THE EFFECT OF FEEDING VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A ON THE PERFORMANCE, SCOURING INDEX, GASTROINTESTINAL MEASUREMENTS AND IMMUNITY OF WEANLING AND GROWING-FINISHING PIGS

by

Gary A. Apgar

Thesis submitted to the Graduate Faculty of Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Animal Science
(Animal Nutrition)

APPROVED:

E. T. Kornegay, Chairman

M. D. Lindemann

C. M. Wood

August 1991

Blacksburg, Virginia

THE EFFECT OF FEEDING VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A ON THE PERFORMANCE, SCOURING INDEX, GASTROINTESTINAL MEASUREMENTS AND IMMUNITY OF WEANLING AND GROWING-FINISHING PIGS

by

Gary A. Apgar

Committee Chairman: E. T. Kornegay
Animal Science

(Abstract)

Four trials using 312 weanling pigs (average initial wt of 7.2 kg) were conducted to examine the effectiveness of Bifidobacterium globsum a (BGA) on the growth performance, scour scores, humoral and cell-mediated immune response and pH and chloride ion concentration (CIC) of feces and gastrointestinal section contents. The effect of continuous feeding of BGA from weaning to market weight on performance and carcass characteristics was evaluated using pigs from Trial 3 (n=80). Dietary treatments were 0, 5.0×10^4, 6.7×10^6 and 7.5×10^8 colony forming units (CFU)/d in Trial 1 and 0, 6.0×10^4, 5.0×10^5 and 5.0×10^6 CFU/d in Trials 2 through 4 and the grower-finisher trial. In Trial 1, ADG was effected quadratically at wk 1-2 and 1-5 ($P < .05$) and wk 3-5 ($P < .01$) with pigs fed the medium (6.7×10^6) BGA level having higher ADG than control pigs. Quadratic diet effects were also observed for average daily feed intake (ADFI) at wk 1-2, 1-5 ($P < .10$) and 3-5 ($P < .05$) with pigs fed the medium level of BGA having greater ADFI than

control. In Trials 2 and 3 combined, quadratic diet effects were observed for ADG at wk 3-5 ($P < .05$) with pigs fed both the low and medium BGA levels experiencing higher ADG than controls. A quadratic diet effect for ADFI was also observed at wk 3-5 ($P < .10$) with pigs fed the low and medium BGA level having greater ADFI. In Trial 4, linear diet effects were observed for ADG at wk 3-5 ($P < .10$) and 1-5 ($P < .05$) and ADFI at wk 1-2 ($P < .10$), 3-5 and 1-5 ($P < .05$) with pigs fed the high (5.0×10^6) level of BGA having lower ADG and ADFI than controls. Feed to gain (F:G) ratios were generally not affected by BGA treatment, except in Trial 1 where the quadratic diet effects at wk 1-2 ($P < .10$) suggested that pigs fed the (7.5×10^8) level of BGA were less efficient. Severe scouring was not a problem in any of the trials and BGA did not show any consistent effect upon the scouring of weanling pigs. BGA treatment also had inconsistent effects upon the pH and chloride ion concentration of feces and various gastrointestinal section contents. BGA did not influence cell-mediated immunity as measured by an intradermal injection of phytohemagglutinin. Linear diet effects ($P < .01$) were observed for the secondary response to injected sheep red blood cells in Trial 2 with all BGA treatments having higher titers than the control pigs. BGA treatment did not effect titers in the primary reaction or in either reaction in Trial 1. In

summary, BGA treatment improved feed intake and weight gain of weanling pigs in three of four trials with no consistent effect upon scour scores, fecal or gastrointestinal pH and chloride ion concentration or humoral or cell-mediated immune response. BGA treatment did not influence the performance and backfat thickness of grower-finisher swine, but loin eye muscling tended to be increased for the higher levels of BGA.
Key words: Bifidobacterium, Scours, Immune Response, Swine, Growth

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Dr. E. T. Kornegay for allowing me the chance to study under his direction and for all the technical and practical experiences that I have gained through his influence.

I would also like to thank Dr. M. D. Lindemann for giving me the chance to see and learn many things in areas other than the ones I have been exposed to, as well as, helping me to see things from a different perspective, and Dr. C. M. Wood for general pig knowledge and thesis assistance.

A very special thank you goes to my wife, Becky, without whom I would have lost the self-confidence and will to continue my education.

A grateful thank you goes to Gene Ball, Duke Reynolds, Kenny Hines and Mike Graham for lending a hand when needed, as well as, listening to me while I cleared my mind of frustrations. A special thank you to Cindy Hixon for tireless word processing instruction and good sound advice. A friendly thank you goes to Tim Schell for being there when I needed a hand and a partner, to Chad Risley for giving me scholastic and research advice, and to Han Swinkels, Wei Zhou and Lisa Flory for all their assistance. Also, Anne Dudley deserves a warm thank you for all the help with statistical analysis and explanation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDIX TABLES

Chapter I

INTRODUCTION

Early weaned pigs are exposed to changes in environmental, social and dietary regimes that usually cause a "postweaning lag" characterized by depressed growth and immune response, scours and generally poor performance (Tzipori et al., 1980; Barnett et al., 1989). It has been suggested that the poor growth of early weaned pigs is due primarily to a low feed intake and not a poor feed to gain ratio (Braude and Newport, 1977). It is also possible that the young pig is unable to produce enough hydrochloric acid within the gut to cause enzymatic activation and efficient nutrient utilization (Kidder and Manners, 1978). Cranwell (1985) suggested that the high pH may be due to the buffering capability of the ingested feedstuffs, however, he did recognize that young pigs do not produce as much HCl as older pigs.

It has been recognized that a pathogenic bacterial flora contribute to the poor postweaning performance usually observed after weaning (Parker, 1991). Therefore, if a beneficial microflora could be introduced to the host animal, perhaps the ill effects of the "postweaning lag" could be reduced.

Many combinations of viable and non-viable bacterial products have been supplemented to weanling pigs in an effort to improve the poor postweaning performance. If a beneficial microflora could improve the performance of the weanling pig, it can be postulated that improved performance could also be attained when the treatments are given to grower-finisher pigs. Bifidobacteria, an acetic and lactic acid producing microbe, is found to occur naturally in the highest concentrations in newborn humans who were birthed traditionally and breast fed (Hughes and Hoover, 1991). Hughes and Hoover (1991) cited research that stated that bifidobacteria accounts for 92% of the intestinal fora of breast fed infants but only 20% of bottle fed or weaned infants. It is possible that this established bifidobacteria flora may aid in the growth and health of these children. Given the similarities between human and porcine digestive systems, bifidobacteria may have similar effects in weanling pigs. Thus, the objectives of this study were to evaluate the effect of the addition of Bifidobacteria globsum a on the growth performance, scour score, gastrointestinal and fecal pH and chloride ion concentration and humoral and cell-mediated immune responses of weanling pigs. Also, the effect of continuous feeding of Bifidobacterium globsum a throughout the starter, grower and finisher phases on the performance and carcass characteristics of grower-finisher pigs was evaluated.

Chapter II

LITERATURE REVIEW

Weaning. The efficiency of a swine operation can be improved by weaning piglets earlier because the extra time allows the producer to increase the flow through the production system and subsequently increase the number of pigs marketed per year. Early weaning, however, tends to increase mortality rates and decrease the growth rate of pigs, especially during the early postweaning period (Leece et al., 1979). This "postweaning lag" is characterized by poor growth, increased scouring and increased mortality. It is thought to be due primarily to a low feed intake and not a poor feed to gain ratio (Braude and Newport, 1977; Armstrong and Clawson, 1980). The lower feed intake is attributed primarily to the switching of dietary regime, going from hourly liquid feed or nursing to solid feed and water, although other factors may be involved (Leece et al., 1979). During this postweaning period, a concomitant decrease in immunity has been seen for pigs weaned at 3 wk of age (Barrow et al., 1977).

Kidder and Manners (1978) have reported that early weaned pigs lack the ability to produce sufficient quantities of hydrochloric acid (HCl) in the stomach. Because of this lack in HCl production, gastric pH does not decrease enough to allow for the activation of secreted zymogens to occur. This, in turn, decreases the pig's ability to digest and subsequently utilize the ingested food. Therefore, to increase proper utilization of nutrients during the postweaning phase, pH must be lowered sufficiently to allow for enzymatic activation and the complete digestion of feedstuffs (Manners, 1976). Although the feed efficiency of weanling pigs is not thought to be poor enough to be the sole cause of poor performance, any improvement that could be made in the efficiency of the utilization of the limited amount of feed ingested could increase the performance of the pig. One way this may be accomplished is by feeding or dosing a lactic-acid producing microbe that may colonize the gastrointestinal tract and decrease gut pH (Barrow et al., 1977; Watkins and Miller, 1983).

A lower pH also accentuates the inhibitive action of lactic acid as well as other organic acids by increasing the undissociated form, which makes them more powerful as an anti-microbial (Sandine, 1979). The stresses incurred at weaning may result in an upset within the gastrointestinal tract which allows the proliferation of pathogenic organisms. This proliferation in turn, leads to an increase in scouring and may be a causative factor in the decreased feed intake of the pig.

Severe postweaning scouring that occurs in early weaned pigs may be caused by many problems, including low feed consumption and depressed immune response (Barnett et al., 1989; Bonnette et al., 1990; Sweet et al., 1990), and proliferation of pathogenic organisms within the gastrointestinal tract (Hill et al., 1970a,b; Muralidhara et al., 1977; Lyons, 1987). Supplementing the weanling pig with a favorable microflora could partially alleviate this shift in microflora and consequently improve postweaning performance.

Blecha et al. (1983) suggested that the cellular immunity of early weaned pigs (< 5 wk) was decreased due to detrimental physiologic changes brought on by weaning. Haye and Kornegay (1979) conducted research that showed a decrease in antibody production (response to injected sheep red blood cells) by pigs weaned at 3 wk of age when compared to suckling pigs. This decrease in immunocompetence may be a contributing factor to the poor postweaning growth performance.

Microbial Additives. Many digestive and perhaps systemic conditions can be influenced by the microflora within the gastrointestinal tract. Stress during weaning may create imbalances in the microflora of the weaned pig, thereby allowing growth of pathogenic microbes, resulting in poor performance (Pollmann 1986; Fuller, 1989). Parker (1991) proposed that treatments containing desirable microflora could halt the proliferation of pathogenic bacteria during times of stress. This could lessen the detrimental effects seen during early weaning. The added microbes may stop the pathogenic growth in many ways. Most have not been proved in vivo but are based on in vitro properties of the microbes (Porubcan, 1990). Fuller (1989) suggested three possible modes of action of microbial additives:

1. Suppression of viable pathogenic counts by
   a. production of antibacterial compounds
   b. competition for nutrients
   c. competition for adhesion sites

2. Alteration of microbial metabolism
   a. increased enzyme activity
   b. decreased enzyme activity

3. Stimulation of immunity
   a. increased antibody levels
   b. increased macrophage activity

Microbial additives may come in two forms, viable organisms and non-viable fermentation products (Pollmann, 1986). The reasoning behind adding viable organisms to the diet of weanling pigs was discussed above. Feeding non-viable fermentation products, however, is based upon a different postulate. Colonization of the gastrointestinal tract can not be accomplished by feeding the non-viable organisms, but the products may exert some influence over the indigenous microflora through some of the antimicrobial (antibiotic) compounds produced by the organism during fermentation. These non-viable products also contain many of the enzymes and organic acids that the viable organisms produce. By feeding these compounds, it is assumed that the enzymes and acids ingested by the host will remain active within the animal's gastrointestinal tract, thereby influencing the pH of the ingesta and the enzymatic digestion that occurs prior to nutrient absorption.

Postweaning performance. Parker (1991) reviewed numerous studies involving the use of microbial additives in swine diets and found the results on growth rates to be quite variable. Lessard and Brisson (1987) fed weaned pigs a lactobacillus fermentation product and observed a significant increase in weight gain and feed intake for the treated animals. Pollmann et al. (1980b) fed commercially available probiotics [Probios (L. acidophilus) and Feed-Mate 68 (Streptococcus faecium type cernelle 68)] to weanling swine. The probiotic treatments tended to increase average daily gain (ADG) and feed efficiency. In another weanling pig trial, Pollmann et al. (1980a) found that Probios and lactose tended to improve average daily gain, but suggested that the improvement could have been due to the added dietary carbohydrate source. Hale and Newton (1979) supplemented weanling pigs with diets containing a lactobacillus species fermentation product. Although no significant increases in ADG were observed, the feed to gain ratios of the treated animals were significantly lower than controls. Ratcliffe et al. (1986) reported that yoghurt and milk fermented with viable L. reuteri when fed to pigs weaned at 2 d increased lactobacillus counts throughout the gut over pigs fed the base milk. The microbial treatments also significantly decreased the pH within the gut of the treated animals.

There have also been reports of little or no response by pigs to microbial supplementation. Kluber et al. (1985) fed artificially reared pigs milk fortified with Streptococcus faecium and observed no advantage for the treated group over control for weight gain, feed efficiency or feed intake. The S. faecium treatment group actually had a higher incidence of mortality than the control group. The lack of treatment effect on performance is in agreement with data from Kornegay (1986), who found no beneficial effect of dosing nursing pigs with L. acidophilus. Kornegay (1971) also reported no effect of S. faecium additions on the growth of weanling pigs. Kornegay and Thomas (1973) also reported no effect for S. faecium additions, however they observed improvements in average daily gain and feed intake for pigs fed Lactobacillus acidophilus milk added to starter rations before and after weaning.

Scours. Weanling pigs that are scouring have been shown to have an increased number of E. coli and coliforms in the small intestine (Muralidhara et al., 1977; Lyons, 1987). These researchers also observed a decrease in scouring and E. coli numbers in pigs fed viable lactobacilli. Lactobacilli have also been shown to decrease small intestinal and urinary amine production when fed to early weaned pigs with postweaning scours (Hill et al., 1970a). Fernandes et al. (1988) suggested that pathogenic scour-causing agents may be inhibited by lactic acid producing bacteria because they produce antimicrobial substances that inhibit pathogenic bacteria in vitro. Pollmann et al. (1980c) reported that gnotobiotic pigs treated with L. acidophilus inoculum had significantly higher L. acidophilus counts than control pigs, suggesting that L. acidophilus colonized the gastrointestinal tract of the treated animals. In conventional pigs, lactobacillus counts increase and E. coli counts decrease with age regardless of prior microbial inoculum treatment (Pollmann et al., 1980c).

Ratcliffe et al. (1986) reported a decrease in gut pH for pigs fed yoghurt or milk fermented with L. reuteri. They suggested that the bacteriologic changes within the colon of the treated animals may have been due to the upgrowth of indigenous lactobacilli and their inhibition of E. coli. Although actual scour evaluation was not performed in either of these studies, it can be assumed that conditions within the gastrointestinal tract did not favor organisms that cause scouring. Ratcliffe et al. (1986)

summarized their experiments by stating that the effects on the gut microflora lend support to the claims for beneficial effects of yoghurt supplementation on gastrointestinal disease by lowering gut pH and subsequently aiding in digestion.

Bifidobacterium sp., a strong acetic and lactic-acid producing microbe closely associated with the lactobacillus genus, has been shown to inhibit the growth of pathogenic organisms (Sung et al., 1985; Fernandes et al., 1988). The beneficial effects of ingesting bifidobacterial populations are well known on other continents. Bifidus milk products are marketed extensively across Japan and Europe. Japanese doctors readily prescribe the use of bifidus milk products to people suffering from intestinal problems.

Bifidobacteria have been thought to be responsible for the reduced tendencies for diarrhea in breast-fed human infants, as they are the predominant microbe found in the intestinal tract (Tamura, 1983). After a review of available research, Tamura (1983) suggested that bifidobacteria may be established within the intestines, if the host is supplied with viable organisms. Tanaka et al. (1983) reported that when bifidobacteria were administered with a growth factor to humans, the organisms altered the intestinal microflora to a more favorable one.

Hughes and Hoover (1991) reviewed the literature in regard to bifidobacteria and suggested that although these microbes inhibit pathogenic proliferation by production of acids and low pH, the predominant bifidobacteria microflora in infants is susceptible to fluctuations caused by small disturbances of diet.

Immunity. Studies have been conducted in which supplemental viable microbes caused an increase in immune response. Perdigon et al. (1986) perorally administered L. casei and L. bulgaris to mice and found increased activation of macrophages in the treated animals. Antitumor activity of L. casei given intraperitoneally to mice has been reported (Kato et al., 1981; Yasutake et al., 1984). Mice treated with L. casei lived longer than controls when both had allogeneic and syngeneic tumors (Kato et al., 1981). Perdigon et al. (1987) showed an enhancement of immune response in Swiss mice fed viable cultures of S. thermophilus and L. acidophilus. The phagocytic activity of peritoneal macrophages was greater for treated animals. Mice fed microbes also showed accelerated phagocytic function of the reticuloendothelial system.

L. brevis and L. plantarum were used by Bloksma et al. (1979) to evaluate their adjuvanticity when administered to mice. Viable lactobacilli stimulated delayed hypersensitivity, and heat-killed microbes had an adjuvant effect on the production of antibodies. Lessard and Brisson (1987) showed that lactobacillus fermentation products, when fed to pigs, increased serum Ig G levels compared with pigs fed the control diet on the day of vaccination and at the end of the feeding period. Bifidobacterium breve (Yasui et al., 1989) and B. longum (Yamazaki et al., 1985) have been shown to increase the intestinal and cell-mediated immune response in mice.

Because of the inferences made by these studies that link microbial flora to increases in immunity, one must consider the possibility that the use of a proper microbial feed additive could enhance not only the growth of weaned animals, but their health as well. Feeding a microbe that would enhance cell-mediated or humoral immune response could improve overall efficiency within the nursery of swine operations largely by decreasing mortality and improving postweaning performance.

Growing-finishing performance. The benefit of a probiotic administered to growing-finishing pigs is questionable because these animals are stressed less, have greater immunocompetence and an established microflora (Fox 1988). Harper et al. (1983) fed growing-finishing pigs a diet supplemented with a lactobacillus probiotic and reported no improvement in ADG, feed intake or feed efficiency. Pollmann et al. (1980b) fed growing-finishing pigs commercially available microbial products and showed no effect on the performance of treated pigs. Kornegay et al. (1990) fed L. acidophilus to growing-finishing pigs and observed no beneficial effect for performance or carcass characteristics.

Baird (1977), however, showed in three trials using grower pigs that supplementation with Probios (L. acidophilus) improved ADG (10.8%) and feed efficiency (7.2%) over control pigs. Maxwell et al. (1982) reported that growing-finishing pigs fed Feedmate 68 (S. faecium type cernelle 68) or Primalac (L. acidophilus) had significantly greater ADG than control pigs, with the increase greater for pigs fed Feedmate 68. Although not statistically significant, feed to gain ratios were numerically improved for pigs given either treatment.

Chapter III

THE EFFECT OF FEEDING VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A ON THE PERFORMANCE, SCOURING INDEX, GASTROINTESTINAL MEASUREMENTS AND IMMUNITY OF WEANLING AND GROWING-FINISHING PIGS

G. A. Apgar, E. T. Kornegay, M. D. Lindemann and C. M. Wood
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

Abstract

Four trials using 312 weanling pigs (average initial wt of 7.2 kg) were conducted to examine the effectiveness of Bifidobacterium globsum a (BGA) on the growth performance, scour scores, humoral and cell-mediated immune response and pH and chloride ion concentration (CIC) of feces and gastrointestinal section contents. The effect of continuous feeding of BGA from weaning to market weight on performance and carcass characteristics was evaluated using pigs from Trial 3 (n=80). Dietary treatments were 0, 5.0×10^4, 6.7×10^6 and 7.5×10^8 colony forming units (CFU)/d in Trial 1 and 0, 6.0×10^4, 5.0×10^5 and 5.0×10^6 CFU/d in Trials 2 through 4 and the grower-finisher trial. In Trial 1, ADG was effected quadratically at wk 1-2 and 1-5 ($P < .05$) and wk 3-5 ($P < .01$) with pigs fed the medium (6.7×10^6) BGA level having higher ADG than control pigs. Quadratic diet effects were also observed for average daily feed intake (ADFI) at wk 1-2, 1-5 ($P < .10$) and 3-5 ($P < .05$) with pigs fed the medium level of BGA having greater ADFI than control. In Trials 2 and 3 combined, quadratic diet effects

were observed for ADG at wk 3-5 ($P < .05$) with pigs fed both the low and medium BGA levels experiencing higher ADG than controls. A quadratic diet effect for ADFI was also observed at wk 3-5 ($P < .10$) with pigs fed the low and medium BGA level having greater ADFI. In Trial 4, linear diet effects were observed for ADG at wk 3-5 ($P < .10$) and 1-5 ($P < .05$) and ADFI at wk 1-2 ($P < .10$), 3-5 and 1-5 ($P < .05$) with pigs fed the high (5.0×10^6) level of BGA having lower ADG and ADFI than controls. Feed to gain (F:G) ratios were generally not affected by BGA treatment, except in Trial 1 where the quadratic diet effects at wk 1-2 ($P < .10$) suggested that pigs fed the (7.5×10^8) level of BGA were less efficient. Severe scouring was not a problem in any of the trials and BGA did not show any consistent effect upon the scouring of weanling pigs. BGA treatment also had inconsistent effects upon the pH and chloride ion concentration of feces and various gastrointestinal section contents. BGA did not influence cell-mediated immunity as measured by an intradermal injection of phytohemagglutinin. Linear diet effects ($P < .01$) were observed for the secondary response to injected sheep red blood cells in Trial 2 with all BGA treatments having higher titers than the control pigs. BGA treatment did not effect titers in the primary reaction or in either reaction in Trial 1. In summary, BGA treatment improved feed intake and weight gain

of weanling pigs in three of four trials with no consistent effect upon scour scores, fecal or gastrointestinal pH and chloride ion concentration or humoral or cell-mediated immune response. BGA treatment did not influence the performance and backfat thickness of grower-finisher swine, but loin eye muscling tended to be increased for the higher levels of BGA.
Key words: Bifidobacterium, Scours, Immune Response, Swine, Growth

Introduction

Early weaned pigs are exposed to changes in environmental, social and dietary regimes that usually result in decreased gain and immune response, increased scouring and overall poor performance (Tzipori et al., 1980; Barnett et al., 1989). Numerous approaches, such as decreasing dietary pH, feeding subtherapeutic levels of antibiotics, offering creep feed (preweaning) and weaning at night, have been tried with only limited success. Some evidence suggests that the feeding of lactic acid producing microbes can be helpful in alleviating some of these postweaning problems by decreasing the pH within the gastrointestinal tract, and thus aiding in the digestive process (Barrow et al., 1977; Watkins and Kratzer, 1983); by reducing scours, via antibiotic production or colonization of the tract (Shahani and Ayebo, 1980; Watkins and Kratzer, 1983); and possibly by increasing immune response (Yamakazi et al., 1985; Sasaki et al., 1987; Lessard and Brisson, 1987; Yasui et al., 1989). Pollmann et al. (1980b) showed an improved ADG and feed utilization in pigs fed a microbial probiotic, but others have reported no improvement (Kluber et al., 1985; Kornegay, 1986). Watkins and Miller (1983) showed that oral dosing of chicks with Lactobacillus acidophilus reduced pathogenic bacteria in the alimentary tract via competitive exclusion.

The objectives of this study were to evaluate the effect of the addition of Bifidobacterium globsum a (BGA) on the performance, scour score, gastrointestinal and fecal pH and chloride ion concentration, and humoral and cell mediated immune response of weanling pigs, and to observe the effects of continuous feeding of BGA on the growth performance and carcass characteristics of growing-finishing pigs.

Materials and Methods

Crossbred weanling pigs (n=312, average initial wt of 7.2 kg) were used in four trials to evaluate the effectiveness of Bifidobacterium globsum a (BGA)[1] as a feed additive. Pigs were randomly allotted to four dietary treatments in each trial from outcome groups based on sex and weight, with the restriction that littermates be

---

[1]Supplied by Bio Techniques Laboratories, Inc., Redmond WA.

balanced across pens. Two pigs were held per pen (0.6 m x 1.2 m) in Trials 1 (nine replicates, n=72), 2 (nine replicates, n=72) and 3 (twelve replicates n=96) and three pigs were held per pen (1.2 m x 1.2 m) in Trial 4 (six replicates, n=72). Pens had wire bottom floors in Trials 1 and 2 and plastic coated welded wire floors in Trials 3 and 4, all were located in totally enclosed, heated and ventilated rooms.

Pigs were fed a 20% CP corn-soybean meal diet formulated to meet or exceed NRC (1988) requirement estimates (Table 1). The predetermined amounts [0, 5.0 x 10^4, 6.7 x 10^6 and 7.5 x 10^8 colony forming units (CFU)/d in Trial 1; and 0, 6.0 x 10^4, 5.0 x 10^5 and 5.0 x 10^6 CFU/d in Trials 2, 3 and 4] of freeze-dried BGA concentrate were rehydrated with deionized water and mixed with the appropriate amount of diet either daily in Trials 1 and 3, or every other day in Trials 2 and 4, to ensure uniform pig inoculation. At the end of each feeding interval, residual feed was weighed and discarded. The amount of feed to mix at each feeding was estimated to be slightly greater than the total amount the pigs would ingest. The amount was based on the feed consumption from the prior 1 or 2 d interval and the increasing needs of the pigs. Thus, diet and water (nipple waterers) were available at all times. Pigs were weighed and feed consumption was recorded weekly in all trials. Subjective scour scores were determined by visual appraisal of each pen every other day using a five point scoring system: 1=hard feces (rarely seen); 2=normal consistency of feces formed (no scours); 3=soft, partially formed feces (mild scours); 4=loose, semi-liquid feces (moderate scours) and 5=watery feces (severe scours). In Trials 1 and 2, fecal pH (Fisher Scientific, Pittsburgh, PA) and chloride ion concentration (CIC) (Orion Research, Cambridge, MA) were determined weekly. A 2 g fecal sample was collected per pen, fully suspended in 18 ml of deionized water, and measurements were made within 15 min.

Also in Trials 1 and 2, pigs were injected with 1 ml of sheep red blood cells (5.0 x 10^9 cells) intraperitoneally at wk 1 (d 7) and 3 (d 21). Blood was collected from the anterior vena cava at wk 1 (d 7), 3 (d 21) and 5 (d 35) for determination of the immune response to the imposed antigen. Hemagglutination assays were performed as described by Schurig et al. (1978). Cell-mediated immune response was evaluated by administering an intradermal injection of .1 ml phytohemagglutinin (PHA) (1000 μg/ml) 5 cm posterior to the last nipple and 5 cm from the midline of the ham on d 35 as described by Blecha et al. (1983). The immune response was assessed on d 36 by measuring the skin-fold thickness using a constant tension dial micrometer (Model 7305, Ralmike's Tool-A-Rama, So. Plainfield, NJ).

Five barrows per treatment (one from each of five randomly selected replicates) in both Trial 1 and 2 were killed via electrocution and exsanguination at the termination of the trials. The stomach, jejunum, cecum and lower colon were immediately exposed by a midline incision and removed following double ligation. The contents were removed from each gut portion, and pH and chloride ion concentration were determined as described by Risley et al. (1991).

A grower-finisher study was conducted using 80 pigs [all females (n=48), and males from 8 of 12 randomly selected replicates (n=32)] from starter Trial 3. Pigs were continued on the same dietary treatments and were fed daily through wk 6 and every other day thereafter until each replicate mean averaged approximately 104 kg. Grower-finisher pigs were housed five per pen (three females and two males) in partially slatted concrete floored pens that allowed 0.89 square meters per pig in a totally enclosed and ventilated building. Pigs were weighed and feed consumption was recorded biweekly. Feed efficiency was calculated. Ultrasonography (Aloka 500 realtime ultrasound machine, Corometrics Medical Sys. Inc. Wallingford, Conn., with a 3.5 Mhz probe) was used to obtain measurements of fat depth and loin muscle area at the tenth rib for all five pigs in each pen. In addition, standard carcass characteristics were measured by slaughtering all the males and determining carcass length, fat depth at the last rib midline, loin muscle area, backfat at the tenth rib, dressing percentage and hot carcass weight.

Performance data from each trial were analyzed using the General Linear Model (GLM) procedures of the Statistical Analysis System (SAS, 1990), with pen mean as the experimental unit. The final model included the effects of replicate and diet, after determining that gender and two-way interactions were nonsignificant. Orthogonal contrasts were used to discern treatment effects. Linear and quadratic contrasts were also evaluated. For each trial, individual pig values for fecal pH, chloride ion concentration, scour score and PHA data were analyzed using the GLM procedure of SAS (1990) with a model that included replicate and diet. In addition, data from Trials 2 and 3 were pooled and analyzed because the design was similar in both trials. The model for these data included trial, replicate within trial, and diet. Individual pig ultrasonographic and carcass data were analyzed utilizing the GLM procedure of SAS (1990). The models included the effects of diet and replicate for the carcass data, and diet, replicate and sex for the ultrasound data. Final weight was also included in both models as a covariate.

Results

Performance. In Trial 1, quadratic diet effects were evident during wk 1-2 ($P < .05$), 3-5 ($P < .01$) and 1-5 ($P < .05$) with the pigs fed the medium BGA level having the highest ADG (Table 2). In Trials 2 and 3 combined, a quadratic diet effect occurred at wk 3-5 ($P < .05$) with pigs fed the low (6.0×10^4) and medium (5.0×10^5) BGA level having the higher ADG than controls (Table 3). In Trial 4, however, ADG was not improved with supplemental BGA (Table 4), and linear diet effects were observed at wk 3-5 ($P < .10$ and 1-5 ($P < .05$), with the pigs fed the high BGA level experiencing lower gains than control pigs.

In Trial 1, quadratic diet effects were observed for average daily feed intake (ADFI) at wk 1-2 ($P < .10$), 3-5 ($P < .05$ and 1-5 ($P < .10$) with pigs fed the medium BGA level having higher ADFI than controls (Table 2). A quadratic diet effect was observed for ADFI in Trials 2 and 3 combined at wk 3-5 ($P < .10$) also with pigs fed the medium BGA level having greater ADFI than controls (Table 3). In Trial 4, linear diet effects were observed for ADFI during wk 1-2 ($P < .10$), 3-5 and 1-5 ($P < .05$), with pigs fed the high BGA level having less ADFI than controls (Table 4).

Feed per gain ratios (F:G) were not affected by BGA treatments in Trials 2 and 3 or 4 (Tables 3 and 4). In Trial 1, quadratic diet effects ($P < .01$) were observed for

F:G at wk 3-5 and 1-5 with pigs fed the medium BGA level having the highest F:G (Table 2).

In the grower-finisher phase of Trial 3, a linear diet effect was observed for ADG during wk 4 ($P < .10$) with pigs fed the high BGA level having higher ADG than controls (Appendix Table 16). Overall ADG and ADFI were numerically greater than controls for all BGA treatments but differences were not significant (Appendix Table 17). Supplementation of BGA did not affect F:G at any point during the trial (Appendix Table 18).

pH and Chloride ion concentration. Fecal pH and chloride ion concentration (CIC) were generally unaffected by all levels of BGA fed in both Trials 1 and 2 with only a few exceptions in Trial 1 for pH and CIC (Appendix Tables 19 and 20). A linear diet effect was observed for fecal pH during wk 3 ($P < .10$) with pigs fed the high (7.5×10^8) level of BGA having lower pH than controls and for fecal CIC during wk 5 ($P < .05$) with pigs fed the high BGA level having greater CIC. Quadratic diet effects were observed for CIC at wk 2 and wk 5 ($P < .10$) with pigs fed the high level of BGA having the greater CIC.

In Trial 1, linear diet effects were observed for stomach content pH ($P < .05$) and CIC ($P < .01$) with pigs fed the high (7.5×10^8) level of BGA having lower pH and higher CIC than controls (Appendix Table 21). A quadratic diet effect was also observed for stomach CIC ($P < .10$). In Trial 2, quadratic diet effects occurred for jejunum and lower colon pH ($P < .10$) and for cecum CIC ($P < .05$) (Appendix Table 22). Pigs fed the high (5.0×10^6) BGA level had higher jejunum pH and lower cecum CIC than controls, while pigs fed the medium (5.0×10^5) BGA level had a lower pH of lower colon contents than control pigs.

Scour score. Only very mild scouring was observed during the first several days after weaning in all trials, and BGA feeding generally did not affect scour scores. Both lower and higher scour scores were observed for pigs fed the various levels of BGA compared with the controls, with no consistent pattern evident. For example, in Trial 1, a quadratic diet effect ($P < .05$) occurred at d 7 with pigs fed the medium (6.0×10^6) BGA level having lower scores while a linear diet effect ($P < .05$) occurred at d 9 with pigs fed the high (7.5×10^8) level of BGA having higher scores than control pigs (Appendix Table 23). In Trial 2, linear diet effects were observed at d 3 ($P < .05$) and d 9 ($P < .10$) with pigs fed the medium and high BGA levels having higher scores than the control pigs, respectively (Appendix Table 24). A quadratic diet effect was also observed at d 5 with the pigs fed the medium BGA level having lower scores and pigs fed the low BGA level having higher scores than control pigs, respectively (Appendix

Table 25). In Trial 4, a quadratic diet effect ($P < .10$) was observed at d 9 with pigs fed the low BGA level having higher scores than controls (Appendix Table 26).

Immune response. The reaction to an intradermal injection of a phytohemagglutinin was not influenced by BGA feeding in either Trials 1 or 2 (Appendix Table 27). Neither the primary nor secondary response to sheep red blood cells in Trial 1 was influenced by BGA feeding (Appendix Table 28). However, in Trial 2, a linear diet effect ($P < .01$) was observed for the secondary response with pigs fed all levels of BGA having higher responses than control pigs.

Carcass characteristics. BGA treatment had no effect upon the carcass characteristics of slaughtered pigs (Appendix Table 29). Live ultrasound measurements, however, showed significant ($P < .05$) linear and quadratic diet effects upon loin muscle area with pigs fed the medium and high BGA levels having the greatest loin eye areas. Although dietary treatments did not influence fat depth, a significant sex effect was observed ($P < .01$), with females having less fat than castrated males.

Discussion

Performance. Improved ADG and ADFI in three of four trials for weanling pigs fed BGA is in agreement with data reported by Pollmann et al. (1980b) and Lessard and Brisson

(1987). Pollmann et al. (1980b) reported that the addition of a lactobacillus probiotic to starter diets improved ADG (9.7%) and F:G (4.4%). Lessard and Brisson (1987) observed increased weight gain (9.0%) and feed intake (16.7%) for pigs fed lactobacillus fermentation product; but F:G ratios were unaffected. Other researchers, however, have reported no response to supplemented microbial products. Kluber et al. (1985) observed no advantage for pigs artificially reared and fed milk fortified with S. faecium; treated pigs had a higher mortality than controls. Kornegay (1986) also observed no effect on the performance of weanling pigs dosed with L. acidophilus. The variation in reponses to microbial supplementation is widely documented. The most common reason given for a lack of response to dietary additions of microbes is a lack of consistently viable organisms. The viability was not checked in our study.

The data from the grower-finisher trial showed no significant differences in ADG, F:G or ADFI, although means numerically favored the treatment groups in all except F:G. Harper et al. (1983) showed that dietary additions of a lactobacillus probiotic to grower-finisher pigs had little or no beneficial effect on growth. Hale and Newton (1979) reported that pigs fed a non-viable lactobacillus fermentation product had numerically greater weight gains than control pigs. However, in contrast to our data, pigs treated with the non-viable lactobacillus fermentation product were more efficient than controls. Pollmann et al. (1980b) who had observed an improvement in the performance of starter pigs fed a commercial probiotic (Probios), did not obtain an improvement for grower-finisher pigs. Our data suggest perhaps small improvements may be seen when grower-finisher pigs are fed a diet supplemented with BGA.

Scour score. Although microbial treatments have been reported to decrease scouring in pigs (Shahani and Ayebo, 1980) and in chicks (Watkins and Kratzer, 1983), BGA treatments in our trials did not consistently aid in scour reduction. However, scouring was not considered to be a problem in our trials.

pH and Chloride ion Concentration. Fecal pH and CIC were also inconsistently affected by BGA treatment. Although dietary effects were seen in Trial 1, Trial 2 showed no effect throughout. The data must therefore be interpreted with caution.

The pH and CIC of various gastrointestinal tract contents of BGA treated pigs appeared to be inconsistent. In Trial 1, treated pigs had lower stomach pH and concomitant higher CIC. These data suggest that perhaps the change in pH was due to an increase in hydrochloric acid production. Risley et al. (1991), however, reported that CIC is probably more a reflection of chloride present in the feed than actual hydrochloric acid production. We agree because although all pigs were fed the same basal diet, they were not uniformly slaughtered at predetermined time periods after feeding. Therefore, the CIC is probably due to varying amounts of diet present within the tract.

Immune response. Results from our cell-mediated immune response data agree with those presented by Kluber et al. (1985), who reported no affect of S. faecium treatment of weaned pigs on the cell-mediated immune response. The increased secondary immune response to sheep red blood cells, however, more closely follows the results of researchers who reported increased immune responses in animals treated with microbial products. Perdigon et al. (1986) showed increased macrophage activation in mice fed L. casei and L. bulgaris. Mice treated with S. thermophilus and L. acidophilus have also been shown to have higher phagocytic activity of peritoneal macrophages and the reticuloendothelial system (Perdigon et al., 1987). Lactobacilli have been reported to possess antitumor properties when given to mice (Kato et al., 1981; Yasutake et al., 1984). The absence of a major effect upon the immune responses measured in this study could be due to the type of immunity investigated. The bacterial treatment may have increased phagocytic activity, however, this measurement was not investigated.

Carcass characteristics. Dietary BGA addition had no effect upon carcass measurements obtained after slaughter, which corroborates with results reported by Kornegay et al. (1990); they reported that feeding L. acidophilus to grower-finisher pigs did not improve carcass characteristics as measured by slaughter and ultrasonographic techniques. Our data, however, showed BGA treatments positively affected loin muscle areas of grower-finisher pigs as measured by ultrasonography, although carcass measurements showed no differences. This could be due, in part, to the differences in numbers of animals measured.

Implications

Dietary additions of Bifidobacterium globsum a increased the growth performance of weanling pigs in three of four trials. Therefore, additions of these microbes to starter diets may help to alleviate some of the poor performance of early weaning.

Table 1. PERCENTAGE COMPOSITION OF DIETS FOR STARTER AND GROWER-FINISHER PIGS[a]

Item	Starter	Grower
Corn	64.00	76.41
Soybean meal (44% CP)	33.10	21.25
Ground limestone	.83	.63
Deflourinated phosphate	-	.93
Dicalcium phosphate	1.40	-
Salt (plain)	.25	.25
Vitamin-Se premix[b]	.25	.25
Copper sulfate (25% Cu)	-	.08
Trace mineral premix[c]	.10	.05
Tylosin[d]	-	.15
Lysine	.04	-

[a]Calculated to supply:(starter) 20% crude protein, .80% Ca, .65% P and 1.15% lysine;(grower) 16% crude protein, .60% Ca, .5% P.
[b]Supplied per kilogram of diet: (starter) 4,400 IU vitamin A, 440 IU vitamin D, 11 IU vitamin E, 4.4 mg riboflavin, 22 mg d-pantothenic acid, 22 mg niacin, 489.5 mg choline, .022 mg vitamin B_{12}, .5 mg menadione, .44 mg d-biotin and .3 mg Se; (grower) 4,492 IU vitamin A, 449.2 IU vitamin D_3, 11.2 IU vitamin E, 4.5 mg riboflavin, 22.5 mg d-pantothenic acid, 22.5 mg niacin, 449 mg choline, .022 mg vitamin B_{12}, .45 mg d-biotin and .3 mg Se.
[c]Supplied per kilogram of diet: (starter) 105 mg Zn, 123 mg Fe, 42 mg Mn, 12 mg Cu, 2 mg I;(grower) 110 mg Zn, 50 mg Fe, 2.25 mg Mn, 5.5 mg Cu and .75 mg I.
[d]Supplied per kg of diet: 33.7 mg tylosin.

Table 2. LEAST SQUARES MEANS OF PERFORMANCE DATA FROM STARTER PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 1

Items	Treatments[a]				SEM
	Control	5.0×10^4	6.7×10^6	7.5×10^8	
Body weight, kg					
Initial	7.7	7.7	7.7	7.7	.03
Final	21.0	21.4	22.2	20.0	.44
Average daily gain, g					
wk 1-2[b]	183	204	219	159	17
3-5[c]	510	515	540	481	15
1-5[b]	379	390	412	352	13
Average daily feed intake, g					
wk 1-2[d]	295	312	360	293	22
3-5[b]	894	915	1000	836	35
1-5[d]	654	674	744	619	28
Feed per gain ratios					
wk 1-2[d]	1.68	1.62	1.64	1.96	.12
3-5	1.76	1.77	1.86	1.74	.05
1-5	1.72	1.72	1.80	1.76	.04

[a]Nine pens (two pigs per pen) per treatment mean.
[b]Quadratic diet effect ($P < .05$).
[c]Quadratic diet effect ($P < .01$).
[d]Quadratic diet effect ($P < .10$).

Table 3. LEAST SQUARES MEANS OF PERFORMANCE DATA FROM STARTER PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIALS 2 AND 3

	Treatments[a]				
Items	Control	6.0×10^4	5.0×10^5	5.0×10^6	SEM
Body weight, kg					
Initial	6.6	6.6	6.5	6.6	.02
Final	17.3	17.8	17.9	17.2	.31
Average daily gain, g					
wk 1-2	134	127	140	129	7
3-5[b]	408	438	435	413	10
1-5	300	315	318	300	9
Average daily feed intake, g					
wk 1-2	218	207	219	201	7
3-5[c]	680	713	736	678	20
1-5	498	514	533	490	14
Feed per gain ratios					
wk 1-2	1.73	1.70	1.61	1.69	.09
3-5	1.66	1.61	1.68	1.63	.02
1-5	1.66	1.62	1.67	1.63	.02

[a]Twenty one pens (two pigs per pen) per treatment mean.
[b]Quadratic diet effect ($P < .05$).
[c]Quadratic diet effect ($P < .10$).

Table 4. LEAST SQUARES MEANS OF PERFORMANCE DATA FROM STARTER PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 4

	Treatments[a]				
Items	Control	6.0×10^4	5.0×10^5	5.0×10^6	SEM
Body weight, kg					
Initial	7.9	8.1	8.0	8.0	.06
Final	22.0	21.5	21.6	20.6	.41
Average daily gain, g					
wk 1-2	232	208	213	212	10
3-5[b]	543	528	531	483	18
1-5[c]	415	397	400	371	11
Average daily feed intake, g					
wk 1-2[b]	328	326	327	317	15
3-5[c]	881	894	896	837	36
1-5[c]	654	660	662	623	26
Feed per gain ratios					
wk 1-2	1.42	1.57	1.53	1.50	.06
3-5	1.61	1.70	1.69	1.73	.06
1-5	1.57	1.67	1.65	1.67	.05

[a]Twelve pens (three pigs per pen) per treatment mean.
[b]Linear diet effect ($P < .10$).
[c]Linear diet effect ($P < .05$).

Chapter IV

Literature Cited

Armstrong, W. D. and A. J. Clawson. 1980. Nutrition and management of early weaned pigs: effect of increased nutrient concentrations and (or) supplemental liquid feeding. J. Anim. Sci. 50(3):377-384.

Baird, M. 1977. Probiotics help boost feed efficiency, seminar told. Sept. 19, Feedstuffs, p 11.

Barnett, K. L., E. T. Kornegay, C. R. Risley, M. D. Lindemann and G. G. Schurig. 1989. Characterization of creep feed consumption and its subsequent effects of immune response, scouring index and performance of weanling pigs. J. Anim. Sci. 67:2698-2708.

Barrow, P. A., R. Fuller and M. J. Newport. 1977. Changes in the microflora and physiology of the anterior intestinal tract of pigs weaned at 2 days, with special reference to the pathogenesis of diarrhea. Infect. Immun. 18(3):586-595.

Blecha, F., D. S. Pollmann and D. A. Nichols. 1983. Weaning pigs at an early age decreases cellular immunity. J. Anim Sci. 56(2):396-400.

Bloksma, N., E. De Heer, H. Van Dijk and J. M. Willers. 1979. Adjuvanticity of lactobacilli: differential effects of viable and killed bacteria. Clin. Exp. Immunol. 37:367-375.

Bonnette, E. D., E. T. Kornegay, M. D. Lindemann and D. R. Notter. 1990. Influence of two supplemental vitamin E levels and weaning age on performance, humoral antibody production and serum cortisol levels of pigs. J. Anim. Sci. 68:1346-1353.

Braude, R. and M. J. Newport. 1977. A note on a comparison of two systems for rearing pigs weaned at 2 days of age, involving either a liquid or pelleted diet. Anim. Prod. 24(2):271-279.

Cranwell, P. D. 1985. The development of acid and pepsin secretory capacity in the pig; the effects of age and weaning. Br. J. Nutr. 54:305-320.

Fernandes, F. C., K. M. Shahani and M. A. Amer. 1988. Control of diarrhea by lactobacilli. J. Appl. Nutr. 40(1):32-43.

Fox, S. M. 1988. Probiotics/intestinal inoculants in animal production. Proc. II World Conference on Animal Production, June 27-July 1, p 443.

Fuller, R. 1989. Probiotics in man and animals. J. Appl. Bacteriol. 66:365-378.

Hale, O. M. and G. L. Newton. 1979. Effects of a nonviable lactobacillus species fermentation product on performance of pigs. J. Anim. Sci. 48(4):770-775.

Harper, A. F., E. T. Kornegay, K. L. Bryant and H. R. Thomas. 1983. Efficacy of virginiamycin and a commercially-available lactobacillus probiotic in swine diets. Anim. Feed Sci. Techn. 8:69-76.

Haye, S. N. and E. T. Kornegay. 1979. Immunoglobin G, A and M and antibody response in sow-reared and artificially-reared pigs. J. Anim. Sci. 48(5):1116-1122.

Hill, I. R., R. Kenworthy and P. Porter. 1970a. Studies of the effect of dietary lactobacilli on intestinal and urinary amines in pigs in relation to weaning and post-weaning diarrhoea. Res. Vet. Sci. 11:320-326.

Hill, I. R., R. Kenworthy and P. Porter. 1970b. The effect of dietary lactobacilli on in-vitro catabolic activities of the small-intestinal microflora of newly weaned pigs. J. Med. Microbiol. 3:593-605.

Hughes, D. B. and D. G. Hoover. 1991. Bifidobacteria: their potential for use in American dairy products. Food Techn. Apr. 74-83.

Kato, I., S. Kobayashi, T. Yokokura and M. Mutai. 1981. Antitumor activity of lactobacillus casei in mice. Jpn. J. Cancer Res. 72:517:523.

Kidder, D. E. and Manners, M. J. 1978. In: Digestion in the pig. Kingston Press, Bath, 212 pp.

Kluber, E. F., D. S. Pollmann and F. Blecha. 1985. Effect of feeding Streptococcus faecium to artificially reared pigs on growth, hematology and cell-mediated immunity. Nutr. Rpts. Intl. 32(1):57-65.

Kornegay, E. T. 1971. Comparison of S. faecium and antibiotics in starter rations. Res. Div. Rep. 135:25-27. Virginia Poly. Inst. State Univ. Blacksburg.

Kornegay, E. T. 1986. Effect of dosing or feeding Lactobacillus acidophilus on blood cholesterol levels and growth rate of weanling and growing pigs. Anim. Sci. Res. Rpt. 5:14-19. Virginia Poly. Inst. State Univ. Blacksburg.

Kornegay, E. T. and H. R. Thomas. 1973. Bacterial and yeast preparations for starter and grower rations. Res. Div. Rep. 149. 5 pp. Virginia Poly. Inst. State Univ. Blacksburg.

Kornegay, E. T., C. M. Wood, G. G. Ball and C. R. Risley. 1990. Use of Lactobacillus acidophilus for growing and finishing pigs. Anim. Sci. Res. Rpt. 9:13-16.

Leece, J. G., W. D. Armstrong, P. C. Crawford and G. A. Ducharme. 1979. Nutrition and management of early weaned piglets: liquid vs. dry feeding. J. Anim. Sci. 48(5):1007-1014.

Lessard, M. and G. J. Brisson. 1987. Effect of a lactobacillus fermentation product on growth, immune response and fecal enzyme activity in weaned pigs. Can. J. Anim. Sci. 67:509-516.

Lyons, T. P. 1987. Probiotics: an alternative to antibiotics. Pig News Info. 8:157-164.

Manners, M. J. 1976. The development of digestive function in the pig. Proc. Nutr. Soc. 35:49-281.

Maxwell, C. V., D. S. Buchanan, F. N. Owens, S. E. Gilliland and W. G. Luce. 1982. Effect of probiotic supplementation on performance, fecal parameters and digestibility in growing-finishing swine. J. Anim. Sci. 55(Suppl.1):284-285.

Muralidhara, K. S., G. G. Sheggeby, P. R. Elliker, D. C. England and W. E. Sandine. 1977. Effect of feeding lactobacilli on the coliform and lactobacilli flora of intestinal tissue and feces from piglets. J. Food Prot. 40(5):288-295.

NRC. 1988. Nutrient requirement of swine (9th ed.). National Academy Press, Washington DC, 93 pp.

Parker D. 1991. In: Direct-fed microbials in animal production a review of literature. Natl. Feed Ingred. Assoc., 93 pp.

Perdigon, G., M. E, Nader de Macias, S. Alvarez, G. Oliver and A. A. Pesce de Ruiz Holgado. 1987. Enhancement of immune response in mice fed with Streptococcus thermophilus and Lactobacillus acidophilus. J. Dairy Sci. 70:919-926.

Perdigon, G., M. E. Nader de Macias, S. Alvarez, G. Oliver and A. A. Pesce de Ruiz Holgado. 1986. Effect of perorally administered lactobacilli on macrophage activation in mice. Infect. Immun. 53(2):404-410.

Pollmann, D. S., D. M. Danielson and E. R. Peo Jr. 1980a. Effect of Lactobacillus acidophilus on starter pigs fed a diet supplemented with lactose. J. Anim. Sci. 51(3):638-644.

Pollmann, D. S., D. M. Danielson and E. R. Peo Jr. 1980b. Effects of microbial feed additives on performance of starter and growing-finishing pigs. J. Anim. Sci. 51(3):577-581.

Pollmann, D. S., D. M. Danielson, W. B. Wren, E. R. Peo Jr. and K. M. Shahani. 1980c. Influence of Lactobacillus acidophilus innoculum on gnotobiotic and conventional pigs. J. Anim. Sci. 51(3):629-637.

Pollmann, D.S. 1986. Probiotics in pig diets. Rec. Adv. Anim. Nutr. 193-204.

Porter. P. 1976. Immunoglobulin mechanisms in health and nutrition from birth to weaning. Proc Nutr. Soc. 35:273-282.

Porubcan, R. S. 1990. Probiotics in the 1990s. Comp. Cont. Educ. Pract. Vet. 12(9):1353-1359.

Ratcliffe, B., C. B. Cole, R. Fuller and M. J. Newport. 1986. The effect of yoghurt and milk fermented with a porcine intestinal strain of Lactobacillus reuteri on the performance and gastrointestinal flora of pigs weaned at two days of age. Food Microbiol. 3:203-211.

Risley, C. R., E. T. Kornegay, M. D. Lindemann and S. M. Weakland. 1991. Effects of organic acids with and without a microbial culture on performance and gastrointestinal tract measurements of weanling pigs. Feed Sci. and Tech. In Press.

Sandine. W. E. 1979. Roles of lactobacillus in the intestinal tract. J. Food Protect. 42(3):259-262.

SAS. 1990. Statistical analysis system, SAS user's guide: Statistics. SAS Inst., Inc., Cary, NC, 921 pp.

Sasaki, T., Y. Maede and S. Namioka. 1987. Immunopotentiation of the mucosa of the small intestine of weaning piglets by peptidoglycans. Jpn. J. Vet Sci. 49(2):235-243.

Schurig, G. G., J. R. Duncan and A. J. Winter. 1978. Elimination of genital vibrosis in female cattle by systemic immunization with killed cells or cell free extracts of Campylobacter fetus. J. Infect. Dis. 138:463-472.

Shahani, K. M. and A. D. Ayebo. 1980. Role of dietary lactobacilli in gastrointestinal microecology. Am. J. Clin. Nutr. 33:2448-2457.

Sung, M. G., H. J. Shin and K. H. Kang. 1985. Effect of Bifiobacterium longum on growth inhibition of enterotoxigenic Escherichia coli A_2. Sanop Misaengmil Hakhoechi 13(3):203-207.

Sweet, L. A., E. T. Kornegay and M. D. Lindemann. 1990. The effects of dietary luprosil NC on the growth performance and scouring index of weanling pigs. Agribiol. Res. 43(4):271-282.

Tamura, Z. 1983. Nutriology of bifidobacteria. Bifidobac. Microflora 2(1):3-16.

Tanaka, T., H. Takayama, M. Morotomi, T. Kuroshima, S. Ueyama, K. Matsumoto, A. Kurodo and M. Mutai. 1983. Effects of administration of TOS and Bifidobacterium breve 4006 on the human fecal flora. 2(1):17-24.

Tzipori, S., D. Chandler, M. Smith, T. Makin and K. Hennessy. 1980. Factors contributing to postweaning diarrhoea in a large intensive piggery. Austr. Vet. J. 56:274-278.

Watkins, B. A. and B. F. Miller. 1983a. Competitive gut exclusion of avian pathogens by Lactobacillus acidophilus in gnotobiotic chicks. Poult. Sci. 62:1772-1779.

Watkins, B. A. and F. H. Kratzer. 1983b. Effect of oral dosing of lactobacillus strains on gut colonization and liver biotin in broiler chicks. Poult. Sci. 62:2088-2094.
Watkins, B. A. and F. H. Kratzer. 1984. Drinking water treatment with a commercial preparation of a concentrated lactobacillus culture for broiler chickens. Poult. Sci. 63:1671-1673.

Yamazaki, S., K. Machii, S. Tsuyuki, H. Momose, T. Kawashima and K. Ueda. 1985. Immunological responses to monoassociated Bifidobacterium longum and their relation to prevention of bacterial invasion. Immunol. 56:43-50.

Yasui. H., A. Mike and M. Ohwaki. 1989. Immunogenicity of Bifidobacterium breve and change in antibody production in peyer's patches after oral administration. J. Dairy Sci. 72:30-35.

Yasutake, N., I. Kato, M. Ohwaki, T. Yokokura and M Mutai. 1984. Host-mediated antitumor activity of Lactobacillus casei in mice. Gann 75:72-80.

Appendix Table 1. LEAST SQUARES MEANS OF AVERAGE DAILY GAIN (ADG) OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 1

Item	Treatments[a]				SEM	Diet effect (P-values)
	Control	$5.0x10^4$	$6.7x10^6$	$7.5x10^8$		
Body weight, kg						
Initial	7.7	7.7	7.7	7.7	.03	-
Final	21.0	21.4	22.2	20.0	.44	.026
ADG, g						
wk 1	130	154	182	141	20	.291
2[b]	236	254	255	177	22	.065
3[b]	426	433	488	356	24	.009
4	478	470	516	477	33	.764
5	624	642	618	610	30	.899
1-2[b]	183	204	219	159	17	.101
1-3[c]	264	280	308	224	16	.008
1-4[b]	318	328	360	289	13	.006
1-5[b]	379	390	412	352	13	.021
3-5[c]	510	515	540	481	15	.076
4-5	551	556	566	544	22	.899

[a]Nine pens (two pigs per pen) per treatment mean.
[b]Quadratic diet effect ($P < .05$).
[c]Quadratic diet effect ($P < .01$).

Appendix Table 2. LEAST SQUARES MEANS OF AVERAGE DAILY GAIN (ADG) OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 2

Item	Diet[a]				SEM	Diet effect (P-value)
	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$		
Body weight, kg						
Initial	6.2	6.1	6.1	6.1	.08	-
Final	17.8	18.6	19.0	18.0	.45	.234
ADG, g						
wk 1	84	56	91	46	11	.023
2	216	228	237	236	13	.676
3	332	362	351	332	20	.670
4[bc]	465	521	547	484	18	.022
5	502	530	541	530	24	.732
1-2	150	142	141	164	10	.422
1-3	210	216	226	205	12	.654
1-4	280	300	315	282	12	.220
1-5	324	344	358	330	12	.222
3-5	434	474	483	450	16	.154
4-5[b]	482	525	544	505	17	.092

[a]Nine pens (two pigs per pen) per treatment mean.
[b]Linear diet effect ($P < .10$).
[c]Quadratic diet effect ($P < .05$).

Appendix Table 3. LEAST SQUARES MEANS OF AVERAGE DAILY GAIN (ADG) OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 3

	Diet[a]					Diet effect
Item	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$	SEM	(P-value)
Body weight, kg						
Initial	7.0	7.1	6.9	7.0	.03	-
Final	16.7	17.1	16.7	16.4	.41	.751
ADG, g						
wk 1	39	47	36	36	9	.794
2	197	177	195	187	15	.778
3	275	290	288	257	20	.417
4	386	428	407	396	19	.432
5	483	488	463	475	18	.767
1-2	118	112	115	111	10	.957
1-3	170	160	173	160	11	.810
1-4	224	236	231	219	11	.751
1-5	276	286	278	270	12	.825
3-5	382	402	386	376	15	.650
4-5	435	458	435	435	16	.676

[a] Twelve pens (two pigs per pen) per treatment mean.

Appendix Table 4. LEAST SQUARES MEANS OF AVERAGE DAILY GAIN (ADG) OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 4

Item	Diet[a]				SEM	Diet effect (P-value)
	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$		
Body weight, kg						
Initial	7.9	8.1	8.0	8.0	.06	-
Final	22.0	21.5	21.6	20.6	.41	.137
ADG, g						
wk 1[b]	205	188	188	161	15	.159
2	259	228	239	262	16	.405
3	472	452	497	440	31	.579
4[c]	581	553	528	485	22	.039
5	582	588	575	532	30	.618
1-2	232	208	213	212	10	.234
1-3	312	289	308	288	14	.374
1-4[b]	379	355	363	337	12	.090
1-5[b]	415	397	400	371	11	.062
3-5[d]	543	528	531	483	18	.126
4-5[d]	582	570	550	507	22	.160

[a]Six pens (three pigs per pen) per treatment mean.
[b]Linear diet effect ($P < .05$).
[c]Linear effect ($P < .01$).
[d]Linear effect ($P < .10$).

Appendix Table 5. LEAST SQUARES MEANS OF AVERAGE DAILY FEED INTAKE (g) OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 1

Week	Diet[a]				SEM	Diet effect (P-value)
	Control	$5.0x10^4$	$6.7x10^6$	$7.5x10^8$		
1	214	226	259	234	21	.507
2	376	397	461	352	30	.085
3[b]	664	698	768	582	32	.004
4[c]	940	969	1056	888	33	.011
5	1077	1086	1176	1038	55	.353
1-2[d]	295	312	360	293	22	.138
1-3[c]	418	441	496	390	23	.022
1-4[c]	548	570	636	514	24	.011
1-5[d]	654	674	744	619	28	.026
3-5[d]	894	915	1000	836	35	.024
4-5	1008	1024	1116	963	41	.083

[a]Nine pens (two pigs per pen) per treatment mean.
[b]Quadratic diet effect ($P < .01$).
[c]Quadratic diet effect ($P < .05$).
[d]Quadratic diet effect ($P < .10$).

Appendix Table 6. LEAST SQUARES MEANS OF AVERAGE DAILY FEED INTAKE (g) OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 2

	Diet[a]					Diet effect
Week	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$	SEM	(P-value)
1	152	138	154	122	10	.113
2	306	306	342	318	16	.389
3	636	672	677	664	29	.774
4	844	898	948	855	32	.118
5[b]	806	908	927	797	36	.028
1-2	230	222	248	220	12	.370
1-3	366	372	390	368	16	.702
1-4	498	517	544	502	20	.352
1-5[c]	558	593	619	560	20	.130
3-5[c]	766	829	855	776	27	.087
4-5[d]	826	902	938	828	29	.026

[a]Nine pens (two pigs per pen) per treatment mean.
[b]Quadratic diet effect ($P < .01$).
[c]Quadratic diet effect ($P < .10$).
[d]Quadratic diet effect ($P < .05$).

Appendix Table 7. LEAST SQUARES MEANS OF AVERAGE DAILY FEED INTAKE (g) OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 3

Week	Diet[a]				SEM	Diet effect (P-value)
	Control	6.0×10^4	5.0×10^5	5.0×10^6		
1[b]	118	104	96	94	7	.056
2	292	280	286	268	14	.642
3	401	390	421	380	20	.481
4	616	627	633	599	32	.884
5	765	776	795	759	35	.891
1-2[c]	205	192	191	181	9	.353
1-3	271	258	268	247	12	.498
1-4	357	350	359	335	16	.706
1-5	438	435	446	420	19	.791
3-5	594	598	616	579	27	.811
4-5	690	701	714	679	32	.885

[a]Twelve pens (two pigs per pen) per treatment mean.
[b]Linear diet effect ($P < .01$).
[c]Linear diet effect ($P < .10$).

Appendix Table 8. LEAST SQUARES MEANS OF AVERAGE DAILY FEED INTAKE (g) OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 4

	DIET[a]					
Week	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$	SEM	Diet effect (P-value)
1[bc]	251	261	237	215	16	.056
2	406	390	417	418	19	.364
3	621	669	675	612	31	.333
4[b]	936	888	933	879	43	.108
5[de]	1120	1164	1110	1049	46	.001
1-2[f]	328	326	327	317	15	.286
1-3	426	440	443	415	19	.334
1-4[b]	553	552	565	531	23	.152
1-5[b]	654	660	662	623	26	.059
3-5[b]	881	894	896	837	36	.062
4-5[d]	1021	1015	1015	958	42	.038

[a]Six pens (three pigs per pen) per treatment mean.
[b]Linear diet effect ($P < .05$).
[c]Quadratic diet effect ($P < .10$).
[d]Linear effect ($P < .01$).
[e]Quadratic effect ($P < .05$).
[f]Linear effect ($P < .10$).

Appendix Table 9. LEAST SQUARES MEANS OF FEED TO GAIN RATIOS OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 1

	Diet[a]					
Week	Control	$5.0x10^4$	$6.7x10^6$	$7.5x10^8$	SEM	Diet effect (P-value)
1[b]	1.78	1.56	1.45	1.96	.185	.242
2[c]	1.68	1.70	1.82	2.17	.163	.151
3	1.56	1.61	1.64	1.72	.114	.784
4	2.00	2.18	2.13	1.93	.173	.736
5	1.73	1.70	1.94	1.73	.087	.241
1-2[b]	1.68	1.62	1.64	1.96	.117	.168
1-3[b]	1.58	1.57	1.61	1.82	.088	.162
1-4	1.73	1.75	1.76	1.79	.047	.837
1-5	1.72	1.72	1.80	1.76	.040	.465
3-5	1.76	1.77	1.86	1.74	.049	.351
4-5	1.83	1.84	1.98	1.78	.053	.084

[a]Nine pens (two pigs per pen) per treatment mean.
[b]Quadratic diet effect ($P < .10$).
[c]Linear diet effect ($P < .10$).

Appendix Table 10. LEAST SQUARES MEANS OF FEED TO GAIN RATIOS OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 2

Week	Diet[a]				SEM	Diet effect (P-value)
	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$		
1[b]	.81[c]	2.46	1.69	2.65	1.245	.174
2	1.42	1.34	1.50	1.35	.072	.394
3	1.92	1.86	1.98	2.06	.072	.252
4	1.82	1.73	1.74	1.76	.038	.351
5	1.60	1.71	1.78	1.55	.098	.378
1-2	1.54	1.60	1.54	1.58	.073	.920
1-3	1.74	1.74	1.74	1.81	.045	.568
1-4	1.77	1.73	1.73	1.78	.028	.400
1-5	1.72	1.72	1.72	1.70	.026	.874
3-5	1.76	1.74	1.78	1.72	.029	.674
4-5	1.71	1.71	1.73	1.64	.036	.323

[a]Nine pens (two pigs per pen) per treatment mean.
[b]Quadratic diet effect ($P < .05$).
[c]Based on ADFI and ADG values in Tables 2 and 3.

Appendix Table 11. LEAST SQUARES MEANS OF FEED TO GAIN RATIOS OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 3

Week	Diet[a]				SEM	Diet effect (P-value)
	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$		
1	1.87	1.68	4.19	3.21	1.713	.690
2	1.57	1.76	1.48	1.54	.127	.445
3[b]	1.47	1.35	1.47	1.50	.045	.086
4	1.62	1.46	1.57	1.52	.048	.138
5	1.58	1.59	1.71	1.59	.040	.097
1-2	1.92	1.80	1.68	1.81	.146	.711
1-3	1.64	1.51	1.57	1.60	.063	.547
1-4	1.62	1.49	1.56	1.55	.039	.135
1-5	1.60	1.52	1.60	1.56	.027	.116
3-5	1.56	1.48	1.59	1.54	.027	.050
4-5	1.59	1.53	1.63	1.56	.032	.121

[a]Twelve pens (two pigs per pen) per treatment mean.
[b]Quadratic effect ($P < .05$).

Appendix Table 12. LEAST SQUARES MEANS OF FEED TO GAIN RATIOS OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 4

	Diet[a]					
Week	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$	SEM	Diet effect (P-value)
1	1.22	1.43	1.29	1.36	.081	.401
2	1.59	1.74	1.76	1.60	.098	.524
3	1.32	1.51	1.36	1.43	.096	.640
4[b]	1.60	1.62	1.78	1.82	.073	.218
5	1.92	2.00	1.95	1.99	.093	.773
1-2	1.42	1.57	1.53	1.50	.063	.545
1-3	1.36	1.53	1.44	1.46	.065	.501
1-4	1.45	1.56	1.56	1.58	.046	.484
1-5	1.57	1.67	1.65	1.67	.049	.933
3-5	1.61	1.70	1.69	1.73	.059	.927
4-5	1.74	1.79	1.85	1.90	.074	.768

[a]Twelve pens (three pigs per pen) per treatment mean.
[b]Quadratic effect ($P < .10$).

Appendix Table 13. LEAST SQUARES MEANS OF AVERAGE DAILY GAIN (ADG) OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIALS 2 and 3 COMBINED

Item	Diet[a]				SEM	Diet effect (P-value)
	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$		
Body weight, kg						
Initial	6.59	6.60	6.54	6.55	.020	.060
Final	17.26	17.81	17.86	17.23	.309	.751
ADG, g						
wk 1	62	51	64	42	6.88	.201
2	207	203	216	211	10.20	.833
3[b]	304	326	320	295	12.60	.270
4[b]	426	475	477	440	13.60	.027
5	493	509	502	503	14.70	.921
1-2	134	127	140	129	7.13	.599
1-3	191	194	200	183	7.93	.522
1-4[c]	253	268	273	250	8.71	.225
1-5	300	315	318	300	8.72	.361
3-5[b]	408	438	435	413	11.06	.186
4-5[c]	459	492	490	470	11.87	.211

[a]21 pens (two pigs per pen) per treatment mean (Trial 2 (nine pens) Trial 3 (twelve pens)).
[b]Quadratic diet effect ($P < .05$).
[c]Quadratic diet effect ($P < .10$).

Appendix Table 14. LEAST SQUARES MEANS OF AVERAGE DAILY FEED INTAKE (g) OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIALS 2 and 3 COMBINED

Week	Diet[a]				SEM	Diet effect (P-value)
	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$		
1[b]	135	121	125	108	6	.017
2	300	293	314	293	11	.496
3	519	531	549	522	17	.579
4	730	763	791	727	23	.239
5[c]	786	842	861	778	25	.097
1-2	218	207	219	201	7	.260
1-3	318	315	329	308	10	.481
1-4	427	434	452	419	12	.338
1-5	498	514	533	490	14	.197
3-5[d]	680	713	736	678	20	.158
4-5[d]	758	802	826	753	23	.114

[a]21 pens (two pigs per pen) per treatment mean (Trial 2 (nine pens) Trial 3 (twelve pens)).
[b]Linear diet effect (P < .01).
[c]Quadratic diet effect (P < .05).
[d]Quadratic diet effect (P < .10).

Appendix Table 15. LEAST SQUARES MEANS OF FEED TO GAIN RATIOS OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIALS 2 and 3 COMBINED

Week	Diet[a]				SEM	Diet effect (P-value)
	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$		
1	2.06	1.18	2.94	3.92	1.130	.384
2	1.49	1.55	1.49	1.44	.080	.723
3[b]	1.69	1.61	1.73	1.78	.040	.027
4[cd]	1.72	1.60	1.65	1.64	.033	.053
5	1.59	1.65	1.74	1.57	.048	.077
1-2	1.73	1.70	1.61	1.69	.090	.743
1-3	1.69	1.63	1.65	1.71	.041	.479
1-4[e]	1.70	1.61	1.65	1.67	.026	.083
1-5	1.66	1.62	1.67	1.63	.019	.166
3-5	1.66	1.61	1.68	1.63	.020	.052
4-5	1.65	1.62	1.68	1.60	.024	.069

[a]21 pens (two pigs per pen) per treatment mean (Trial 2 (nine pens) Trial 3 (twelve pens)).
[b]Quadratic diet effect ($P < .01$).
[c]Linear diet effect ($P < .10$).
[d]Quadratic diet effect ($P < .10$).
[e]Quadratic diet effect ($P < .05$).

Appendix Table 16. LEAST SQUARES MEANS OF AVERAGE DAILY GAIN OF GROWER-FINSHER PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d).

Item	Diet[a]				SEM	Diet effect (P-value)
	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$		
Body weight, kg						
Initial	18.1	18.4	18.2	17.5	1.57	.982
Final	100.5	103.3	101.7	102.2	3.58	.954
ADG, g						
wk 2	662	652	696	690	25	.551
4[b]	799	843	825	882	27	.244
6	896	865	855	849	32	.738
8	929	990	931	971	30	.424
10	910	935	895	937	26	.619
12	760	790	859	755	54	.520
14[c]	947	973	905	950	60	.875
15[d]	788	1100	635	950	-	-
2-4	730	747	761	786	24	.462
2-6	785	787	792	807	19	.858
2-8	821	838	827	848	21	.812
2-10	839	857	840	866	17	.623
2-12	826	846	844	847	20	.858
2-14	838	860	854	860	17	.766
2-15	798	841	790	859	-	-
Final	838	864	851	862	24	.707

[a]Four pens (five pigs per pen) per treatment mean.
[b]Linear diet effect (P < .10).
[c]Three pens (five pigs per pen) per treatment pen.
[d]One pen (five pigs per pen) per treatment.

Appendix Table 17. LEAST SQUARES MEANS OF AVERAGE DAILY FEED INTAKE (kg) OF GROWER-FINISHER PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d).

Week	Diet[a]				SEM	Diet effect (P-value)
	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$		
2	1.47	1.40	1.57	1.44	.049	.153
4	1.92	2.17	2.13	2.17	.112	.389
6	2.51	2.66	2.49	2.52	.114	.741
8	3.03	3.25	3.18	3.25	.180	.802
10	3.36	3.50	3.51	3.68	.175	.656
12	3.01	2.90	3.32	3.24	.107	.068
14[b]	3.20	3.48	3.23	3.55	.166	.396
15[c]	3.06	2.72	3.42	3.36	-	-
2-4	1.69	1.78	1.85	1.81	.077	.566
2-6	1.97	2.07	2.06	2.05	.080	.787
2-8	2.23	2.37	2.34	2.35	.100	.778
2-10	2.46	2.59	2.58	2.61	.110	.757
2-12	2.55	2.64	2.70	2.72	.100	.655
2-14	2.62	2.74	2.76	2.81	.097	.573
2-15	2.54	2.43	2.71	2.66	-	-
Final	2.58	2.71	2.73	2.78	.147	.569

[a]Four pens (five pigs per pen) per treatment mean.
[b]Three pens (five pigs per pen) per treatment pen.
[c]One pen (five pigs per pen) per treatment.

Appendix Table 18. LEAST SQUARES MEANS OF FEED TO GAIN RATIOS OF GROWER-FINISHER PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d).

Week	Diet[a]				SEM	Diet effect (P-value)
	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$		
2	2.22	2.14	2.26	2.09	.064	.323
4	2.39	2.56	2.57	2.45	.107	.591
6	2.80	3.09	2.92	2.97	.190	.757
8	3.27	3.27	3.41	3.37	.201	.942
10	3.70	3.76	3.92	3.93	.212	.830
12	4.09	3.69	3.88	4.31	.283	.475
14[b]	3.37	3.55	3.63	3.73	.161	.488
15[c]	3.88	2.48	5.39	3.53	-	-
2-4	2.31	2.38	2.43	2.29	.075	.592
2-6	2.50	2.63	2.60	2.53	.107	.787
2-8	2.72	2.82	2.83	2.76	.126	.907
2-10	2.93	3.03	3.06	3.02	.141	.922
2-12	3.09	3.13	3.20	3.21	.141	.922
2-14	3.13	3.19	3.23	3.27	.127	.881
2-15	3.19	2.88	3.43	3.09	-	-
Final	3.09	3.13	3.20	3.22	.143	.873

[a]Four pens (five pigs per pen) per treatment mean.
[b]Three pens (five pigs per pen) per treatment pen.
[c]One pen (five pigs per pen) per treatment.

Appendix Table 19. LEAST SQUARES MEANS OF FECAL PH AND CHLORIDE ION CONCENTRATION OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 1

Item	Diet[a]				SEM	Diet effect (P-value)
	Control	$5.0x10^4$	$6.7x10^6$	$7.5x10^8$		
pH						
wk 1	7.08	6.88	7.16	7.05	.122	.390
2	7.16	7.11	7.13	7.02	.122	.874
3[b]	7.20	7.02	7.06	6.94	.122	.268
4	6.86	6.80	6.87	6.74	.122	.928
5	6.71	6.70	6.74	6.75	.122	.986
Chloride ion conc. (M)						
wk 1	.004	.003	.004	.004	.001	.864
2[c]	.004	.004	.004	.005	.001	.238
3	.007	.006	.007	.007	.001	.682
4	.010	.007	.009	.011	.001	.560
5[dc]	.002	.002	.002	.004	.001	.103

[a]Nine pens (one pig per pen) per treatment mean.
[b]Linear diet effect (P < .10).
[c]Quadratic diet effect (P < .10).
[d]Linear diet effect (P < .05).

Appendix Table 20. LEAST SQUARES MEANS OF FECAL PH AND CHLORIDE ION CONCENTRATION OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 2

	Diet[a]					
Item	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$	SEM	Diet effect (P-value)
pH						
wk 1	7.09	7.14	7.20	7.02	.160	.822
2	6.93	7.07	6.93	6.70	.160	.312
3	7.20	7.14	7.06	6.59	.160	.352
4	6.86	6.94	7.05	6.82	.160	.424
5	6.90	6.73	6.81	6.66	.160	.279
Chloride ion conc. (M)						
wk 1	.007	.007	.008	.006	.002	.730
2	.014	.018	.014	.016	.002	.428
3	.006	.006	.008	.006	.002	.414
4	.019	.014	.019	.014	.002	.550
5	.014	.013	.014	.014	.002	.957

[a]Nine pens (one pig per pen) per treatment mean.

Appendix Table 21. LEAST SQUARES MEANS OF PH AND CHLORIDE ION CONCENTRATION (M) IN THE GASTROINTESTINAL TRACT OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 1.

	Diet[a]					Diet
Item	Control	$5.0x10^4$	$6.7x10^6$	$7.5x10^8$	SEM	effect (P-value)
pH						
Stomach[b]	4.40	3.28	3.72	3.10	.304	.044
Jejunum	5.72	5.60	5.73	5.86	.207	.847
Cecum	6.03	6.04	5.70	5.97	.176	.503
Lower colon	6.72	7.04	6.89	6.88	.126	.385
Chloride ion conc. (M)						
Stomach[cd]	.025	.047	.030	.041	.003	.003
Jejunum	.082	.056	.068	.074	.010	.343
Cecum	.011	.008	.012	.012	.002	.448
Lower colon	.006	.012	.006	.006	.004	.562

[a]Five pens (one pig per pen) per treatment mean.
[b]Linear diet effect ($P < .05$).
[c]Linear diet effect ($P < .01$).
[d]Quadratic diet effect ($P < .10$).

Appendix Table 22. LEAST SQUARES MEANS OF PH AND CHLORIDE ION CONCENTRATION (M) IN THE GASTROINTESTINAL TRACT OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 2

Item	Diet[a]				SEM	Diet effect (P-value)
	Control	6.0×10^4	5.0×10^5	5.0×10^6		
pH						
Stomach	3.74	4.04	4.18	3.73	.570	.924
Jejunum[b]	5.74	5.60	5.92	6.07	.151	.198
Cecum	5.65	5.62	5.74	5.66	.077	.701
Lower colon[b]	6.90	6.68	6.60	6.98	.130	.188
Chloride ion conc. (M)						
Stomach	.027	.021	.026	.030	.006	.734
Jejunum	.058	.058	.062	.059	.008	.990
Cecum[c]	.016	.010	.012	.008	.002	.140
Lower colon	.011	.009	.011	.011	.001	.709

[a]Five pens (one pig per pen) per treatment mean.
[b]Quadratic diet effect ($P < .10$).
[c]Quadratic diet effect ($P < .05$).

Appendix Table 23. LEAST SQUARES MEANS OF SCOUR SCORES[a] OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 1

Day	Diet[b]				SEM[c]	Diet effect (P-value)
	Control	$5.0x10^4$	$6.7x10^6$	$7.5x10^8$		
1	2.28	2.28	2.38	2.33	.133	.922
3	2.06	2.11	2.16	2.22	.104	.700
5	2.11	2.06	2.11	2.00	.048	.316
7[d]	2.40	2.40	2.11	2.61	.108	.022
9[e]	2.16	2.16	2.22	2.44	.096	.148
11	2.33	2.28	2.28	2.33	.118	.974
13	2.50	2.44	2.33	2.50	.146	.835
15	2.44	2.44	2.28	2.44	.127	.734
17	2.28	2.11	2.16	2.28	.108	.619
19	2.22	2.16	2.16	2.22	.096	.953
21	2.22	2.22	2.28	2.22	.108	.977
23	2.11	2.16	2.11	2.28	.088	.502
25	2.22	2.16	2.10	2.16	.100	.693
27	2.22	2.22	2.11	2.10	.092	.492
29	2.22	2.16	2.22	2.22	.100	.972
31	2.28	2.11	2.28	2.28	.092	.492
33	2.11	2.16	2.11	2.22	.092	.801
35	2.33	2.22	2.10	2.28	.111	.336

[a]Five point scoring system: 1=dry, 2=normal, 3=moist, 4=wet and 5=severe.
[b]Nine pens (two pigs per pen) per treatment mean.
[c]Pooled standard error.
[d]Quadratic diet effect ($P < .05$).
[e]Linear diet effect ($P < .05$).

Appendix Table 24. LEAST SQUARES MEANS OF SCOUR SCORES[a] OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 2

	Diet[b]					
Day	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$	SEM[c]	Diet effect (P-value)
1	2.16	2.28	2.11	2.00	.088	.178
3[d]	2.06	2.06	2.28	2.22	.073	.081
5[e]	2.11	2.22	2.06	2.28	.088	.278
7	2.11	2.11	2.16	2.06	.078	.801
9[f]	2.00	2.00	2.16	2.33	.100	.072
11	2.06	2.06	2.00	2.06	.048	.801
13	2.06	2.11	2.06	2.11	.068	.880
15	2.06	2.22	2.11	2.16	.088	.578
17	2.11	2.22	2.11	2.16	.092	.801
19	2.22	2.16	2.16	2.16	.092	.964
21	2.28	2.16	2.16	2.22	.100	.838
23	2.00	2.00	2.06	2.11	.048	.316
25	2.11	2.28	2.16	2.11	.096	.578
27	2.06	2.16	2.16	2.16	.088	.754
29	2.11	2.00	2.16	2.06	.068	.357
31	2.16	2.16	2.06	2.11	.083	.748
33	2.11	2.28	2.16	2.16	.100	.693
35	2.06	2.16	2.11	2.16	.083	.748

[a]Five point scoring system: 1=dry, 2=normal, 3=moist, 4=wet and 5=severe.
[b]Nine pens (two pigs per pen) per treatment mean.
[c]Pooled standard error.
[d]Linear diet effect ($P < .05$).
[e]Quadratic diet effect ($P < .10$).
[f]Linear diet effect ($P < .10$).

Appendix Table 25. LEAST SQUARES MEANS OF SCOUR SCORES[a] OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 3

	Diet[b]					
Day	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$	SEM[c]	Diet effect (P-value)
1	2.13	2.21	2.03	2.14	.094	.620
3	2.06	2.14	2.07	2.11	.074	.860
5[d]	2.79	2.50	2.24	2.57	.156	.103
7[e]	2.17	2.47	2.19	2.06	.094	.020
9	2.18	2.31	2.14	2.28	.102	.623
11	2.15	2.56	2.13	2.24	.129	.081
13	2.50	2.39	2.35	2.25	.136	.632
15	2.47	2.21	2.22	2.26	.131	.459
17	2.42	2.14	2.43	2.40	.124	.298
19	2.29	2.17	2.19	2.28	.087	.683
21	2.22	2.11	2.18	2.22	.084	.763
23	2.19	2.14	2.24	2.29	.096	.713
25	2.35	2.13	2.25	2.18	.097	.412
27	2.25	2.11	2.07	2.13	.089	.515
29	2.14	2.06	2.07	2.24	.078	.353
31	2.21	2.11	2.21	2.03	.084	.363
33	2.19	2.11	2.21	2.10	.091	.762
35	2.25	2.08	2.08	2.08	.102	.581

[a]Five point scoring system: 1=dry, 2=normal, 3=moist, 4=wet and 5=severe.
[b]Twelve pens (two pigs per pen) per treatment mean.
[c]Pooled standard error.
[d]Quadratic diet effect ($P < .10$).
[e]Quadratic diet effect ($P < .05$).

Appendix Table 26. LEAST SQUARES MEANS OF SCOUR SCORES[a] OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIAL 4

	Diet[b]					
Day	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$	SEM[c]	Diet effect (P-value)
1	2.17	2.06	2.28	2.17	.088	.372
3	2.11	2.06	2.28	2.06	.068	.080
5	2.00	2.06	2.06	2.00	.039	.577
7	2.22	2.17	2.11	2.06	.083	.533
9[d]	2.11	2.44	2.11	2.06	.100	.033
11	2.33	2.67	2.33	2.28	.130	.148
13	2.39	2.44	2.28	2.28	.121	.702
15	2.33	2.61	2.39	2.44	.121	.409
17	2.22	2.22	2.11	2.28	.111	.757
19	2.17	2.11	2.17	2.22	.092	.866
21	2.22	2.33	2.17	2.28	.118	.775
23	2.33	2.44	2.44	2.39	.124	.907
25	2.39	2.39	2.56	2.33	.127	.637
27	2.17	2.28	2.44	2.33	.104	.306
29	2.11	2.22	2.22	2.17	.092	.801
31	2.06	2.11	2.28	2.22	.092	.316
33	2.11	2.17	2.22	2.22	.092	.801

[a]Five point scoring system: 1=dry, 2=normal, 3=moist, 4=wet and 5=severe.
[b]Six pens (three pigs per pen) per treatment mean.
[c]Pooled standard error.
[d]Quadratic effect ($P < .10$).

Appendix Table 27. LEAST SQUARES MEANS OF SKIN FOLD THICKNESS AS INFLUENCED BY PHYTOHEMAGGLUTININ INJECTION ON DAY 35 OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIALS 1 AND 2.

Trial 1	Diet[a]					
Item	Control	$5.0x10^4$	$6.7x10^6$	$7.5x10^8$	SEM	Diet effect (P-value)
PHA, mm	6.94	7.00	6.88	7.09	.254	.960
Saline, mm	2.58	2.56	2.82	2.87	.131	.222
Difference, mm[b]	4.36	4.44	4.06	4.22	.260	.732
Trial 2	**Diet**					
Item	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$	SEM	Diet effect (P-value)
PHA, mm	7.58	7.88	7.86	7.95	.296	.810
Saline, mm	3.63	3.62	3.44	3.75	.078	.068
Difference, mm	3.94	4.25	4.41	4.20	.314	.769

[a]Nine pens (two pigs per pen) per treatment mean.
[b]PHA - saline.

Appendix Table 28. LEAST SQUARES MEANS OF HEMMAGGLUTINATION TITERS OF WEANLING PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d). TRIALS 1 AND 2

Trial 1	Diet[ab]					
Item	Control	$6.0x10^4$	$6.7x10^6$	$7.8x10^8$	SEM	Diet effect (P-value)
Primary reaction						
	3.94	4.11	4.28	3.72	.402	.791
Secondary reaction						
	5.17	4.67	4.72	4.39	.372	.534

Trial 2	Diet					
Item	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$	SEM	Diet effect (P-value)
Primary reaction						
	3.56	3.22	3.44	3.28	.328	.883
Secondary reaction[c]						
	4.11	4.89	5.22	4.78	.241	.024

[a]Values are log_2 of dilution where last reaction (button) occurred.
[b]Zero values indicate no reaction and were deleted.
[c]Linear diet effect (P < .01).

Appendix Table 29. LEAST SQUARES MEANS OF CARCASS DATA FROM SLAUGHTERED AND MARKET GROWER-FINISHER PIGS FED VARYING LEVELS OF BIFIDOBACTERIUM GLOBSUM A (CFU/d).

Item	Diet				SEM	Diet effect (P-value)
	Control	$6.0x10^4$	$5.0x10^5$	$5.0x10^6$		
Slaughtered animals[ab]						
Length(cm)	80.1	80.0	79.8	79.6	.45	.877
Last rib Fat(mm)	29.2	30.6	28.8	30.8	1.70	.805
Tenth rib Fat(mm)	35.9	36.2	33.9	36.8	2.12	.785
Loin muscle area(cm^2)	28.6	29.9	29.2	28.9	1.19	.919
Dressing percent[c]	73.7	74.0	73.8	74.2	.46	.874
Hot carc. wt.(kg)	76.9	77.3	77.0	77.5	.48	.862
Market animals[bd]						
Fat(mm)[e]						
female	26.4	24.8	23.7	26.8	1.22	.247
male	30.7	30.4	28.1	28.0	1.60	.100
Loin muscle area(cm^2)[f]						
female	28.7	27.1	29.5	30.4	.97	.474
male	27.3	28.4	29.8	30.8	1.17	.215

[a]Four pens (two males per pen) per treatment mean.
[b]Data is adjusted for final weight.
[c]Percentage is equal to live weight/hot carcass weight x 100.
[d]Four pens (three females and two males per pen) per treatment mean. Data obtained using ultrasonography (Aloka 500 realtime ultrasound machine, 3.5 Mhz probe) at the tenth rib.
[e]Sex effect ($P < .01$).
[f]Linear and quadratic diet effects ($P < .05$).

VITA

Gary A. Apgar, son of Grant and Dorothy Apgar, was born on June 9, 1967 in Neptune, New Jersey. He graduated from Freehold Regional High School in June of 1985. He entered Delaware Valley College of Science and Agriculture in the fall of 1985 where he received his Bachelor of Science degree in Animal Husbandry in May of 1989. He married Rebecca S. Rice in Hope, New Jersey on August 5, 1989, and entered Virginia Polytechnic Institute and State University in the fall of 1989, where he began working towards a Master of Science degree in Animal Science (Animal Nutrition).

He is a member of the Bethesda United Methodist Church and a Block and Bridle alumnus.

Gary A. Apgar

Gary A. Apgar