A COMPARISON OF VIRGINIAMYCIN AND A LACTOBACILLUS PROBIOTIC AS FEED ADDITIVES FOR SWINE, AND THE EFFECTS OF VIRGINIAMYCIN SUPPLEMENTATION AND CROWDING STRESS ON SWINE PERFORMANCE

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Chapter I

INTRODUCTION

Since their introduction in the early 1950's, antibiotic feed additives have been used extensively in animal production. Swine producers are particularly reliant on antibiotic feeding and it was estimated that in 1978 1.4 million kg of antibiotics or about 40% of the feed additives antibiotics produced in the United States were used in swine production (NRC, 1979). The primary benefits associated with feeding subtherapeutic levels of antibiotics to swine include improved rate of gain and feed efficiency. The response of these traits to antibiotic feeding is quite variable and may be related to the amount of stress imposed on the animal. Stresses which are often encountered in modern swine production systems include subclinical disease, transporting, mixing and overcrowding.

In recent years public concern over the use of antibiotics in animal feeds has increased. This concern in based primarily on the premise that antibiotic feeding may influence human health through the development of resistant microbial populations and through drug residues in meat for human consumption. The livestock industry has responded to these concerns by searching for alternatives to antibiotic feed additives as well as by developing antibiotics to be used specifically in animal feeds.

The search for alternatives to antibiotic feed additives has stimulated a renewed interest in lactobacillus probiotics as potential growth promotants in swine. These products consist of freeze dried cultures of lactic acid producing bacteria, primarily *Lactobacillus acidophilus*. At the present time several of these products are commercially available for use in swine diets.

Several antibiotics have been developed solely for use in animal feeds. Included in this group is virginiamycin, a gram positive antibiotic produced by *Streptomyces virginiae*. This antibiotic was approved by the United States Food and Drug Administration for usage in swine feeds in December, 1974.

The work presented in this thesis was conducted to: 1) compare the feedlot performance of swine fed diets containing a commercially available lactobacillus probiotic and virginiamycin, an antibiotic developed for use in animal feeds, and 2) to evaluate the feedlot performance of swine housed under conditions of restricted and adequate space allowance fed diets with and without virginiamycin.

Chapter II

REVIEW OF LITERATURE

EFFICACY OF VIRGINIAMYCIN IN SWINE DIETS

Effects on Feedlot Performance

During the early 1960's several swine researchers reported that virginiamycin supplementation improved feedlot performance of young, growing swine (Barnhart et al., 1960; Griffin et al., 1961; Miller and Barnhart, 1961; Griffin and Lidvall, 1962). More recently, Miller et al. (1972) reported improvements in growth rate of 16.5 and 19.2% in growing pigs fed 11 and 44 ppm virginiamycin, respectively. Later work by Hays et al. (1973) demonstrated a linear improvement in daily gain and feed efficiency in growing pigs fed 0, 22 and 88 ppm virginiamycin. Linear improvements with increasing virginiamycin levels up to 88 ppm have also been reported by Cromwell et al. (1975), but the major portion of the response was obtained at a level of 11 ppm. Russett et al. (1976) reported an 8.2% improvement in rate of gain with both 27.5 and 55 ppm levels of virginiamycin. A similar response was obtained with 11 ppm by Edgerton (1975) who reported increases of 7.5% in daily gain and 5.9% in feed efficiency up to 55 kg of body weight.

As with other antibiotics, the response to virginiamycin is lower over the finisher and grower-finisher phases than during the starter-grower phase. Krider et al. (1975a) reported that 5.5 and 11 ppm virginiamycin significantly improved performance during the initial 90 days of the grower phase, but improvements were only slight and nonsignificant from 55 to 91 kg of body weight. In a review of some European research, Oakley (1976) indicated a 3.9% improvement in daily gain and a 3.0% improvement in feed efficiency for finishing pigs fed 5 ppm virginiamycin. In another study, 10 ppm virginiamycin improved daily gain 2.9% and feed efficiency 1.6% during the combined growing-finishing phases (Barber et al., 1978). These responses are lower than those obtained by Langlois et al. (1978) and Plumlee et al. (1981b) who reported improvements of 6.8 and 7.6% in daily gain and 4.7 and 3.0% in feed efficiency, respectively, for growing pigs fed to market weight. In contrast to these improvements, Powley et al. (1981) reported no response to 27.5 ppm virginiamycin during the growing phase or to 11 ppm during the finishing phase.

The response to virginiamycin, as with other antibiotics, varies considerably among different studies. Several factors have been implicated that could contribute to this variation in responses to antibiotic feeding; they include performance of the control pigs, type and cleanliness of facilities and overall health of the pigs (Braude et al., 1953; Melliere et al., 1973; Natz, 1973). In an effort to determine the average expected response to various antibiotic feed additives under research conditions, Hays (1978) pooled the data from many journal articles and field day reports. The response to virginiamycin above control pig performance was 11.0% in daily gain and 5.02% in feed efficiency for starter pigs (start to 16 kg body weight), 10.69% in daily gain and 6.6% in feed efficiency for grower pigs (16 to 57 kg body weight) and 5.73% in daily gain and 3.25% in feed efficiency for growing-finishing pigs (16 kg to market weight).

Effects in Conjunction with Other Dietary Variations

At least three researchers have evaluated the effects of virginiamycin supplementation in combination with growth promotant levels of copper. Barber et al. (1978) individually fed growing-finishing pigs 0 or 250 ppm dietary copper sulfate and 0 or 10 ppm virginiamycin in a 2 x 2 factorial design. The main effects of this experiment showed slight but significant improvements of 1.9 and 2.9% in daily gain and 2.8 and 1.6% in feed efficiency for copper and virginiamycin supplementation, respectively. The interaction was not significant, but the data suggested an additive effect of copper and virginiamycin. To the contrary, de Lima et al. (1977) reported that feeding combinations of virginiamycin (27.5 ppm) and copper (250 ppm) to growing-finishing pigs did not result in improvements beyond that obtained with either additive fed alone. Stahly et al. (1980), with a similar design using weaned pigs, also reported improved gains and feed efficiency with dietary copper (250 ppm) and virginiamycin (27.5 ppm) while only copper supplementation improved pig survival rate. An additive effect of copper and virginiamycin was observed with the combination of the two supplements yielding improvements over either fed alone in growth rate (9.7%) and feed efficiency (4.3%).

Jones and Pond (1963) fed growing pigs a 12% crude protein basal diet in a factorial design with supplemental L-lysine (.16%) and virginiamycin (44 ppm). In the combined analysis of three trials, both lysine and virginiamycin improved rate of gain with no interaction between the two supplements. Pelura III et al. (1980) reported that 44 ppm virginiamycin improved rate of gain in growing pigs fed either an

18% crude protein diet or a 15% crude protein diet plus .22% L-lysine but not in pigs fed a 15% crude protein diet. In contrast to this interaction, Veum and Jewell (1981) reported that virginiamycin improved daily gain in starter-grower-finisher pigs fed a low (1.02%, .81%, .66%) lysine sequence but not when fed a high (1.13%, .90%, .73%) lysine sequence. Castell (1977) varied the protein source with rapeseed meal or soybean meal in grower-finisher diets supplemented with and without virginiamycin (11 ppm). Virginiamycin improved daily gain 4.6% and, although the interaction was not significant, the improvement was greater with soybean meal (5.5%) than with rapeseed meal (3.6%).

The interactive effects of dietary fiber level and virginiamycin on pig performance has been investigated. Cromwell et al. (1981) fed growing-finishing pigs 0, 5, 10, 15 or 20% dried brewers grains with 0 or 11 ppm virginiamycin. Growth rate was depressed with diets containing high levels of brewers grains (15 and 20%) without virginiamycin, but was not when virginiamycin was included in the diet. Powley et al. (1981), however, reported no interactive effect between additional dietary fiber and virginiamycin (27.5 ppm) on performance of growing pigs. In this experiment, alfalfa meal was used as the fiber source.

Potential Modes of Action

Most research suggests that improvements in performance with virginiamycin are due to a nutrient sparing effect. Through this mode of action antibiotics in the digestive tract may favor the growth of desirable organisms which synthesize vitamins or amino acids, depress organisms which compete with the host animal for nutrients and (or) improve the absorptive capacity of the intestinal tract (Hays, 1978). Virginiamycin has been shown to depress intestinal lactobacilli in vivo in the chick (Eyssen et al., 1962) and both in vitro and in vivo in the pig (De Mey et al., 1976; Anonymous, 1981). Veryaeke et al. (1979) reported that the depressed intestinal lactobacilli population in pigs fed virginiamycin resulted in a depression in lactic acid production and thus reduced carbohydrate fermentation by these microbes. By combining both in vivo and in vitro data, these workers calculated that 50 ppm dietary virginiamycin results in 2.68% more net energy being available for growth in the pig. In addition to repression of carbohydrate fermentation by lactobacilli, Hedde (1981) reported that virginiamycin enhances production of the more efficiently utilized volatile fatty acid, propionic acid, in the cecum of the growing pig.

Indirect evidence of nutrient sparing with virginiamycin supplementation has also been demonstrated with balance trials. Ewan (1981) reported that 11 ppm virginiamycin improved apparent energy and nitrogen digestibilities in growing pigs. This agrees with work by Ravindran et al. (1982) who reported that gilts fed a high fiber diet (7.29%) had improved digestibility of dry matter, energy and nitrogen when fed virginiamycin. Improved energy digestibility with supplemental virginiamycin has also been demonstrated in chicks (March et al., 1978) as well as reduced fecal fat excretion (Eyssen and De Somer, 1963).

Data explaining improved nitrogen digestibility with virginiamycin is limited. Dierick et al. (1980) reported that with virginiamycin treatments, resorption of amino acids was improved by 8% in an isolated segment of the pig ileum.

Still other work suggests that improved performance with virginiamycin may be, at least in part, due to a slowing of the rate of ingesta passage. While considerable variation among individual animals occurs, two researchers have presented data indicating that inclusion of virginiamycin in swine diets slows the average rate of ingesta passage (Fausch, 1981; Ravindran et al., 1982).

Summary

In most cases inclusion of virginiamycin in swine diets results in improved rate of gain and feed efficiency. According to the review by Hays (1978) virginiamycin supplementation improves growth rate in starter, grower and grower-finisher pigs 11.0, 10.7 and 5.7%, respectively, while improvements in feed efficiency are 5.0, 6.6 and 3.2%. Responses, however, to the antibiotic did vary among different trials. Furthermore, the reports suggest that most of the response to virginiamycin can be obtained at doses as low as 11 ppm. Also, while results are not consistent, the degree of response to virginiamycin can be influenced by certain dietary variations such as protein (amino acid) and fiber levels. The potential mode of action of virginiamycin which has the most research support is that nutritional doses of this antibiotic suppress intestinal lactobacilli which compete with the host animal for nutrients.

EFFICACY OF LACTOBACILLUS PROBIOTICS IN SWINE DIETS

Effects on Feedlot Performance

Several feeding trials have been conducted with weanling pigs to evaluate lactobacillus probiotics. Reported results, however, are inconsistent and the efficacy of lactobacillus probiotics in this class of swine has not been fully elucidated. In 1975, Hughs reported that the addition of 400 ppm of a dried Lactobacillus species culture to the diets of starter pigs did not improve rate or efficiency of gain. Other workers have also reported no response in starter pigs fed 500 ppm (Holden, 1976; Combs and Copelin, 1981) or 1500 ppm (Mahan and Newland, 1976) of a dietary lactobacillus probiotic. Furthermore, supplementation of lactobacillus probiotic (1500 ppm) caused a significant reduction in average daily gain in one of two starter trials conducted by Cline et al. (1976). No explanation for this reduced performance was given. Still other workers have reported slight but nonsignificant improvements in daily gain and feed efficiency in starter pigs fed diets supplemented with lactobacillus probiotics (Tanksley et al., 1978; Noland et al., 1978; Pollmann et al., 1980b). In contrast, Pollmann et al. (1980a) reported that supplementing weaned pig diets with 750 ppm of a dried lactobacillus probiotic resulted in significant improvements of 9.7 and 4.4% in daily gain and feed efficiency, respectively. Additionally, significant improvements of 2% in daily gain (Handlin et al., 1978) and 8% in feed efficiency (Hale and Newton, 1979) of starter pigs have been documented. Two European researchers have also evaluated a dried lacto-bacillus probiotic in starter diets, but no comparison with a negative control diet was made (Stekar and Rotar, 1977). These workers did report, however, that the daily gain of pigs fed the probiotic was 15.8% lower than that for pigs fed the antibiotic carbadox.

Most researchers have reported that the addition of 500 to 2000 ppm of lactobacillus probiotics to growing-finishing swine diets does not result in improvements in either rate or efficiency of gain (Hines and

Koch, 1971; Hale and Newton, 1979; Pollman et al., 1980a; Wahlstrom and Libal, 1981). Kornegay and Thomas (1973) reported on a grower trial in which a lactobacillus probiotic significantly improved feed intake, but daily gain and feed efficiency were not affected. Slight, nonsignificant improvements in daily gain and feed efficiency in growing-finishing pigs fed lactobacillus probiotics have been obtained by Baird (1978). King (1968), however, reported that the feeding of a lactobacillus probiotic significantly improved weekly gains 3.1% and feed efficiency 3.6% in growing pigs (50 to 68 kg of body weight).

Effects in Conjugation with Other Feed Additives and Dietary Variations

The interactive effects of lactobacillus probiotics and feed additive antibiotics on pig performance have been investigated by some researchers. Baird (1977) reported that both antibiotics and lactobacillus probiotics fed alone improved rate and efficiency of gain in feeder pigs, but that the two additives fed in combination did not result in an additive response. The antibiotics used in these trials were not specified. Pollman et al. (1980a) conducted an experiment with starter pigs using a lactobacillus probiotic in a 2 x 4 factorial arrangement with the antibiotic feed additives, ASP-250[1], lincomycin and tylosin. Results of this work showed that antibiotics, regardless of source, and lactobacillus probiotics fed alone improved the feedlot performance of weaned pigs and that there was a trend for an additive effect of lincomycin and lactobacillus probiotic. These same workers reported that feeding virginiamycin and (or) lactobacillus probiotic to growing-

[1]Contains 40% chlortetracycline, 40% sulfamethazine and 20% penicillin.

finishing pigs resulted in no interactive effects. Furthermore, Combs and Copelin (1981) reported no interactive effects of ASP-250 and lactobacillus probiotics in starter pigs.

Lactobacillus probiotics have also been evaluated in conjunction with certain nutrient variations. Protein level and lactobacillus probiotic supplementation have been shown not to interact in growing-finishing trials (Hines and Koch, 1971; Wahstrom and Libal, 1981). Furthermore, starter trials with diets containing 0 or 10% lactose and 0 or 1000 ppm lactobacillus probiotic resulted in no significant interaction between these two additives (Pollmann et al., 1980b).

Potential Modes of Action

It has been suggested that feeding or dosing swine with lactobacillus probiotics may result in a more desirable microflora in the gastrointestinal tract and subsequent prevention or control of enteric disturbances (Parker, 1975; Moon, 1975). Kohler and Boh (1964) reported that oral doses of lactobacillus acidophilus milk was partially effective in preventing diarrhea in newborn pigs, but a dried culture of lactobacillus acidophilus was not. Effective treatment of diarrhea in young pigs with lactobacillus acidophilus milk has also been reported (Redmond and Moore, 1965). Studies indicate that control and treatment of enteric disturbances in pigs with lactobacillus is related to an increase in lactobacilli with a concurrent decrease in coliforms within the gastrointestinal tract. Hill et al. (1970) demonstrated that feeding lactobacillus acidophilus milk reduced the amount of toxic amine synthesis associated with colibacillosis in the small intestines of the young pig. Feeding piglets a frozen concentrate of Lactobacillus lactis has been reported by Muralidhara et al. (1977) to increase the lactobacillus to coliform ratio 640 fold and significantly decrease the incidence of colibacillary diarrhea. Furthermore, microbiological studies indicated large numbers of gram-positive bacilli throughout the small intestine of lactobacillus fed piglets while scouring control piglets had many coliform bacteria present. Increased intestinal lactobacilli with a concurrent decrease in coliforms has also been demonstrated in chicks supplemented with a lactobacillus culture via the drinking water (Tortuero, 1973). To the contrary, Pollmann et al. (1980c) reported that inoculation of piglets with a lactobacillus culture increased both lactobacilli and coliforms of the cardiac region of the stomach.

The production of antibiotic substances by Lactobacillus bacteria has been demonstrated in vitro (Shahani et al., 1976; 1977) and this may be involved in the mode of action for lactobacilli benefits. Antibiotic production by Lactobacilli, however, has not been demonstrated in the intestinal tract of animals.

Also suggested as a potential mode of action for lactobacilli benefits is the production of lactic acid by these microorganisms with concomitant reduction in intestinal pH (Herrick, 1972). Supplementing the young pig's diet with lactic acid has been reported to reduce the severity of scouring (White et al., 1969) and to improve feed conversion (Pollmann et al., 1980a).

Summary

In some cases feeding lactobacillus probiotics to starter pigs has resulted in improvements of up to 9.7% in rate of gain and 8% in feed efficiency. Most studies, however, have shown no response or only a slight improvement in starter pig performance. Also, most studies have shown no improvement in growing-finishing pig performance with added lactobacillus probiotics. The limited reports available suggest that feeding lactobacillus probiotics and antibiotic feed additives do not result in interactive or additive effects on feedlot performance. Also, there appears to be no interactive effects of protein level or lactose supplementation (10%) and lactobacillus probiotics. The potential mode of action for lactobacillus probiotic benefits which has received the most attention is the establishment of a more desirable microflora in the gastrointestinal tract with subsequent prevention or control of enteric disturbances.

THE EFFECTS OF CROWDING STRESS ON SWINE PERFORMANCE

The crowding stress that often occurs in intensive swine confinement systems consists primarily of two elements: a decreased amount of space per pig and an increased number of pigs per group (Randolph et al., 1981). Both of these factors may effect swine feedlot performance.

Effects on Starter Pigs

Several researchers have investigated the effects of crowding stress on starter pigs reared in conventional nursery pens with slotted floors and elevated pens with perforated floors. Jensen et al. (1966) conducted a feeding trial in which the number of pigs per pen was four, six or eight and the floor space allowance was .21, .28 or .35 m^2 per pig. Group size had no effect on performance, but pigs allowed .21 m^2 of floor space grew slower and consumed less feed than those allowed .28 and .35 m^2. In a second trial these workers reported that nursery groups of 24 pigs per pen consumed less feed and had a slightly lower rate of gain than did groups of eight or 16 pigs per pen when floor space allowance per pig was equal across treatments at .3 m^2. This agrees with the results of Suss et al. (1977) in which groups of 20 and 30 pigs performed poorer than groups of 10 and 15 when space per pig was equal across treatments. McConnel et al. (1981) also reported a trend for decreased performance in starter pigs as group size increased from eight to 16 to 24 pigs. In 1980, Combs and Copelin reported that groups of 12 and 24 pigs allowed .19 m^2 of floor space per pig grew 7.6% slower and consumed 7.6% less feed from 10 to 26 kg of body weight than did groups of eight and 16 pigs allowed .28 m^2 of floor space per pig. No significant effect of group size was obtained in these trials. Lindval (1981) reported the findings of a study in which eight, 12 or 16 pigs were housed in pens of equal size. Space allowance per pig was .25, .17 and .13 m^2, respectively. A 7.7% depression in average daily gain was observed for 12 pigs per pen and 20.1% for 16 pigs per pen as compared with pigs reared in groups of eight per pen. Feed efficiency was not significantly affected by number of pigs per pen because crowded pigs had lower feed intakes. Brent et al. (1975) suggested that the required floor space allowance per weaned pig on partially or totally slotted floors is .09 m^2 per 12 kg of body weight.

The use of wire cages arranged in batteries or tiers has been shown to be an efficient means of rearing weaned pigs (Kornegay et al., 1979a, b) and several studies have investigated the effect of crowding on starter pigs in this type of facility. Le Dividich (1979), using 1.2 x 1.2 m cages, reported a significant depression in average daily gain and average daily feed intake when eight pigs were housed per cage as compared to six and four pigs per cage. This researcher also suggested that the minimum floor space requirement for optimum performance of starter pigs from 5 to 27 kg of body weight was .25 m^2 per pig. Also using 1.2 x 1.2 m triple decked nursery cages, Kornegay et al. (1980) reported that after seven weeks in the nursery, pigs caged in groups of 10 had significantly lower body weights and average daily gains than did pigs caged in groups of eight or six per cage. In a second study using similar decked cages (Kornegay et al. (1981), pigs caged in groups of 12 had significantly lower body weights than pigs caged in groups of six after five weeks in the nursery while groups of nine pigs per cage had intermediate body weights. Furthermore, average daily gain and daily feed intake was progressively lower at the end of the six week trial as the number of pigs increased from six to nine to 12 per pen. Based on these studies, Kornegay et al. (1980; 1981) suggested that a maximum of 10 pigs (.144 m^2/pig) may be housed per 1.2 x 1.2 m nursery cage from 5 to 12 kg of body weight and that a maximum of eight pigs (.18 m^2/pig) may be housed from 12 to 22 kg of body weight.

Effects on Growing-Finishing Pigs

Much of the early work on space allowance and group size effects on growing-finishing pigs reared in confinement involved trials utilizing pens with solid concrete floors. In 1959, Noland et al. reported that growing-finishing pigs allowed 1.48 m^2 of concrete floor space per pig in an open fronted building grew faster and more efficiently than did pigs allowed .74 m^2, but increasing space allowance to 2.23 m^2 was of no additional benefit. Wingert and Knodt (1960) reported that pigs fed from 66 to 91 kg of body weight had average daily gains of .73, .91 and .96 kg and feed per gain ratios of 4.28, 3.57 and 3.39 for concrete floor space allowances per pig of .91, 1.37 and 1.82 m^2, respectively. These workers also reported that the incidence of structural unsoundness was greatest for pigs housed with .91 m^2 of floor space per pig. Heitman et al. (1961) conducted growing-finishing trials utilizing a 3 x 3 factorial design with space allotments of .46, .93 and 1.86 m^2 per pig and group sizes per pen of three, six and 12 pigs. Results of this work indicated that pigs allowed 1.86 m^2 of floor space per pig grew 6% faster than those allowed .93 m^2 and 10.5% faster than those allowed .46 m^2. Space allowance had no significant effect on feed intake but feed efficiency was poorest for pigs allowed .46 m^2 of space per pig. Group size did not affect gains in this study, but pigs in groups of 3 consumed significantly more feed and thus had poorer feed efficiencies than pigs reared in groups of six or 12. A similar response to restricted space allowance has been reported by Hugh and Reimer (1967). More recently, Randolph et al. (1981) reported that growth rate of growing-finishing pigs decreased as space allowance per pig decreased from 1.64 m^2 to .82 m^2 per pig. Furthermore, these workers suggested that space allowance has a greater effect on feedlot performance than does group size.

The effects of floor space allowance and group size on the performance of growing-finishing swine confined to pens with partially or totally slotted floors has also been investigated. In an effort to develop space allowance recommendations for growing-finishing swine confined on slotted floors, Gehlbach et al. (1966) conducted feeding trials utilizing three different sequences of floor space allowance. Results indicated that, for pigs fed up to 50 kg of body weight, .18 m^2 of floor space per pig resulted in a significant depression in daily gain as compared to .36 and .54 m^2 of floor space. Furthermore, .36 m^2 of floor space per pig depressed gains as compared to .54 and .72 m^2 from 50 to 70 kg of body weight and .54 m^2 depressed gains compared to .72 and .90 m^2 from 70 to 90 kg of body weight when the mean barn temperature was relatively high (26 C). However, no significant differences in gains were observed among these space allowances when the mean barn temperature was low (21 C) which indicated that season or temperature can affect the optimum space requirement. These workers also reported that the first noticeable response to crowding stress is a reduction in voluntary feed intake. These results were later confirmed by Jensen et al. (1973), who also reported that the response to suboptimal space allowance was similar for both barrows and gilts. Hanke and Mead (1971a, b) also reported that the response to crowding stress is not significantly influenced by sex. Other studies have indicated that feed efficiency may also be depressed when growing-finishing pigs on slotted floors are not provided with adequate space allowance (Krider et al., 1975b; Plumlee et al., 1976).

The effects of group size with feeder and floor space per pig held constant has been inconsistent. Plumlee et al. (1976) reported that group size had no effect on the performance of growing-finishing pigs on slotted floors while Jensen and Curtis (1976) reported a reduction in feed efficiency in finishing pigs housed in groups of 16 as compared to groups of eight. Miller (1976) reported that groups of 24 growing-finishing pigs gained faster than groups of 12 and suggested that pen shape may have been involved in this response.

Behavioral and Health Effects

Krider et al. (1975b) reported that growing-finishing pigs reared with restricted space allowance spent a greater percentage of time lying and a lower percentage of time standing than did pigs allowed adequate floor space. In contrast, Ross and Curtis (1976), using growing pigs, reported that pigs with adequate floor space spent 23% more time lying and suggested that increased aggressive behavior for pigs with restricted space may have prevented prolonged lying periods. These workers also reported twice as much locomotor activity with adequate space allowance. In most studies, the percentage of time spent feeding and drinking was not affected by space allowance, but, similar feeding times do not necessarily result in similar feed intakes (Bryant and Ewbank, 1974; Ross and Curtis, 1976).

Decreasing the floor space allowance per pig with group size held constant has been shown to increase the aggressive behavior of growing pigs, with pigs of the lower sector of the peck order participating in more offensive and retaliatory fights (Ewbank and Bryant, 1972). Increased group size with space per pig held constant has also been reported to increase aggressive behavior, but retaliations by lower peck order pigs was less frequent (Bryant and Ewbank, 1972). Randolph et al. (1981) has also reported increased aggressive behavior in growing and growing-finishing pigs as crowding stress increased.

Some studies also indicate that cannibalism may be affected by crowding. Krider et al. (1975b) reported on a trial in which the incidence and severity of tail biting tended to be greater in growing-finishing pigs allowed .43 m^2 of floor space per pig as compared to those allowed .63 m^2. Docking tails, however, alleviated this problem at both space allowances. Similar crowding levels have been shown to increase the incidence and severity of cannibalism when a protein deficient diet was fed but not when protein level was adequate (Plumlee et al., 1976).

Additionally, crowding stress has been shown to increase the incidence and severity of gastric ulcers in growing-finishing pigs (Pickett et al., 1969; Pond and Maner, 1974).

Summary

The minimum pen space allowance for optimum performance is directly related to the size of the pigs. Substantial decreases in the feedlot performance of starter pigs housed in conventional slotted floor pens and battery cages will occur at per pig space allowances below .14 m^2 from 5 to 12 kg of body weight, .18 m^2 from 12 to 22 kg and .25 m^2 from 5 to 30 kg. Minimum floor space allowances for growing-finishing pigs on partially or totally slotted floors are approximately .36 m^2 from 18 to 46 kg of body weight, .54 m^2 from 46 to 68 kg and .72 m^2 from 68 to 96 kg. Requirements for this class of swine on solid concrete floors is greater being about .54, .81 and 1.08 m^2 for similar weight ranges, respectively. Group size within a pen can also affect feedlot performance and studies indicate that starter pig performance may be depressed as group size increases beyond 16 pigs per pen. Results of group size on growing-finishing pig performance are inconsistent and thus less conclusive. It appears, however, that the effect of group size on swine performance is apparently not as great as that of space allowance alone. Furthermore, other factors such as temperature and pen shape may affect the response to space allocation and group size. Most studies have associated the depressed gains in crowded pigs with a decrease in voluntary feed intake, but some studies show that feed efficiency can also be adversely affected. Finally, crowding may decrease movement and increase aggressive behavior of pigs as well as increase the incidence and severity of gastric ulcers.

INTERACTIVE EFFECTS OF ANTIBIOTICS AND SPACE ALLOWANCE

Effects in Starter Pigs

Most experiments investigating the interactive effects of antibiotics and space allowance on the performance of starter pigs have utilized factorial designs with various space allowances and 0 or 250 ppm of the triple combination antibiotic ASP-250 (contains 40% chlortetracycline, 40% sulfamethazine and 20% penicillin). Leibbrandt (1981) varied space allowance per weaned pig by housing either 5 (.28 m^2/pig) or 14 (.09 m^2/pig) pigs in 1.2 x 1.2 m nursery pens and fed diets with or without ASP-250. Daily gain, feed intake and feed efficiency were depressed with restricted space allowance and daily gain and feed intake were improved with antibiotic supplementation. No significant space allowance by antibiotic interaction was obtained. Although ASP-250 supplementation improved performance of crowded pigs, crowded pigs still did not perform as well as pigs not fed antibiotic with adequate space allowance. Similarly, Libal et al. (1981) reported a 5.9% reduction in weight gain and a 10.7% reduction in feed efficiency when floor space was restricted (.14 vs .23 m^2/pig) and improvements of

7.7% in weight gain and 8.8% in feed efficiency with ASP-250 supplementation. Additionally, these workers obtained a significant space allowance by antibiotic interaction with ASP-250 supplementation improving feed efficiency in crowded pigs but not in pigs with adequate space allowance. Using similar treatments, Hogberg et al. (1981) reported the same interactive effect on feed efficiency.

Other workers have conducted starter trials with ASP-250 and space allowance as factors in which space allowance was varied by changing pen size with the number of pigs per pen held constant. Adjusting space allowance in this manner, Wilson et al. (1981) reported that ASP-250 supplementation improved daily gains of starter pigs when space allowance was .23 m^2 per pig but not when space allowance was .14 m^2 per pig. Hines (1981), using the above treatments with a third space allowance of .33 m^2 per pig, reported a 10% reduction in daily gain with .14 m^2 of floor space per pig as compared with .23 m^2 and .33 m^2 and a 10% increase in daily gain with ASP-250 supplementation. The interactive effects and other main effect differences were not significant.

Effects in Growing-Finishing Pigs

Research investigating the interactive effects of antibiotics and space allowance on growing-finishing pig performance is very limited. Plumlee et al. (1981b) conducted a growing-finishing trial in which the number of pigs per pen was varied such that floor space per pig was .43 or .63 m^2. Dietary antibiotic treatments included a control with no antibiotic during the entire trial, 4.4 ppm bambermycin during the growing phase followed by 2.2 ppm during the finishing phase and 44 ppm tylosin during the growing phase followed by 22 ppm during the finishing phase. Over the entire trial, tylosin supplementation produced a significant improvement of 3.7% in daily gain while bambermycin fed pigs gained slightly less than the controls. Space restriction significantly depressed gains 8.3% and the overall response to antibiotic was not affected by crowding stress. During the growing phase (35 to 55 kg) of this trial, however, tylosin significantly improved gains and the response appeared to be greater for pigs given .63 m^2 of floor space (16.1%) than for those given .43 m^2 of floor space (11.9%).

Summary

Although limited in number, studies investigating the interactive effects of antibiotics and space allowance are in consensus with studies dealing with each of these elements alone in that supplemental antibiotics will generally improve swine performance and restricted space allowance will depress performance. Of the five starter trials reviewed, all used ASP-250 as the antibiotic. In two of the starter trials, a significant interaction was obtained for feed efficiency with ASP-250 improving efficiency in crowded pigs but not in pigs allowed adequate floor space. An interactive effect on daily gain was obtained in a third starter trial with ASP-250 improving gains in pigs with adequate floor space but not in pigs with restricted floor space. In the only growing-finishing trial reviewed, no significant interaction was obtained. Due to the limited amount of research in this area, more studies are needed to fully elucidate the response to feed additive antibiotics under different levels of crowding stress.

Chapter III

EFFICACY OF VIRGINIAMYCIN AND A COMMERCIALLY AVAILABLE LACTOBACILLUS PROBIOTIC IN SWINE DIETS

SUMMARY

Eight feeding trials using 708 crossbred pigs were conducted to evaluate the addition of virginiamycin and a commercially available lactobacillus fermentation product (probiotic) to starter, grower and finisher diets based on corn and soybean meal. Virginiamycin was added at a level of 11 mg/kg of diet, and lactobacillus probiotic at 1 g/kg in starter diets and 500 mg/kg in grower and finisher diets. In the combined analysis of four starter trials, pigs fed on diets containing virginiamycin tended to eat more and grow faster than pigs fed on the control diet, but feed efficiency was not different. Furthermore, daily gain, daily feed intake and feed efficiency were not improved by the addition of lactobacillus probiotic to starter diets. In the combined analysis of a starter-grower-finisher and a grower-finisher trial, virginiamycin supplementation did not alter overall pig performance compared with control. Pigs fed on a positive control diet containing chlortetracycline, penicillin and sulfamethazine had a nonsignificant greater daily gain and feed intake. Daily gain for the lactobacillus probiotic fed pigs was lower ($P < .05$) than that of the negative controls, but daily feed intake and feed efficiency were not significantly different. In three growing-finishing trials in which virginiamycin and lactobacillus probiotic were compared in a 2 x 2

factorial arrangement of treatments, daily gain and feed intakes were greater ($P < .01$) for pigs given virginiamycin. The lactobacillus probiotic did not improve daily gain, feed intake or feed efficiency. Overall, no interaction between virginiamycin and lactobacillus probiotic occurred.

INTRODUCTION

The use of antibiotics at subtherapeutic levels as growth promotants plays a significant role in livestock and poultry production. This extensive use of subtherapeutic levels of antibiotics has increased public concern about potential problems such as resistant organisms and tissue residues. The livestock industry has responded to these concerns by searching for alternatives to antibiotic feed additives as well as by developing antibiotics to be used specifically in animal feeds.

The search for alternatives to antibiotic feed additives has stimulated a renewed interest in the addition of lactobacillus probiotics to swine diets. Several researchers have observed that these preparations can improve performance (Parker, 1975; Baird, 1977; Hale and Newton, 1979; Pollman et al., 1980). Other workers (Hines and Koch, 1971; Kornegay and Thomas, 1973; Mahan and Newland, 1976; Cline et al., 1976), however, have observed no significant improvement in swine growth performance with lactobacillus probiotics.

Virginiamycin, a gram positive antibiotic produced by *Streptomyces virginiae*, was developed solely for use as a feed additive. Several researchers have demonstrated improved swine growth performance with virginiamycin (Hays et al., 1973; Castell, 1977; Barber et al., 1978; Stahly et al., 1980; Pelura et al., 1980).

The objective of this study was to compare the feedlot performance of swine fed on diets containing a commercially available lactobacillus probiotic and virginiamycin, an antibiotic developed for use in animal feeds.

EXPERIMENTAL PROCEDURES

General

Eight performance trials involving 708 crossbred pigs were conducted either at the Virginia Polytechnic Institute and State University Swine Center in Blacksburg, Virginia, or at the Tidewater Research and Continuing Education Center in Suffolk, Virginia. In each trial, pigs were randomly allotted to dietary treatments from outcome groups based on weight, sex and ancestry. Body weight and feed consumption were determined weekly for starter pigs and biweekly for growing-finishing pigs. The diets utilized were based on corn and soybean meal (table 1). All diets and water were available ad libitum.

Trials 1, 2 and 3

Three starter trials were conducted in which 384 pigs were weaned at 25 $\pm$ 3 days of age and allotted to one of three dietary treatments. The treatments consisted of a control diet with no feed additive, a diet containing 11 mg/kg of virginiamycin (SmithKline Animal Health Products, Philadelphia, PA 19101) and a diet containing 1 g/kg of a commercially available lactobacillus probiotic. The probiotic was reported by the manufacturer to be composed primarily of a freeze dried culture of *Lactobacillus acidophilus* containing approximately 4×10^6 viable cells per gram (Pioneer Hi-Bred International, Portland, OR 97207). Pigs were

TABLE 1. COMPOSITION OF BASAL DIETS

Item (%)	Crude protein (%)					
	22	20	18	16	15	14
Ingredients						
Ground corn (IFN 4-03-005)	54.86	59.84	74.33	79.28	81.99	84.78
Soybean meal (IFN 5-04-612)	32.71	27.73	23.37	18.62	16.06	13.47
Dried whole whey (IFN 4-01-182)	10.00	10.00	---	---	---	---
Limestone (IFN 6-02-632)	.75	.75	.58	.64	.73	.81
Defluorinated phosphate (IFN 6-01-780)	1.03	1.03	1.09	.90	.67	.44
Salt	.30	.30	.30	.30	.30	.30
Trace mineral premix[a]	.10	.10	.08	.06	.06	.05
Vitamin-selenium premix[b]	.25	.25	.25	.20	.25	.15

[a]Contained: 20% Zn, 10% Fe, 5.5% Mn, 1.1% Cu and 0.15% I.
[b]Supplied per kilogram of premix: 1.75 g riboflavin, 8.8 g pantothenic acid, 8.8 g niacin, 8.8 mg vitamin B_{12}, 176 g choline, 176,000 IU vitamin D_3, 4,400 IU vitamin E, 440 mg menadione dimethylprimidinol bisulfite and 40 mg selenium.

housed in triple deck pens (1.2 m x 1.2 m) located in an environmentally controlled nursery. Pigs in each pen within a stack were fed on the same diet in order to prevent pigs from ingesting a feed additive, other than that assigned, via the feces from a pen above. A 22% crude protein diet was fed until pigs averaged 6.8 kg of body weight. A 20% crude protein diet was fed from 6.8 to 11.4 kg of body weight and an 18% crude protein diet for the remainder of the trials. Trials 1 and 2 lasted 42 days while trial 3 lasted 43 days. Individual body weight and pen feed consumption were determined weekly.

Trials 4 and 5

A starter-grower-finisher trial was conducted in which 96 pigs were weaned at 25 $\pm$ 3 days of age and allotted to four dietary treatments. The dietary treatments were a control diet with no feed additive, a diet containing 11 mg/kg of virginiamycin, a diet containing 1 g/kg of lacto-bacillus probiotic until pigs weighed approximately 20 kg then 500 mg/kg for the remainder of the trial, and a positive control diet containing 275 mg/kg of the triple combination antibiotic, ASP-250 (contains 40% chlortetracycline, 40% sulfamethazine and 20% penicillin). Also, a grower-finisher trial was conducted in which 40 pigs averaging 35 kg in weight were allotted to the same four dietary treatments. The protein sequence for the starter phase of trial 4 (weaning to 20 kg) was the same as that of trials 1 through 3. A 16% crude protein basal diet was fed from 20 to 45 kg of body weight and a 14% crude protein diet for the remainder of the trials. Pigs were housed in total confinement in pens with partially slotted concrete floors. The starter-grower-finisher trial lasted 179 days while the grower-finisher trial lasted 126 days.

Trials 6, 7 and 8.

Three growing-finishing trials were conducted in which 228 pigs initially averaging 31.2 kg were fed on diets containing two levels of virginiamycin (0 or 11 mg/kg) and two levels of lactobacillus probiotic (0 and 500 mg/kg) in a 2 x 2 factorial arrangement of treatments. Pigs were housed in total confinement on either expanded metal or partially slotted concrete floors. In trials 6 and 7, a 16% crude protein basal diet was fed until pigs averaged approximately 45 kg of body weight and then a 14% crude protein diet was fed for the remainder of the trials. In trial 8, a 15% crude protein basal diet was used for the entire trial. The trials lasted 84 days with body weights and pen feed consumption being determined at 2-week intervals.

Statistical analysis.

All data were subjected to the standard procedure used in the analysis of variance. The data of trials 1 through 5 were subjected to Dunnett's test to determine if active treatment means differed from control means (Dunnett, 1955). Starter phase data of trial 4 were combined with those of trials 1 through 3, and the positive control treatment (ASP-250) of trial 4 was eliminated for this purpose. Pen means were used as the experimental unit.

RESULTS

Trials 1 through 4.

The addition of 11 mg/kg of virginiamycin to the diets of weaned pigs tended to improve daily gain and feed intake by 5 and 3%, respectively (table 2). These differences, however, were not significant ($P < .05$). The Dunnett's t-value for significance at P = 95% was 1.98;

TABLE 2. EFFECTS OF VIRGINIAMYCIN AND PROBIOTIC SUPPLEMENTATION ON THE PERFORMANCE OF WEANED PIGS, TRIALS 1, 2, 3 AND 4[a]

Items	Treatments			SE[d]
	Control	Virginiamycin[b]	Probiotic[c]	
No. of pigs	152	152	152	
Avg initial weight, kg	6.68	6.66	6.64	.04
Avg final weight, kg	19.52	20.18	19.23	.27
Daily gain, g	322	338	317	6.40
Daily feed, g	625	643	616	12.71
Feed/gain	1.94	1.90	1.94	.02

[a]Each mean represents 22 pens of six to eight pigs per pen.
[b]Virginiamycin at 11 mg/kg of diet.
[c]Lactobacillus probiotic at 1 g/kg of diet.
[d]Average standard error of the mean.

the t-value for daily gain was 1.85 and 1.00 for daily feed intake. Supplementation of the diet with 1 g/kg of lactobacillus probiotic did not improve daily gain or feed intake. Feed efficiency was not significantly improved by either of the treatments.

Trials 4 and 5.

The results of the combined analysis of trials 4 and 5 are summarized in table 3. Virginiamycin supplementation did not alter pig performance as compared to the negative control for any of the traits measured. The positive control (ASP-250) diet produced nonsignificant improvements for daily gain and feed intake. Daily gains of pigs fed on diets supplemented with lactobacillus probiotic were lower ($P < .05$) than gains of pigs fed on the negative control diet, but differences in feed intake or feed efficiency were not significant.

Trials 6 through 8.

The addition of virginiamycin to the diets of growing-finishing pigs improved ($P < .01$) daily gain 5.2% and feed intake 5.9% (table 4). Lactobacillus probiotic supplementation showed nonsignificant trends for improved daily gain and feed intake over the control. No significant interaction was observed. Feed efficiency was similar for all treatments.

Discussion

Virginiamycin supplementation, under these experimental conditions, did not significantly improve the feedlot performance of weaned pigs. The data of starter trials 1 through 4, however, indicate a trend for improved performance. Pelura et al. (1980) reported improved growth rate in weaned pigs with the addition of virginiamycin at 44 mg/kg of

TABLE 3. EFFECTS OF VIRGINIAMYCIN, PROBIOTIC AND A TRIPLE COMBINATION ANTIBIOTIC SUPPLEMENTATION ON THE FEEDLOT PERFORMANCE OF STARTING AND GROWING-FINISHING SWINE, TRIALS 4 AND 5[a]

Items	Treatments				SE[e]
	Control	Virginiamycin[b]	Probiotic[c]	ASP-250[d]	
No. of pigs	34	34	34	34	
Avg initial weight, kg	16.7	16.9	16.7	16.9	.12
Avg final weight, kg	101.3	102.3	98.1	103.6	1.18
Daily gain, g[f]	590	590	556	607	9.08
Daily feed, kg	1.88	1.87	1.83	1.97	.04
Feed/gain	3.19	3.17	3.29	3.25	.05

[a]Each mean represents 6 pens of five to six pigs per pen.
[b]Virginiamycin at 11 mg/kg of diet.
[c]Lactobacillus probiotic at 1 g/kg of diet to 20 kg of body weight then at 500 mg/kg of diet.
[d]Chlortetracycline at 110 mg/kg, penicillin at 55 mg/kg and sulfamethazine at 110 mg/kg of diet.
[e]Average standard error of the mean.
[f]Probiotic lower ($P < .05$) than control (Dunnett, 1955).

TABLE 4. EFFECTS OF VIRGINIAMYCIN AND (OR) PROBIOTIC SUPPLEMENTATION ON THE FEEDLOT PERFORMANCE OF GROWING-FINISHING SWINE, TRIALS 6, 7 AND 8[a]

Virginiamycin[b] probiotic[c]	0 0	+ 0	0 +	+ +	SE[d]
No. of pigs	57	57	57	57	
Avg initial weight, kg	31.1	31.4	31.1	31.2	.12
Avg final weight, kg[e]	84.9	88.9	86.3	88.9	.78
Daily gain, kg[e]	.73	.77	.74	.78	.01
Daily feed, kg[e]	2.17	2.32	2.22	2.33	.04
Feed/gain	2.99	3.00	2.99	3.00	.04

[a]Each mean represents 10 pens of five to six pigs per pen.
[b]Virginiamycin at 11 mg/kg of diet.
[c]Lactobacillus probiotic at 500 mg/kg of diet.
[d]Average standard error of the mean.
[e]Virginiamycin effect ($P < .01$).

diet. Furthermore, Stahly et al. (1980) reported improved growth rate and feed efficiency in weaned pigs fed on diets containing 27.5 mg/kg of virginiamycin. In this study, virginiamycin was added at 11 mg/kg of diet as this level was recommended by the manufacturer.

The overall performance of pigs in trials 4 and 5 was not improved by virginiamycin supplementation. However, the results of growing-finishing trials 6, 7 and 8 are similar to those of Castell (1977) in which improved daily gain and feed intake were observed with virginiamycin supplementation. Barber et al. (1978) also observed improved feed efficiency with dietary additions of 10 mg/kg of virginiamycin; this finding was not observed in this study.

The addition of a commercially available lactobacillus probiotic to the diets of weaned pigs did not improve growth performance or feed efficiency. This is in agreement with the work of Hines and Koch (1971) and Mahan and Newland (1976). To the contrary, Baird (1977) and Pollman et al. (1980) observed improved performance in starter pigs fed diets with lactobacillus probiotics. In trials 4 and 5, overall daily gain was depressed with lactobacillus probiotic supplementation. No explanation for this depressed gain is available, however, it is doubtful that this was a toxic dose as most researchers have reported that similar levels of lactobacillus probiotic resulted in no difference or a small improvement as compared to control pigs. Furthermore, the addition of lactobacillus probiotic to growing-finishing diets (trials 6 through 8) did not significantly improve pig performance.

Growth rate and feed intake were generally improved when virginiamycin was added to diets of growing and finishing hogs, but the response was less consistent when added to starter diets. Lactobacillus probiotic in diets for starter, grower and finisher pigs proved to be of little or no value.

CHAPTER IV

THE EFFECTS OF CROWDING STRESS AND VIRGINIAMYCIN SUPPLEMENTATION ON THE FEEDLOT PERFORMANCE OF SWINE

SUMMARY

Three series of trials involving 732 pigs were conducted to evaluate the feedlot performance of starter and grower-finisher pigs housed under conditions of restricted and adequate space allowance fed diets with and without virginiamycin (11 mg/kg). In starter trials 1 through 4, space allowance was altered by housing either 12 (.12 m^2/pig) or 6 (.24 m^2/pig) pigs in 1.2 x 1.2 m pens. Increasing the number of pigs per pen from 6 to 12 caused depressions ($P<.001$) of 6.1% in final weight, 9.2% in daily gain, 6.4% in daily feed intake and 3.4% in feed efficiency. Virginiamycin supplementation improved final weight ($P < .05$) 3.0%, daily gain ($P < .05$) 4.6% and feed efficiency ($P < .001$) 4.3%. In starter trials 5 and 6, space allowance was altered by varying pen size with six pigs per pen across treatments. Decreasing space allowance from .24 to .12 m^2 per pig caused depressions ($P<.05$) of 4.9% in final weight, 7.1% in daily gain and 4.6% in feed efficiency. No significant effect of virginiamycin supplementation on performance was obtained. In grower-finisher trials 7 through 9, space allowance was altered by varying pen size with 5 pigs per pen across treatments. Decreasing space allowance from .78 to .43 m^2 per pig caused depressions of 7.4% ($P<.01$) in final

weight, 8.3% ($P<.01$) in daily gain, 6.4% ($P<.05$) in daily feed intake and 2.0% ($P<.1$) in feed efficiency. Virginiamycin supplementation improved ($P<.08$) feed efficiency 2.3% over the entire trial. The virginiamycin by crowding interaction was significant in only one instance with virginiamycin improving feed efficiency 6.2% when pigs were housed at a density of six/pen but only 2.5% when housed at 12/pen (trials 1 through 4). The data indicate that housing pigs under crowded conditions does not increase the level of response of starter and grower-finisher pigs to virginiamycin supplementation. The data also indicate that housing starter and grower-finisher pigs under crowded conditions will depress growth rate by depressing feed consumption and feed efficiency.

INTRODUCTION

Antibacterial feed additives continue to be used extensively in swine production to improve rate of gain and feed efficiency. Their effectiveness in improving these traits was well documented in a review by Hays (1978). However, the degree of response to antibiotics varies considerably among different studies. It has been suggested that the level of response to antibiotics is related to the amount of stress imposed on the pigs, but research dealing with the interactive effects of stress and antibiotic feeding on pig performance is limited.

Crowding stress can alter the performance of swine. Substantial decreases in the individual feedlot performance of starter pigs reared in slotted floor nursery pens and battery cages occur when floor space allowance per pig is reduced below .14 m^2 from 5 to 12 kg of body weight, .18 m^2 from 12 to 22 kg and .25 m^2 from 5 to 30 kg (Jensen et al., 1966; LeDividich, 1979; Kornegay et al., 1980; Kornegay et al., 1981; Lindvall, 1981). For growing-finishing pigs reared in slotted floor pens, decreases in performance occur at space allowances per pig below .36 m^2 from 18 to 46 kg of body weight, .54 m^2 from 46 to 68 kg and .72 m^2 from 68 to 96 kg (Gehlbach et al., 1966; Jensen et al., 1973).

The objective of these studies was to evaluate the feedlot performance of starter and grower-finisher swine housed under conditions of restricted and adequate space allowance fed diets with and without virginiamycin, a gram-positive antibiotic.

EXPERIMENTAL PROCEDURES

Trials 1 through 4

Four starter trials were conducted in which 516 pigs initially averaging 6.3 kg were fed diets containing two levels of virginiamycin (0 or 11 mg/kg) and housed at two pen densities (6 or 12 pigs per pen) in a 2 x 2 factorial arrangement of treatments. Triple deck (trials 1 and 4) or double deck (trials 2 and 3) cages were used to house the pigs with the restriction that pens of pigs within the same stack of cages had to be fed the same level of virginiamycin. Pen floor dimensions were 1.2 x 1.2 m thus pens with six pigs allowed .24 m^2 of floor space per pig and pens with 12 pigs allowed .12 m^2 of floor space per pigs. Feeder length per pig was 18.6 and 9.3 cm in the triple deck cages and 14.8 and 7.4 cm in the double deck cages for 6 and 12 pigs per pen, respectively. One nipple waterer per every six pigs was provided across all treatments. There were a total of 17 replicates of six pigs per pen and 13 replicates of 12 pigs per pen. All pigs were on test for 42 days with the exception of six pens in trial 1 which were on test for 35 days. In addition to growth and feed efficiency data, pigs in trials 1 through 3 were subjectively scored at the end of the trials by a committee of three individuals working independently to evaluate the general appearance of body condition and health. This evaluation was termed the bloom score and was assigned on a scale of 1 to 5 with 5 being assigned to full bodied pigs with smooth hair coats that appeared to be in good health and 1 to thin bodied pigs with rough hair coats and pale skin. In order to minimize biases resulting from cleanliness differences, pigs were washed with a mild soap and water prior to bloom scoring.

Trials 5 and 6

Two starter trials were conducted in which 96 pigs initially averaging 6.9 kg were fed diets containing two levels of virginiamycin (0 or 11 mg/kg) and housed with two floor space allowances (.24 or .12 m^2 per pig) in a 2 x 2 factorial arrangement of treatments. Double deck nursery cages (1.2 x 1.2 m) were used to house the pigs with the restriction that pigs within the same stack of cages had to be fed the same level of virginiamycin. Six pigs were housed in each pen and steel rod panels were attached in the appropriate pens to reduce floor space allowance per pig from .24 to .12 m^2. Feeder length per pig was 14.8 cm for pigs allowed .24 m^2 of floor space per pig and 7.4

cm for pigs allowed .12 m^2 of floor space per pig. One nipple waterer was provided for each pen. There were a total of four replicates for each of the four treatments. All pigs were on test for 42 days. Bloom scores were assigned at the end of the trials as described for trials 1 through 3.

Trials 7 through 9

Three growing-finishing trials were conducted in which 120 pigs initially averaging 22.7 kg were fed diets containing two levels of virginiamycin (0 or 11 mg/kg) and housed with two floor space allowances (.78 or .43 m^2 per pig) in a 2 x 2 factorial arrangement of treatments. Pigs were housed in a totally enclosed confinement building on partially slotted concrete and aluminum flooring. There were five pigs per pen across all treatments with a two-hole self feeder and a nipple waterer being provided in each pen. Pens providing .78 m^2 of floor space per pig were 3.05 m in length and 1.42 m in width with the feeder occupying .44 m^2 of floor space in the front of the pen. Pens providing .43 m^2 of floor space per pig had tubular steel panels attached across the rear of the pen and plywood panels attached in the front of the pens such that pen length was reduced to 1.59 m with the feeder occupying .11 m^2 of floor space. In each of the three trials there were two replicates of each treatment. Replications were taken off test when pigs allowed .78 m^2 of floor space per pig averaged approximately 98 kg in body weight.

General

Pigs were randomly allotted to treatments from outcome groups based on litter and sex. Individual body weight and pen feed consumption were determined weekly in starter trials and biweekly in grower-finisher trials. All diets were corn-soybean meal based (table 5) and were available ad libitum. In starter trials, a 22% crude protein diet containing 10% dried whole whey was fed until pigs in a pen averaged 6.8 kg, a 20% diet was fed to 11.3 kg and an 18% crude protein diet without whey was fed for the remainder of the trials. In the growing-finishing trials, a 16% crude protein diet was fed to 45 kg and a 14% crude protein diet was fed for the remainder of the trials. The nurseries were environmentally controlled with the temperature set at approximately 29 C for the first 2 wk, followed by a gradual decrease in temperature to a minimum of 25 C at the end of the trials. Temperature recordings indicated that mean temperatures for the entire trials were 23 ± 3 C in the triple deck nursery and 24 ± 3 C in the double deck nursery. Mean relative humidities for the entire trials were 69 ± 11% in the triple deck nursery and 57 ± 17% in the double deck nursery. In the growing-finishing trials, fan speed and inlet width were set to provide five to 10 cfm per pig in the summer and 48 to 100 cfm per pig in the winter depending on the size of the pigs. Also a small, thermostatically controlled gas heater was provided which was set to come on when the barn temperature fell below 15 C.

Data were subjected to analysis of variance using the Statistical

TABLE 5. COMPOSITION OF BASAL DIETS

Item (%)	Crude protein, %				
	22	20	18	16	14
Ground corn (IFN 4-03-005)	54.86	59.84	74.33	79.28	84.78
Soybean meal (IFN 5-04-612)	32.71	27.73	23.37	18.62	13.47
Dried whole whey (IFN 4-01-182)	10.00	10.00	-	-	-
Limestone (IFN 6-02-632)	.75	.75	.58	.64	.81
Defluorinated phosphate (IFN 6-01-780)	1.03	1.03	1.09	.90	.44
Salt	.30	.30	.30	.30	.30
Trace mineral premix[a]	.10	.10	.08	.06	.05
Vitamin-Selenium premix[b]	.25	.25	.25	.20	.15
Additives[c]					

[a]Contained: 20% Zn, 10% Fe, 5.5% Mn, 1.1% Cu and .15% I.

[b]Supplied per kilogram of premix: 1.75 g riboflavin, 8.8 g pantothenic acid, 8.8 g niacin, 8.8 mg vitamin B_{12}, 176 g choline, 176,000 IU vitamin D_3, 4,400 IU vitamin E, 440 mg menadione dimethylprimidinol bisulfite and 40 mg selenium.

[c]Eleven ppm virginiamycin was supplied in the appropriate diets by adding .05% Stafac 22 premix containing 22 g of virginiamycin per kg.

Analysis System of Barr et al. (1976). Pen means served as the experimental unit. Prior to statistical analysis, data for starter pigs in trials 1 through 4 and grower-finisher pigs in trials 7 through 9 were adjusted for initial weight differences using regression coefficients of performance traits on initial weight. In starter trials 5 and 6, data was adjusted for initial weight differences by including initial weight in the model.

RESULTS

Trials 1 through 4

Increasing the number of starter pigs housed in 1.2 x 1.2 m nursery pens from 6 to 12 resulted in depressions ($P<.001$) of 6.1% in final weight, 9.2% in daily gain, 6.4% in daily feed intake and 3.4% in feed efficiency (table 6). Supplementation of the diet with 11 mg/kg of virginiamycin resulted in improvements of 3.0% ($P<.05$) in final weight, 4.6% ($P<.05$) in daily gain and 4.3% ($P<.001$) in feed efficiency with no significant effect on daily feed intake. Furthermore, average bloom score tended to be slightly higher for pigs fed diets containing virginiamycin (3.44 vs 3.33, $P<.08$) and for pigs housed at a density of 12 per pen (3.43 vs 3.34, $P<.12$). A significant virginiamycin by pigs/pen interaction for feed efficiency was obtained with virginiamycin improving this trait 6.2% when pigs were housed at a density of six/pen but only 2.5% when pigs were housed at a density of 12/pen. No significant virginiamycin by pigs/pen interaction for the other traits measured was obtained. Overall main effects of pigs/pen and virginiamycin are shown in appendix table 9.

TABLE 6. THE EFFECTS OF VIRGINIAMYCIN SUPPLEMENTATION AND NUMBER OF PIGS PER PEN ON THE PERFORMANCE OF WEANED PIGS, TRIALS 1, 2, 3 AND 4[a]

Items	Treatments				
Pigs/pen	12	12	6	6	
Virginiamycin, mg/kg	0	11	0	11	SE[b]
No. of pigs	156	156	102	102	
Avg initial weight, kg	6.3	6.3	6.3	6.3	
Avg final weight, kg[c,d]	18.1	18.6	19.2	19.8	.2
Avg daily gain, g[c,d]	288	301	317	332	4.9
Avg daily feed, g[c]	569	580	618	609	9.10
Feed/gain[c,e,f]	1.98	1.93	1.95	1.83	.01
Avg bloom score[g,h]	3.38	3.49	3.28	3.39	.06

[a]Means of 12 pigs per pen represent 13 pens and means of six pigs per pen represent 17 pens.
[b]Average standard error of the mean.
[c]Effect of number of pigs/pen ($P < .001$).
[d]Effect of virginiamycin ($P < .05$).
[e]Effect of virginiamycin ($P < .001$).
[f]Virginiamycin x pigs/pen interaction ($P < .05$).
[g]Effect of virginiamycin ($P < .08$).
[h]Scores assigned at the end of trials 1, 2 and 3 on a scale of 1 to 5, with 5 being assigned to full bodied pigs with smooth hair coats that appeared to be in good health and 1 to thin bodied pigs with rough hair coats and pale skin.

The main effects of number of pigs/pen on weekly performance are shown in figures 1 and 2. Performance was generally poorer for 12 pigs/pen after 2 wk in the nursery. Differences were significant at 3, 4, 5 and 6 wk for body weight, at 3, 5 and 6 wk for daily gain, at 1, 4, 5 and 6 wk for daily feed intake and at 3 and 6 wk for feed efficiency. Improvements in weekly performance with virginiamycin supplementation were significant at 5 and 6 wk for body weight, at 4, 5 and 6 wk for daily gain and at 4 and 5 wk for feed efficiency (figures 3 and 4). Treatment effects on weekly performance are shown in appendix figures 9 and 10.

Trials 5 and 6

Decreasing the space allowance per pig from .24 to .12 m^2 with number of pigs/pen held constant resulted in depressions ($P<.05$) of 4.9% in final weight, 7.1% in daily gain and 4.6% in feed efficiency (table 7). Daily feed intake also favored pigs allowed .24 m^2 of floor space but the difference was not significant. The effect of virginiamycin and the virginiamycin by space allowance interaction was not significant for any of the traits measured. The overall main effects of space allowance and virginiamycin are shown in appendix table 10.

The main effects of space allowance on weekly performance are shown in figures 5 and 6. Performance was similar at both space allowances until the sixth week at which time performance favored pigs which were allowed more floor space (.24 m^2/pig). Differences were significant at wk 6 for body weight and daily gain and at wk 2 for daily feed intake. Consistent improvements in performance were not obtained

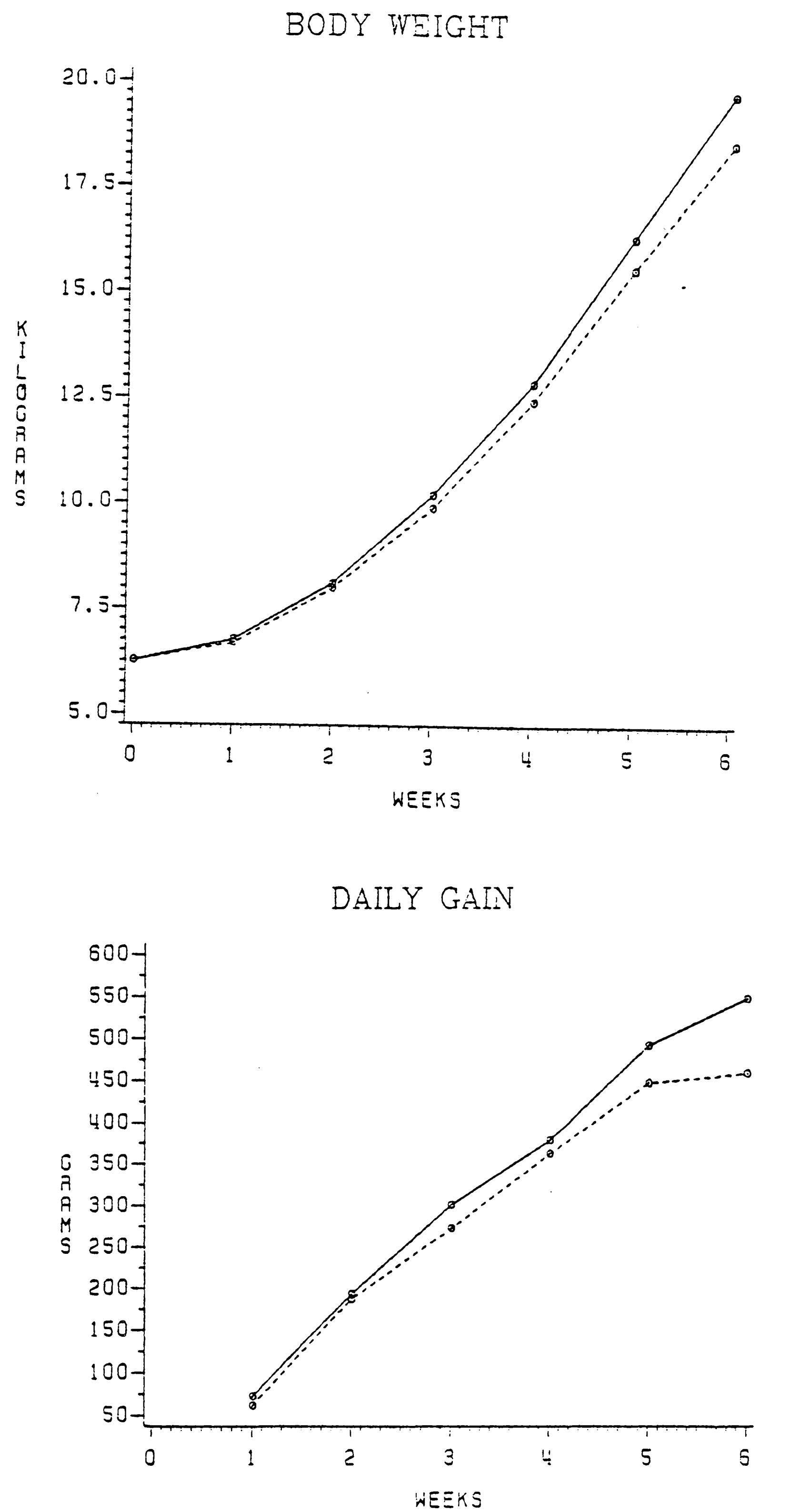
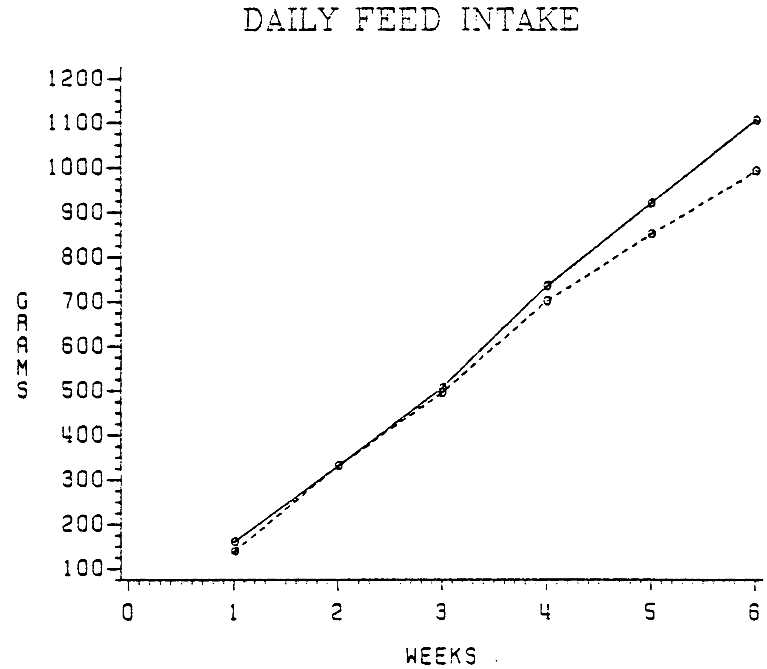


Figure 1. The weekly main effects of 12 (o----o) and 6 (o——o) pigs per pen on body weight and daily gain for starter pigs in trials 1 through 4.



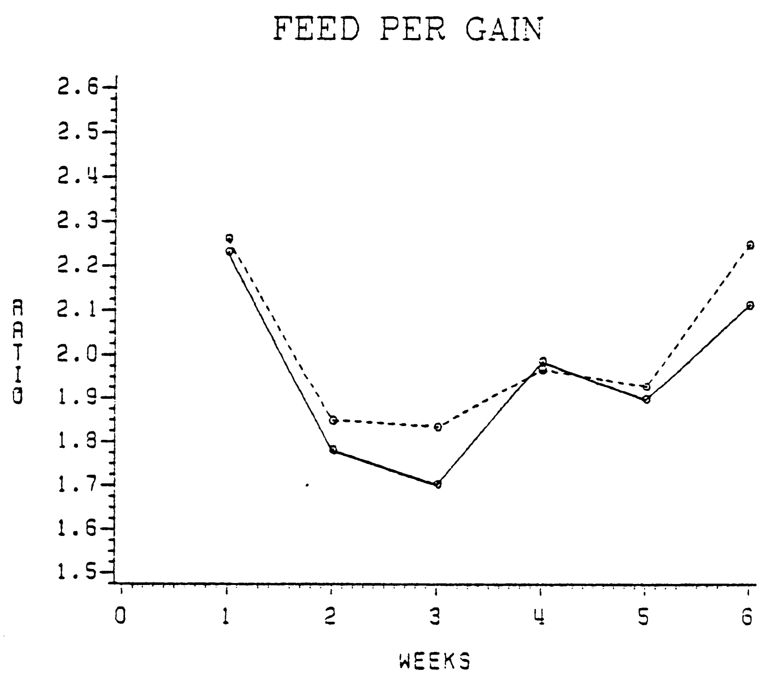


Figure 2. The weekly main effects of 12 (o----o) and 6 (o——o) pigs per pen on daily feed intake and feed efficiency of starter pigs in trials 1 through 4.

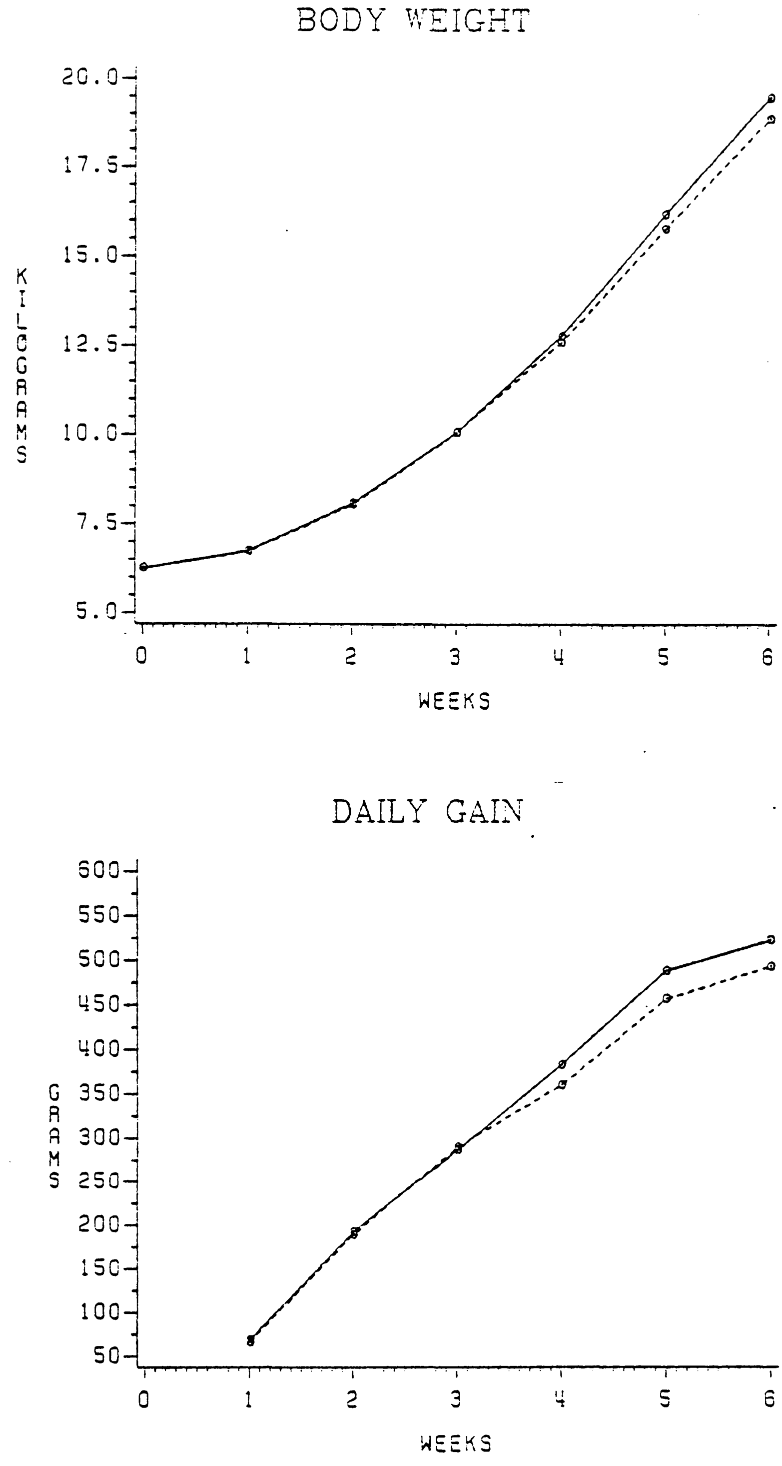
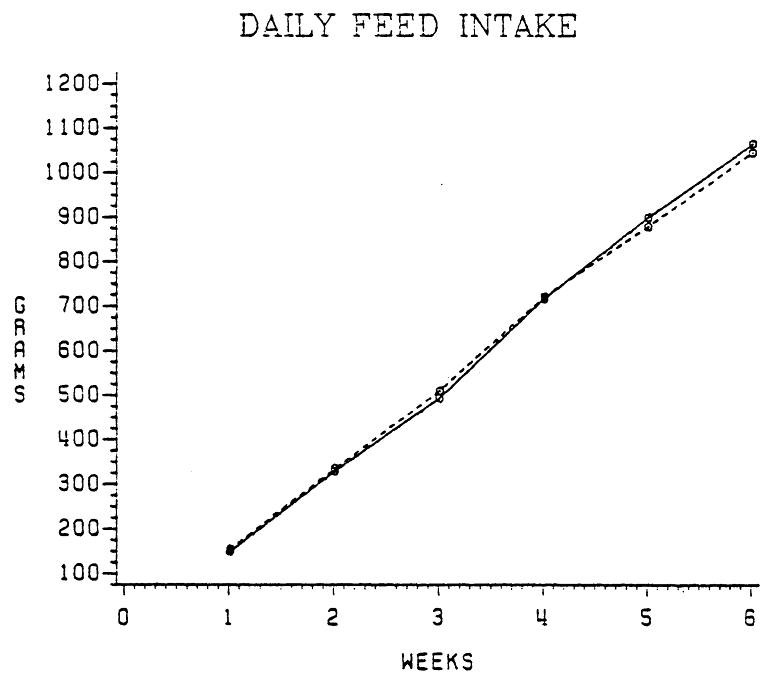


Figure 3. The weekly main effects of 0 (o----o) and 11 (o——o) mg/kg of virginiamycin on body weight and daily gain of starter pigs in trials 1 through 4.



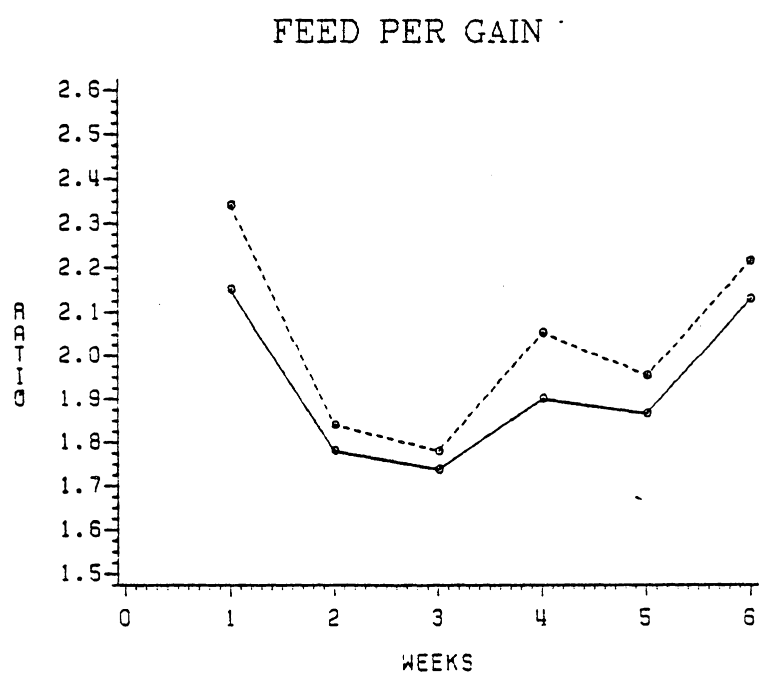
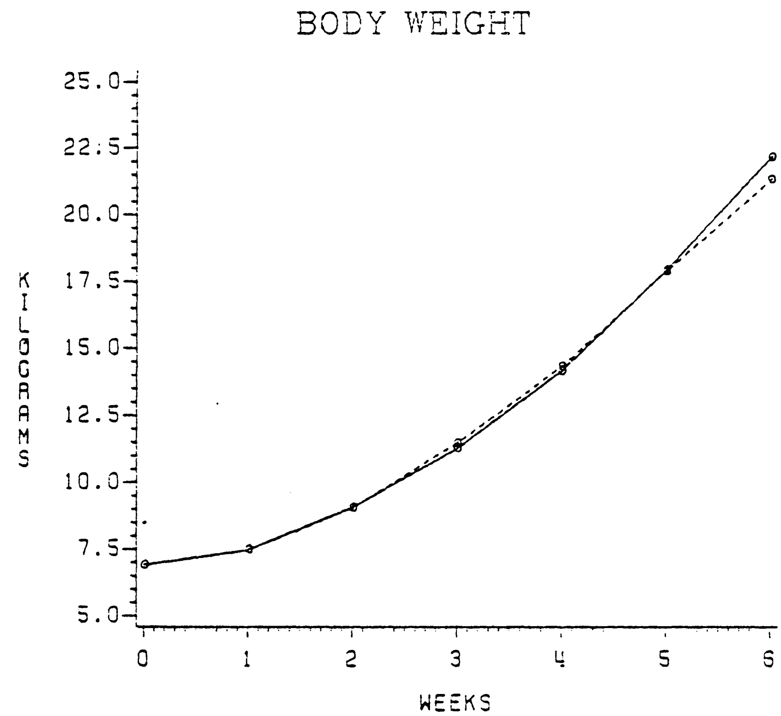


Figure 4. The weekly main effects of 0 (o----o) and 11 (o——o) mg/kg of virginiamycin of daily feed intake and feed efficiency of starter pigs in trials 1 through 4.

TABLE 7. THE EFFECTS OF VIRGINIAMYCIN SUPPLEMENTATION AND SPACE ALLOWANCE ON THE PERFORMANCE OF WEANED PIGS, TRIALS 5 AND 6[a]

Items		Treatments				
	Space allowance, m^2/pig	.12	.12	.24	.24	
	Virginiamycin, mg/kg	0	11	0	11	SE[b]
No. of pigs		24	24	24	24	
Avg initial weight, kg		6.9	6.9	6.9	6.9	
Avg final weight, kg[c]		21.1	21.3	22.1	22.5	.3
Avg daily gain, g[c]		338	342	361	371	7.0
Avg daily feed, g		641	660	665	675	16.6
Feed/gain[c]		1.90	1.93	1.84	1.82	.03
Avg bloom score[d]		3.77	3.62	3.87	3.77	.09

[a]Each mean represents four pens of six pigs per pen.
[b]Average standard error of the mean.
[c]Effect of space allowance ($P < .05$).
[d]Scores assigned at the end of the trials on a scale of 1 to 5, with 5 being assigned to full bodied pigs with smooth hair coats that appeared to be in good health and 1 to thin bodied pigs with rough hair coats and pale skin.



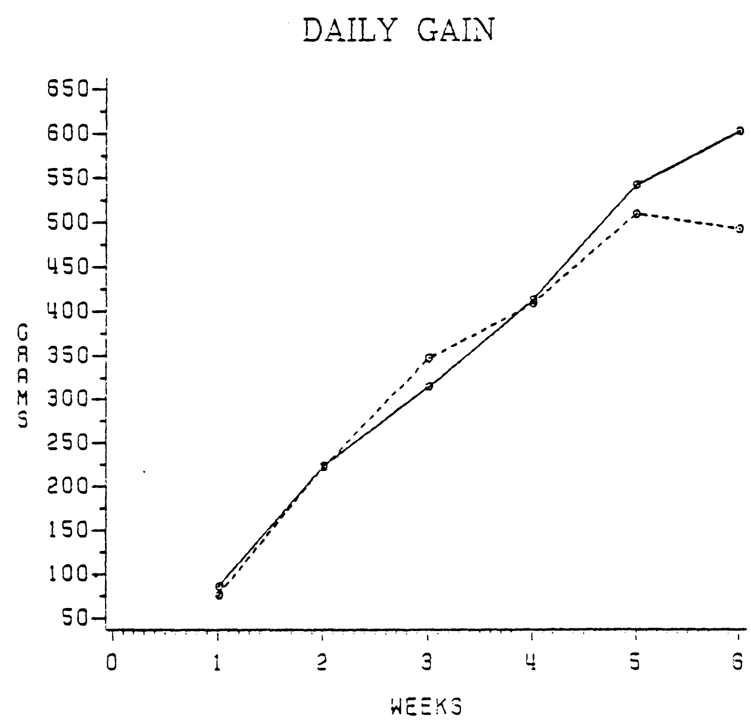
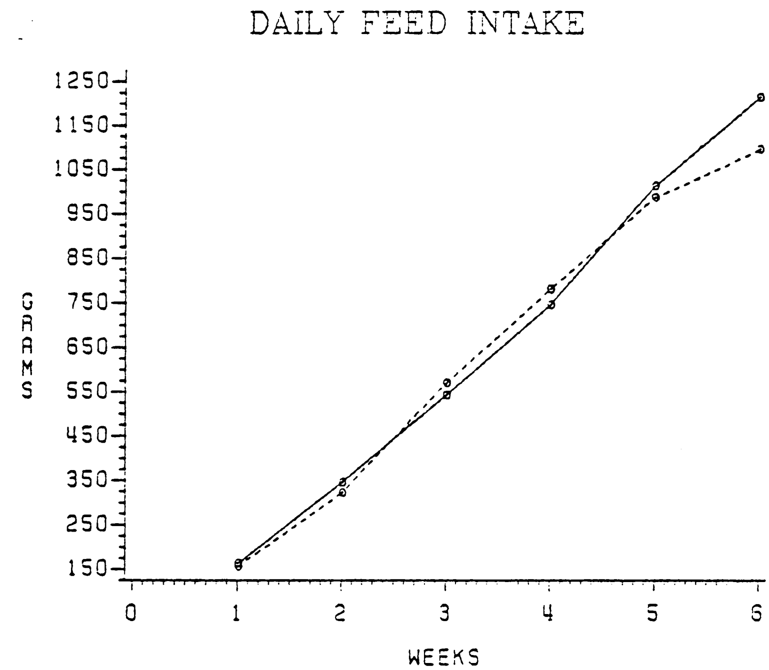


Figure 5. The weekly main effects of .12 (o----o) and .24 (o——o) m^2 of floor space per pig on body weight and daily gain of starter pigs in trials 5 and 6.



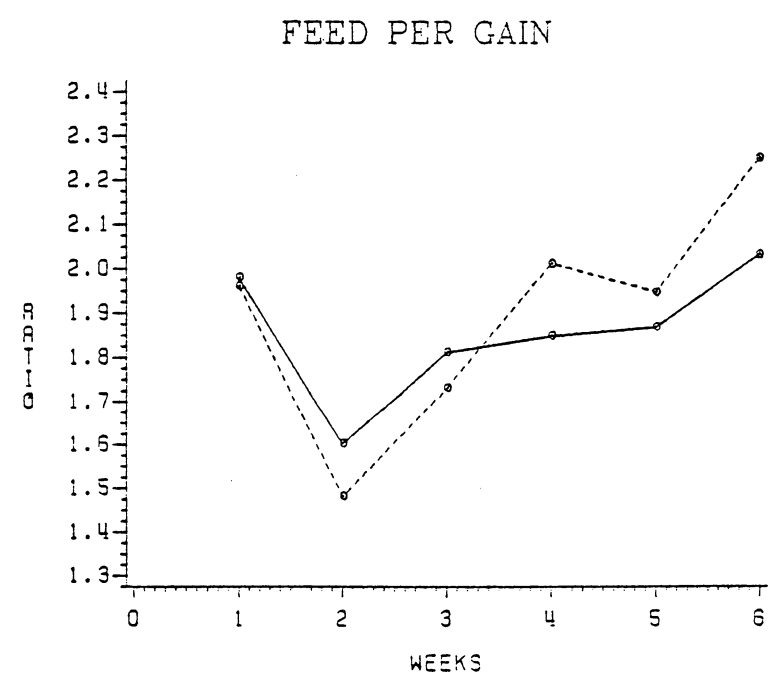


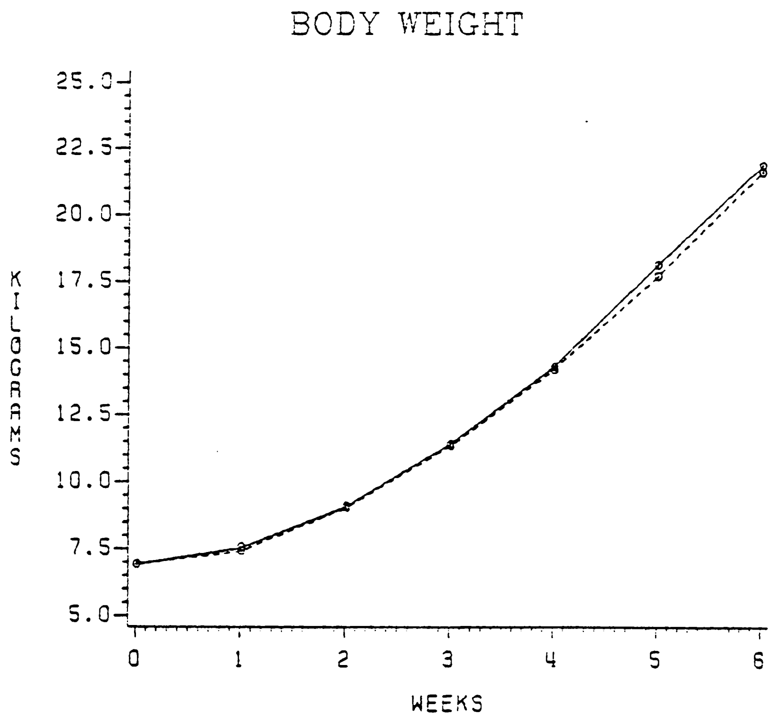
Figure 6. The weekly main effects of .12 (o----o) and .24 (o——o) m^2 of floor space per pig on daily feed intake and feed efficiency of starter pigs in trials 5 and 6.

with virginiamycin supplementation (figures 7 and 8). At wk 5, however, virginiamycin fed pigs tended to have improved ($P<.11$) daily gains which was primarily due to an increase ($P<.10$) in daily feed intake. Treatment effects on weekly performance are shown in appendix figures 11 and 12.

Trials 7 through 9

Treatment effects for the grower, finisher and grower-finisher phases are presented in table 8 and main effects are presented in appendix table 11. In the grower phase (start to 65 kg), reducing floor space allowance from .78 to .43 m^2 per pig resulted in significant depressions of 5.8% in final weight, 8.8% in daily gain, 5.9% in daily feed intake and 3.0% in feed efficiency. During the finisher phase (65 kg to finish), restricting space allowance caused significant depressions of 7.9% in daily gain and 5.7% in daily feed intake. Virginiamycin supplementation had no significant effect on performance in either the grower or finisher phases. For the grower-finisher phases combined, restricting space allowance caused significant depressions of 7.4% in final weight, 8.3% in daily gain, 6.4% in daily feed intake nad 2.0% in feed efficiency. Virginiamycin supplementation improved ($P<.08$) feed efficiency 2.3% over the phases combined but had no significant effect on the other performance traits measured. The virginiamycin by space allowance interaction was not significant for any traits during any phases.

Depressions in performance with restricted space allowance varied considerably among trials. This resulted in significant trial by space allowance interactions for several of the performance traits measured. In



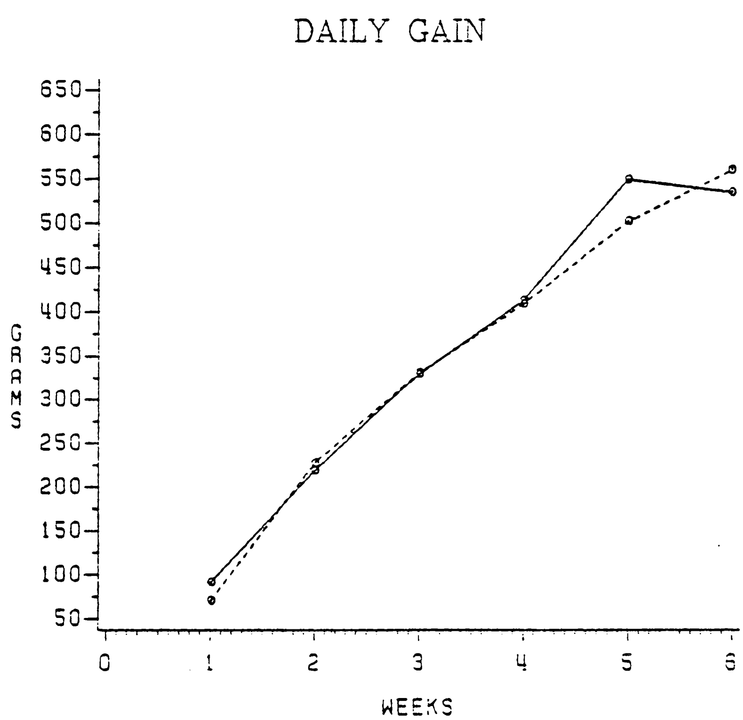
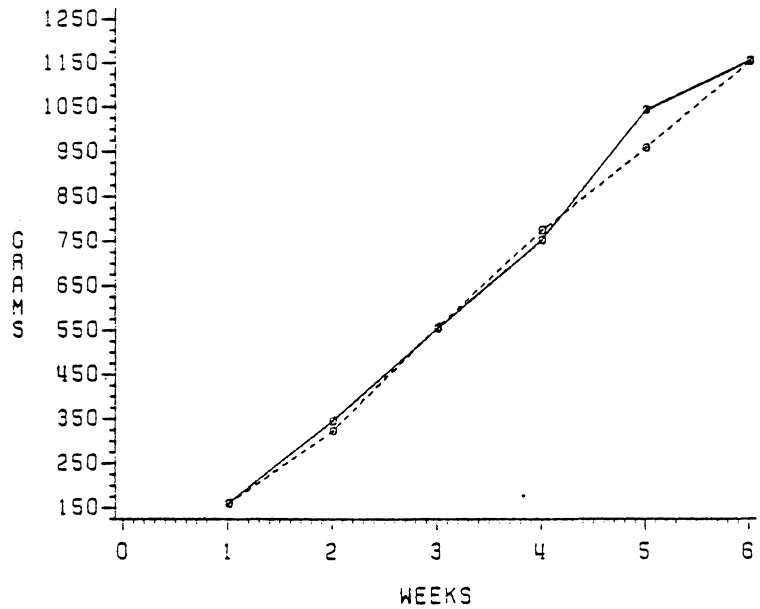


Figure 7. The weekly main effects of 0 (o----o) and 11 (o——o) mg/kg of virginiamycin on body weight and daily gain of starter pigs in trials 5 and 6.

DAILY FEED INTAKE



FEED PER GAIN

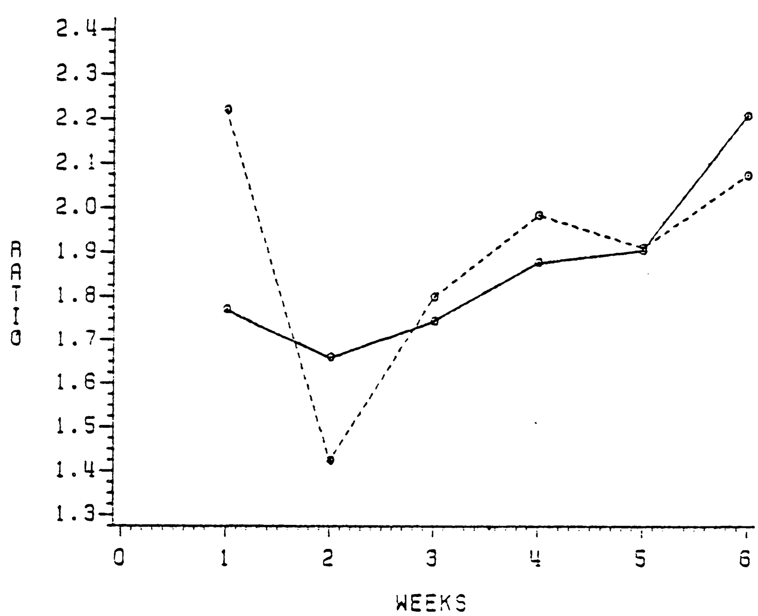


Figure 8. The weekly main effects of 0 (o----o) and 11 (o——o) mg/kg of virginiamycin on daily feed intake and feed efficiency of starter pigs in trials 5 and 6.

TABLE 8. THE EFFECTS OF VIRGINIAMYCIN AND SPACE ALLOWANCE ON THE PERFORMANCE OF GROWING-FINISHING PIGS, TRIALS 7,8, AND 9[a]

Items		Treatments				
	Space allowance, m^2/pig	.43	.43	.78	.78	
	Virginiamycin, mg/kg	0	11	0	11	SE[b]
No. of pigs		30	30	30	30	
Grower phase						
Avg initial weight,kg		22.7	22.7	22.7	22.7	
Avg final weight,kg[c,d]		63.0	64.6	67.7	67.8	.7
Avg daily gain,g[c,d]		717	743	800	800	12.0
Avg Daily feed,kg[e,f]		1.98	2.00	2.12	2.11	.04
Feed/gain[e,f]		2.76	2.69	2.65	2.64	.03
Finisher phase						
Avg daily gain,g[c]		776	776	844	841	6.3
Avg daily feed,kg[e]		2.68	2.59	2.81	2.79	.06
Feed/gain		3.45	3.34	3.33	3.32	.05
Grower and finisher phases						
Avg final weight kg[c,d]		89.8	91.9	97.7	98.5	.8
Avg daily gain,g[c,f]		735	753	808	814	9.2
Avg daily feed,kg[e]		2.27	2.25	2.42	2.41	.05
Feed/gain[d,g,h]		3.09	2.99	3.00	2.96	.03

[a]Each mean represents six pens of five pigs per pen.
[b]Average standard error of the mean.
[c]Effect of space allowande (P<.01).
[d]Trial by space allowance interaction (P<.05).
[e]Effect of space allowance (P<.05).
[f]Trial by space allowance interaction (P<.1).
[g]Effect of space allowance (P<.1).
[h]Effect of virginiamycin (P<.08).

general, depressed performance with restricted space allowance was more severe in trials 7 and 8 than in trial 9. Over the phases combined, depressions in performance for trials 7, 8 and 9, respectively, were 9.1, 9.5 and 3.3% in final weight, 12.3, 8.8 and 3.6% in daily gain, 6.4, 10.0 and 2.5% in daily feed intake and 7.1, 0 and 1.2% in feed efficiency.

Discussion

As expected from previous work by Kornegay et al. (1980;1981), increasing the number of starter pigs housed in 1.2 x 1.2 m nursery cages from 6 to 12 caused substantial reductions in individual performance. The reduced performance with restricted floor and feeder space became apparent after 3 wk in the nursery or when pigs reached an average body weight of 11.5 kg. In starter trials 5 and 6, reductions in performance were also obtained with restricted floor and feeder space but the differences did not become apparent until after 5 wk in the nursery (18 kg body weight). Also the magnitude of the depression in performance with restricted space allowance appeared to be greater in trials 1 through 4 than in trials 5 and 6. Some researchers have indicated that in addition to space allowance, group size also affects starter pig performance with smaller groups having better performance (Suss et al., 1977; McConnel et al., 1981). Space allowance per pig was identical across treatments in all starter trials of this study but group size was either 12 or six pigs per cage in trials 1 through 4 and constant at six pigs per cage in trials 5 and 6. Additionally, most studies have indicated that the reduced growth rate of starter pigs with restricted space allowance is primarily due to reduced feed consumption (LeDividich, 1979; Kornegay et al., 1980;

Kornegay et al., 1981; Lindvall, 1981). However, the results of the starter trials in this study indicate that crowding stress may adversely affect feed consumption and feed conversion.

In grower-finisher trials 7 through 9, the reduced growth rate of pigs housed with restricted floor space (.43 m^2/pig) appeared to be primarily due to reduced feed consumption but feed efficiency was also significantly depressed during the grower phase and the phases combined. Two studies have indicated that the major negative response of pigs to restricted space allowance is a reduced voluntary feed intake with no significant effect on feed efficiency (Gehlbach et al., 1966; Jensen et al., 1973). Other studies, however, using similar space restrictions have shown that feed cnnversion may also be adversely affected (Krider et al., 1975b; Plumlee et al., 1976).

Depressed performance with restricted space allowance was generally greater in trials 7 and 8 than in trial 9. This resulted in significant trial by space allowance interactions for several of the traits measured. No definite explanation for this is available but it may be related to variations in environmental temperature across trials. Gehlbach et al. (1966) has reported that restricting space allowance depressed gains more severely when the mean barn temperature was relatively high (26 C) than when it was relatively low (21 C). In this study, all trials were conducted in the same facility with trial 7 being conducted from July 24 to October 21, trial 8 from October 11 to December 17 and trial 9 from December 11 to March 12. While barn temperature was not monitored, it was apparent that the barn temperature was substantially lower during trial 9 than during trials 7 and 8.

The response of starter pigs to virginiamycin supplementation was not consistent across both series of starter trials. In trials 1 through 4 significant improvements in final weight, daily gain and feed efficiency were obtained while in trials 5 and 6 there were no significant effects on performance. No definite explanation for this is available but variability in the level of response to antibiotics is not uncommon (Hays, 1978). Several factors have been implicated that contribute to this variability including performance of the control pigs, type and cleanliness of facilities and overall health of the pigs (Braude et al., 1953; Melliere et al., 1973; Natz, 1973). Overall performance was better in trials 5 and 6 than in trials 1 through 4 (353 g vs 310 g and 1.87 vs 1.92 for daily gain and feed/gain, respectively) and this may offer some explanation for the differences in level of response. Hays (1978) has reviewed the effects of virginiamycin supplementation on starter pig performance and estimated that the average response is an 11.0% improvement in daily gain and a 5.02% improvement in feed efficiency. In this study improvements were 4.6% and 4.3% in trials 1 through 4 and 2.0% and 0% in trials 5 and 6 for daily gain and feed efficiency, respectively.

In the grower-finisher trials the overall improvements with virginiamycin were slight with feed efficiency showing the only significant improvement. Krider et al. (1975a) reported that virginiamycin improved performance during the first 49 days of a grower-finisher trial but not in the remainder of the trial. Other workers have reported significant improvements in gains and feed efficiency throughout the grower-finisher phases (Langlois et al., 1978; Plumlee et al., 1981b). In contrast, Powley et al. (1981) reported no response to virginiamycin in either the growing or finishing phases.

Results of the bloom score data for the starter trials are inconclusive. In trials 1 through 4 the score favored ($P<.08$) those pigs fed virginiamycin. In trials 5 and 6 the differences were not significant but those pigs fed the basal diet had higher bloom scores. Furthermore, the level of crowding stress had no significant effect on bloom score. It is believed that such a score is at best a very subjective evaluation and is of limited importance in determining the effects of nutritional and environmental treatments on swine productivity.

In general, crowding stress did not influence the level of response of starter pigs to virginiamycin supplementation. In trials 1 through 4, however, a significant interaction did occur. Virginiamycin improved feed efficiency 6.2% when pigs were housed at a density of six/pen but only 2.5% when housed at a density of 12/pen. This is in contrast to the interaction obtained by Libal et al. (1981) and Hogberg et al. (1981) using the triple combination antibiotic ASP-250 (contains 40% chlortetracycline, 40% sulfamethazine and 20% penicillin). These workers reported that the antibiotic improved feed efficiency when starter pigs were housed under crowded conditions but not when pigs were allowed adequate pen space. Additionally, crowding stress did not influence the response of growing-finishing pigs to virginiamycin supplementation as no significant virginiamycin by space allowance interaction was obtained. Under the conditions of this experiment, it appears that housing pigs under crowded conditions did not increase the level of response of starter and grower-finisher pigs to virginiamycin.

CHAPTER V

CONCLUSIONS

As shown in the comparison of the two feed additives, in no case did the lactobacillus probiotic significantly improve performance above that observed for the control pigs. In one instance the probiotic fed pigs actually performed poorer than the controls. Virginiamycin supplementation, however, showed a trend for increased gains and feed intake in a series of starter trials and significant increases in gains and feed intake in a series of grower-finisher trials. Based on these results, virginiamycin is superior to the lactobacillus probiotic as a growth promotant for swine. Additionally, even though virginiamycin appears superior to the probiotic, the response to this antibiotic is not consistent among different trials. This was apparent in the results of both studies with responses ranging from no improvement in performance to highly significant improvements.

Housing starter and grower-finisher pigs with less than the recommended amount of floor space allowance will depress feedlot performance. A decrease in voluntary feed intake has been frequently reported to be the major negative response of pigs housed under crowded conditions, but the **results of the crowding study indicate** that the efficiency of feed conversion may also be adversely affected. In general, the levels of crowding stress imposed did not alter the response of starter and grower-finisher pigs to supplemental virginiamycin. Under the conditions of this study it appears that the effects of the feed additive, virginiamycin, was not enhanced by housing pigs under crowded conditions.

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CHAPTER VI

APPENDIX

TABLE 9. THE MAIN EFFECTS OF VIRGINIAMYCIN SUPPLEMENTATION AND NUMBER OF PIGS PER PEN ON THE PERFORMANCE OF WEANED PIGS, TRIALS 1, 2, 3 AND 4[a]

Items	Virginiamycin, mg/kg		Pigs/pen		SE[b]
	0	11	12	6	
No. of pigs	258	258	204	312	
Avg initial weight, kg	6.3	6.3	6.3	6.3	
Avg final weight, kg[c,d]	18.7	19.2	18.4	19.5	.1
Avg daily gain, g[c,d]	303	316	294	325	3.5
Avg daily feed, g[c]	593	595	575	613	6.4
Feed/gain[c,e,f]	1.96	1.88	1.96	1.89	.01
Avg bloom score[g,h]	3.33	3.44	3.43	3.34	.04

[a] Means for virginiamycin effects represent 30 pens each; means for 12 pigs per pen represent 26 pens and means for 6 pigs per pen represent 34 pens.
[b] Average standard error of the mean.
[c] Effect of number of pigs per pen ($P < .001$).
[d] Effect of virginiamycin ($P < .05$).
[e] Effect of virginiamycin ($P < .001$).
[f] Virginiamycin x pigs/pen interaction ($P < .05$).
[g] Effect of virginiamycin ($P < .08$).
[h] Scores assigned at the end of trials 1, 2 and 3 on a scale of 1 to 5, with 5 being assigned to full bodied pigs with smooth hair coats that appeared to be in good health and 1 to thin bodied pigs with rough hair coats and pale skin.

TABLE 10. THE MAIN EFFECTS OF VIRGINIAMYCIN SUPPLEMENTATION AND SPACE ALLOWANCE ON THE PERFORMANCE OF WEANED PIGS, TRIALS 5 AND 6[a]

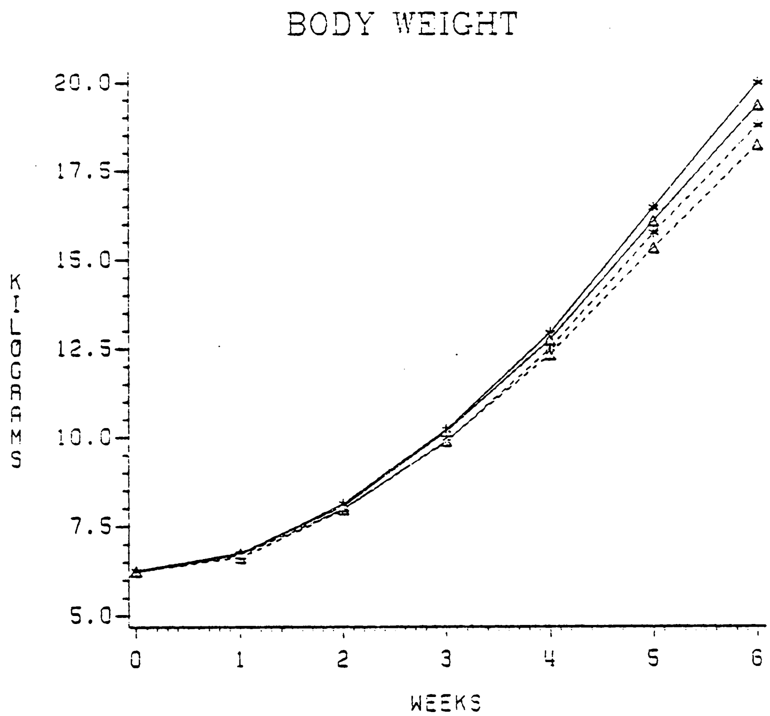
Items	Virginiamycin, mg/kg		Space allowance, m^2/pig		SE[b]
	0	11	.12	.24	
No. of pigs	48	48	48	48	
Avg initial weight, kg	6.9	6.9	6.9	6.9	
Avg final weight, kg[c]	21.6	21.9	21.2	22.3	.2
Avg daily gain, g[c]	349	357	340	366	4.9
Avg daily feed, g	653	668	651	670	11.7
Feed/gain[c]	1.87	1.87	1.91	1.83	.02
Avg bloom score[d]	3.82	3.70	3.70	3.82	.06

[a]Each mean represents eight pens of six pigs per pen.
[b]Average standard error of the mean.
[c]Effect of space allowance ($P < .05$).
[d]Scores assigned at the end of the trials to each pig on a scale of 1 to 5, with 5 being assigned to full bodied pigs with smooth hair coats that appeared to be in good health and 1 to thin bodied pigs with rough hair coats and pale skin.

TABLE 11. THE MAIN EFFECTS OF VIRGINIAMYCIN AND SPACE ALLOWANCE ON THE PERFORMANCE OF GROWING-FINISHING PIGS, TRIALS 7,8 and 9[a]

Items	Virginiamycin, mg/kg		Space allowance, m^2/pig		SE[b]
	0	11	.43	.78	
No. of pigs	60	60	60	60	
Grower phase					
Avg initial weight, kg	22.7	22.7	22.7	22.7	
Avg final weight, kg[c,d]	65.4	66.2	63.8	67.7	.5
Avg daily gain, g[c,d]	758	772	730	800	8.5
Avg daily feed, kg[e,f]	2.05	2.05	1.99	2.11	.03
Feed/gain[e,f]	2.70	2.66	2.73	2.64	.02
Finisher phase					
Avg daily gain, g[c]	810	809	776	843	11.5
Avg daily feed, kg[e]	2.74	2.69	2.63	2.80	.04
Feed/gain	3.38	3.33	3.39	3.32	.03
Grower and finisher phases					
Avg final weight, kg[c,d]	93.7	95.2	90.9	98.1	.6
Avg daily gain, g[c,f]	771	783	744	811	6.5
Avg daily feed, kg[e]	2.34	2.33	2.26	2.41	.03
Feed/gain[d,g,h]	3.04	2.98	3.04	2.97	.02

[a]Each mean represents 12 pens of five pigs rer pen.
[b]Average standard error of the mean.
[c]Effect of space allowance ($P<.01$).
[d]Trial by space allowance interaction ($P<.05$).
[e]Effect of space allowance ($P<.05$).
[f]Trial by space allowance interaction ($P<.1$).
[g]Effect of space allowance ($P<.1$).
[h]Effect of virginiamycin ($P<.08$).



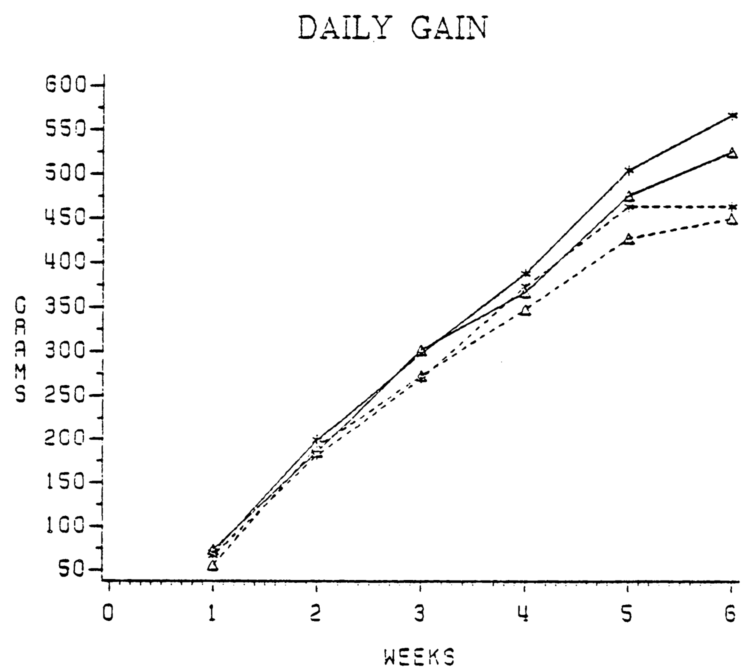


Figure 9. Weekly body weight and daily gain for starter pigs in trials 1 through 4 for the following treatments:
12 pigs/pen - 0 mg/kg virginiamycin (Δ----Δ),
12 pigs/pen - 11 mg/kg virginiamycin (*----*),
6 pigs/pen - 0 mg/kg virginiamycin (Δ——Δ),
6 pigs/pen - 11 mg/kg virginiamycin (*——*).

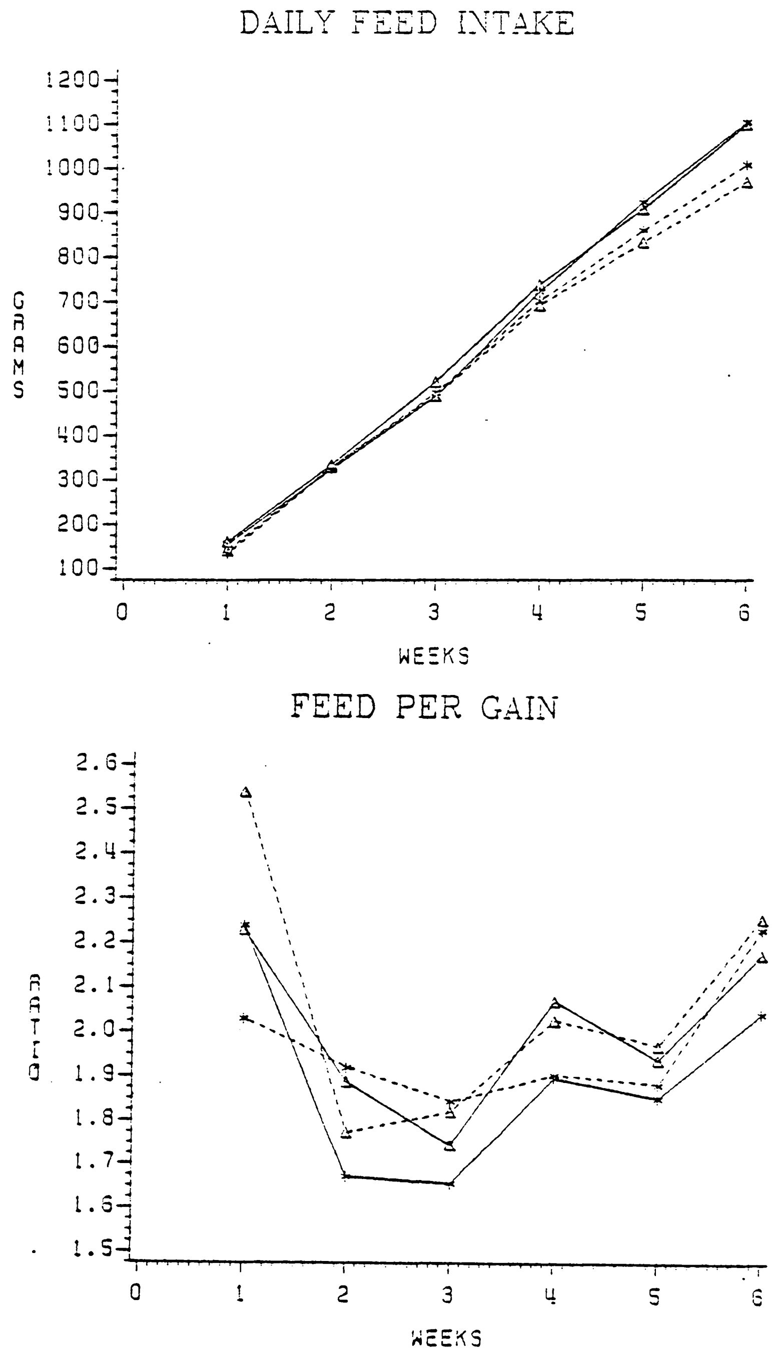
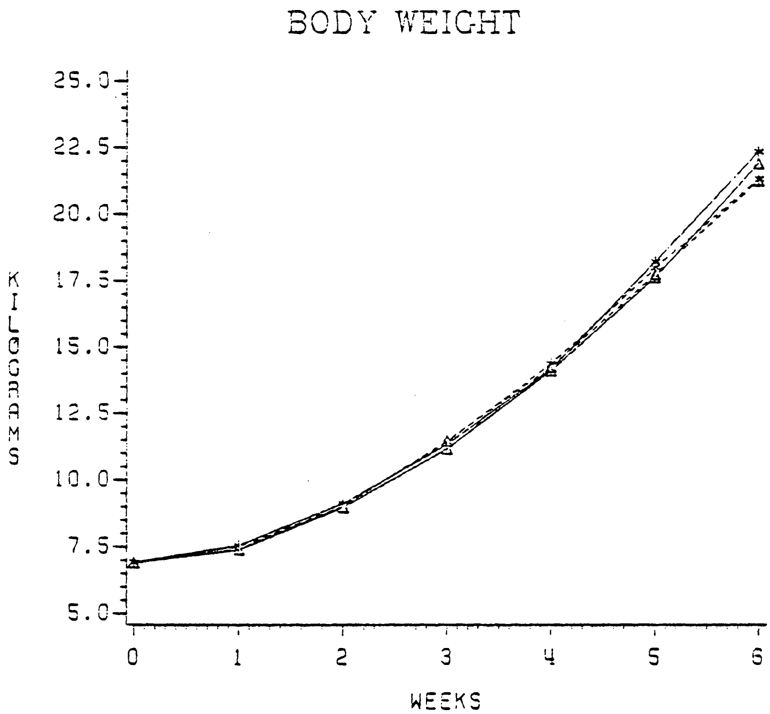


Figure 10. Weekly daily feed intake and feed efficiency for starter pigs in trials 1 through 4 for the following treatments:
12 pigs/pen - 0 mg/kg virginiamycin (△-----△),
12 pigs/pen - 11 mg/kg virginiamycin (*-----*),
6 pigs/pen - 0 mg/kg virginiamycin (△———△),
6 pigs/pen - 11 mg/kg virginiamycin (*———*).



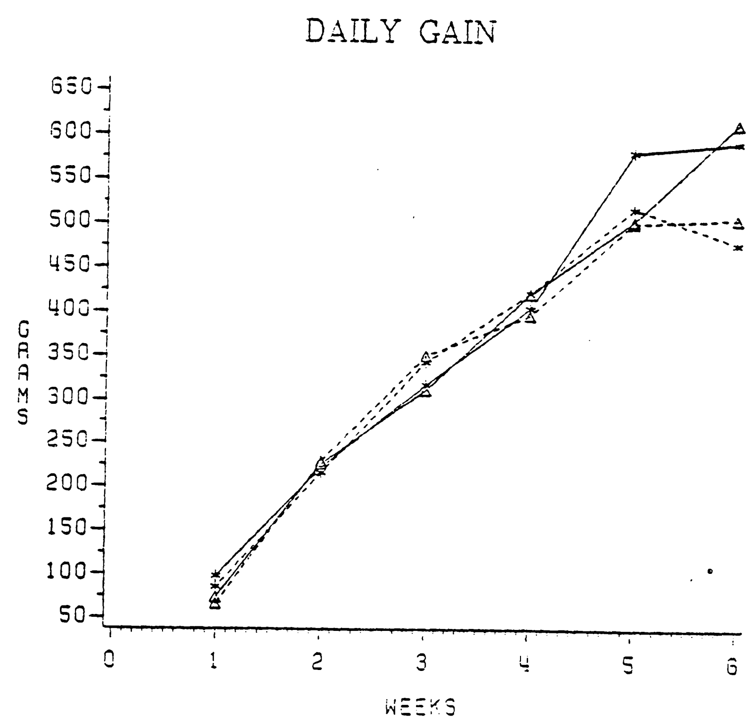


Figure 11. Weekly body weight and daily gain for starter pigs in trials 5 and 6 for the following treatments: .12 m^2 of floor space per pig - 0 mg/kg virginiamycin (△----△), .12 m^2 of floor space per pig - 11 mg/kg of virginiamycin (*----*), .24 m^2 of floor space per pig - 0 mg/kg virginiamycin (△——△), .24 m^2 of floor space per pig - 11 mg/kg of virginiamycin (*——*).

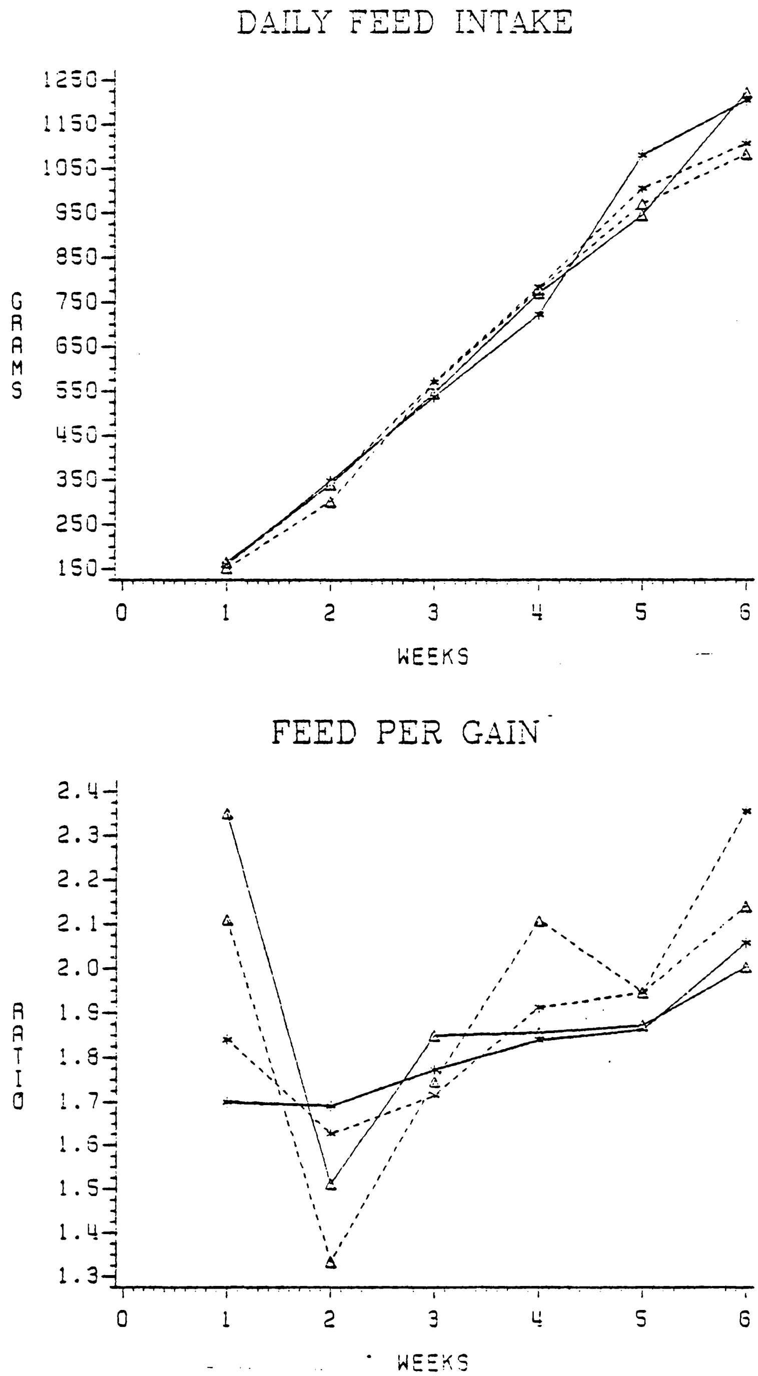


Figure 12. Weekly daily feed intake and feed efficiency for starter pigs in trials 5 and 6 for the following treatments: .12 m^2 of floor space per pig - 0 mg/kg virginiamycin (Δ----Δ), .12 m^2 of floor space per pig - 11 mg/kg virginiamycin (*----*), .24 m^2 of floor space per pig - 0 mg/kg virginiamycin (Δ——Δ), .24 m^2 of floor space per pig - 11 mg/kg of virginiamycin (*——*).

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A COMPARISON OF VIRGINIAMYCIN AND A LACTOBACILLUS PROBIOTIC AS FEED ADDITIVES FOR SWINE AND THE EFFECTS OF VIRGINIAMYCIN SUPPLEMENTATION AND CROWDING STRESS ON SWINE PERFORMANCE

by

Allen Foster Harper

(ABSTRACT)

Two experiments were conducted to compare the feedlot performance of swine fed diets containing a commercially available lactobacillus probiotic and virginiamycin, a gram-positive antibiotic (experiment I) and to evaluate the feedlot performance of starter and grower-finisher swine housed under conditions of restricted and adequate space allowance fed diets with and without virginiamycin (experiment II).

For experiment I, in four starter trials, pigs fed diets containing virginiamycin tended to eat more and grow faster than pigs fed the control diet while lactobacillus probiotic had no effect on performance. In the combined analysis of a starter-grower-finisher and a grower-finisher trial, virginiamycin supplementation had no effect on performance while the pigs fed the probiotic had significantly poorer gains than the control pigs. In three grower-finisher trials, virginiamycin supple-

mentation improved daily gain and feed consumption while lactobacillus probiotic had no significant effect on performance.

For experiment II, in four starter trials, increasing the number of pigs in 1.2 x 1.2 m nursery pens from six to 12 caused significant depressions in final weight, daily gain, feed intake, and feed efficiency. Virginiamycin supplementation significantly improved final weight, daily gain and feed efficiency. In two starter trials, reducing space allowance from .24 to .12 m^2 per pig caused significant depressions in final weight, daily gain and feed efficiency but virginiamycin had no effect on performance. In a series of grower-finisher trials, decreasing space allowance from .78 to .43 m^2 per pig caused significant depressions in final weight, daily gain, feed intake and feed efficiency while virginiamycin improved feed efficiency. The virginiamycin X space allowance interaction was significant in only one instance with virginiamycin improving feed efficiency 6.2% when starter pigs were given adequate space allowance but only 2.5% when crowded.

These findings suggest that virginiamycin is superior to the probiotic as a growth promotant for swine. Also, housing pigs under crowded conditions does not increase the level of response to virginiamycin.