This is to certify that the

thesis entitled

Effects of Different Management Strategies and Dietary Spray-Dried Porcine Plasma on Early-Weaned Pig Performance and The Occurence of Gastrointestinal Hemolytic Escherichia coli

presented by

Florian A. Chirra

has been accepted towards fulfillment of the requirements for

M.S. degree in Animal Science

Dale W. Rozeboom

Major professor

Date 12/10/98

PLACE IN RETURN BOX to remove this checkout from your record.
TO AVOID FINES return on or before date due.
MAY BE RECALLED with earlier due date if requested.

DATE DUE	DATE DUE	DATE DUE

1/98 c/CIRC/DateDue.p65-p.14

Effects of Different Management Strategies and Dietary Spray-Dried Porcine Plasma on Early-Weaned Pig Performance and The Occurrence of Gastrointestinal Hemolytic *Escherichia coli*

By

Florian A. Chirra

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Animal Science

1998

ABSTRACT

EFFECTS OF DIFFERENT MANAGEMENT STRATEGIES AND SPRAY-DRIED PORCINE PLASMA ON EARLY-WEANED PIG PERFORMANCE AND THE OCCURRENCE OF GASTROINTESTINAL HEMOLYTIC *ESCHERICHIA COLI*

By

Florian A. Chirra

Two replications were completed in an experiment with weaning pigs designed in management strategies(Segregated Early Weaning; (SEW), high bio-security on-site; (HBOS), and low bio-security on-site (LBOS)) and if adding spray-dried porcine plasma to a corn-soybean meal, milk diet will influence pig performance and the presence of hemolytic *E. coli* in the gastrointestinal tract. Overall (d 0 to 49) ADG, ADFI, and G:F were greater ($P<.01$) for the SEW management treatment compared to HBOS and LBOS management treatments. Thirty-six pigs, one per pen, in each replication were killed at the end of the first week. One gram of digesta was collected from the stomach, pooled (jejunum and ileum), cecum and the large intestine, serially diluted and streaked onto MacConkey Agar plates. Isolated *E. coli* colonies were streaked onto Blood Agar plates to determine if the *E. coli* populations were hemolytic. Hemolytic *E. coli* populations were present in all sample portions of the gastrointestinal tract. There was a relationship between management strategy and spray dried porcine plasma to presence of hemolytic *E. coli*.

ACKNOWLEDGMENTS

In completion of my Masters Degree, I am grateful and forever indebted to my wife, Patricia. She has been my cheerleader, inspiration and never-ending source of encouragement during my pursuit of this degree and I share with her in its accomplishment. I am also very proud and extremely grateful for our daughter, Joy. She also has been an inspiration in my life, plus presenting me a challenge to graduate before she graduated from high school. I am very proud to dedicate this thesis to Patricia and Joy.

I am very proud to have the opportunity to pursue my further education at Michigan State University and to have had the opportunity to meet many great and outstanding people.

I am very much indebted to Dr. Dale Rozeboom for his interest in my life and education. Being around an outstanding educational leader is an honor that I will cherish for a lifetime. I also would like to thank Dr. Melvin Yokoyoma for his help in a 23-hour microbiology laboratory--what a project! Thanks for helping me realize I didn't want to pursue a degree in microbiology! Again, thanks for your help and encouragement with this project.

Likewise, I thank Dr. Gretchen Hill and Dr. Gerald

Schwab for their encouragement in pursuing this degree. I would be amiss if I didn't say a thank you to fellow Williams Countian,(that's God's country), Dr. E. R. Miller. It was a great honor to have the chance to meet and get to know this distinguished leader in Animal Science.

I also thank the Swine Team at the Michigan State University barn for help in caring for the pigs. I especially thank Dr. Sue Hengemuchle for her untiring assistance and encouragement in the laboratory.

I am grateful to have been associated with many of my fellow graduate students and thank them for their friendship, support and assistance with this project. Their friendship and support will always be remembered and cherished.

I thank the people back at the Ohio State University Extension Williams County office for their support and nagging to get this thing done.

Finally, I thank my parents for allowing me many years ago to have the opportunity work with livestock through 4-H club work. Because of that it has instilled in me that "rewards await them who pursue excellence."

TABLE OF CONTENTS

List of Tables

LIST OF FIGURES

GLOSSARY OF ABBREVIATIONS

ADFI - Average Daily Feed Intake

ADG - Average Daily Gain

DSM - Dried Skim Milk

DW - Dried Whey

ETEC - Enterotoxigenic Escherichia coli

G/F - Feed Efficiency

HBOS - High Bio-security on Site

LBOS - Low Bio-security On-site

SDPP - Spray-dried Porcine Plasma

SEW - Segregate Early Weaning

SMFM - Selected Menhaden Fish Meal

INTRODUCTION:

Swine production technologies have changed dramatically in the past twenty years, especially in how producers manage and feed pigs from weaning to market. Multiple-site production strategies (sow herd, nursery, grow-finish) and phase feeding strategies have been implemented widely to lower disease pressure, lessen antibiotic use, and maximize performance of the growing pig. Multiple-site production and intense nutritional management are typically large-scale, highly capitalized, and technology intensive.

Not all producers are willing or able to incorporate these new production strategies into their operation. Some own smaller herds, older buildings, and have less land. They desire to continue pork production long term, but want to do so on a single-farm site. If possible and profitable, they would like to incorporate the new herd health technologies used in the larger multiple-site systems into their smaller, one site operations.

One of the new strategies used on large swine operations and frequently considered by smaller producers is Segregated Early Weaning (SEW). Many smaller producers want to know if they can obtain the same benefits of SEW strategy with a single-site production system using strict bio-security, as obtained in larger multi-site production systems.

Literature Review:

Segregated Early-Weaning (SEW)

SEW technology evolved from research done by Alexander et al. (1980) in which he sought to raise pathogen-free pigs nonsurgically. This technology was originally called Medicated Early Weaning (MEW). It involved isolating the pregnant sows from the infected herd and heavily medicating the sows prior to farrowing. The newborn pigs, after farrowing, were also heavily medicated. At five days of age only the largest piglets were weaned into an isolated nursery located several miles from the farrowing unit or the source sow farm. This approach was impractical to implement on a large scale, because of cost, death lost, morbidity, and increased sow non-productive days.

Shortly thereafter, the early-weaning procedure was altered and called Modified Medicated Early-Weaning (MMEW) (Harris, 1988; Connors, 1990). Notably, sows were not isolated or removed from the original farm, eliminating the isolation farrowing accommodations. Medication, administered to the sows and pigs was decreased and weaning age was increased to 21 days.

Most recent SEW practices do not include any piglet medication, but wean pigs at an early age, about 14 to 17 days and segregate to off-site nurseries. New advances in high nutrient-dense diets have made meeting the nutritional demands of the early-weaned pig more successful (Dritz et al.,1994). The results are an improved health status in the pigs which leads to increase in average daily gain (ADG), increase in average daily feed intake (ADFI) and an improved feed efficiency (Table 1).

SEW is effective for several reasons. It takes advantage of passive immunity. The separation of pigs from older swine prevents disease spread. Phase-feeding and high-quality feed ingredients provide proper nutrition for the very young pig. And lastly, the use of strict bio-security and sanitation maintains a higher-health status.

Weaning the pig at an early age, while the pig still has some passive immunity from the sow, helps to break the sow/pig disease cycle. Newborn piglets have very low levels of blood-borne immunoglobulin (< 1 mg/ml) and after ingesting colostrum from the sow, blood levels rise to (30 mg/ml). The immunoglobulin acquired from the sow's colostrum reaches minimal levels in the pig's serum by the time the pig reaches 3 to 5 weeks of age. The pigs ability to synthesize antibodies is poor so the immune protection remains low until 6 to 8 weeks of age. Table 2 describes weaning ages which break transmission of diseases from dam to offspring.

Segregating pigs from the sow and other pigs on the farm by moving to off-site nurseries has helped limit aerosol transmission of disease. Even though pigs are co-mingled upon arrival to the nursery, the pigs experienced better health and growth compared to conventional continuous-flow nurseries (typical nurseries found at older swine units, in which weaned pigs are introduced into the nursery while older pigs are still present). Table 3 describes the distances away from other pigs to prevent transmission of certain disease agents.

Phase feeding recognizes that the pig's digestive system undergoes dramatic changes pre and post weaning and that diets need to be formulated to match the pig's changing digestive capabilities. Phase feeding programs provide a high nutrient- dense diet containing an edible grade of high quality ingredients in the immediate post-weaning period. As the pig's digestive system matures a lower nutrient density diet is used with lower priced ingredients.

General industry recommendations for phase feeding are described below.

Phase 1 diet is designed to be fed to early-weaned pigs until they weigh about 11 pounds. This diet typically consists of (25-30%) corn, (15-18%) soybean meal (SBM), (20-25%) dried whey (DW), (6-7%) selected menhaden fish meal (SMFM), (7-8%) edible grade lactose, and (7-8%) spray dried porcine plasma(SDPP) to provide about 3400 kcal/kg of metabolizable energy (ME), 22 to 23% crude protein, and 1.5 to 1.7% lysine. Phase 2 diets generally are fed for one week or from 10 to 15 pounds. This diet typically contains (40-41%) corn, (17-18%) SBM, (20 -25%) DW, (7-8%) SMFM, (4%) edible grade lactose, and (2.5%) SDPP to provide a nutrient composition of 3400 kcal/kg of ME, 22 crude proteins with 1.45 to 1.5% lysine. Fat is added to both Phase 1 and 2 diets to facilitate pelleting (mini pellet 0.15 mm in diameter).

Phase 3 diets are typically fed for two weeks or until the pigs weigh between 20 and 25 pounds. This diet should contain roughly (56-58%) corn, (18-22%) SBM, (8-10%) DW, (4-5%) SMFM to provide a nutrient composition of about 3400 kcal/kg of ME, 19 to 20% crude protein with 1.20 to 1.25% lysine. Phase 4 diet is typically fed for three weeks, or from 25 to 60 pounds. This diet contains about (60-65%) corn, (26-28%) SBM, to provide a nutrient composition of 3400 kcal/kg of ME, 19 to 20% crude protein with 1.15 to 1.2% lysine. All four phase diets contain therapeutic levels of antibiotic, copper sulfate and zinc oxide for growth promotion.

Bio-security is the procedure swine operations use to control flow of traffic, personnel and pigs into and out of a facility. Any time bio-security is broken, disease pathogens can be introduced into the facility and everything gained by early-weaning and segregation is lost. Thus, a concentrated effort must be made always to maintain tight security. Suggested bio-security measures are listed in Table 4.

It is readily accepted that growth rate is correlated with the degree of sanitation of a facility. Studies performed 30-40 years ago aptly illustrated that chickens housed in a germ-free environment grew 15% faster than those grown in a conventional environment, and chickens housed in clean, disinfected quarters grew faster and more efficiently than those in less sanitary conditions, Coats et al.,(1963). Furthermore, the depressed growth associated with unsanitary environments was made more tolerable when the immune system was suppressed by feeding antibiotics. But with cleaner environments there is an increased growth performance without all of the antibiotics.

The off-site new nurseries which are being built offer a cleaner environment compared to older conventional nurseries. The newer building materials available offer easier cleaning compared to woven wire flooring, and pens can be more thoroughly cleaned.

High Bio-security On-Site Nursery:

Clark et al. (1995) states that the conversion to segregated early-weaning requires that the entire system of production be redesigned. There must be separation between the pigs and other hogs on the swine operation and this can be done only with strict bio-security.

Purdue University Extension's "Positioning Your Pork Operation For The 21st Century" suggests a possible method of developing a high bio-security on-site nursery. They make the assumption that the on-site nursery will be made using an existing facility designed in-line building, meaning that the farrowing, nursery and grow-finisher are built right next to each other in line.

The Purdue model states that all passage ways must be sealed including manure pits between rooms and shared ventilation airways. New entrances for farm employees and pigs to enter into the nursery must be installed.

The technology of earth tubes system (ETS) can be adopted to bring in fresh uncontaminated air into the nursery. ETS was originally designed as a cost saving way of heating air during the cooler months of the year. ETS accomplishes this by drawing air through pipes laid in the ground, as the soil is always warmer than the cooler air above, before exhausting this air into the nursery. By placing the ETS up-wind of the buildings, it is providing fresh air to the SEW nursery and any saving in heat is another benefit.

The use of ETS is a minimal capital method of adopting SEW technology. Since the nursery is still part of the existing structure, bio-security measures are harder to maintain, thus it may not be practical for every operation.

Immunity:

Because the new-born pig has no acquired immunity at the time of birth, it is extremely important for the pig to receive sow's colostrum to receive immunoglobulin for early protection. This passive immunity is short term and starts dwindling by the time the pig reaches weaning age two to three weeks of age. The pig has a limited ability to synthesize antibodies until it reaches six to eight weeks of age.

Immunity in swine is accomplished by a collection of white blood cells called lymphocytes. These specialized white blood cells arise, as do all blood cells, from common precursor cells (stem cells) in the bone marrow.

Lymphocytes, unlike red blood cells, leave the blood vessels and patrol intercellular spaces for foreign intruders. The lymphocytes eventually return to the blood via lymphatic vessels, but not before interacting with specialized lymphoid tissues.

Neutrophils constitute 50% of the lymphocytes, and are the first line of defense for invading bacteria. They non-specifically engulf the invading bacteria and in turn secrete a number of inflammatory agents such as cytokines which activate the immune system and make major metabolic adjustments within the body.

Cytokines may act directly on target tissues or indirectly by changing levels of endogenous hormones such as insulin and glucagon. There are two major cyctokines involved in metabolic adjustments: interlukin-1 and tumor necrosis factor. The major metabolic adjustments are; 1)elevated metabolic rate; 2) elevated body core temperature; 3) depressed feed intake; 4) reduced protein accretion, particularly in skeletal muscle; 5) an elevated rate of protein degradation; 6) decreased rate of body fat accretion. These metabolic adjustments take nutrients away from potential growth and redirect them to support the immune system (Williams et al.,1995).

There are two additional defense mechanisms operating in the pig immune system that are more complex and enable long-term immunity against specific antigens, these are: cellular and humoral immunity. **Cellular,** guards against viral infected cells, fungi, parasites, and foreign tissue, and is mediated by T lymphocytes or T cells, because their development occurs in the pig's thymus.

Humoral, immunity is most effective against bacterial infections and extracellular phases of viral infections, and is mediated by proteins known as antibodies or immunoglobulin. These antibodies are produced by B lymphocytes or B cells, which mature in the pig's bone marrow.

Recovery from an infection by a pathogen gives the pig immunity from that particular pathogen. This so called secondary immune response is mediated by long-lived memory T cells and memory B cells, which upon re-encountering their cognate antigen at a later time after its previous appearance, proliferate faster and more massively than do virgin T and B cells.

<u>Immunology by Nutrition Interactions</u>

Williams et al., (1995) indicates that the level of chronic immune system (IS) activation that pigs experience influences the rate and composition of growth, as well as the amino acid needs of both the nursery and growing-finishing pigs. Furthermore, the amount of dietary nitrogen excreted per pound of body weight gain averaged 16.4% less in low versus high IS pigs.

There is a major shift in energy metabolism during an immune challenge. Energy intake is reduced during periods of immune challenge and fatty acid oxidation is increased to provide energy. Glucose uptake in peripheral tissue of immune challenged animals is dampened, which allows energy to be redirected to meet the needs of specific cells and tissues which are responsible for the immune response. Even though the cytokines-induced alterations in insulin function is not surprising, the mechanism which influences insulin receptor signaling and glucose uptake are not known (Spurlock et al.,1997).

Protein synthesis and degradation are also altered by cytokines during an immune challenge. There are increases in nitrogen needs for synthesis of acute phase proteins and other immune related processes. This with a reduction in feed intake, leads to less amino acids being available for muscle synthesis; possibly even causing greater degradation of muscle tissue for maintenance amino acids needs.

The prevailing hypothesis on cytokines states that during periods of stress or immune challenge, these mediators orchestrate a homeorrhetic response in which the potential for growth is reduced and nutrients are redirected to support the stress or immune response (Spurlock et al.,1997).

Insulin-like growth factor-I (IGF-I) has shown to be affected when there is poor growth performance. Hathway et al.,(1993), states that conventionally-weaned pigs had lower serum insulin-like growth factor-1 (IGF-1) concentrations than SEW pigs. Also pigs which were fed an antimicrobial agent had higher IGF-I and better growth performance than the control pigs which did not receive an antibiotic.

This reduction in IGF-I likely reflects a decreased synthesis and increased clearance of IGF-I in multiple tissues in response to proinflammatory cytokines. It appears the normal regulatory linkage between growth hormone (GH) and IGF-I may be uncoupled during an immune challenge. In pigs, the overall impact of an immune challenge on GH seems minimal, but with IGF-I there is a prolonged affect. This reduction in IGF-I circulation seems to have an integral part of homeorhesis necessary to support the immune response.

Concentrations of IGF binding protein (IGF-BP) in the blood are also altered during an immune challenge. The immune response causes an increase in IGF-BP which is likely a response to lower insulin and(or) increase glucocorticoid concentrations.

In conclusion, the immune system in the pig is a very complex system which is not activated until birth. No antibodies are passed through the placenta but they are passed to the pig in the colostrum. This passive immunity drops off logarithmically in the first three weeks of life. Early weaning helps to eliminate the sow as a source of immunity challenge. Moving the pigs into clean environments lessens subsequent immune challenges avoiding activation of cytokines which allows the pig enhanced growth opportunity. If the immune system is activated it diverts energy and proteins away from growth to protecting the body.

DIGESTIVE SYSTEM DEVELOPMENT:

Weaning causes a dramatic change for the pig going from a liquid milk diet provided by the sow, and is fed every sixty minutes, to a more complex diet made from ingredients originating from plants and animal by-products. Not only the change in diets, but the social stress of being removed from the sow further complicates the situation. It appears to take about two days before the pig starts to regain its appetite. This period of malnutrition, and change in diet, starts changing the whole digestive system from hormonal levels to enzymes.

There is evidence the weaned pig's digestive system begins undergoing physical changes with weaning. Cera et al.,(1988) reported that early weaning (21 days) causes a lower small intestinal weight the first few days postweaning when compared to pigs left nursing the dam. Mostly this is caused by malnutrition. This reverses quickly and the small intestinal weight per kilogram of empty body weight increases at a much faster rate from day 21 to 35 days of age compared to pigs left on the sow of the same chronological age. This suggests that nutrients are used for development of the small intestine following weaning rather than used for growth. Efird et al.,(1982) confirms this, reporting that intestinal weight of early weaned pigs was greater in soy fed diets than in milk diets and as age increased; intestinal length was decreased.

Most nutrient absorption takes place in the cranial portion of the small intestine, commonly called the duodenum and the jejunum. Microvilli in the small intestine increases absorption area. Nutrients are passed from the intestinal lumen into the intestinal epithelial cell of the microvilli and then into the blood or lymph system. This is accomplished by three different ways: passive diffusion, active transport and pinocytosis (pinocytosis occurs in newborn animals when immunoglobulin are absorbed from the milk).

Weaning, which includes a change in diet, meal patterns, and social stress affects the villi of the small intestine. Miller and co-workers (1986) found that villus length of the intestine of 4-6 week-old suckling pigs was reduced to half of the length within 5 days after weaning.

Cera and co-workers,(1988) also showed that weaning caused a decline in villus height in the small intestine. This change occurred within three days in pigs weaned at either 21 or 35 days of age. This study also showed that villi exist closer to each other after weaning which results in a smoother luminal surface. This condition continues for 7 days post-weaning where upon villi height increases. The villi do not appear finger-like but more longitudinal flattened, which increases the luminal surface area eventually. As the villi change it can predispose the pig to malabsorption, possible dehydration, diarrhea and enteric infections which are commonly seen on swine farms.

Not only is the digestive tract changing, but there is a need for additional digestive enzymes as the pig starts consuming plant proteins. It has been well documented that early-weaned pigs tolerate diets formulated with milk protein better than diets formulated with soybean protein. With early-weaning, most digestive enzymes are present, but the abrupt change in diet may affect digestive hormonal levels released in response to feeding, and the resultant release of enzymes into the digestive tract.

The importance of digestive enzymes from the pancreas was noted by Pekas et al. (1964). Their research involved the elimination of pancreas secretions through a ligation of the pancreatic duct and their results showed that the pancreas played a more important role in the digestion of soybean proteins than for milk proteins.

Lindemann et al.(1986) found there was a positive allometry relationship between a pig's body weight and pancreatic weight from birth to six weeks of age. From birth to four weeks of age, pancreatic growth occurs by hyperplasia and after four weeks by hyperplasia and hypertrophy. This relationship is altered right after weaning, as weaning (change of diet) causes an increase in pancreas growth.

The pancreatic enzymes lipase, amylase, chymotrypsin and trypsin are present at birth. Enzymatic development varies according to the enzyme being considered and its relationship to the diet. Thus the diet before and after weaning induces specific changes in digestive enzyme secretion by the pancreas of the pig.

Efird et al. (1982) showed that pancreatic trypsin and chymotrypsin activities are not functional until about three weeks of age normally. Owsley and others (1986), found trypsin activity in the intestinal contents was affected by age. Total activity, units/kg body weight and units/g pancreas weight increased from birth to 14 d, stayed constant from 14 to 27 d and decreased sharply to 31 d. From 31 to 42 d trypsin increased 40-fold, but stayed the same from 42 to 56 d on body weight and pancreas weight basis. Efird and co-workers (1982b) found pigs fed a soy protein diet tended to have higher levels of trypsin and chymotrypsin activity in the intestinal mucosal contents and lower levels in the pancreas than pigs fed a milk protein diet. The increase in trypsin appears to be related to increase in pancreas weight not necessarily increase in the ability of the pig to secrete more trypsin.

Makkink et al., (1994) and Jensen et al., (1997) found that secretion of trypsin was low before weaning and increased after weaning and developed more rapidly than did chymotrypsin. Makkink and co-workers also found that chymotrypsin tended to decrease after weaning and did not reach weaning levels for at least 10 days. Diets had a further effect on chymotrypsin as skim milk powder in the diet led to higher levels of chymotrypsin from the pancreas than did soybean protein concentrate.

In work done by Shields et al.(1980), the sum of amylase activities in ten week old pigs from all locations measured was higher in groups weaned at 2 weeks of age than those weaned later. This effect was primarily due to differences in pancreatic activity, since amylase presence in the mucosa and contents of the small intestine was similar for both groups. Although the enhanced pancreatic amylase activities were in part due to heavier pancreatic weights, activity per gram of pancreas was 2.5-fold higher in pigs weaned at two weeks.

The pancreatic contribution of total amylase activity increased steadily with age, representing 33% at birth, and 50% at four weeks of age. Mucosal amylase activity increases with age, but its relative contribution to the total amylase fell from 60% at birth to only 8% by 10 weeks. This is because amylase of mucosal origin breaks down starch very slowly compared to pancreatic amylase.

The stress of weaning is dramatic for the pig, changing from a diet of milk to a diet of plant origin. This forces the digestive tract to change rapidly in development and enzymes produced, (Fig. 2). Complementing ingredient digestibility with the pig's digestive capabilities is critical. Therefore, diets must be formulated with an understanding of the development of the digestive enzymes of the young pig.

HIGH QUALITY FEEDSTUFF USED IN PHASE FEEDING:

With high nutrient dense diets ingredients must be of high quality. Following is a list and brief description of ingredients used in this phase feeding concept with high nutrient dense diets.

Dried Whey and Dried Skim Milk

Dried whey (DW) and dried skim milk (DSM) are by-products of the cheese and milk industry. Both products contain high lactose (milk sugars) concentrations and milk protein components (lactalbumin and lactoglobulin). DW contains about 70% lactose, whereas DSM contains 50%. DSM contains over twice as much crude protein as DW (33% vs.13%). DW sources differ in quality and feeding value, stemming from variation in manufacturing techniques. The Maillard Reaction can occur during the drying process which binds some of the lysine to the lactose giving the DW a tannish color, and less feed value.

Usually edible-grade DW is added to the diet at approximately 20 to 25% which provides a highly digestible carbohydrate source for the young weanling pig. Research done by Mahan, (1992) indicates that during the early post-weaning period much of the nutritional value of whey resides in its carbohydrate fraction (lactose). Mahan (1993) found that during the initial 0 to 7-days post-weaning period there was a growth response only when lactose was added to a corn gluten, soybean meal, dried whey diet(CGM-SBM-DW). When lactalbumin was added to the CGM-SBM-DW diet no improvement in growth rate occurred. This suggests that the limiting nutritional factor immediately post-weaning was energy, notably, carbohydrate, not amino acids. After eight days the diet containing the lactose had a reduction in gain compared to the diet which had lactalbumin. Thus, after 7 days amino acids become the limiting factor.

Furthermore, Newton and coworkers, (1993) completed work with 180 crossbred 21 day old pigs which were fed diets of either soybean meal, soy protein concentrate as protein sources and cornstarch, DW and lactose as carbohydrate sources. The early weaned pigs benefitted from the addition of lactose to the diet as either lactose or DW. This indicates that dietary levels of lactose for the weaned pig initial post-weaning may need to be higher than that provided when the diet contains 20 to 25% DW and that it may prove beneficial for the entire starter period.

Giesting et al., (1985) indicated that the carbohydrate and protein fractions of skim milk had an additive effect on the performance of starter pigs. The weaned pig, suffering from the stress of weaning and with an underdeveloped digestive system, needs a diet high in energy for the first week following weaning. DW plus additional lactose would be a better source to fulfill that energy need, than DSM. Even though there is an additive effect with DSM, the pig's protein needs may be better met by other protein sources.

Selected Menhaden Fish Meal

The ultimate value of fish meal as a protein source depends on its quality and its affect on the total amino acid balance of the diet. Fish meal is a general term for a number of different products that vary in type of raw material and methods of production. Kjeldsen et al. (1983) found fish meal prepared from material with the lowest total volatile N content resulted in the best growth and efficiency of feed utilization. They suggest that the total volatile N may be used as an indicator of fish meal value for swine.

Work done by Bayley and Homer (1972) found that solvent extracted fish meal plus DW could replace DSM without hurting performance of pigs weaned at 10 days of age. Other studies indicated that fish meal (Menhaden) or fish protein hydrolysate, fed alone or in combination with DW in a corn-soybean meal diet would support excellent growth of weanling pigs.

Stoner et al.(1988) found in a high nutrient-dense diet, selected Menhaden fish meal(SMFM)along with DW could be used to replace up to 50% DSM without effecting growth performance of pigs weaned at 21 days. They also noted there needed to be a minimum of 19 to 24% lactose in the diet to sustain growth in a high nutrient dense diet. Stoner et al. (1990) found that 4% SMFM could replace half of the DW in a starter pig diet containing 20% DW without altering growth or performance. Thus SMFM could be used as a major source of protein for early-weaned pigs.

Spray Dried Blood Products

Recently, spray dried blood products have been included in complex starter diets; primarily spray dried porcine plasma (SDPP). SDPP is manufactured from blood which is collected at packing plants. It is then refrigerated in tanks and coagulation is prevented by the addition of sodium citrate. Centrifugation is then used to separate the plasma fraction from the blood cells. The plasma fraction is then stored at 25° F until it is ready for the spray drying process.

The spray drying process consists of 1) preheating for 25 minutes at 90° F, 2) spray drying for 1 to 2 minutes at 405° F. This results in a fine-grained light tan powder that contains about 70% crude protein. SDPP is made up of albumin, globin and globin fractions of blood.

Gatnau and Zimmerman (1990) showed that early weaned pigs fed SDPP in a corn soybean meal diet had greater ADG than pigs fed a conventional corn-soybean meal and DW diet; (Table ?). Gatnau and Zimmerman (1990b) observed increased feed intake and gains when pigs were fed diets containing SDPP rather than casein, meat extract or isolated soybean protein. Their research demonstrates that porcine plasma was superior to dried skim milk or soybean meal. The increase in growth was due to the increased feed intake of pigs fed SDPP. Also noted in the study was a decrease in gain to feed (G/F) ratio because of the increased feed intake. Sohn et al. (1991) replaced DSM with SDPP found that SDPP was an effective alternate for DSM with improved performance when compared to DSM.

Hansen et al. (1992) observed pigs had an increase in ADG when SDPP replaced DSM in the phase 1 diet. This increase in ADG was due to an increase in feed intake. Hansen et al. (1993) and Kats et al.(1994) noticed a decrease in growth performance during day 14 to 28 post-weaning of pigs previously fed SDPP. Kats et al. (1994) noticed pigs fed diets with SDPP had the greatest ADG during weeks one and two and the poorest ADG during weeks three and four. Also it was noted during week five post-weaning that pigs fed SDPP during weeks one and two had greater ADG compared to pigs fed other experimental protein sources from day 0 to 14 post-weaning.

Ermer et al., (1992 and 1994) states that during the first two weeks post-weaning, weanling pigs consume 50% more of a diet containing SDPP than one containing DSM. After the first two weeks consumption of a DSM diet increased to equal that of a SDPP diet. Could the possible explanation for increased consumption during the first two weeks be the pig prefers the palatable found in the SDPP versus the milk diet or could it be a novelty?

Ermer et al. (1994) states that diet palatability affects both the rate of feed consumption and meal size. He found in the first week after weaning pigs which consume the SDPP diet had increase both in feed consumed and meal size. After day 14 the consumption of the DSM diet was also associated with increased meal size, which he states could be compensatory gain for the low feed intake during the first two weeks.

However when not offered a choice between the two diets, pigs only consume more of the SDPP diet for approximately 7 days. Thus the increased consumption of diets containing SDPP may be due to greater palatability. The mechanism which triggers the response for the first 7 to 14 d is still not known.

Gatnau et al. (1991) and Gatnau and Zimmerman (1992) observed improvement in performance of early weaned pigs fed up to 6% SDPP. Kats et al. (1994) demonstrated that nursery pig performance is improved with SDPP included up to 10% of the diet when methionine is maintained at or above the pig's requirement.

Owen et al. (1995) indicates that the high nutrient dense diets for nursing pigs (using SDPP or SDBM) may have for its first limiting amino acid, methionine. Because those protein sources contain relatively low concentrations of methionine (8.6% and 14.5% relative to lysine).

Generally the sulfur amino acids (methionine and cystine) are considered to be the fourth and fifth limiting amino acids in most grain-soybean meal diets. NRC (1988) recommendations for total sulfur amino acids, for 5 to 10 kg pigs, is .58% of the diet with a range of .5 to .7%.

Chung and Baker (1992) state that for the 5 to 20 kg pigs that the total sulfur amino acids should be .58% of the diet, if 50% of the sulfur amino acid requirement can be furnished by cystine. They suggest that a 5 to 20 kg pig requires approximately .29% total methionine when fed a diet containing 1.29% lysine, which will support ADG between 302 to 351 g and G:F of .57 and .62.

Owens et al., (1995) found that early weaned (21 day old) pigs fed a high nutrient dense diet requires approximately .40 to .44 % dietary methionine to maximize growth performance from day 0 to 14 post-weaning, which corresponds to .345 to .385 apparent digestible methionine and 1.10 and 1.36 g/d of apparent digestible lysine. From day 14 to 35 post-weaning, when pigs are fed a less-complex starter diet, .36% total dietary methionine (.339 digestible) is required to maximize growth performance to be cost-effective.

Owen et al., (1995b) observed that SEW pigs (7 to 12 day old pigs) fed a diet of 1.8% lysine requires approximately .48 to .52% dietary methionine to maximize growth performance from day 0 to 14 post-weaning. This corresponds to .437 to .477% apparent digestible methionine and .90 g/d of methionine intake. Thus the methionine to lysine ratio of 285 is obtained.

Soybean Products

Research has shown certain feeds can contribute to the post-weaning lag by reducing growth performance and possible diarrhea. This is especially true when traditional soybean meal products have been used in diets of early-weaned pigs. Traditional soybean products cause a transient hypersensitivity response (allergy) likely due to the soybean proteins, (Newby et al.,1984); Giesting et al., 1986; Li et al.,1990 and Friesen et al.,1991). When early-weaned pigs are placed on Phase 1 diets which contain various amounts of soybean meal, antibodies specific to soy protein antigen mount an immune response at the intestinal level. This caused damage to the microvilli lining, reducing absorption capacity of the intestinal tissue. Pigs still nursing on the sow can be exposed (sensitized) to soyproteins via sow feed or creep feed taken at 600g. Once the pig has been sensitized to the soy proteins, antibodies specific to these proteins are produced by the pig to protect against future invasions of soy proteins in the intestines. Soybean proteins, glycinin and beta-conglycinin appear responsible for the hypersensitivity response of the pig.

Attempts to improve the utilization of soybean proteins through improved processing have been somewhat successful too, Wilson and Leibholz (1981) and Walker et al. (1986). Recent studies have shown that some sources of refined soybean proteins could serve as a suitable replacement for DSM in diets of early-weaned pigs Dietz et al.,(1988); Geurin et al.,(1988) and Sohn et al., (1994). These refined soybean proteins are soy protein isolate (SPI), soy protein concentrate (SPC) and modified soy flour (MSF).

SPI is produced by using precipitation techniques to separate the large storage proteins of defatted soy flakes from the soluble and insoluble carbohydrates, lipids and smaller proteins (including trypsin inhibitors). This provides a high quality soy product that is approximately 90% crude protein. SPC is produced by extracting the soluble carbohydrates from defatted soy flakes, resulting in a product containing about 70% crude protein. MSF is produced by fine grinding dehulled soybean meal and then further processing it by toasting or extrusion to form a 55% crude protein product.

These processed soy products are better utilized by the early-weaned pig than soybean meal and result in lower antisoy titer (Jones et al. 1990). Of the three, SPI and SPC appear to have greater nutritional value.

Can the increased growth rate achieved from using high nutrient density diets combined with phase feeding prove to be economically feasible to the operation for the cost of the complex starter diets that are used compared with the traditional simple diets? Shurson et al.(1992) attempted to answer this question by how the decreased days to market could benefit an operation compared to the cost of the complex starter diets. He concluded the value of reduced days to market is meaningful only if it can be achieved consistently, and if the production flow can be adjusted to put more pigs through the unit.

Mahan and co-workers (1997), found that high nutrient dense diets are important but weaning weight seemed to affect post-weaning performance. Heavier weanling pigs reached 105 kg of bodyweight approximately eight days sooner than the lighter pigs at weaning, and on less feed. Pigs with lower birth weight have a lower number of muscle fibers, therefore slower gain and poorer feed efficiency, and lower RNA:DNA ratio which is affected by lower consumption of sows colostrum and milk.

DIGESTIVE SYSTEM MICROBIOLOGY:

At the time of birth, the digestive tract is bacteria free according to Kenworth and Crabb,(1963). Gut flora grows rapidly, originating from bacteria population in the birthing canal, feces of the sow, and the bacteria present in the environment of the farrowing room. Within two hours after birth *E.coli* and *streptococci* may be detected in the pigs feces. Within five to six hours after parturition the populations of these two bacteria species are very high (10^9 to 10^{10} bacteria per gram of feces). *Lactobacilli* appear more slowly and constitute a dominant flora 48 hours after birth. Most of the gastrointestinal flora of the pig is composed of facultatively anaerobic bacteria in the proximal tract (stomach, duodenum, jejunum) whose numbers range from 10^3 to 10^7. The number of bacteria increases dynamically in the ileum. In the distal intestine there are strictly anaerobic bacteria found among the dominant flora (e.g. *Bacteroides, Eubacterium, Bifidobacterium, Propionibacterium, Fusobacterium, Clostridium species*).

When the pig is born, different species of bacteria can colonize the GI tract easily because the stomach with its relatively high pH, allows bacteria to pass through it into the digestive tract. When pigs start nursing there is a decrease in the stomach pH, due to lactic acid production, only acid-tolerant bacteria are able to survive and proliferate. Sow milk also contains some bacteriostatic properties (IgG and IgA) that can suppress *E.coli*, which may help promote a more rapid stabilization of the indigenous population, (Ducluzeau, 1985, Varley,1996).

Escherichia coli

Cox & Houvenaghel (1993), reported that enterotoxigenic Escherichia coli (ETEC) are important in causing diarrhea in young animals. Pathogenicity is determined by strain, fimbriae types, enterotoxins and endotoxins production and nutritional status and age of the host. Not all serogroups of *E. coli* are pathogenetic. Hemolysis of blood agar is one of the laboratory test to decide if *E. coli* is pathogenetic, thus in some literature it will be stated as hemolytic *E. coli*.

The first step in pathogenesis of ETEC is adhesion to specific receptors or receptor sites. The adhesion is mediated by long threadlike protein polymers from the surface of the ETEC. Fimbriae or pili can be classified according to their distinctive physical, chemical, functional, and antigenic characteristic. There are four distinct types of fimbriae: K88, K99, P987, and F41 that are found on ETEC strains and produce one or more of the fimbriae antigens F4, F5, F6, and F41. In pigs with post-weaning diarrhea, often $K88^{+}$ ETEC strains and infrequently P987 and $K99^{+}$ strains are identified, Wilson & Francis (1986).

The fimbria adhesion occurs on the receptor sites for K88, K99, F41 and $P987^{+}$ *E.coli* on the brush border of villi enterocytes from neonatal pigs has been shown in vitro adhesion assays using isolated small intestine enterocytes or brush borders, reported by Nagy et al. (1990). These studies reveal that in some pigs, one or more of the K88 variant positive strains will adhere in low numbers or they may not adhere at all.

It was shown that the presence of receptor or receptor sites for $K88^{+}$ *E. coli* is genetically determined, Sellwood et al. (1975). It is not known if there is an inheritance pattern for P987 and $F41^{+}$ receptor or receptor sites.

Cox and Houvenaghel (1993), found that $K88^+$ strains adhered in higher numbers to villi of the jejunum than to villi of the duodenum or ileum. The $K99^+$ strains adhered more to villi of the caudal region of the small intestine than to the villi of duodenum and the cranial jejunum.

In some cases of post-weaning diarrhea, ETEC without detectable adhesive fimbriae are isolated. In these cases it appears that other viral enterotoxin are produced from ETEC which cause diarrhea.

Porcine ETEC produces one or more of the thermostable STa and STb enterotoxins and the thermolabile LT enterotoxin that causes a net fluid secretion from the intestine, resulting in diarrhea. STa enterotoxin is methanol soluble and causes secretion in infant mice and piglets, whereas STb enterotoxin is methanol insoluble and is active in piglets but not in mice. LT enterotoxin causes intestinal secretion in piglets and induces cytotoxic change in CHO and Vero cell cultures, Broes et al., (1988).

It has been established that microbial interactions in the digestive tract also play an important part in the balance of the digestive microflora. Bacteria of the dominant flora exerts an environmental barrier effect on other bacteria, by either blocking fimbriae, or decreasing the number of available receptors or receptor sites.

Mathew et al., (1991), states regardless of diet, pigs experience a decrease in *Lactobacillus* populations on day 2 following weaning until eight days when colony numbers increased to near preweaning levels. *E.coli* numbers tended to be the highest on day 2 (proportion of *E. coli* with $K88^+$ fimbriae was lowest), and gradually decreased to day 13.

In addition, the change from a milk diet to a dry feed often leads to reduced feed intake during the first few days after weaning. This causes a decreased flow of digesta through the small intestine that would cause an increase in the pH of the small intestine, brought on by an over-buffering by pancreatic and other secretions until normal intake resumes. The reduced digesta flow and the increased pH may allow several serogroups of *E. coli* to colonize the anterior small intestine. This would lower the $K88^+$ to total *E. coli* ratio within the first two days after weaning. As feed consumption increases the portion of $K88^+$ to total *E. coli* increased, Mathew et al., (1993).

It is possible that high nutrient dense diets may help reduce incidence of ETEC diarrhea. Little research has been done on the effect SDPP has on *E. coli* population. Hansen and coworkers (1993) propose there may be some immunoglobulin present in the SDPP that still have some degree of specificity to bind bacteria intraluminal, thereby preventing secretion of enterotoxin that are produced by ETEC.

Effects of different management strategies and dietary spray-dried porcine plasma on early-weaned pig performance and the occurrence of gastrointestinal hemolytic *Escherichia coli*.

ABSTRACT

The benefits of segregated early-weaning (SEW) and feeding high nutrient-dense diets to early-weaned pigs is well documented. Whether an improvement in pig performance can be attained without having off-site nurseries but with implementation of strict bio-security measures is not known. The mechanism whereby spray-dried porcine plasma (SDPP) enhances growth performance of weaned pigs is also unknown. Therefore, the objectives of this experiment were: (1) to compare three different early-weaning management strategies (SEW), high bio-security on-site (HBOS), and low bio-security on-site continuous-flow nursery (LBOS), and (2) to determine if adding SDPP to a corn-soybean meal, milk diet will influence pig performance and the presence of hemolytic *Escherichia coli (E. coli)* in the gastrointestinal tract. Three hundred and twenty-four crossbred pigs(3.8 ± .07 kg and 12.1 ± 1.8 d) were allotted by weight, sex, and litter to one of six treatments in a 3 x 2 factorial designed experiment. Factors were management strategies and the inclusion of SDPP (0 or 7.5% in the phase 1 and 0 or 2.5% in the phase 2 diet fed during wk 1 and 2, respectively). All

pigs received the same phase 3 and 4 diets during wk 3-4 and 5-7, respectively, which did not contain SDPP. All diets (Phases 1-4) met or exceeded NRC (1988) requirements for nursery pigs. Feed disappearance and pig weight were recorded weekly. Overall (d 0-49) ADFI, ADG and G/F were greater ($P < .01$) for the SEW management treatment compared to HBOS and LBOS management treatments (764, 683, 598 g; 0.414, 0.267, 0.265 kg; 0.54, 0.39, 0.44, respectively). Overall (d 0-49) ADFI, ADG and G/F did not differ ($P > .05$) between 0 or 7.5% SDPP dietary treatments. Diet by location interactions were not significant ($P > .05$). Sixteen pigs (per replication; one per pen) were killed at the end of the first week. One g of digesta was collected from the stomach, ileum jejunum, cecum and the large intestine, serially diluted, and streaked onto MacConkey Agar plates. Isolated *E. coli* colonies were streaked onto Blood Agar plates to determine if the *E. coli* populations were hemolytic. Hemolytic *E. coli* populations were present in all sampled portions of the gastrointestinal tract. Management strategy and SDPP were not related to presence of hemolytic *E. coli*.

Key words: Spray-Dried Porcine Plasma, Management Nursery Pig

Introduction

Swine production has changed greatly in the past decade, especially in how producers manage and feed pigs from weaning to market. Multiple-site and phase-feeding production strategies have been implemented widely to lower disease pressure, lessen antibiotic use, and maximize performance of the growing pig.

Off-site nurseries(built several miles from breeding herd and growing-finishing facilities) separate early-weaned pigs from older animals. Access to the nursery is limited to trained farm personnel, thus providing a high degree of bio-security. This practice has become known as segregated early-weaning or (SEW). Conventional nurseries used in the past decades were generally connected to the farrowing room, were easily accessible by all farm personnel, and were often operated continuous-flow (allowing no time for cleaning between groups of pigs).

Some existing swine operations are not large enough or financially positioned to justify the building of an off-site nursery. Owners of these farms desire to continue raising hogs long term, but want to do so on a single farm site. If possible and profitable they would like to employ modern bio-security practices to receive the high health benefits of SEW without the segregation or off-site nursery.

Research is needed to determine whether on-site nurseries can be operated to achieve the performance benefits seen with SEW.

Phase feeding involves specially-developed protein and carbohydrate ingredients matching the nutrient needs of the pig to its age or stage of growth. The use of spray-dried porcine plasma(SDPP) in starter diets has been evaluated in recent years, (Gatnau and Zimmerman, 1990); Sohn et al, 1991; and Hansen et al.,1993). All of these researchers have shown that SDPP in nursery pig diets will increase growth rate and feed intake, compared to dried skim milk (DSM) as a protein source. The physiological mechanism by which SDPP causes improved performance is not known. It is possible that immunoglobulins in SDPP may have a localized effect in the digestive tract, controlling microbial growth. To date no evidence of this has been reported.

Therefore the objectives of this study were: (1) to compare three different nursery management strategies: SEW, on-site nursery with high bio-security (HBOS) and on-site nursery with low bio-security (LBOS),and (2) to determine if adding SDPP to a corn-soybean meal, milk diet influences pig performance and the presence of hemolytic *Escherichia coli* (*E. coli*) in the gastrointestinal (GI)tract.

Material and Methods

Animal Care and Use

The experimental protocol used in this study was approved by the Michigan State University Animal Care and Use Committee.

Animals

A total of 324 early-weaned, crossbred pigs (initially 3.8 kg ± 0.7 and 12.1 ± 1.8 d of age; Newsham[R] X (Yorkshire X Landrace)) were used. Dams were vaccinated prebreeding for parvovirus, leptospirosis and erysipelas; prefarrowing for bordetella, *E. coli,* pasteurella, Transmissible Gastroenteritis, erysipelas and clostridium.

Processing pigs on day one after birth included: ear notching, clipping of needle teeth, tail docking, iron shots of 1.5ml iron dextran and 0.25 ml. of ceftiofur hydrochloride. One day prior to weaning, pigs were weighed individually for allotment to treatment. At weaning 0.5 ml of long-acting penicillin was given for prevention of *Streptococcus suis* infection. Pigs were not vaccinated, or submersed in disinfectant at weaning.

Experimental Treatments

A 3 x 2 factorial design was employed. The main effects were management strategies (SEW, HBOS, LBOS), and the inclusion of SDPP (0 or 7.5% in the phase 1 diet and 0 or

2.5% in the phase 2 diet fed wk 1 and 2, respectively Figure 3.

Management Strategies

Management strategies involved different nursery locations and varying degrees of bio-security. The **SEW** nursery was located 3/4 mile northeast of the existing Michigan State University Swine Farm at Veterinary Isolation Facility, G-Barn. Pigs at this facility were housed in three rooms (2 pens per room). One person was in charge of feeding and animal care. This person showered both upon arrival and departure, wore clothes kept at the facility and was not responsible for the care of any other pigs throughout the duration of the trial.

The **HBOS** was located at the Michigan State University's Swine Farm, in a mono-slope building which also contained one other nursery room and two, six crate farrowing rooms. All rooms were connected by a common hallway. The nursery room used for this experiment was remodeled just prior to this experiment. Disposable boots, coveralls and foot baths were used before entering the room. The person in charge of this barn only worked with this group of pigs during the experiment.

The **LBOS** was one of two, 20 year old converted trailer homes, at the Michigan State University's Swine Farm. These nurseries are located about 200 yards east of the HBOS and connected to a commons area which is shared with an older confinement grow-finish facility. This conventional nursery has an unrestricted entrance policy allowing various farm personnel and general public to enter at all times. Feeding and care was provided by personnel available to perform the task on a given day, regardless of their previous exposure to other pigs.

Diets

Two dietary treatments were used and differed depending on the addition of SDPP (AP920; American Proteins, Ames IA) to diets fed pigs d 0 to 14 post-weaning. Phase 1 and phase 2 diets were formulated as part of a four phase nursery diet sequence, and were fed during wk 1 and wk 2, respectively (Table 7). In the first dietary treatment (0% SDPP) DSM was added as a high-quality protein source to both phase 1 and phase 2 diets (22% and 15%, respectively). In the second dietary treatment, SDPP was included as a high-quality protein source in both phase 1 and 2 diets (7.5% and 2.5%, respectively). DL-methionine was added to the SDPP diets to obtain a minimum methionine to lysine ratio of 0.28. DSM diets exceed this ratio without the addition of supplemental DL-methionine. All pigs received similar phase 3 (wks 3-4) and phase 4 (wks 5-7) diets. Diets fed in phase 3 and 4 were corn-soybean meal based without DSM or SDPP. All diets met or exceeded NRC (1988) suggested mineral and vitamin requirements for pigs of corresponding ages and weights.

Housing

Pigs were placed in 1.22 x 1.83 m pens at each of the three locations. The first week there were nine pigs per pen, after sacrificing one pig for the microbiology study on d 7, there were eight pigs per pen. Flooring varied among nursery facilities: OSHB woven wire, HBOS facility TriBar^{R} (FarmTek, Dyersville IA) and at the LBOS ½ concrete and ½ woven wire. All rooms at each facility were disinfected with Tek-Trol^{R} (BIO-TEK Ind. Inc., Atlanta GA) at 14.8 ml/3.786 L, two days prior to the arrival of the pigs. Temperature was thermostatically controlled at each location so that the ambient temperature remained within the thermoneutral zone recommended for pigs of this age (PIH 18). For replication one, at all locations, additional heat lamps and heat pads were used for the first week due to cold weather. During the first week all pigs at each location were fed 50 g per pen per day on 45.72 cm by 45.72 cm wooden trays, and also had access to fenceline feeders. Pigs had access to two nipple waterers per pen. During wk 1 nipple waterers were set to drip continually to help avoid navel sucking.

Microbiology

One pig from each pen was randomly selected on d 7, and euthanatized. Digestive samples were collected from the stomach, jejunum, cecum and large intestine. In the second replication only the jejunum and cecum were sampled. Digestive samples were collected and placed in sealed sterile test tubes, labeled and placed on ice to be transported to the laboratory.

For *E. coli* determinations, 1 g aliquot of the digestive samples were serially diluted in EC Broth (Difco, Detroit MI), and were incubated for 48 hrs at 37.5^0 C. Total lactobacilli was determined by serially diluting 1 g of digest sample aliquots in Bacto Rogosa Broth (Difco, Detroit MI) for 24 hrs at 35^0 C.

A sample was taken from each of the 10^1 EC Broth dilution tubes and streaked on Petri dishes containing MacConkey Agar (Difco, Detroit MI). Petri dishes were incubated for 24 hrs at 35^0 C. Colonies which appeared reddish or pink in color on the MacConkey agar were streaked to Petri dishes containing Blood Agar (Baxter, McGaw Park, IL) to determine if *the E.coli* was hemolytic. The plates were incubated for 24 hrs at 35.5^0 C. Lysing in the blood agar indicated hemolytic *E.coli* strains were present. The *lactobacillus sp.* was used as a comparison when looking at *E. coli* numbers.

Statistics

Data were analyzed as a randomized complete block design in a 3 x 2 factorial arrangement(Fig. 3). Pen was the experimental unit for all growth performance response criteria. Individual pig was the experimental unit for microbiology measures. Analysis of performance data and *E. coli* data by least squares means was performed using General Linear Model Procedure of SAS (1988). Hemolytic *E.coli* response was analyzed using Chi Square, Gill(1987).

Results

From 0 to 14 d SEW pigs grew faster, ate more feed, and were more efficient than HBOS and LBOS pigs ($P<.01$; Table 8). Performance during this period was also influenced by diet. Feeding SDPP diet resulted in higher ADFI than feeding DSM (286 vs. 263 g, respectively; $P<.05$). However, pig weight gains were not affected by diet. Consequently, pigs receiving DSM were more efficient than pigs fed SDPP ($P< .05$). There were no diet by management interactions on pig performance during the first two weeks.

Incidental flanking and navel sucking were observed at all sites. The most severe problems were in two pens during the second replications under the HBOS management strategy.

Problem pigs were removed.

From 14 to 28 d, there were no dietary treatment effects. The SEW and HBOS pigs had greater ADFI than LBOS ($P<.05$)and SEW and LBOS pigs had greater ADG than HBOS ($P<.05$)

Cumulative 0 to 28 d, pigs in the SEW management strategy grew faster than HBOS and LBOS pigs (298, 244, 240 g/d respectively; $P<.05$). Pigs on HBOS ate the same amount of feed as those on SEW, and both were greater than LBOS ($P<.05$). HBOS pigs were less efficient than either SEW or LBOS pigs (0.56, 0.65, 0.62 respectively; $P<.05$). There were no dietary treatment effects over the first 28 days.

From 28 to 49 d, pigs on the SEW management strategy increased their performance advantage over HBOS and LBOS with higher ADFI, ADG and G:F. The accelerated growth of SEW pigs compared to the slower growth of HBOS and LBOS pigs is illustrated in Figure 2. The HBOS and LBOS management strategy pigs maintained or increased slightly their average daily gain during d 28 to 49 over that which was observed during d 0 to 28 (0.298 vs. 0.574 g/d, 0.244 vs. 0.296 g/d and 0.240 vs. 0.301 g/d during d 0 to 28 and 28 to 49 d for SEW, HBOS, and LBOS, respectively;). Pigs on the SEW treatment ate more feed and were more efficient than either HBOS or LBOS pigs ($P<.05$). There were no dietary treatment effects. However numerically, pigs on the DSM phase 1 and 2 diets ate more feed within the SEW and HBOS management strategies.

Throughout the 49 d feeding trial, pigs in the SEW management strategy had the highest ADG, ADFI and G/F ($P<.01$). SEW pigs fed DSM or SDPP Phase 1 and 2 diets performed similarly (0.316 g/d, 0.316 g/d; 686 g, 677 g; 0.45, 0.45; respectively $P<.05$) for ADG, ADFI and G/F. Pigs in the HBOS management strategy had the poorest feed efficiency throughout the trial ($P<.01$). Pigs in the LBOS environment ate the least amount of feed ($P<.01$).

Economically the SEW pigs had the least cost per pound of gain, with the DSM diet being the lowest. The HBOS pigs had the highest cost per pound of gain. While the LBOS pigs ate less feed they were still not as economical as the SEW pigs (Table 10).

During the trial, no pigs developed diarrhea. Hemolytic *E. coli* and *lactobacilli* were identified throughout the digestive tract (Table 9).

The number of *E. coli* colony forming units per gram of stomach digesta were greater for pigs fed the DSM diet than those fed SDPP (3.51 vs 2.53; $P<.05$). Within the SEW pigs, the number of colony forming units per gram of digesta of *E. coli* in the stomach were higher for pigs on SDPP dietary treatment. Whereas HBOS and LBOS pigs had higher number of *E. coli* colony forming units per gram of digesta with DSM diets (P<.05). The numbers of *E. coli* and *lactobacilli* colonies formed per gram of stomach digesta were similar across all the management strategies. There was a location by diet interaction observed with stomach *E. coli*, with the DSM dietary treatment having the highest number of *E. coli* colonies within HBOS and LBOS management strategies and the SDPP dietary treatment having the greater numbers within the SEW management strategy.

In contrast to microbiological results observed with stomach content, no dietary effect was observed on *E. coli* and *lactobacilli* population in contents taken from the small intestine. Also unlike stomach results, a management strategy effect was observed for *E. coli* in the small intestine samples. Digesta samples from LBOS pigs had greater populations of *E. coli* than those samples taken from HBOS and SEW pigs (P< .05). Microbiological assays of large intestine samples provided results which were similar to those observed with digesta obtained from the small intestine. Again, no dietary differences were observed. The LBOS strategy had greater *E. coli* population than either HBOS or SEW (P<.05).

In the cecal there was a diet effect observed across management strategies with pigs on the DSM dietary treatment having a greater number of *E. coli* colony forming units per gram of digesta than pigs fed SDPP (P<.01). Like the small intestinal results, cecal *E. coli* populations tended to be greater in samples taken from pigs reared in LBOS management versus pigs reared in SEW or HBOS environments (P=.08).

Differences were observed in number of colony forming units per gram of digesta between replications for *E. coli* present in the cecum and *lactobacilli* in the small intestine and cecum (P<.05) Numbers were greater/smaller in the first replication compared to the second replication. There was a diet effect observed across management strategies with pigs on the DSM dietary treatment having a greater number of *E. coli* colony forming units per gram of digesta than pigs fed SDPP (P<.01).

Discussion

Segregated early-weaning with an off-site nursery improved early-weaned pig performance (ADG, ADFI, and G:F) throughout the entire 49 d on trial. These results are similar to those of Edmonds and others, (1997), who also found that nursery pigs raised off-site had greater ADG, and ADFI compared to those reared in on-site nursery. However, the results of the present study are contrast to those of

Fangman et al., (1996) which indicated that the nursery site need not necessarily be physically distanced from the farrowing site to obtain those growth advantages.

SEW reduces disease stress on the early-weaned pig by providing a cleaner environment. Dritz (1996) states that even dust, endotoxin and dandruff in the environment can cause stress to the early-weaned pig. The amount, duration and intensity of these stressors influence the degree of response by the immune system, (Kelly et al.,1982). When there is an immune challenge to the pig several cellular immune responses occur. These include antigen-specific defenses such as cell mediated or antibody-mediated responses. Other defenses include non-specific measures such as the inflammatory and acute-phase responses. The inflammatory and acute-phase responses are mediated by hormone-like compounds termed cytokines. An increase in cytokines causes decreased voluntary food intake, increase in energy expenditure and body temperature and alter nutrient metabolism (Klasing, 1988). The prevailing hypothesis on cytokines states that during periods of stress or immune challenge, these mediators orchestrate a homeorrhetic response in which the potential for growth is reduced and nutrients are redirected to support the stress or immune response, (Spurlock et al.,1997).

In the present study the reason HBOS and LBOS management strategies led to compromised performance may be breaks in bio-security or disease contamination in each nursery. In the HBOS system, a common hallway which was shared with two farrowing rooms housing adult females. These sows may have shed diseases particularly at the time of labor. This study did not measure air contaminates but there may have been enough contaminates in the air in the HBOS and LBOS nurseries to activate the immune response, which is evident after 28 d as the ADG and G\F decrease to below the 28 d average in pigs fed either diet. The shared hallway at HBOS was used by other farm personnel in doing chores and moving animals. The hallway was designed for bringing in fresh air near floor level and mixing it with warmer air before being drawn in to each room through the air inlets. Our research team attempted to set up a dressing area where disposable coveralls and boots could be put on before going into the experimental nursery room. This dressing area may have needed to be a more secure area, and fresh air brought in through a unique opening other than the common hallway.

In the LBOS nursery there was a general storage and walk through area connected to another nursery and a grower finisher unit. Through this common area, farm personnel doing chores would have access to pigs ranging from 2 to 26 wk in age. The LBOS was also ran as a continuous flow nursery.

In this study there was no growth advantage by including SDPP in the starter diet. There was no interaction between management strategy and inclusion of SDPP. This is in contrast to Coffey and Cromwell (1995) who indicated that the response to SDPP was more pronounced in pigs reared in conventional on-site nurseries as opposed to cleaner, off-site nurseries. The lack of agreement between this study and the present may be due to several factors; such as the age and weight of pigs, and the number of days pigs were on a particular diet 7 d vs. 14 d.

SDPP has been identified as an effective protein source for early-weaned pigs. Gatnau and Zimmerman (1990) showed that early-weaned pigs fed SDPP in a corn-soybean meal had a greater ADG than pigs fed a conventional corn-soybean meal-dried whey diet. Sohn et al., (1991) showed that DSM could be replaced with SDPP and performance ADG and ADFI would be improved by 29%, 24%, respectfully. Gatnau et al., (1991) and Gatnau and Zimmerman (1992) reported that 6% SDPP in a corn-soybean meal-dried whey was needed to maximize growth rate and feed intake in pigs weaned at 25 to 28 days of age. Kats et al., (1994) found that 10% SDPP level could be effective in improving growth performance as long as methionine level is maintained at or above pig's requirement. Both researchers found that daily gains increased linearly as the level of SDPP increased from 0 to 10% and the maximum feed consumption occurred around 8.5% SDPP.

Research has shown that when SDPP is fractionated into different molecular weight components, the immunoglobulin fraction retains its stimulatory effects on feed intake (Gatnau et al., 1995; Owen et al., 1995; Weaver et al., 1995). The mechanism for this response remains unknown. It is believe that the immunoglobulin may still hold some degree of specificity and be able to bind bacteria intraluminally, thereby prevent growth of microbial populations or preventing secretion of endotoxin especially from *E. coli*.

In this study *E. coli* was present throughout the digestive tract. *E. coli* concentrations in digesta were influenced by diet to some degree, with a greater number of *E. coli* present in the stomach and cecum of pigs fed DSM versus SDPP. This suggests that SDPP, possibly through immunoglobulin has some degree of local and immediate influence on microbial growth and the pig's appetite. These results combine with greater ADFI during the first two wks of this study for pigs fed SDPP suggest that a change in microbial populations may be a mechanism whereby SDPP affects starter pig performance. However, this proposed mechanism is largely refuted because the dietary effect of SDPP on microbial populations and on pig performance was not observed in combination in other locations of the gastrointestinal tract and on ADG and G:F. Furthermore, overall (0-49 d) performance of pigs fed DSM or SDPP did not differ and therefore difference in *E. coli* numbers found in the stomach and cecum on d 7 appear to have no long term relationship to pig performance.

The management strategy by diet interaction for the number of E. coli colony forming units in the stomach follows the performance response observed by Coffey and Cromwell (1994). Pigs fed SDPP in a dirty environment or (LBOS) had less *E. coli* in the stomach than pigs fed DSM in the same environment. However the importance of this interaction diminish quickly. Reasons why *E. coli* numbers in the stomach were higher in SEW pigs fed SDPP versus DSM are not known and probably incidental. Additionally, the d seven microbial differences observed between diets and within management strategy were not coincident with any short or long term pig performance measure. Microbial differences observed on d seven again appear to have little relationship to overall pig performance.

Management strategy appears to have a greater influence on *E. coli* populations throughout the gut as observed in the stomach, small intestine, cecum and large intestine. In all segments of the gastrointestinal tract the LBOS strategy resulted in greater numbers of *E. coli* than either HBOS or SEW strategies. Management strategies effects on microbiology populations did not coincide with similar management strategies effects on performance. Notably, E. coli populations in pigs from HBOS and SEW were similar but performance measure HBOS pigs were vastly inferior to SEW pigs; being similar to those of LBOS pigs.

No attempt was made to quantify *E. coli* that was hemolytic, but hemolytic *E. coli* was determined qualitatively to be consistently throughout the tract. Mathew et al.,(1993) also found an increase in *E. coli* colony forming units two days after weaning due to the decrease in feed intake as the pig switches from the sow's milk diet to a dry cereal grain based diet. Mathew observed the increase in *E. coli* population may have been from other serogroups which are not pathogenetic to pigs. Even though hemolytic *E. coli* was present along the GI tract in this study, no diarrhea was noted. This may have been due to a failure to achieve a threshold population or because the inclusion of SDPP eliminated or interfered with receptor sites along the microvilli or lastly because the antimicrobial and growth promoting agents (carbadox, 55 ppm; Cu, 250 ppm; Zn, 3000 ppm) were included in our experimental diets.

Implications

Early-weaned pig performance is improved with management strategies that include segregation of early-weaned pigs from older swine. On-site nursery management with bio-security as utilized in this study does not result in comparable performance. SDPP or DSM maybe used in the starter diet with equivalent impacts on starter pig performance, despite having differing influences on gut microflora. Deciding which ingredient to use will depend on availability of high quality complimentary feedstuffs and ingredient cost.

Table 1. Measuring pig performance by the percent change in average daily gain (ADG), average daily feed intake (ADFI) and feed efficiency (G:F), with the inclusion of spray-dried porcine plasma (SDPP) in the diet versus dried skim milk (DSM).

Study	Age,d	BWT, kg	%SDPP	Alternate Ingredient	Day on test, d	% Change ADG	% Change ADFI	% Change G:F
Gatnau, et al., (1991)	28	7.1	6	20% DSM	14	36	19	29
Sohn, et al., (1991)	24	-	4	10% DSM	7	33	29	4
					14	26	104	0
Hansen, et al., (1993)	21	5.3	10%	20% DSM	7	12	21	-9
					14	15	28	-10

Table 2. Suggested Weaning Ages to Prevent Transmission of Disease in a Segregated Early-Weaning Program	
Disease	**Age at Weaning (days)**
Enzootic pneumonia	10
Atrophic rhinitis	10
Pseudorabies infection	21
Swine dysentery	21
Transmissible gastroenteritis	21

Table 3. Recommended Separation of Sites From Other Pigs to Prevent Transmission of Certain Disease Agents	
Disease or Agent	**Distance (Miles)**
Transmissible Gastroenteritis	0.5
Actinobacillus Pleuropneumonia	0.5
Atrophic rhinitis	0.5
Streptococcus Suis	0.5
Pseudorabies	2.0
Enzootic pneumonia	2.0

Table 4. Suggested Bio-security Measures for Segregating Early-Weaning Production

Bio-security Measures:
* Locate as far away from other pigs as possible.
* Evaluate disease status of herd of origin.
* Isolate all incoming breeding stock.
* Prohibit vehicles that have not been cleaned and disinfected from transporting pigs.
* Use proper loading out facilities that ensures a pig leaving the complex cannot return.
* Use aggressive control procedures for rodents, flies and stray animals.
* Exclude all nonessential personnel from the farm.
* Ensure that farm personnel have no contact with swine outside the herd.
* Use pathogen-free feed sources.
* Institute methods of feed delivery that closely control access of potentially contaminated trucks into the farm.
* Dispose of dead animals promptly.
* Use fences and locks to restrict entry of unauthorized personnel.

Table 5. Measuring pig performance by the percent change in average daily gain (ADG), average daily feed intake (ADFI) and feed efficiency (G:F) in on-site versus off-site nurseries with the inclusion of spray-dried porcine plasma (SDPP).

Study	Age,d	BWT, kg	Days on test	% Change ADG	% Change ADFI	% Change G:F
Coffey and Cromwell (1994)	18	5.2	14	-12	-28	-15
			28	-27	-28	0.6
Coffey and Cromwell (1995)	-	5.4	14	-36	-41	-6
			28	-53	-35	13

Table 6. Nutrient composition of Spray-dried Porcine	
Crude protein	78.0
Dry matter	92.0
Chloride	1.5
Calcium	0.15
Phosphorus	1.71
Arginine	4.55
Cystine	2.63
Histidine	2.55
Isoleucine	2.71
Leucine	7.61
Lysine	6.84
Methionine	0.75
Phenylalanine	4.42
Threonine	4.72
Tryptophan	1.36
Tyrosine	3.53
Valine	4.94

[a]All values taken from NRC (1998)

Table 7. Composition of diets fed in experiment.

Diets	Phase 1		Phase 2		Phase 3	Phase 4
Treatment	SDPP	DSM	SDPP	DSM	-	-
Ingredients						
Corn dent yellow	29.50	29.12	40.80	40.15	57.64	65.11
Soybean meal	15.30	15.31	17.88	17.87	21.05	27.85
Skim milk, dried	-	22.00	-	15.01	-	-
Whey, dried	25.00	20.00	20.00	15.01	10.00	-
Fish meal,	6.62	6.00	7.50	4.89	5.00	-
Spray-dried Por.[a]	7.50	-	2.50	-	-	-
Ed. Grd Lactose	7.50	-	4.00	-	-	-
Choice White	5.00	5.00	4.00	4.00	3.00	3.00
Mono-Dical-Phos	0.24	0.34	0.77	0.66	1.35	1.62
Vitamin Premix[b]	0.60	0.60	0.60	0.60	0.60	0.60
Salt	0.50	0.50	0.50	0.50	-	-
Zinc oxide[c]	0.38	0.38	0.38	0.38	-	-
Limestone	1.11	0.07	0.37	0.35	0.63	1.18
Antibiotic[d]	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral[e]	0.23	0.23	0.23	0.23	0.23	0.23
Copper sulfate[f,g]	0.05	0.05	0.05	0.05	0.10	0.10
L-Lysine HCl 78.8%	0.10	0.15	0.09	0.05	0.15	0.15
DL-Methionine	0.13	-	0.06	-	-	-
Nutrient						
ME, kcal/kg	3429.40	3513.29	3409.09	3457.36	3396.40	3408.00
CP,%	23.40	23.70	21.48	22.11	19.64	19.19
Lysine	1.70	1.70	1.45	1.45	1.25	1.15
Met+Cys	0.50	0.50	0.45	0.45	0.36	0.32
Ca,%	1.08	0.90	0.91	0.88	0.90	0.80
P,% avail	0.53	0.57	0.58	0.53	0.54	0.41
Na,%	0.77	0.61	0.57	0.50	0.16	0.01

[a]AP 920; American Protein, Ames, IA.

[b]Supplied per kilogram of diet: vitamin A, 5512 IU; vitamin D_3, 551 ICU; vitamin E, 66 IU; vitamin K (as menadione sodium bisulfite complex) 4.4 mg; riboflavin,4.4 mg; pantothenic acid 17.6 mg; niacin, 26.4 mg; vitamin B_{12}, 33 mg; thiamin,1.10 mg; pyridoxine, 1.0 mg.

[c]Supplied 3000 mg of Zn per kilogram of diet (in addition to that provided by trace mineral premix.

[d]Supplied 55 mg of carbadox per kilogram of diet.

[e]Supplied per kilogram of diet: Zn, 10 mg; Cu, 10 mg; Fe, 100 mg; Mn, 10 mg; I, 0.15 mg; Se, 0.3 mg.

[f]Supplied 125 mg of Cu per kilogram of diet (in addition to that provided by trace mineral premix in Phase 1 and 2.)

[g]Supplied 250 mg of Cu per kilogram of diet (in addition to tha provided by trace mineral premix in Phase 3 and 4.)

Table 8. Effects of management strategy and dietary treatments on growth performance of early-weaned pigs.

Management Strategy[a]	SEW		HBOS		LBOS		
Dietary Treatments[b]	SDPP	DSM	SDPP	DSM	SDPP	DSM	MSE
Oberservations	6	6	6	6	6	6	
Days 0 to 14							
ADG, g[c]	233.37	238.42	170.96	180.61	155.34	149.36	1401.99
ADFI, g[d,e]	317	292	298	279	241	216	1197.61
G:F[c,d]	0.73	0.82	0.57	0.65	0.64	0.69	0.01
Days 14 to 28							
ADG, g	357.00	371.38	313.81	325.20	334.15	331.42	2786.23
ADFI, g	620	636	574	607	561	522	5897.90
G:F[e]	0.58	0.59	0.55	0.53	0.60	0.60	0.002
Days 0 to 28							
ADG, g[c]	292.94	302.89	238.34	250.63	241.99	237.63	1452.51
ADFI, g[d]	464	459	430	438	396	380	2666.29
G:F[f]	0.63	0.66	0.56	0.57	0.61	0.63	0.0028
Days 28 to 49							
ADG, g[c]	567.92	581.04	298.69	294.09	320.38	282.28	4815.35
ADFI, g[g]	1174	1192	1021	1078	895	882	10715.80
G:F[g]	0.48	0.49	0.3	0.27	0.36	0.32	0.004
Days 0 to 49							
ADG, g[c]	408.23	420.00	263.57	270.83	274.98	256.50	1944.18
ADFI, g[g]	762	768	665	701	606	590	4011.88
G:F[g]	0.54	0.55	0.4	0.38	0.45	0.43	0.002

[a]Management Strategies: Segregated Early-Weaning (SEW), High Bio-security On-site (HBOS), Low Bio-security On-site (LBOS).
[b]Dietary Treatments: Spray-dried Porcine Plasma (SDPP), Dried Skim Milk (DSM).
[c]Management Strategy Effect: SEW> HBOS or LBOS, (P<.05).
[d]Management Strategy Effect: Both SEW and HBOS greater then LBOS, (P<.01).
[e]SDPP greater than DSM, (P<.05).
[f]Both SEW and LBOS greater than HBOS, (P<.01).
[g]SEW greater than HBOS which was greater than LBOS, (P<.01)

Table 9. Effect of management strategy and dietary treatment on number of *E. coli* and *lactobacilli* in segments of the gastro-intestinal tract on d 7 post-weaning.

Management Strategy[a]		SEW		HBOS		LBOS		
Dietary Treatment[b]	n	SDPP	DSM	SDPP	DSM	SDPP	DSM	MSE
Stomach								
Eschericia coli[c,d]	18	2.97	2.00	2.33	3.67	2.30	4.87	0.8722
Lactobacillus	18	7.73	6.13	6.67	6.00	5.96	6.80	1.317
Small Intestine								
Eschericia coli[e]	36	4.32	4.25	4.16	4.46	6.25	6.98	3.6594
Lactobacillus	36	8.15	7.82	8.15	7.07	8.33	7.72	1.5039
Cecum								
Eschericia coli[d]	36	6.13	6.73	5.04	7.50	6.35	8.92	3.3701
Lactobacillus	36	8.50	8.55	8.68	8.88	8.70	8.25	1.3464
Large Intestine								
Eschericia coli[e]	18	4.99	5.73	3.70	5.80	7.93	7.23	3.352
Lactobacillus	18	9.00	8.40	8.33	8.47	8.33	7.35	0.861

[a]Management Strategies: Segregated Early Weaning (SEW), High Bio-security On-site (HBOS), Low Bio-security On-site (LBOS).
[b]Dietary Treatments: Sprayed-dried Porcine Plasma (SDPP), Dried Skim Milk (DSM).
[c]Location Diet Interaction ($P<.05$).
[d]Diet effect ($P<.05$).
[e]Location effect ($P<.05$).

Table 10. Effects of different management strategies and dietary treatments on economics of early-weaned pigs.

	Management Strategy[a]					
	LBOS		SEW		HBOS	
Diets[b]	SDPP	DSM	SDPP	DSM	SDPP	DSM
Avg. Starting wt., lb.	8.40	8.35	8.30	8.25	8.36	8.42
Phase 1 (d 0 to 6)						
Weight gain, lb	2.31	1.88	3.50	3.35	2.73	2.59
ADG, lb/d	0.33	0.27	0.50	0.48	0.39	0.37
Feed intake, lb	2.66	2.31	3.5	3.29	2.87	2.73
ADFI, lb/d	0.38	0.33	0.50	0.47	0.41	0.39
Price/lb complete feed	0.35	0.26	0.35	0.26	0.35	0.26
Feed cost $	0.93	0.60	1.23	0.86	1.00	0.71
Feed cost/lb gain	0.40	0.32	0.35	0.26	0.36	0.27
Phase 2 (7 to 13)						
Weight gain, lb	3.85	3.99	5.67	5.46	4.27	4.20
ADG, lb/d	0.55	0.57	0.81	0.78	0.61	0.60
Feed intake, lb	4.90	4.48	6.44	5.88	6.51	5.88
ADFI, lb/d	0.75	0.64	0.92	0.84	0.93	0.84
Price/lb complete feed	0.22	0.21	0.22	0.21	0.22	0.21
Feed cost $	1.08	0.92	1.42	1.23	1.43	1.22
Feed cost/lb gain	0.28	0.23	0.25	0.23	0.33	0.29
Phase 3 (d 14 to 27)						
Weight gain, lb	10.36	10.22	10.99	11.44	9.66	10.08
ADG, lb/d	0.74	0.73	0.78	0.82	0.69	0.72
Feed intake lb	17.22	16.1	19.1	19.59	17.64	18.76
ADFI, lb/d	1.23	1.15	1.36	1.40	1.26	1.34
Price/lb complete feed	0.13	0.13	0.13	0.13	0.13	0.13
Feed cost $	2.24	2.09	2.48	2.55	2.29	2.44
Feed cost/lb gain	0.22	0.20	0.23	0.22	0.24	0.24
Phase 4 (d 28 to 49)						
Weight gain, lb	14.80	13.04	26.23	26.84	13.80	13.57
ADG, lb/d	0.70	0.62	1.25	1.28	0.66	0.65
Feed intake lb	41.35	40.74	54.18	55.08	47.25	49.71
ADFI, lb/d	1.97	1.94	2.58	2.62	2.25	2.37
Price/lb complete feed	0.09	0.09	0.09	0.09	0.09	0.09
Feed cost $	3.85	3.79	5.04	5.12	4.39	4.63
Feed cost/lb gain	0.26	0.29	0.19	0.19	0.32	0.34
Total (d 0 to 49)						
Weight gain, lb	31.36	29.13	46.39	47.09	30.52	30.44
ADG, lb/d	0.58	0.55	0.84	0.84	0.59	0.56
Feed intake	66.13	63.55	83.19	83.84	74.27	77.00
ADFI, lb/d	1.08	1.02	1.34	1.33	1.21	1.24
Price/lb complete feed	0.122	0.116	0.122	0.116	0.122	0.116
Feed cost $	8.10	7.40	10.17	9.76	9.11	8.73
Feed cost/lb gain	0.26	0.25	0.22	0.21	0.30	0.29

[a]Management Strategies: Low Bio-security On-Site (LBOS), Segregated Early-Weaning (SEW), High Bio-security On-site (HBOS).
[b]Dietary Treatments: SDPP = Spray-dried Porcine Plasma (ingredient price of $2.15/lb.; DSM = Dried Skim Milk (ingredient price of $0.54/lb). Phase 1 diet was corn-soybean meal based and included 7.5% and 22.0% SDPP or DSM, respectively. Phase 2 diet was also corn-soybean meal based and included 2.5% and 15% SDPP or DSM, respectively. Phase 3 and 4 diets were corn-soybean meal diets without SDPP or DSM.

Figure 1. Digestive enzyme development in young pigs.

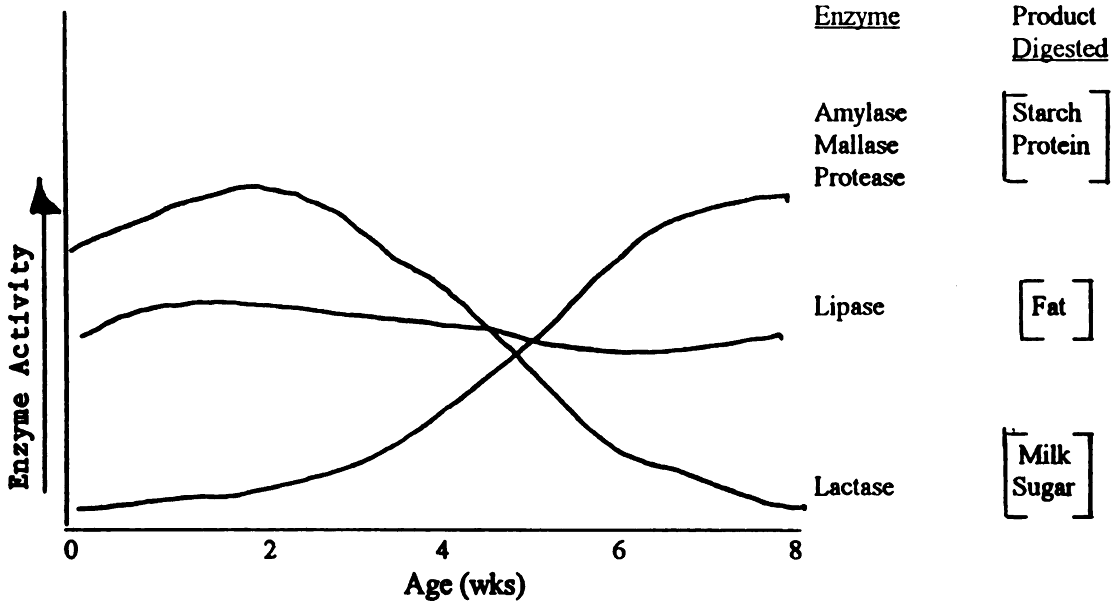
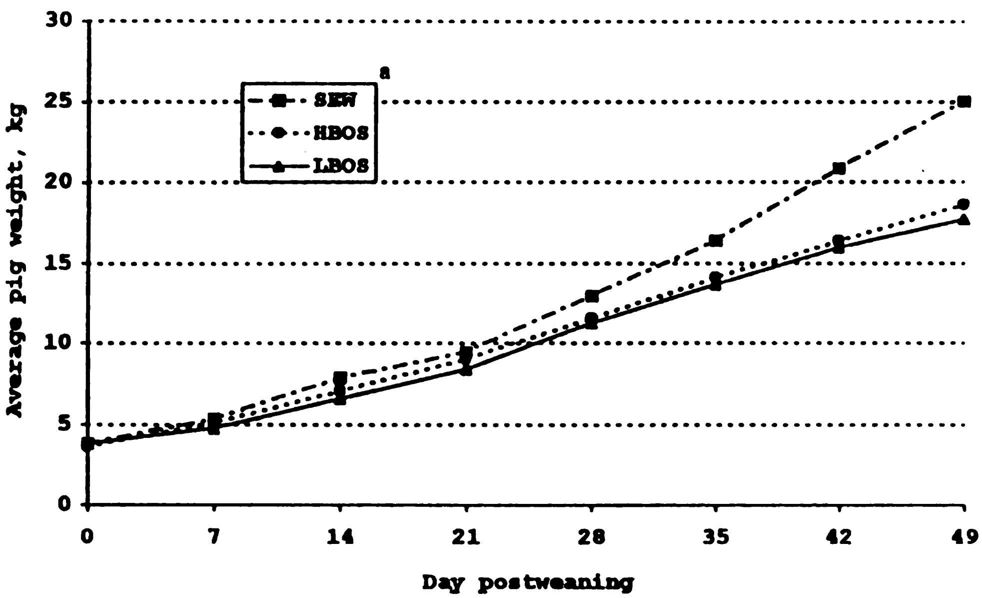


Figure 2. Management strategies affects on average pig weights over 49 d post-weaning.



[a]Segregated Early Weaning (SEW), High Bio-security On-Site (HBOS), and Low Bio-security On-Site (LBOS) management strategies

Figure 3. Experimental design for three management strategy and two diets.

SEW		HBOS		LBOS	
DSM	SDPP	DSM	SDPP	DSM	SDPP

Literature Cited

Alexander, T.J.L., T.K. Boon. 1980. Medicated early weaning to obtain pigs free from pathogens endemic in the original herd. Vet. Rec. 106:114-119.

Bayley, H.S. and J.H.G. Holmes. 1972. Protein sources for early weaned pigs. J.Anim. Sci. 35:1101 (Abstr).

Bergstrom, J.R.,J.L. Nelssen, M.D. Tokach, R.D. Goodband, S.S. Dritz, K.Q. Owen, and W.B. Nessimth, Jr. 1997. Evaluation of spray-dried animal plasma and selected menhaden fish meal in transition diets of pigs weaned at 12 to 14 days of age and reared in different production systems. J. Anim. Sci.75:3004-3009.

Campbell, R.G. and A.C. Dunkin. 1983. The effects of energy intake and dietary protein on nitrogen retention, growth performance, body composition and some aspects of energy metabolism of baby pigs. Br. J. Nutr. 49:221.

Cera, K.R., D.C. Mahan, R.F. Cross, G.A. Reinhart, and R.E. Whitmore. 1988. Effect of age, weaning and post-weaning diet on small intestinal growth and jejunal morphology in young swine. J. Anim. Sci. 66:574.

Chung, T.K., and D.H. Baker. 1992a. Ideal amino acid pattern for 10-kilogram pigs. J. Anim. Sci. 70:3102.

Chung, T.K,. and D.H. Baker. 1992b. Maximal portion of the young pig's sulfur amino acid requirement that can be furnished by cystine. J. Anim. Sci. 70:1182.

Chung, T.K., and D.H. Baker 1992c. Methionine requirements of pigs between 5 and 20 kilograms body weight. J. Anim. Sci. 70:1857.

Coat, M.E., R. Fuller, G.F. Harrison, M. Lev, and S.F. Suffolk. 1963. Brit J Nutr. 17:141-150.

Coffey, R.D. and G.L. Cromwell. 1994. The effects of dried skim milk and spray-dried porcine plasma in diets with or without antimicrobial agents for weanling pigs. J. Anim. Sci. 72(Suppl. 1):635(Abstr.).

Coffey, R.D. and G.L. Cromwell. 1994b. Spray-dried porcine plasma in diets for early-weaned pigs housed either in an experimental or conventional nursery setting. J. Anim. Sci. 72(Suppl. 2):134.

Coffey, R.D., and G.L. Cromwell. 1995. The impact of environment and antimicrobial agents on the growth response of early-weaned pigs to spray-dried porcine plasma. J. Anim. Sci. 73:2532-2539.

Conner, J.F. 1990. Modified medicated early weaning . Pro. Am. Assoc. Swine Pract. 333.

Cox, E. And A. Houvenaghel. 1993. Comparison of the in vitro adhesion of K88, K99, F41 and P987 positive *Escherichia coli* to intestinal villi of 4- to- week old pigs. Vet Microbil. 34:7.

Curtis, J., and F.J. Bourne. 1973. Half-lives of immunoglobulin IgG, IgA and IgM in the serum of new born pigs. Immunology 24:147.

Dietz, G.N., C.V. Maxwell, and D.S. Buchanan. 1988. Effect of protein source on performance of early weaned pigs. J. Anim. Sci. 66(Suppl. 1):314 (Abstr.).

Dritz, S.S., J.L. Nelssen, R.D. Goodband, M.D. Tokach, and M.M. Chengappa. 1994. Application of segregated early weaning technology in the commercial swine industry. The Compendium 677.

Dritz, S.S., K.Q. Owen, R.D. Goodband, J.L. Nelssen, M.D. Tokach, M.M. Chengappa, and F. Belcha. 1996. Influence of lipopolysaccharide-induced immune challenge and diet complexity on growth performance and acute-phase protein production in segregated early-weaned pigs. J. Anim. Sci. 74:1620.

Ducluzeau, R. 1985. Implantation and development of the gut flora in the newborn piglet. Pig News and Information 6:415.

Edmonds, M.S., B.E. Aretson, W.A. Nipper, and D.L. Froe. 1997. Segregated early weaning: effect of raising pigs on-site and off-site with and without vaccinations on performance and economics. J. Anim. Sci.

Efird, R.C., W.D. Armstrong, and D.L. Herman. 1982. The development of digestive capacity in young pigs: effects of age and weaning system. J. Anim. Sci. 55:1380.

Efird, R.C., W.D. Armstrong and D.L. Herman. 1982b. The development of digestive capacity in young pigs: effects of weaning regimen and dietary treatment. J. Anim. Sci. 55:1370.

Ekkel, E.D., C.E.A. van Doorn, M.J.C. Hessing, and M.J.M. Tielen. 1995. The specific-stress-free housing system has positive effects on productivity, health, and welfare of pigs. J. Anim. Sci. 73:1544.

Ermer, P.M., P.S. Miller, A.J. Lewis, and M.A. Giesemann. 1992. The preference of weanling pigs for diets containing either dried skim milk or spray-dried porcine plasma. J. Anim. Sci. 70(Suppl.1):60 (Abstr.).

Ermer, P.M., P.S. Miller, and A.J. Lewis. 1994. Diet preference and meal patterns of weanling pigs offered diets containing either spray-dried porcine plasma or dried skim milk. J. Anim. Sci. 72:1548.

Friesen, K.G., R.D. Goodband, J.L. Nelssen, F. Blecha, D.N. Reddy, P.G. Redy, and B.T.Richert. 1991. The effect of pre-weaning exposure to soybean meal on subsequent post-weaning growth performance in the early-weaned pig. Kansas State Univ. Swine Res. Rep.,p 30.

Gatnau, R., P.S. Paul, and D.R. Zimmerman. 1989. Spray dried porcine plasma as a source of immunoglobulin for newborn piglets. J. Anim. Sci. 67(Suppl. 1):599 (Abstr.).

Gatnau, R. And D.R. Zimmerman. 1990. Spray dried porcine plasma (SDPP) as a source of protein for weanling pigs. J. Anim. Sci. 68(Suppl.1):374 (Abstr.).

Gatnau, R. And D.R. Zimmerman. 1990. Evaluation of different sources of protein for weanling pigs. Iowa State Univ. Swine Res. Rep.,p.14.

Gatnau, R., D.R. Zimmerman, T. Diaz, and J. Johns. 1991. Determination of optimum levels of spray dried porcine plasma (SDPP) in diets for weanling pigs. J. Anim. Sci. 69(Suppl.1):433 (Abstr.).

Gatnau, R., and D.R. Zimmerman. 1992. Determination of optimum levels of inclusion of spray-dried porcine plasma (SDPP) in diets for weanling pigs fed in practical conditions. J. Anim. Sci. 70 (Suppl. 1):60 (Abstr.).

Geurin, H.B., G.A. Kesel, W.T. Black, T.B. Hatfield, and C.N. Daniels. 1988. Effect of isolate soy protein and whey on replacing dried skim milk in a prestarter for weaned baby pigs. J. Anim. Sci. 66(Suppl. 1):320 (Abstr.).

Giesting, D.W., R.A. Easter and B.A. Roe. 1985. A comparison of protein and carbohydrate sources of milk and plant origin for starter pigs. J. Anim. Sci. 61(Suppl. 1):299 (Abstr.).

Giesting, D.W., K.W. Kelly and R.A. Easter. 1986. Evaluation of early exposure to soy protein on pre and post-weaning performance and immunological characteristics of young pigs. J. Anim. Sci. 63(Suppl. 1):278 (Abstr.).

Gill, J.L. 1987. Design and analysis of experiments in the animal and medical sciences. Vol. 1. Iowa State University Press, Ames Iowa.

Graham, P.L., D.C. Mahan, and R.G. Shields, Jr. 1981. Effect of starter diet and length of feeding regimen on performance and digestive enzyme activity of 2-week old weaned pigs. J. Anim. Sci. 53:299.

Harris, D.L. 1988. Alternative approaches to eliminating endemic diseases and improving performances of pigs. Vet. Rec. 123:422.

Hansen, J.A., J.L. Nelssen, and R.D. Goodband. 1991. Evaluation of plasma proteins and meat extract as replacement protein sources for dried skim milk in swine starter diets. J. Anim. Sci. 69 (Suppl. 1):439 (Abstr.).

Hansen, D.L., J.L. Nelssen, R.D. Goodband, and T.L. Weeden. 1993. Evaluation of animal protein supplements in diets of early-weaned pigs. J. Anim. Sci. 71:1853.

Haye, S.N., and E.T. Kornegay. 1979. Immunoglobulin G, A, and M and antibody responses in sow-reared and artificially-reared pigs. J. Anim. Sci. 48:1116.

Jensen, M.S., S.K. Jensen, and K. Jakobsen. 1997. Development of digestive enzymes in pigs with emphasis on lipolytic activity in the stomach and pancreas. J. Anim. Sci. 75:437-445.

Johnson, L.J., J.E. Pettigrew and J.W. Rust. 1991. Response of maternal-line sows to dietary protein concentration during lactation. J. Anim. Sci. 69 (Suppl.1):118 (Abstr.).

Jones, D.B., J.D. Hancock, P.G. Reddy, R.D. Klemm, and F. Belcha. 1990. Effects of replacing dried skim milk with soy products on function and morphology of the small intestine in nursery pigs. Kansas State Univ. Swine Res. Rep.,p.41.

Kats, L.J., J.L. Nelssen, M.D. Tokach, R.D. Goodband, J.A. Hansen, and J.L. Laurin. 1994. The effect of spray-dried porcine plasma on growth performance in the early-weaned pig. J. Anim. Sci. 72:2075.

Katouli, M., A. Lund, P. Wallgren, I. Kuhn, O. Soderlind, and R. Mollby. 1995. Phenotypic characterization of intestinal *Escherichia coli* of pigs during suckling, post-weaning and fattening periods. Appl. Environ. Microbiol. 61:778-783.

Kelly, K.W., R.G. Greenfield, J.F. Everman, S.M. Parish, and L.E. Perryman. 1982. Delayed-type hypersensitivity, contact sensitivity, and phytohemagglutinin skin-test responses of heat and cold-stress calves. Am. J. Vet. Res. 43:775.

Kenworthy, R., and W.E. Crabb. 1963. The intestinal flora of young pigs with reference to early weaning and *Escherichia coli* scours. J. of Comp. Pathol. 73:215.

Kjeldsen, N.J., V. Danielsen, A. Just, H.E. Nielsen and B.O. Eggum. 1983. Inclusion of fish meal manufactured from fish with different degrees of freshness in diets for early weaned pigs. Natl. Inst. Anim. Sci., Copenhagen Newsletter no. 449.

Klasing, K.C. 1988. Nutritional aspects of leukocytic cytokines. J. Nutr. 118:1436-1446.

Klobasa, A.J., E. Werhahn and J.E. Butler. 1987. Composition of sow milk during lactation. J. Anim. Sci. 64:1458.

Kuby, J. 1992. Immunology. W.H. Freeman and Company, New York.

Li, D.R., J.L. Nelssen, P.G. Reddy, F. Blecha, J.D. Hancock, G.L. Atlee, R.D. Goodband, and R.D. Klemm. 1990. Hypersensitivity to soybean meal in early weaned pigs. J. Anim. Sci. 68:1790.

Lindemann, M.D., S.G. Cornelius, S.M. El Kandelgy, R.L. Moser, and J.E. Pettigrew. 1986. Effect of age, weaning and diet on digestive enzyme levels in the piglet. J. Anim. Sci. 62:1298.

Mahan, D.C. 1992. Efficacy of Dried Whey and its lactalbumin and lactose componets at two dietary lysine levels on post-weaning pig performance and nitrogen balance. J. Anim. Sci. 70:2182.

Mahan, D.C. 1993. Evaluating two sources of dried whey and the effects of replacing the corn and dried whey component with corn gluten meal and lactose in the diets of weanling swine. J. Anim. Sci. 71:2860.

Makkink, C.A., .P.J.M. Berntsen, B.M.L.op den Kamp, B. Kemp and M.W.A. Verstegen. 1994. Gastric protein breakdown and pancreatic enzyme activities in response to two different dietary protein sources in newly weaned pigs. J. Anim. Sci. 72:2843.

Mathew, A.G., A.L. Sutton, A.B. Scheidt, J.A. Patterson, and D.T. Kelly. 1990. Nutritional factors which influence enteric bacterial populations and performance of the weanling pig. J. Anim. Sci. 68(Suppl. 1): 353(Abstr.).

Mathew, A.G., A.L. Sutton, A.B. Scheidt, J.A. Patterson, D.T. Kelly, and K.A. Meyerholtz. 1993. Effect of galactan on selected microbial populations and pH and volatile fatty acids in the ileum of the weanling pig. J. Anim. Sci. 71:1503.

Mathew, A.G., W.G. Upchurch, and S.E. Chattin. 1998. Incidence of antibiotic resistance in fecal *Escherichia coli* isolated from commercial swine farms. J. Anim. Sci. 76:429-434.

McMurtry, M.R., E.L. Stephas, M.A. Fowler, R.M. DeGregorio, and B.L. Miller. 1994. Effects of immunoglobulin-containing pig milk replacer fed to seven and ten day old piglets. J. Anim. Sci. 72(Suppl. 1):99 (Abstr.).

Miller, B.L., R.M. DeGregorio, J.J. Thomas. 1990. Effect of immunoglobulin-containing milk replacer feeding on post-weaning pig performance. J. Anim. Sci. 68(Suppl.1):309(Abstr.).

Nagy, B., T.A. Casey, and H.W. Moon. 1990. Phenotype and genotype of Escherichia coli isolated from pigs with post-weaning diarrhoea in Hungary. J. Clin. Microbiol. 28:651.

Newby,T.J., B. Miller, C.R. Stokes, D. Hampson and F.J. Bourne. 1984. Local hypersensitivity responses to dietary antigens in early weaned pigs. In: Recent Advances in Animal Nutrition, p.49.

Newton, E.A., A.J. Lewis, P.S. Miller, and C.K. Wolerton. 1993. Effects of soy protein and carbohydrate source on performance of weanling pigs. J. Anim. Sci. 71(Suppl. 1):349 (Abstr.).

NRC. 1998. Nutrient Requirements of Swine (10th Ed.) National Academy Press, Washington DC.

Owen, K.Q., J.L. Nelssen, R.D. Goodband, M.D. Tokach, L.J. Kats, and K.G. Friesen. 1995a. Added dietary methionine in starter pig diets containing spray-dried blood products. J. Anim. Sci. 73:2647.

Owen, K.Q., R.D. Godband, J.L. Nelssen, M.D. Tokach, and S.S. Dritz. 1995b. The effect of dietary methionine and its relationship to lysine on growth performance of the segregated early-weaned pig. J. Anim. Sci. 73:3666.

Owsley, W.F., D.E. Orr, Jr., and L.F. Tribble. 1986. Effects of age and diet on the development of the pancreas and the synthesis and secretion of pancreatic enzymes in the young pig. J. Anim. Sci. 63:497.

Pekas, J.C., V.W. Hays, and A.M. Thompson. 1964. Exclusion of the exocrine pancreatic secretion: effect on digestibility of soybean and milk protein by baby pigs of various ages. J. Nutr. 82:277.

Pettigrew, J.E. et al. 1977. J. Anim. Sci. 45:261. Sellwood, R., R.A. Gibbons, G.W. Jones, and J.M. Rutters. 1975. Adhesion of enterpathogenic *Escherichia coli* to pig intestinal brush borders: the existence of two pig phenotypes. J. Med. Microbiol. 8:405.

SAS Institute. 1985. SAS User's Guide: Basics. 5th Edition. Cary, NC.

Shields, Jr., R.G., K.E. Ekstrom, and D.C. Mahan. 1980. Effect of weaning age and feeding method on digestive enzyme development in swine from birth to ten weeks. J. Anim. Sci. 50:257.

Sohn, K.S., C.V. Maxwell and D.S. Buchanan. 1991. Spray-dried porcine plasma as a protein source. Oklahoma Agr. Exp. Station MP-134:342.

Sohn, K.S., C.V. Maxwell, L.L. Southern, and D.S. Buchana. 1994. Improved soybean protein sources for early-weaned pigs: II. effects on ileal amino acid digestibility. J. Anim. Sci. 72:631.

Spurlock, M.E., G.R. Frank, S.G. Cornelius, R.P. Chapple, and G.M. Willis. 1997. Environment, disease impact on performance reviewed. Feedstuff 69(44):13-19.

Stoner, G.R., J.L. Nelssen and R.H. Hines. 1988. Replacing dried skim milk with selected menhaden fish meal in a high density diet. Kansas State Univ. Swine Res. Rep.,p.57.

Stoner, G.R., G.L. Allee, J.L. Nelssen, M.E. Johnston and R.D. Goodband. 1990. Effect of select menhaden fish meal in starter diets for pigs. J. Anim. Sci. 68:2729.

Tokach, M.D., J.L. Nelssen, and G.L. Allee. 1989. Effect of protein and or carbohydrate fractions of dried whey on performance and nutrient digestibility of early weaned pigs. J. Anim. Sci. 67:1307.

Veum, T.L., and J.P. Mateo. 1986. Swine in biomedical research. Vol. 2. Pp. 1125-1135. New York: Plenum Press.

Wilson, R.A., and D.H. Francis. 1986. Fimbriae and entertoxins associated with *Escherichia coli* serogroups isolated from piglets with colibacillosis. Am. J. Vet. Res.,47:213.

Williams, N.H., T.S. Stahly, and D.R. Zimmerman. 1995. Influence of immune system activation on the digestibility, retention, and excretion of dietary protein (nitrogen) in growing pigs. Iowa State University Swine Research Report AS-633:19.

Zarmora, R.G., and T.L. Veum. 1978. Nutr. Rep. Int. 18:495.