Dressing percentage values of all groups showed no statistically significant differences; however in Experiment II, barrows dressed out significantly higher ($P < .05$) than did gilts.

10. Groups supplemented with 3-nitro, 4-hydroxy phenylarsonic acid at either .00375 or .005 per cent levels very closely approximated the control group and did not deviate significantly in any of the observations made.

11. Hemoglobin levels were not affected by ration supplements nor sex, but increased consistently throughout the experimental period.

12. No differences were recorded in blood lipid phosphorus levels due to antibiotic supplementation, however in Experiment II correlations with rate of gain indicated faster gaining hogs had lower lipid phosphorus levels (r = 74.8, highly significant $P < .05$) as opposed to seemingly contrary observations in Experiment I.

13. Blood calcium did not vary as a result of any antibacterial supplementation to the ration.

14. A linear increase was noted in blood inorganic phosphorus levels during the course of the experiment for all hogs. Ration and sex differences were statistically nonsignificant.

15. Groups supplemented with the three antibacterial agents exhibited lower (statistically nonsignificant)

blood glucose levels than the control group.

16. Correlations of blood levels of amino acid nitrogen and rate of gain showed a nonsignificant trend towards lower values for faster gaining hogs. Differences due to ration groups were not significant statistically.

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A P P E N D I X

APPENDIX A

Experiment I

Analysis of variance of performance and carcass data

Source of Variation	Degrees of Freedom	Mean Squares: Total Weight Gain	Total Feed Consumption	Feed Efficiency	Dressing Percentage
Ration	3	341.08	4,550.8	84.01	1.0189
Basal vs. Penicillin	1	22.78	1,069.5	164.27	.4651
Basal vs. Aureomycin	1	731.53	9,800.0	1.07	1.9306
Basal vs. Phenylarsonic Acid	1	.41	18.0	1.07	.2592
Sex	1	973.44*	14,370.0	52.36	.2966
Ration-Sex Interaction	3	223.88	5,364.1	591.70	1.2111
Experimental Error	8	179.83	2,710.2	562.99	2.8509
Total	15	---	---	---	---
Adjusted Error[1]	11	191.84	3,433.99	570.82	2.4037

[1] Error adjusted by pooling with nonsignificant interaction term.

* Significant at P = .05.

APPENDIX A

Experiment I

Analysis of variance (split-plot design) of blood data

Source of Variation	Degrees of Freedom	Mean Squares: Hemoglobin	Mean Squares: Lipid Phosphorus
Ration	3	.405	2.069
Sex	1	.163	.031
Ration-Sex Interaction[1]	3	1.582	1.680
Period	2	24.094**	9.716*
Ration-Period Interaction	6	.683	1.414
Sex-Period Interaction	2	2.835	2.473
Ration-Sex-Period Interaction	6	.444	2.373
Experimental Error	24	1.252	1.920
Total	47	---	---
Adjusted Error[2]	30	1.090	2.010

1 Used as error term for testing significance of Ration and Sex.

2 Error adjusted by pooling with nonsignificant 3-way interaction term.

* Significant at P = .025

** Significant at P = .005

APPENDIX B

Experiment II

Analysis of variance of performance and carcass data

Source of Variation	Degrees of Freedom	Mean Squares: Average Daily Weight Gain	Average Daily Feed Intake	Feed Efficiency	Dressing Percentage
Ration	3	.23420**	3.9976	238.3	10.807
Basal vs. Penicillin	1	.07980	.8134	---	---
Basal vs. Aureomycin	1	.54392***	8.6882**	---	---
Basal vs. Phenylarsonic acid	1	.00063	.0099	---	---
Sex	1	.00774	.6848	575.4	33.931*
Ration-Sex Interaction	3	.02264	.0112	1,590.3	10.276
Experimental Error	8	.04432	1.6661	1,128.1	3.647
Total	15	---	---	---	---
Adjusted Error[1]	11	.03841	1.2147	1,254.1	5.455

[1] Error adjusted by pooling with nonsignificant interaction term.

* Significant at P = .05

** Significant at P = .025

*** Significant at P = .005

APPENDIX B

Experiment II

Analysis of variance (split-plot design) of carcass and blood data

Source of Variation	Degrees of Freedom	Mean Squares: Back Fat Depth	Hemoglobin	Blood Calcium	Blood Inorganic Phosphorus	Blood Glucose	Lipid Phosphorus	Amino Acid Nitrogen
Ration	3	.0791	.226	1.571	4.458	307.9	10.60	.423
Basal vs. Aureomycin	1	.2017*	----	----	4.327	----	----	.810
Sex	1	.0602	.110	.001	1.802	1,274.1	.11	.369
Ration-Sex Interaction[1]	3	.0147	2.186**	1.118	1.400	316.3	7.45	.474
Period (Location for Backfat Depth)	2	2.5431***	11.145***	60.085***	48.766***	2,321.3***	751.08***	40.200***
Ration-Period (Location)	6	.3429***	.331	.806	2.036	346.9	17.37	1.775**
Sex-Period (Location)	2	.0152	.214	.038	1.921	----	.78	1.518*
Ration-Sex-Period Interaction	6	.0838	.188	.134	.480	363.7	3.01	.281
Experimental Error	24	.0660	.617	.934	1.622	121.4	10.66	.592
Total	47	----	----	----	----	----	----	----
Adjusted Error[2]	30	.0696	.531	.774	1.394	169.9	9.13	.529

[1] Used as error term for testing significance of Ration and Sex.

[2] Error adjusted by pooling with nonsignificant 3-way interaction term.

* Significant at P = .05

** Significant at P = .025

*** Significant at P = .005