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Methods for artificially rearing colostrum-deprived and early weaned pigs with subsequent survival, performance and serum profile

Jerry A. McClain

To the Graduate Council:

I am submitting herewith a thesis written by Jerry A. McClain entitled "Methods for artificially rearing colostrum-deprived and early weaned pigs with subsequent survival, performance and serum profile." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

John P. Hitchcock, Major Professor

We have read this thesis and recommend its acceptance:

F.B. Masincupp, H.G. Kattesh

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Frank B Masincupp

Henry G Kattesh

Accepted for the Council:

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Date May 18, 1988

METHODS FOR ARTIFICIALLY REARING COLOSTRUM-DEPRIVED AND EARLY WEANED PIGS WITH SUBSEQUENT SURVIVAL, PERFORMANCE AND SERUM PROFILE

A Thesis

Presnted for the

Master of Science

Degree

The University of Tennessee, Knoxville

Jerry A. McClain

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ABSTRACT

A preliminary study (Study 1) utilizing 145 orphaned pigs was conducted to evaluate the feasibility of artificially rearing pigs which were colostrum-deprived or allowed to nurse 4, 48 or 72 hours. Pigs were derived by cesarean section (118) or natural birth (27) on days 112 (36), 113 (57) or 114 (52) of gestation. Survival of colostrum-deprived pigs and pigs which were allowed to nurse for 4, 48 or 72 hours was 16 and 83.3, 94 and 94%, respectively. Pigs consumed approximately 9.8 lbs. of dry milk replacer between birth and 21 days of age. Daily gains of all pigs averaged .31 lb to 21 days and .55 lb to 42 days.

Two additional studies were conducted to assess the value of feeding lyophylized porcine serum and bovine colostrum to orphaned pigs reared in a "practical" environment. Each study included 5 treatments, among which were positive (sow-reared) and negative (milk replacer only) controls. Study 2 pigs were fed lyophylized serum combined with milk replacer for 36 hours, 5 days or allowed to nurse for 36 hours (treatments 1,2 and 3, respectively). Study 3 pigs were intermittently dosed with a total of 160 ml of reconstituted lyophylized serum, colostrum or previously frozen colostrum (treatments 1,2 and 3, respectively).

Eight (Study 2) and 5 (Study 3) newborn pigs averaging 3.1 lbs. were assigned to each treatment. Blood samples were obtained at birth, 36 hours postpartum and weekly thereafter to obtain hematological data. In Study 2, survival of nursed pigs (36h vs. sow-reared) did not differ (87.5%). Both nursed groups had improved ($P < .05$) survival as compared to pigs on treatments 1 and 2 (37.5 and 37.5%), which was better ($P < .05$) than that of negative control pigs (12.5%). In Study 3, survival of sow-reared pigs (100%) also was greater than that of pigs in other groups. Survival rates of pigs on treatments 1,2 and 3 were (40, 60 and 40%, respectively) and was an advantage over survival of negative control pigs (20%). In Study 3 total globulin and serum protein levels were higher ($P < .001$) at 36 hours in nursed pigs (4.5 and 7.2 g/dl, respectively) than in treated pigs (1.9 and 3.6 g/dl, respectively). Treated pigs had higher ($p < .001$) globulin and protein levels than did negative control pigs (0.83 and 3.0 g/dl, respectively). There were no significant differences in weight gains for pigs on any of the treatments. Feed:gain ratios varied among treatments but were not significantly different and averaged 1.1 lb. of dry milk replacer per lb. of gain.

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CHAPTER I

INTRODUCTION

Efforts to devise a suitable method for artificially rearing pigs and concurrently improve sow productivity has been a major focus of some researchers for many years (Leece, 1975,1986; Varley et al., 1986). Theoretically, by weaning pigs at birth or shortly thereafter, three litters per sow per year could be produced. However, for several reasons the sow has yet to be relieved of her rearing duties. In general, the sow is still the most efficient and practical system available for rearing pigs. Furthermore, it has been reported that reproductive performance of early-weaned sows is inconsistent and that productivity is seldom increased (Elliot et al.,1980; Varley and Atkinson, 1985). Yet, there are situations where artificially rearing pigs may be important, or even a necessity. Some examples would be for eradication of sow transmitted diseases, development of specific pathogen-free herds, for nutritional or immunological research, or when there is a shortage of sows due to disease or death. Furthermore, knowledge gained relative to the needs of the artificially reared neonate may lead to practices which would improve the survival of naturally reared pigs as well as neonates of other species.

Two major problems involved in rearing pigs are the lack of circulating immunoglobulins and the limited energy stores at birth (Swiatek et al., 1968; Porter, 1973; Mersmann, 1974; Leece, 1960, 1975). Under ideal conditions both of these deficiencies are readily alleviated by an adequate supply of colostrum from the dam. Any factor which affects the pig's ability to consume colostrum reduces the nutritional status as well as the chance for the acquisition of passive immunity, therefore becoming a serious threat to survival (Leece, 1971; Hendrix et al., 1978; Blecha and Kelley, 1981).

Due to the pig's requirment for colostral antibodies, artificially rearing or weaning pigs very early has depended largely upon the use of isolation units and other special equipment and techniques (Young and Underdahl, 1953; Leece, 1969; Varley et al., 1985). Even utilizing special resources, performance has been variable, and efforts have often been inhibited by high death rates. Diarrhea has often been the major problem (Leece, 1986).

Ingestion of colostrum or a comparable substitute shortly after birth also is necessary to prevent depletion of the pig's limited store of energy. Following birth, liver glycogen is rapidly depleted in order to maintain blood glucose levels (Elliot and

Lodge, 1977). Whole body lipid is very low at birth, generally less than 2%. Therefore, maintenance of glucose and prevention of hypoglycemia is dependent upon the pig's ability to compete successfully with littermates for adequate nutrition from the dam, or by provision of an alternate source of nutrients (Boyd et al.,1981).

The series of studies reported herein deal with a variety of artificial rearing situations. In Study 1, pigs were derived by cesarean section or by natural birth on days 112, 113 or 114 of gestation. The pigs were either deprived of colostrum by necessity or allowed a restricted amount of nursing time. The major objective of Study 1 was to evaluate the feasibility of artificially rearing orphaned pigs using practical methods and inexpensive equipment.

Studies 2 and 3 were designed to investigate the effectiveness of antibodies derived from sources other than sow's colostrum for providing passive immunity to the pig. Sources of antibodies were freeze-dried porcine serum, freeze-dried bovine colostrum and previously frozen bovine colostrum. Survival, performance and hematological parameters were used to evaluate the effectiveness of each source.

CHAPTER II

LITERATURE REVIEW

I. THE NEONATAL PIG

Under natural conditions, the newborn pig depends solely upon its dam for nourishment, protection from disease and various other potentially harmful elements often present in the environment. Initially, with a limited store of energy, newborn pigs depend upon adequate colostrum for energy to prevent the onset of hypoglycemia. Second, colostrum provides the pig with immunoglobulins which provide passive disease protection until the neonate's own immune system develops or becomes active.

The first few days postpartum are very critical for the newborn pig. Exposure to a new and often harsh enviorenment can too often become detrimental. Survival and future performance depend upon a series of events which occur in a very short period. In expectation of high survival rates and good performance, the environment must be controlled to a point which adequately meets the needs of the fragile neonate.

II. ENERGY STORES

The fragility of the newborn pig is due largely to inadequate energy stores. At birth, the pig has as little as 1 to 2% body fat (Manners and McRea, 1963). This small amount of carcass fat limits the amount of lipid available as a possible substrate for oxidation. Also, little insulation against heat loss is provided by the fat or sparse amount of hair which is present at birth. Thus, the pig's ability to maintain body temperature is very limited. Newborn pigs have a high lower critical temperature of about 93° F. It is well known that cold exposure increases heat loss and metabolic rate, which increases the incidence of hypoglycemia, hypothermia and death. According to Kelley (1982), cold exposure also can cause a reduction in colostrum consumption. This would in turn reduce the quantity of immunoglobulins absorbed prior to cessation of pinocytotic activity. Therefore, disease resistance as well as nutritional status would be decreased.

Fortunately, the newborn pig has a relatively large storage of carbohydrate in several tissues. During the first hours of life the pig is dependent upon these reserves (Mersmamm, 1974; Elliot and Lodge, 1977). Although the pig is dependent upon carbohydrate during this early period, the capacity for gluconeogenesis is physiologically immature (Mersmann, 1974; Seerly,1974; Boyd et al., 1981). Blood glucose levels are low at birth and undergo a significant increase shortly after suckling (Bengtsson et al., 1969). At birth, levels generally range between 30 to 60 mg/dl, and after suckling increase and level off at about 95 to 100 mg/dl (Pettigrew et al., 1971).

A broad range of liver and muscle glycogen levels have been reported for the newborn pig. According to Mersmann (1974), muscle glycogen may be as high as 20 mg/g wet weight, while liver levels may be as high as 200 mg/g wet weight. Fetal liver glycogen increases during late gestation and falls rapidly after birth to maintain blood glucose levels. Minimum liver levels are reached at 12 to 18 hours following birth, while skeletal muscles reach their minimum at 36 to 48 hours postpartum (Anderson and Wahlstrom, 1970; Mersmann, 1974; Swiatek et al., 1968). Okai et al., (1978), reported that liver glycogen declines as much as 70% during the first day of life, even in nursing pigs.

There are several challenges threatening the survival of the newborn pig. Glucose homeostasis is one of the major problems and must be remedied during the early stages before an irreversible condition is reached. Starvation during the first week postpartum is a primary cause of baby pig mortality. In a review, England (1986) attributed over 50% of the mortality during the first week of life as being either directly or indirectly caused by starvation.

III. IMMUNOLOGICAL STATUS

Due to the six layered thickness of the sow's placenta separating maternal and fetal circulation, there is virtually no transfer of immunoglobulins to the fetus. Though placental thickness differs among the species, this feature is also true in ruminants and equine. However, it is unlike the human infant, which is born with circulating immunoglobulins (Leece, 1975). In the pig, passive immunity is acquired through colostrum, the first mammary secretions following parturition. Colostrum is rich in immunoglobulins which are rapidly absorbed into the circulatory system following ingestion. Thus, disease resistance during the pig's early life depends upon the prompt ingestion and absorption of adequate colostral antibodies.

The immunoglobulin fraction of colostrum decreases rapidly after normal suckling. Bourne (1969) reported that protein and gamma-globulin fractions of colostral whey decreased 50% after six hours of nursing. The average farrowing time for swine is between 4 to 6 hours; therefore, early born pigs have the opportunity to nurse colostrum which is richer in total protein and gamma-globulin. It also has been reported that pigs which were removed from the sow for 4 hours following birth had a 50% lower gamma-globulin concentration than pigs which were allowed to nurse immediately following birth (Coalson and Leece, 1973).

The nonselective process by which the neonatal pig's gut can absorb intact macromolecules is called pinocytosis (Broughton and Leece, 1970). The macromolecules are absorbed unaltered, supplying the pig's circulation with antibodies which are a reflection of the immunological status of the dam. The duration and explanation for cessation of this process has been the focal point of numerous studies. However, there is general acceptance that for all practical purposes and under normal conditions, pinocytotic activity ceases after approximately 36 hours (Speer et al.,1959; Aspland et al.,1962; Miller et al.,1961; Morgan and Leece, 1964). The length of time preceding closure can be manipulated by starvation. Payne and Marsh (1962) reported that pigs which were starved or received only water, retained the ability to absorb gamma-globulins for 106 hours. Leece et al. (1961) found that pigs maintained by parenteral administration of nutrients were able to maintain pinocytotic activity for at least 5 days. It has been suggested that cessation of pinocytotic activity is a function of the dietary regimen (Leece et al., 1961). It was found that closure was associated with proteins. However, glucose also initiated closure. Therefore, it is not a specific response to colostrum.

IV. IMMUNOLOGICAL MANIPULATION

The major problem associated with rearing colostrum -deprived pigs is the necessity for an effective mechanism for preventing disease in the immunologically deficient neonate. However, pigs can be reared without colostrum if they are delivered in a sterile environment and aseptic conditions are maintained. Unfortunately, this is extremely impractical for most situations (Coalson and Leece, 1973).

Another method of artificially rearing which has been attempted is the transfer of passive immunity by using antibodies from a source other than sow's colostrum. The source of antibodies has often been serum. Immunoglobulins have been precipitated as well as used from whole serum or plasma. Routes of administration have often been orally or by intraperitoneal injection.

Immunoglobulins are often fractionated from serum by saturation with ammonium sulfate (Owen et al.,1961;

Scoot et al., 1972). The use of unfractionated serum was found to be unsatisfactory in the latter study. This basically was due to the large quanity which was needed in order to get the desired immunoglobulin levels.

Varley et al. (1986) administered two sources of immunoglobulins, porcine and equine. The donor horses had been hyperimmunized against common porcine pathogens. Each immunoglobulin source was administered orally as well as by intraperitoneal injection. Each treated pig received 20 ml of serum from the respective treatment source. The pigs were reared to two weeks in an artificial-rearing device which was equipped with automatic, liquid feeders. They were then moved to flat deck cages. An "all in-all out" scheme was utilized. Overall mean survival up to 2 weeks of age was 90%, with an average gain of 143g/day (.32 lb). Survival after 6 weeks was 47%, with an average gain between 2 to 6 weeks of 250g/day (.55 lb.).

Scoot et al. (1972), rearing pigs in a nonisolated environment, reported on 3 experiments using serum derived immunoglobulins as a milk replacer additive. The pooled serum used in these experiments was from porcine blood which had been collected at a slaughter house. Precipitated immunoglobulins as well as unfractionated, lyophylized serum was used in these experiments. In each experiment, pigs were fed immunoglobulins at a rate of

15g/kg of bodyweight on day 1, followed by 2g/Kg of bodyweight on days 2 through 10; or they were fed 10g/kg of bodyweight on day 1, followed by 2g/kg of bodyweight on days 2 through 10. In Experiment 2, the immunoglobulins were fed in the form of unfractionated serum. This was reported as having been impractical due to the large quanity which was needed. Survival rates for treated pigs in the 3 experiments were 83, 83 and 75%, respectively. Conversely, survival rates for negative control pigs were 0, 33 and 25%, respectively. According to the results of these experiments, 10g of immunoglobulins per kg of bodyweight on day 1, followed by 2g/kg of bodyweight was as effective as feeding 15g/Kg on day one. McCallum et al. (1977) conducted a series of trials with the major purpose of determining the oral dosage of gamma-globulin necessary to facilitate survival in a "farm-like" environment. It was concluded that 10g/kg of bodyweight on day 1, followed by 2g/Kg of bodyweight on subsequent days was the minimum amount which was sufficient for providing protection in that particular situation. In these trials, antibodies were derived from porcine and bovine serum which had been collected at a slaughter house. The immunoglobulins were precipitated or fed directly via lyophylized serum. Results related to the use of bovine serum were not as consistent as the ones where porcine serum was administered.

In these trials, (McCallum et al., 1977), bovine colostrum also was used as a substitute for sow's colostrum. Very few incidences of diarrhea and excellent survival rates were reported for pigs which had received this treatment. It is likely that antibodies which are present in colostral sources are more efficient for providing the neonatal pig with passive immunity than those derived from serum. This could be attributed to colostral inhibition of proteolytic degradation and/or a prolonged activity on the surface of the intestine.

V. NUTRITION AND MANAGEMENT

In order to successfully rear pigs weaned at birth or at a few days of age, a suitable substitute for sow's milk is needed. To rear a large number of such pigs, special equipment and techniques also may be desirable. Several automatic feeding devices have been developed (Leece, 1971; Varley et al., 1985). However, such equipment remains costly and still requires a substantial amount of labor. Practical and low cost equipment also is available and has been utilized by some workers. Lambert et al. (1972) artificially reared a total of 1000 pigs which had been weaned at 24 hours of age. The feeding device was a one-gallon bottle inverted over a feeding pan. The device worked similar to a poultry vacuum waterer. Survival rates of the artificially reared pigs were significantly higher ($P < .01$) than those of the sow-reared, control pigs. The milk replacer contained 26% protein and was fed at 15% solids. Protein requirments, as a percent of the diet, decrease with age. Reber et al. (1953) observed that very young pigs performed best when fed a synthetic milk containing 41% crude protein and, that as age increased, lower levels of protein facilitated satisfactory performance. Becker et al. (1954) experimented with pigs between 1 to 4 weeks and reported that 22.4% dietary protein was adequate for pigs in that age group. Decades later, this is still within the accepted range, taking the quality of protein into consideration as well as the quantity (Newport, 1979).

In the very young pig, milk protein appears to be more digestible than protein from other sources (Braude et al.,1970). Unfortunately, the high cost of milk products is a major deterrent to the appeal of its use as a feed source. The use of a dry feed as soon as it becomes feasible can be a factor in the reduction of labor. Braude and Newport (1977) reported on feeding dry, pelleted diets as early as 7 days of age. The experimental animals were weaned to a liquid milk replacer at 2 days of age, and from 7 to 29 days were either kept on the liquid diet, or fed the same diet in a pelleted form. Based on their previous observations, dry matter intake would have been inadequate for proper growth prior to this time. They concluded that a liquid diet was necessary to realize maximum growth potential of pigs weaned at this age. However, this was true due to the lower feed intake of the pigs on the pelleted diet. Feed:gain ratios were very comparable between the two treatment groups. They also suggested that diarrhea, a serious problem in early weaned pigs, can be reduced by caging the pigs individually.

For many years, swine producers have acknowledged a relationship between cold exposure and outbreaks of diarrhea and respiratory complications in pigs. Kelley (1982) attributed the probable cause of these problems as stress-induced changes in the immune system.These changes may allow increased susceptibility to viral and bacterial infections. Thermostability in newborn pigs is poor, but generally is improved substantially by about 72 hours of age. Newborn pigs have a lower critical temperature of approximately 93 degrees F. A room temperature of 70 to 75 degrees F is recommended for farrowing rooms and will allow the newborn pig to reach an area of supplemental heat prior to chilling. The supplementally heated area should be maintained between 85 to 95 degrees F (P I H, 1984).

VI. DIARRHEA

Early weaned and artificially reared pigs are susceptible to a wide variety of diseases, but diarrhea appears to be the major cause of death. The use of antibiotics has not been very effective in controlling the problem (Braude and Newport, 1977). Escherichia coli bacteria are often the major agents responsible but other infections are sometimes involved (Leece and King, 1981; Leece, 1986).

In a recent study utilizing pigs weaned at birth or at one day of age, and orally vaccinated against E. coli, it was found that using an oral vaccine from birth to two weeks of age did not improve survival rate (Varley et al., 1986). Most deaths were caused by acute diarrhea and the organisms responsible were a variety of serotypes of E. coli. Bacteria such as E. coli often cause diarrhea due to their ability to secrete locally active endotoxins. E. coli does not generally kill the intestinal epithelial cells (Kohler, 1972; Moon, 1974), but alters them in such a way that sodium absorption is lessened and sodium loss into the gut lumen is continued. Water also diffuses osmotically along with the sodium, causing dehydration. The glucose driven, Na+ coupled mechanism for amino acid absorption remains functional. Glucose and salt rehydration have been shown to have some therapeutic value. Bywater and Woode (1980) treated pigs with a glucose, glycine,electrolyte solution following experimental infection of the animals with E. coli. Mortality of the treated pigs was 11.6% as compared to 24% in the untreated pigs.

Doyle and Hutchings (1946) observed and described a form of diarrhea caused by transmissible gastroenteritis (TGE). They found that the disease developed promptly following exposure of baby pigs and that the disease was often fatal in the younger animals, but not nearly as severe in mature swine. Haelterman (1972) reported that diarrhea which was caused by TGE virus was due to the infection as well as to the destruction of the epithelial cells. He also suggested that the major route of infection was through ingestion of the virus. A severe loss of epithelial, absorptive surface was noted, which alters fluid and electrolyte balance . Pigs with severe epithelial damage can rapidly dehydrate and die. Fortuanately, swine which have recovered from TGE can transmit passive immunity to suckling offspring through colostrum (Bay et al., 1953). A diarrhea caused by rotavirus was described by Coalson and Leece (1973). Rotavirus resembled TGE, in that it also caused a loss of absorptive surface area. Colostral antibodies to the virus will provide protection for nursing pigs (Bohl et al., 1978). Feeding diets which were made in part with cow's colostrum also has been reported to provide protection from this virus (Leece and King, 1981). Since the virus grows in the pig's gut, circulating antibody does not provide adequate protection.

CHAPTER III

EXPERIMENTAL PROCEDURES

The importance of colostrum as a source of disease protection for the newborn pig is well known throughout the swine industry. The first study reported herein was designed to evaluate the feasibility of rearing orphaned pigs which were either deprived of colostrum or allowed a limited amount of nursing time. Major observations were relative to performance and survival. Studies 2 and 3 were designed to evaluate some alternatives to normal rearing as well as to obtain some preliminary information which may be used later in studying problems which are associated with preweaning mortality.

In Study 2, freeze-dried serum was used as an alternate source of immunoglobulins. In Study 3, two substitutes for sow's colostrum were used, freeze-dried serum and bovine colostrum. Bovine colostrum was used frozen and as a freeze-dried product.

I. ACQUISITION OF ANIMALS

The pigs used in Study 1 were adjunct to other work which was being performed at The University of Tennessee. For the adjunct experiment, all that was required from the pigs was a small sample of blood immediately following birth. Data for Study 1 were collected from a total of 145 pigs. Pigs were either derived by cesarean section or natural birth on day 112, 113 or 114 of gestation. The dams were all first litter gilts of a variety of crosses representing the Landrace, Hampshire and Duroc breeds. Data were collected from an additional 150 pigs which were not directly involved with Study 1, but were from the same source. The gestation ages of these pigs ranged from 90 to 114 days. Hematological and size data for these pigs can be found in Tables 14 and 15 of the appendix.

The pigs used in Studies 2 and 3 were acquired from The University of Tennessee, Blount Farm Swine Research Facility during the October, 1987 and January, 1988 farrowings.

II. GENERAL MANAGEMENT

Immediately following birth, all pigs were identified and weighed. The umbilical cord was dipped in an iodine solution and a blood sample was taken via the anterior vena cava. Following these steps, the pigs were dried and placed in a heated box for the duration of farrowing or surgery. The pigs were then transported to a large enclosed room and placed in a battery of expanded metal cages. A thermostat controlled heat lamp with 4 bulbs was mounted at one end of each cage. The lamps were adjusted to provide an area of selective comfort underneath the heat source. Pieces of carpet were provided as a bedding material and were placed underneath the heat lamps.

In Study 1, two types of feeders were used. One type was a 3 gallon poultry vacuum waterer which was constructed of galvanized metal. The second type of feeder also worked on a vacuum principle, but was a one piece, plastic unit which mounted to the walls of the cages. Each type was designed to facilitate 8 pigs. In Studies 2 and 3 only the one-piece, plastic feeders were used. All feeding equipment was cleaned twice daily, using a powdered household detergent.

Upon completion of immunoglobulin treatment or nursing, pigs were fed a commercial milk replacer designed specifically for baby pigs. Analysis of the milk replacer is listed in Table 1. The milk replacer was reconstituted to 12% solids in water which was approximately 90^{o} farenheit and was fed twice daily. Efforts were made to feed only enough milk replacer to last the pigs until a time close to the next scheduled feeding.

It was often necessary to assist newborn pigs with their first feeding. However, pigs which had previously

TABLE 1. MILK REPLACER AND CREEP FEED ANALYSIS (Study 1)

Milk Replacer	
Crude Protein	28.0% min.
Crude Fat	10.0%
Crude Fiber	0.15%
Vitamin A	20,000 USP units/lb
Vitamin D3	5,000 USP units/lb
Vitamin E	20 USP units/lb
Creep Feed	
Crude Protein	22.0%
Crude Fat	4.0%
Crude Fiber	4.0%

been on a treatment or had nursed rarely needed assistance.

A nipple waterer was present at each end of the cages. The pigs had free access to water as soon as they were ready to consume it.

At 13 days of age, the pigs were offered creep feed in small amounts. Fresh creep feed was added to the feeders daily. A small quantity of dry milk replacer was sprinkled on the creep feed the first two or three feedings to encourage consumption. Table I lists the analysis of the commercial creep feed which was used.

Cages were cleaned prior to the introduction of new animals. The carpet used as a bedding material was replaced when it became badly soiled. The expanded metal cages allowed the urine and most of the fecal material to fall onto the floor which was rinsed twice daily.

III. STUDY 1 TREATMENTS AND PROCEDURES

In Study 1, a total of 118 pigs from 13 litters were derived by cesarean section on days 112, 113, or 114 of gestation. An additional 27 pigs were born by natural birth on days 112, 113, or 114 of gestation. Due to a broad time span and an unusual means by which pigs were made available, it was not possible to evenly distribute pigs to treatments on a littermate basis. The pigs used in this study were deprived of colostrum or allowed 4, 48 or 72 hours of nursing time. The number of pigs, mode of birth, day of gestation and hours of nursing are listed in Table 2.

Following the surgical procedure, pigs which could not be supplied with colostrum were moved directly to the previously described rearing facility. They were immediately offered milk replacer and encouraged to consume it. When it was possible to acquire colostrum for the pigs, they were moved into a stall with the still unconscious sow. The animals which received surgery on days 112 and 113 of gestation invariably had to be injected with oxytocin to make colostrum available to the pigs. The sows and pigs were then closely monitored until the anesthetic wore off and they regained muscle control. Following the allowed nursing interval, these pigs were moved to the rearing facility and treated the same as other pigs. However, with very few exceptions, they did not need encouragement to begin consumption of the milk replacer.

Pigs were weighed and blood sampled at birth and weekly until 6 weeks of age. At each bleeding,5 ml of blood was placed in a heparanized tube. Hematocrit and hemoglobin values were determined immediately. Remaining plasma was stored for glucose analysis.

TABLE 2. DISTRIBUTION OF PIGS (STUDY 1)

Day of Gestation	No. of Pigs	Hours of Nursing	Mode of Birth
112	6	48	natural
112	30	0	cesarean
113	51	0	cesarean
113	6	48	natural
114	11	0	cesarean
114	9	4	natural
114	9	4	cesarean
114	6	48	cesarean
114	17	72	cesarean

IV. STUDY 2 TREATMENTS AND PROCEDURES

A total of 40 pigs were used in Study 2. The pigs were assigned to one of five treatments on a littermate basis. Treatment (1) pigs were dosed with the freeze-dried equivalent of 30 ml of liquid serum shortly after birth. The freeze-dried serum was dissolved in 30 ml of milk replacer and fed by stomach tube. Additional serum was fed by mixing it in the milk replacer being fed in the feeding device. Each pig was offered the freeze-dried equivalent of 100 ml of serum during the first 24 hours. An additional 50 ml equivalent was fed during the following 12 hour period. Treatment (2) pigs were treated the same as Treatment (1) during the first 36 hours. However, serum feeding was continued at the equivalent of 30 ml/pig/day from 36 hours through 5 days of age. Treatment (3) pigs remained on the sows during the first 36 hours. They were then transported to the rearing facility and fed milk replacer. Treatment (4), the positive control group remained on the sows for the duration of the experiment. Treatment (5), a negative control group, was dosed with 30 ml of milk replacer following birth, and received milk replacer throughout the experiment.

All pigs were caught at birth, prior to having an opportunity to nurse. Umbilical cords were dipped as soon as pigs were removed from the farrowing crate. The pigs were then identified, weighed and assigned to a treatment. A second blood sample was taken at 36 hours of age, and subsequent weights and blood samples were taken at 7, 14, and 21 days of age.

At each bleeding, approximately 1 ml of blood was placed in a heparanized tube and used for the determination of hematocrit and hemoglobin values. The remaining 3-4 ml of blood was placed in a serum-separation tube, allowed to clot and then centrifuged. The serum was then poured off and frozen for future determination of glucose, total serum protein and total globulin concentrations.

V. STUDY 3 TREATMENTS AND PROCEDURES

A total of 25 pigs were used in Study 3. Procedures during farrowing and subsequent weighing and bleeding dates were the same as described for Study 2.

Study 3 consisted of five treatments. Treatment (1) pigs were dosed with freeze-dried serum. Treatment (2) pigs were dosed with bovine colostrum. Treatment (3) pigs were dosed with the same colostrum, but in a freeze-dried form. Treatment (4) pigs remained on the sows and treatment (5) pigs were dosed with, and received only milk replacer. Pigs were dosed at approximately 2, 4, 12, 16 and 24 hours of age. All dosing was done in 30 ml units, with the exception of 12 hours, at which time 40 ml was administered. At this dosing many of the pigs had problems tolerating the 40 ml dose. Therefore, dosing was continued using 30 ml units.

VI. PRODUCT PREPARATION

Serum used in the experiments was obtained from 3 market weight hogs which were acquired from The University of Tennessee Swine Reasearch Facility finishing unit. The animals were transported to the university's slaughter facility and taken through the normal slaughter process. The only alteration in the process was that blood was collected in pails rather than allowed to go down the drain. Separation of serum was begun immediately following the bleeding of the last animal. Blood which was not being processed at that moment was stored in a 4 C cooler. The blood was strained through multiple layers of cheese cloth to separate the large clots. The serum was then centrifuged to further reduce the quantity of red cells. Following centrifugation, serum was removed from the containers by vacuum filtration and stored in a cooler in 1000 ml units.

Upon completion of the separation process, approximately a .5 inch layer of serum was poured into several pyrex dishes and the exact amount in each dish was recorded. The serum was then covered and frozen in preparation for the freeze-drying process.

Three containers of serum could be dried during each run which took approximately 14 hours by the particular method being utilized. Initially, the freeze dryer shelf refrigeration temperature was adjusted to-50 C and the condenser temperature to -90 C. When the vacuum reached its minimum level, the fluid and shelf temperatures were adjusted to 80 and 90 C, respectively, for the duration of the process.

Following the drying process, the serum was weighed to determine the percent moisture which had been removed. The dried serum was then placed in previously cleaned and dried glass containers and stored in a dessicator. The serum contained an average of 8% dry matter.

Bovine colostrum for use in Study 3 was obtained from The University of Tennessee dairy farm. All colostrum was from the first milking following calving. The colostrum was initially frozen in approximately .5 gallon units. In preparation for use, it was allowed to thaw in a 4 C cooler overnight. The colostrum was then pooled in an 18 quart container which had been placed in a larger container and surrounded by ice to inhibit any bacterial growth. Part of the colostrum was then refrozen in 30 and 40 ml units for future dosing. The remainder of the colostrum was prepared for freeze-drying in the same manner as was described for the serum.

The first run of product through the freeze-dryer was frozen within the dryer to a temperature of -50 C. The remaining runs were frozen prior to being placed in the dryer. The product was allowed to dry for a total of 24 hours. During the first 8 hour period, the temperature of the product was gradually increased from -50 to 0 C. The temperature was then increased to 25 C and remained at this setting during the second 8 hour period. The last phase of the process was carried out at 40 C. Upon completion of the process, the colostrum was weighed and the amount of moisture removed was calculated. The product was then placed in plastic bags and stored in a dessicator. The colostrum contained an average of 21% dry matter.

VII. PROCEDURES AND METHODS OF ANALYSIS

Hematocrits were determined according to the micromethod described by McGovern et al. (1955). The heparanized blood samples were centrifuged for five minutes at 10,000 r.p.m. in an International "Micro-capillary" centrifuge.

Hemoglobin concentrations were determined using the cyanmethemoglobin method of Crosby et al., (1954). Values were read on a Perkin-Elmer, Fast Scan Spectrophotometer at 540 nm.

Total serum globulin measurements were made using a colorimetric procedure provided by Sigma Chemical Company (No. 560). The procedure is based on the reaction of tryptophan, which is present in high quantities in globulins, with glyoxylic acid in the presence of sulfuric acid and an oxidizing agent. The color response is proportional to the amount of globulin present in the serum. The response was measured at 560 nm on a Perkin-Elmer spectrophotometer.

Total serum protein was measured using a Sigma diagnostic kit (Procedure No. 540). The procedure, which is based on the reaction of copper with serum proteins in an alkaline pH, was devised by Gornall et al., (1949).

Glucose was quantitated using a Sigma diagnostic kit, (Procedure No. 510). The procedure is a modification of the one described by Raabo and Terkildsen, 1960.

VII. STATISTICAL ANALYSIS

The experimental data were analyzed by the Statistical Analysis System (SAS, 1985). Significant differences in total serum protein and total serum globulin concentrations for the different treatments were determined by using orthogonal contrasts. All other reported parameters were tested by analysis of variance. In the case of significant F values, Student-Neumann-Kuels test was used to separate the means.

CHAPTER IV

RESULTS AND DISCUSSION

I. PERFORMANCE OF STUDY 1 PIGS

Throughout this study, numerous observations were made and recorded. However, there were several confounding factors due to the unusual acquisition of the experimental animals, making it extremely difficult to develop an unbiased experimental design. Therefore, limited inferences can be made. Nonetheless, the major purpose of this initial study was to evaluate the feasibility of artifically rearing orphaned pigs in a practical manner and this objective was satisfactorily accomplished.

Total percent survival of pigs which did not receive any colostrum was a low 16% (tables 3 and 4). This is very comparable to other studies using colostrum-deprived pigs (Owen et al., 1961; Scoot et al. , 1972, Varley et al., 1986). Average survivial of all pigs which received 48 or 72 hours of nursing time did not differ and was 94.4% (17/18) and 94.1% (16/17) respectively. The survival rate of pigs which nursed only 4 hours was somewhat lower at 83.3% (15/18). However, these pigs were among the last to enter the

TABLE 3. SURVIVAL AND PERFORMANCE (STUDY 1)

Day of Gest.	No. of Pigs	Hours Nursed	Mode of Delivery	Survival to 6 wks.	ADG 21d	ADG 42d
112	6	48	natural	6	.33	.50
112	30	0	cesarean	3	.29	.59
113	51	0	cesarean	7	.33	.48
113	6	48	natural	5	.35	.60
114	11	0	cesarean	2	.35	.58
114	9	4	natural	9	.31	.62
114	9	4	cesarean	6	.27	.49
114	6	48	cesarean	6	.33	.56
114	17	72	cesarean	16	.27	.57

TABLE 4. SURVIVAL TIME (STUDY 1)

Day Gest.	Hours Nursed	Percent Survival To (days): 0	1	2-3	4-5	6-7	8-14	15-21+
112	0	86.7	83.3	23.3	16.7	16.7	10.0	10.0
113	0	96.0	92.2	58.8	45.1	45.1	17.6	13.7
114	0	100	100	72.7	72.7	45.5	18.2	18.2
112	48	100	100	100	100	100	100	100
113	48	100	100	100	100	100	100	83.3
114	4	100	100	100	83.3	83.3	83.3	83.3
114	48	100	100	100	100	100	100	100
114	72	100	100	100	100	100	94.1	94.1

rearing facility and by this time the pathogen level had doubtlessly increased greatly. These results are very similar to other studies of this nature, and the total survivial would be very acceptable in normal rearing situations where approximately 20% of all pigs die prior to weaning (McCallum et al., 1977; Leece, 1986).

Average weight gain for all pigs to 21 days was .31 lbs/day and incresed to an average of .55 lbs. by the time the pis reached 6 weeks (Table 3). Braude et al. (1970) observed that pigs weaned at two days of age gained weight at a rate of 326g (.72 lbs.) daily between 2 and 28 days of age. Other reports have been more similar to the present study. Varley et al. (1986) reported gains to 2 weeks of age of 140g/day (.31 lbs.). Scoot et al. 1972 artificially reared pigs which gained 140g/day (.31 lb.) up to 21 days. It is likely that differences in weight gains can be attributed to different scales of feeding. In addition, levels of sanitation, health status, genetic potential and a host of other factors would have some influence.

In the present study, pigs were fed so that they would consume all of the milk replacer prior to the next scheduled feeding. The amount being fed was increased according to the apparent appetite of the pigs at the time of feeding, as well as visual observations relative to the time the milk replacer was consumed. If the pigs had been out of milk replacer for a very long period of time, they would be very anxious at the time of feeding. Table 5 lists the average quantity of milk replacer consumed by the pigs at various days up to 21 days of age, at which time they were weaned to a dry feed.

Initially, the primary reason for limiting feed consumption was to attempt to decrease the incidence of diarrhea. Most reports relative to artifically rearing pigs indicated that diarrhea is the major cause of death (Owen et al., 1961; Leece, 1975, 1986; Varley et al., 1986). However, in the present situation, diarrhea could not be attributed as a cause of death in any incidence. Pigs which experienced diarrhea usually did so between 8 to 10 days of age. The diarrhea generally lasted from 24 to 36 hours and the pigs fully recovered.

As can be seen in Table 4, most of the deaths occurred prior to 5 days of age. Only 3 pigs died between 2 and 6 weeks of age. The pigs were moved to the finishing floor at 6 weeks of age. According to the last report, at approximately 90 days, there had been no further deaths. This is unusual for colostrum-deprived pigs which usually continue to experience high death losses beyond 6 weeks of age (Varley, 1986). However, the majority of the pigs which survived until this time had received colostrum, and due to the amount of

TABLE 5. FEEDING OF MILK REPLACER (STUDY 1)

Age (days)	Dry Milk (oz.)	Liquid (oz.)
1	2.10	18
2	3.28	28
3	3.75	32
4-5	5.15	44
6-7	6.56	56
8-9	7.50	64
10-12	9.38	80
13-16	10.00	85
17-18	9.38	80
19-21	7.50	64

exposure, the colostrum-deprived pigs had possibly developed immunocompetence.

Precise cause of deaths was not known, but invariably seemed to fit a general description. Pigs which died at 1 to 2 days of age were generally very weak, thin and dehydrated. The cause of death in these cases could be attributed to refusal to consume the milk replacer, or failure to recover from the anesthetic which was used during surgery. Pigs which died between 3 and 7 days invariably appeared to be retaining a great deal of body fluid. These pigs became extremely immobile, but continued to eat well as long as they could get to the feeder. They often lay for long periods of time with their head resting on the feeder edge, intermittently consuming rather large quantities. The affected pigs were often the larger, stronger pigs in a group. Obvious symptoms included a swollen face, staggering, sitting on the back legs and finally total loss of mobility and death. During the last few hours of life, they were observed lying on their side making continuous kicking motions. Death was usually within two days of the first observed symptoms. Though an exact diagnosis was not made, the symptoms fit the description of Gut Edema (PIH, 1984). Only two pigs were known to show these symptoms and survive. These pigs did not recover to a point of good performance and experienced very small gains during the six week period. None of the pigs which received colostrum experienced such symptoms.

Death rates increased for newborn pigs as the number of pigs already present in the rearing facility increased over time. This was likely due to an increased level of pathogenic organisms within the facility. Others have reported similar situations where the first few litters of colostrum-deprived pigs performed satisfactorily, with subsequent litters experiencing high death rates (Leece and Matrone, 1960; Leece et al., 1961).

The cleaning and feeding for a single group of 8 pigs could be accomplished in approximately 15 minutes. This would include inspection of the pigs for any signs of diarrhea and other illness. This routine was performed twice daily, and the actual amount of time spent on a group decreased as the number of groups increased.

The cost of the commercial milk replacer was $1.20/lb., with an average consumption of 9.8 lbs/pig up to 21 days. The high cost of the milk product makes this type of rearing appealing only in situations of necessity.

The results of this study strongly emphasize the importance of colostrum as a source of passive immunity for the newborn pig. On the otherhand, it has demonstrated that orphaned pigs which have received a limited amount of colostrum, can be reared in a practical manner using inexpensive equipment and simple techniques. An "all in - all out" system of rearing with strict sanitation would likely improve the results.

II. STUDY 2 SURVIVAL AND PERFORMANCE

Study 2 survival and performance data are summarized in Tables 6 and 7. There was no difference in percent survival for pigs which were removed from the sows at 36 hours and those which remained on the sows throughout the experiment. Also, there was no difference in survival between pigs which were dosed for 36 hours or 5 days. Both groups of pigs which received colostrum did survive significantly better (p.<.05) than the two groups which received freeze-dried serum. Survivial of the negative control pigs was significantly less (p.<.05) than both the treated pigs and pigs which received colostrum.

As can be seen in Table 6, pigs which were treated with freeze-dried serum (tmts. 1 and 2) tended to live longer than the negative control pigs (tmt. 5). None of the Treatment (1) pigs died until approximately 60 hours after the termination of the treatment. On the other

TABLE 6. SURVIVAL (Study 2)

Tmt	Percent Survival To Days: 3	5	7	14	21
Serum 1.5d	100	75	50	50	37.5^{b}
Serum 5.0d	87.5	75	62.5	37.5	37.5^{b}
Nurse 1.5d	100	100	100	87.5	87.5^{a}
Sow Reared	100	100	87.5	87.5	87.5^{a}
Milk Repl.	75	12.5	12.5	12.5	12.5^{c}

^{a,b,c}Columns without the same letters in the superscripts indicate differences ($P < .05$).

TABLE 7. PERFORMANCE (Study 2)

Tmt	ADG (lb.) to days[a]: 7	14	21	Feed:Gain (lb.) to days[b]: 7	14	21
Serum 1.5d	.53	.62	.55	.60	.71	.97
Serum 5.0d	.45	.45	.40	.66	1.02	1.21
Nurse 1.5d	.50	.47	.48	___	1.02	1.08
Sow-reared	.39	.41	.44	___	___	___
Milk Repl.	.32	.34	.36	.90	1.26	1.30

[a]Mean ADG did not differ among treatments.
[b]Feed:gain ratios did not differ among treatments.

hand, two of the Treatment (2) pigs died while being fed the freeze-dried serum at the lower level of the equivalent of 30 grams of fluid serum, but not until 60 and 84 hours after the decrease in the level of serum being used. This could indicate a possible advantage to continuation of the treatment at a higher level. Other reports have suggested a greater advantage to continuation of treatment than was experienced in the present study (Owen et al., 1961; Scoot et al., 1972; McCallum et al., 1977). It is recognized that one must be cautious in making comparisons with other studies due to the possible differences in environmental effects, techniques used as well as a host of other factors which could affect the results. Furthermore, in other studies mentioned, immunoglobulins have been precipitated from the serum and the exact amount being used was known. For the sake of practicality, in the present study, the amount of immunoglobulin present in the serum has been estimated based upon the total globulin and total protein contents of the serum.

Performance

The growth rates and feed/gain ratios for the different treatments are given in Table 7, with exception to the sow reared group where only growth rate could be given. Milk replacer and creep feed were fed to all treatment groups at the same rate (Table 8). Milk replacer was mixed in gallon units and distributed according to the number of pigs in a group. Likewise, creep feed was distributed according to the number of pigs in a group. Feed was taken from a container of a known weight. The amount of feed used was recorded prior to refilling the container. Consumption of creep feed was practically negligible prior to weaning from the milk replacer. Transition to a higher consumption of dry feed could likely be hastened by a greater decrease in the amount of milk replacer offered following the introduction of dry feed. The low consumption of creep feed and rapid adjustment to dry feed following the removal of milk replacer suggests that the level of milk replacer being fed was very near an ad-libitum level. However, with a few exceptions during the first few days, all milk replacer was consumed prior to another feeding. Based upon previous experience as well as other reports, limiting consumption has been preferable to ad-lib feeding (Pond et al., 1961; Braude et al., 1970; McCallum et al., 1977).

There were no significant differences in weight gains for any of the treatment groups at any weigh period throughout the study. As can be seen from Table 7, treatment (1) pigs did gain slightly better than the

TABLE 8. MILK REPLACER AND CREEP CONSUMPTION (Study 2)

Age (Days)	Dry Milk (oz.)	Liquid (oz.)	Creep (lb.)
1	2.1	18	-
2	3.2	28	-
3	3.8	32	-
4-5	4.9	42	-
6-7	6.0	51	-
8-9	7.5	64	-
10-12	9.4	80	-
13-16	10.0	85	0.06
17-18	9.4	80	0.05
19-20	7.5	64	0.12
21-28	-	-	1.03

sow reared pigs. The negative control pigs had the least gains at all weigh dates. Only one pig in this group survived until the 21 day weighing. At this time, his growth rate seemed to be improving. The pigs which were allowed to nurse for 36 hours (tmt 3) made a smooth transition from the sow to artificial rearing. The milk replacer was readily consumed and no coaxing was necessary to initiate consumption.

The individual groups of artificially reared pigs all ate at once, similar to pigs nursing a sow. This behavior is possibly a factor in the "post-weaning-lag," particularly if adequate feeder space is not provided.

III. EFFECTS ON SERUM PROFILE

Serum Globulin and Protein Levels.

Measurements of total serum protein and total serum globulin were performed at each bleeding. These parameters were utilized to monitor changes in the serum due to absorption of globulin and other proteins as influenced by the various treatments, as well as the changes which occurred beyond the time of treatment. Each parameter had a high positive correlation with survival. However, globulin level was found to be more highly correlated (.95) with survival than protein (.87).

As can be seen in Table 9 and Figures 1 and 2, by 36 hours of age there was an increase in both globulin and protein levels in pigs on all treatments except the negative control group (tmt 5). Pigs which had nursed during this time showed the greatest increases in both globulin and protein levels. At this time, both globulin and protein levels were significantly higher (P.<.01) in nursed pigs than in pigs which had not nursed. Pigs treated with freeze-dried serum also had significantly higher (P.<.01) globulin and protein levels than the negative control pigs.

Maximum globulin and protein measurements for the nursed pigs were at the 36 hour bleeding. These levels then decreased at all subsequent bleedings through 21 days. Conversely, pigs which did not nurse had continuously increasing levels over the 21 day period.

By 7 days of age, globulin and protein levels of pigs which had nursed for only 36 hours had decreased more, and were lower (P.<.01) than levels in pigs which had remained on the sows. Pigs which had been treated with freeze-dried serum continued to have lower globulin concentrations than the negative control pigs (P.<.05). The total serum protein levels of the serum treated pigs did remain higher (P.<.01) than negative control pigs.

TABLE 9. SURVIVAL AND SERUM PROFILE (Study 2)a,b,c,d

	Serum 1.5 d	Serum 5.0 d	Nurse 1.5 d	Sow Reared	Milk Repl.
Day 0					
globulin g/dl	0.58	0.59	0.55	0.59	0.56
protein g/dl	2.50	2.60	2.44	2.70	2.66
Day 1.5					
globulin g/dlAB	1.08	1.05	4.15	4.32	0.52
protein g/dlAB	2.86	3.14	7.83	8.36	2.14
survival%	100	100	100	100	100
Day 7					
globulon g/dlAD	1.66	1.44	2.50	3.42	1.34
protein g/dlABD	4.32	3.66	5.20	7.46	2.73
survival%	50	62.5	100	87.5	12.5
Day 14					
globulin g/dlA	1.90	1.68	2.52	3.08	1.91
protein g/dlA	4.32	4.05	5.46	6.14	4.23
survival%	50	37.5	87.5	87.5	12.5
Day 21					
globulin g/dlAD	2.19	1.89	2.24	2.73	2.16
protein g/dlA	5.27	4.95	5.09	6.18	5.45
survival%	37.5f	37.5f	87.5e	87.5e	12.5g

aContrast Nursed vs. serum, A differ P< .01.
bContrast Serum vs. milk replacer, B differ P< .01.
cContrast Serum 1.5d vs. serum 5.0d, C differ P< .01.
dContrast Nursed 1.5d vs. Sow-reared, D differ P< .01.
e,f,gSurvival row means without common letters in their superscripts differ (P< .05).

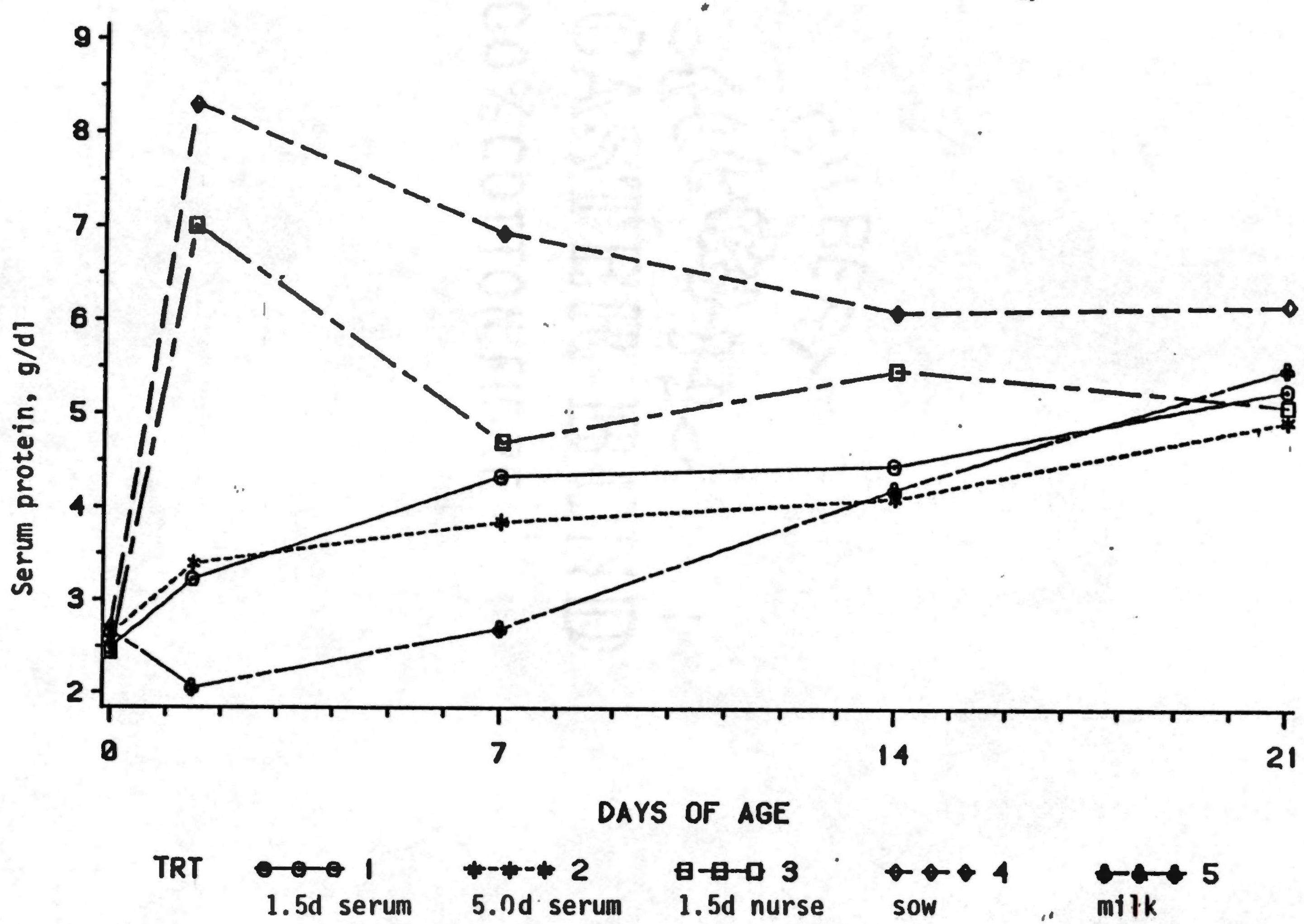

Figure 1. Serum Protein vs Time

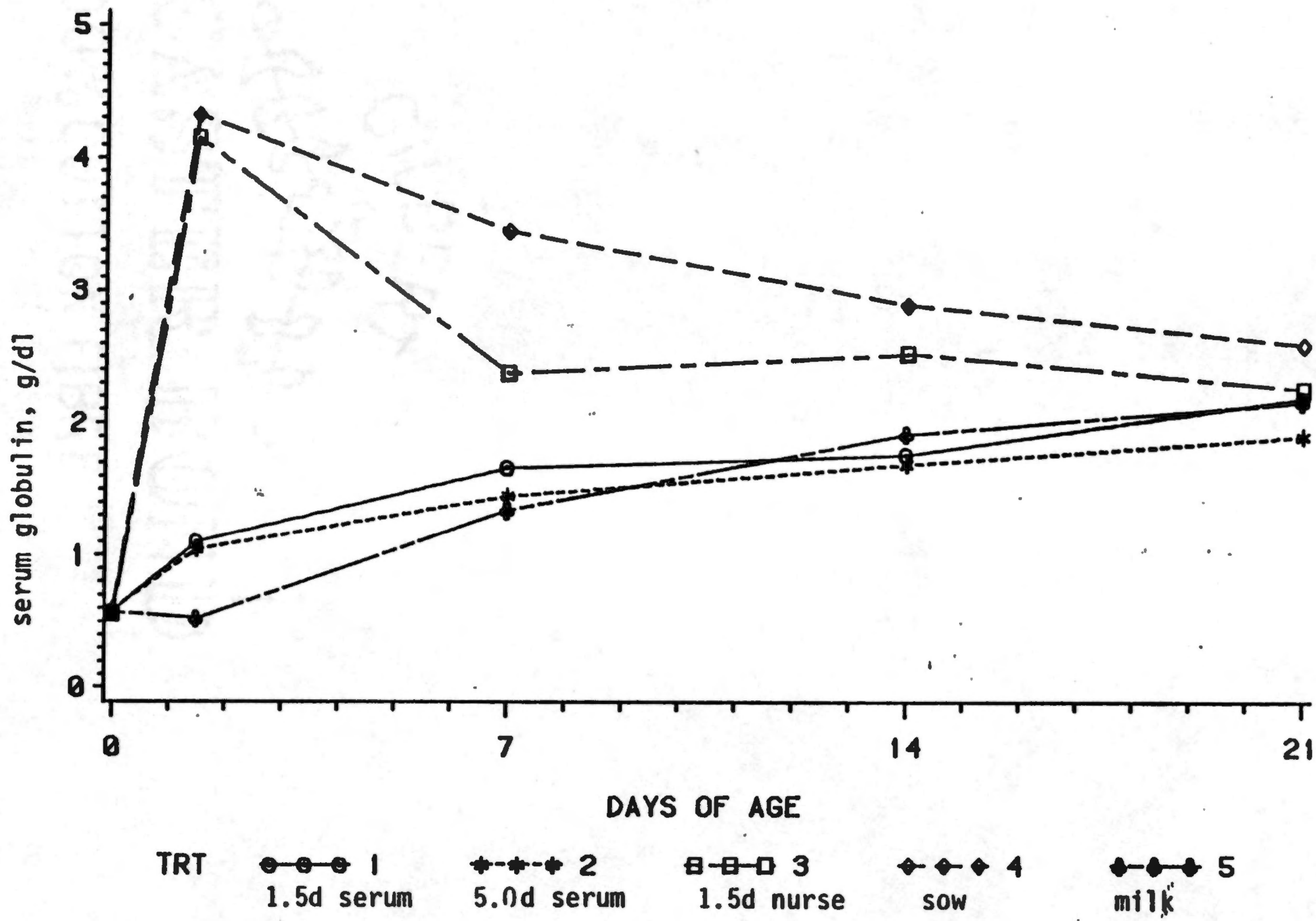

Figure 2. Serum Globulin vs Time

At 14 days of age, globulin and protein levels continued to decrease in the pigs which had remained on the sows. Levels in pigs which had nursed for 36 hours experienced very little change between the 7 and 14 day bleedings, and were no longer significantly lower ($P < .05$) than the sow-reared pigs for either parameter . Pigs which had not nursed continued to have increasing levels, but levels remained significantly lower ($P < .01$) than those of nursed pigs.

Globulin and protein levels continued to change between 14 and 21 days. Pigs which had nursed for 36 hours, again experienced a decrease in levels, and levels were significantly lower ($P < .05$) than those of pigs remaining on the sows. There also was a significant difference in the globulin levels of serum treated pigs and nursed pigs. The serum treated pigs had lower ($P < .05$) globulun levels than the nursed pigs. At this time, there was not a significant difference in protein levels for these groups. Figures 1 and 2 illustrate the changes in globulin and protein levels over the 21 day period.

At birth and subsequent bleedings, total serum protein levels of nursing pigs in the present study were similar to other reports (Machado-Neto et al., 1987; Bengtsson, 1981; Miller et al., 1961). The protein levels reached a maximum near the 36 hour bleeding.

This level diminished continually during the 21 day period.

Total globulin levels were lower at birth in the present study than those reported in the above studies mentioned. However, at subsequent bleedings globulin measurements for the nursed pigs were very comparable to other studies and followed similar patterns.

The response to dosing in this study was not as great as other reports. Owen et al., (1961), reported an average increase in total protein from 1.70g/dl at birth to 4.66g/dl at 2 days of age when pigs were orally dosed with 20 g of immunoglobulins. The method of dosing used in the present study was not as effective as would have been desired. The initial dosing of 30 ml was accomplished by stomach tubing the pigs. The remainder of the serum was mixed in the milk replacer and was by voluntary consumption. Even though practically all of the milk replacer was consumed, it is possible, though not obvious, that a portion of the freeze-dried serum settled out of the mixture.

The literature contains very little information on the use of freeze-dried serum as an alternate source of providing passive immunity to the newborn pig, and there are many questions left to be answered regarding its use. The product used in this study yielded an average 8 percent dry matter when freeze-dried. This can be reconstituted in a concentrated form with which the pigs can be substantially doesd without overfilling the stomach. However, other problems may exist relative to proteolytic degradation of the product or simply a lack of absorption and possible lessened beneficial activity. The presence of a trypsin inhibitor in combination with the product would possibly be advantageous, as colostrum is known to have trypsin inhibitor present.

Hematocrit, Hemoglobin and Glucose

Values for hematocrit, hemoglobin concentration and glucose were also determined at each bleeding. Table 10 lists the different values for each treatment. Treatment did not have a significant effect upon any of these variables.

Hematocrit readings at birth were very normal at an average of 34 percent. At the 36 hour bleeding, hematocrits for all pigs had dropped to an average of 23 percent. Each pig was injected with Iron Dextran at 3 days and again at 10 days. By the 14 day bleeding hematocrit values were back to values similar to those at birth. The highest hematocrit measurements were at the 21 day bleeding, where values averaged over 39 percent.

As would be expected, changes in hemoglobin concentrations followed a pattern almost identical to

TABLE 10. HEMATOCRIT, HEMOGLOBIN AND GLUCOSE (Study 2)a

	Serum 1.5 d	Serum 5.0 d	Nurse 1.5 d	Sow Reared	Milk Repl.
Day 0					
Hct %	33.0	33.9	34.2	34.9	33.2
Hb g/dl	11.2	11.1	11.0	11.2	10.9
Glu mg/dl	61.0	66.2	64.7	66.0	66.9
Day 1.5					
Hct %	24.6	21.4	21.9	25.0	23.0
Hb g/dl	8.9	7.8	7.9	8.5	8.4
Glu mg/dl	139.9	118.9	100.2	106.6	107.0
Day 7					
Hct %	22.0	24.3	24.8	27.0	23.0
Hb g/dl	7.7	7.7	7.9	8.8	7.3
Glu mg/dl	104.5	107.2	137.3	124.6	149.0
Day 14					
Hct %	33.7	30.3	29.9	35.1	34.8
Hb g/dl	11.6	10.3	9.6	12.0	11.9
Glu mg/dl	104.6	128.9	139.5	122.4	103.6
Day 21					
Hct %	40.3	40.7	38.2	39.3	39.8
Hb g/dl	13.1	12.6	12.6	12.0	11.9
Glu mg/dl	115.6	100.1	103.8	107.4	95.2

aMeans did not differ among treatments for any parameter ($P > .05$).

the hematocrit pattern. Concentrations at birth averaged 11.0g/dl and decreased to an average 8.3g/dl by 36 hours. The concentrations continued to decrease at 7 days but had leveled off at approximately 13g/dl by 21 days of age.

Glucose values were variable but followed patterns similar to other reports (Morrill, 1952; Pettigrew et al., 1971). At birth, levels were relatively low at an average of 65 mg/dl. As pigs nursed or were given milk replacer, levels quickly increased to an average 115 mg/dl by 36 hours. Levels were more consistent at subsequent bleedings and by 21 days tended to be leveling off at an average near 100 mg/dl. Table 11 lists the average hematocrit, hemoglobin and glucose values for the various times.

IV. SURVIVIAL AND PERFORMANCE (STUDY 3)

Survivial and performance of Study 3 pigs are summarized in Table 12. The differences in ADG among treatments are obviously substantial, but not significantly (P.>.05) different. Due to the low number of pigs and poor survivial, statistical inferences regarding performance could easily become a fallacy. However, certain points regarding survival and performance seem worthy of discussion.

TABLE 11. AVERAGE HEMATOCRIT, HEMOGLOBIN AND GLUCOSE (Study 2)

	Hct %	Hb g/dl	Glucose mg/dl
Day 0	33.9	11.1	64.9
Day 1.5	23.2	8.3	114.5
Day 7	24.9	8.1	123.0
Day 14	32.5	10.9	138.7
Day 21	39.3	12.8	105.8

This experiment was designed with the realization that colostrum-deprived pigs had poor opportunities for survival in a "practical" environment (Coalson and Leece, 1973; Leece, 1986). However, colostrum-deprived pigs were extremely important for evaluating the effectiveness of other treatments relative to initial changes in serum profile and for comparison of resistance to naturally occurring enteric infection.

The present experiment has supported observations made during previous work involving colostrum-deprived pigs. Colostrum-deprived pigs which survived were almost invariably among the first animals to enter the rearing facility. Obviously, the level of pathogenic organisms was low initially, giving the colostrum-deprived pigs the opportunity to consume a substantial quantity of antibiotic containing milk replacer prior to ingestion of potentially harmful bacteria. Conversely, if the colostrum-deprived pigs had not been exposed to significant levels of pathogenic organisms prior to "closure," it would appear that survival chances would be increased in that closure could occur prior to possible ingestion of harmful bacteria.

All of the Study 3 pigs were farrowed and transported to the rearing facility within a period of 4 days. The first litter brought into the facility had severe diarrhea beginning approximately 48 hours following arrival. Each subsequent litter which was brought to the facility was stricken by severe diarrhea, with the interval of time prior to its onset becoming shorter for each group. Diarrhea had started in the last two groups prior to completion of the treatment period which lasted for 24 hours. There is no logical explanation for the unusually rapid spread of the diarrhea. None of the sow-reared pigs experienced the problem. All of the equipment was thoroughly cleaned prior to being used, and the pigs were maintained in a warm environment.

Only one pig, a negative control, representing the first two litters died during the 21 day study. However, the remaining negative control pig which represented this group died at 25 days of age. All of the pigs from the last 3 litters died by 4 days of age, with the exception of one pig which had been treated with freeze-dried colostrum. This pig had experienced severe diarrhea and failed to recover to a point of satisfactory performance and gained only 5.5 lbs. during the 21 day period.

As can be seen from Table 12, other pigs which recovered performed well and had weights comparable to the sow-reared pigs. Previously reported weight gains of artificially reared pigs have been variable, but the

TABLE 12. SURVIVAL AND PERFORMANCE (Study 3)[a]

	Tmt(1) FDS	Tmt(2) FDC	Tmt(3) FC	Tmt(4) Sow	Tmt(5) Milk
Day 0					
wt. lbs.	3.2	2.9	3.3	3.2	3.1
survival%	100	100	100	100	100
Day 7					
wt. lbs.	6.4	5.4	6.9	6.7	5.0
ADG lbs.	0.45	0.39	0.49	0.48	0.26
feed:gain	0.67b	0.74b	0.60b	--	1.1c
survival%	40	60	40	100	40
Day 14					
wt. lbs.	11.2	8.6	10.5	11.0	5.5
ADG lbs.	0.57	0.43	0.51	0.56	0.16
feed:gain	0.77b	1.08b	0.88b	--	2.7c
survival%	40	60	40	100	20
Day 21					
wt. lbs.	14.5	11.4	13.4	15.9	6.3
ADG lbs.	0.54	0.40	0.48	0.59	0.15
feed:gain	0.89b	1.39b	1.03b	--	3.2c
survival%	40c	60c	40c	100b	20d

[a]FDS=freeze-dried serum, FDC=freeze-dried colostrum, FC=frozen colostrum, Sow=sow-reared, Milk=milk replacer.
[bcd]Row means without a common letter in their superscript differ (P< .05).

ones presented here fall well within the normal range (Braude et al., 1970; Varley et al., 1986).

Varley et al., (1985), reported feed (DM): gain ratios which ranged from 0.83 to 1.30 in artifically reared pigs to 14 days of age. The feed: gain ratios obtained in the present study are very similar. A feed: gain ratio averaging approximately 1:1 appears to be "normal" for pigs reared on milk replacer diets (W. R. Walker, personal communication).

The total dry milk replacer consumption averaged 9.4 lbs/pig for the 21 day period, with an additional 0.54 lbs of creep feed being consumed from day thirteen through day twenty one. The daily allowances of milk replacer and creep are almost identical to those listed in Table 8 (Study 2). These allowances are higher than the manufacturer's recommendations which total 6.2 lbs/pig for a 21 day period. The only major deviations from the recommendation occurred during the last week, at which time we did not choose to reduce the quantity nearly as much as was recommended.

V. EFFECTS ON SERUM PROFILE (STUDY 3)

Total serum protein averaged 2.5g/dl at birth. As can be seen in Table 13, there was an increase in total protein for all treatments at 36 hours. Nursed pigs

TABLE 13. SERUM PROFILE (Study 3)[a]

	Tmt(1) FDS	Tmt(2) FDC	Tmt(3) FC	Tmt(4) Sow	Tmt(5) Milk	C[b] 1	2	3	4
Day 0									
glob[c] g/dl	0.71	0.68	0.64	0.68	0.69				
pro[d] g/dl	2.52	2.47	2.39	2.58	2.67				
Day 1.5									
glob g/dl	1.84	1.89	1.99	4.47	0.83			+	+
pro g/dl	3.36	3.62	3.96	7.21	3.10			+	+
Day 7									
glob g/dl	1.84	1.67	1.52	3.70	1.37			+	+
pro g/dl	4.10	3.90	4.32	7.00	3.89			+	+
Day 14									
glob g/dl	1.90	2.02	2.17	2.85	1.63				*
pro g/dl	4.15	3.68	3.91	5.31	4.19				*
Day 21									
glob g/dl	1.94	2.41	2.52	2.80	2.54				
pro g/dl	4.05	4.37	4.69	5.33	4.15				*

[a]FDS=freeze-dried serum, FDC=freeze dried colostrum, FC=frozen colostrum, Sow=sow-reared, Milk=milk replacer.
[b]Significant contrasts
*p< .05
+p< .01
C1 Freeze-dried serum vs. freeze-dried colostrum.
C2 Freeze-dried serum vs. freeze-dried colostrum and frozen colostrum.
C3 Freeze-dried serum, colostrum and frozen colostrum vs. milk replacer.
C4 Freeze-dried serum, colostrum and frozen colostrum vs. sow-reared.
[c]glob=total serum globulin.
[d]pro=total serum protein.

exhibited the greatest increase, and had significantly higher (P.<.001) levels than treated and negative control pigs. There was not a significant difference (P.>.8) between pigs dosed with freeze-dried or frozen colostrum. The freeze-dried colostrum treatment group had slightly higher but not significantly higher (p>.25) protein levels than the serum treated group. When levels from serum treated pigs were contrasted to both colostrum treated groups (2 and 3), the difference was significant (p.<.04), with the colostrum treated groups being higher.

Serum globulin concentrations at birth averaged 0.68 g/dl for all pigs. Nursed pigs had experienced the greatest change in globulin levels by 36 hours of age and the levels were significantly higher (P.<.001) than other treatment groups. Conversely, all treated pigs had higher (P.<.05) globulin levels than the negative control pigs. There were no significant differences among treatments 1, 2 and 3. Total serum protein levels remained significantly higher (P.<.001) at seven days in nursed pigs when compared with the serum levels of treated pigs. Only 1 negative control pig was surviving at 7 days and his serum protein level was very similar to that of the treated pigs.

The differences in total globulin levels among pigs on different treatments had decreased somewhat by 7 days of age. This was mainly due to the substantially decreased levels in the sow-reared pigs. However, sow-reared pigs maintained significantly higher ($P<.001$) globulin levels than treated and negative control pigs. Globulin levels of the treated pigs and the remaining negative control were very similar.The changes in globulin and protein levels are illustrated in Figures 3 and 4.

Protein and globulin levels in sow-reared pigs remained significantly higher (P.<.05) at 14 days of age. However, there was a continued increase in the levels of treated pigs. This trend was continued through the 21 day period.

It is interesting to note the pattern of the globulin levels which are illustrated in Figure 4. Pigs on the treatments which facilitated the greatest increases in globulin levels at 36 hours subsequently experienced the greatest decreases in globulin levels at 7 days. Conversely, treated pigs which had experienced the greatest decrease at this time, showed the most substantial increase prior to 14 days. These results, in addition to the steady increase in the globulin level of the negative control pig as well as the treated pigs in Study 2 (Figure 1), suggest that certain levels of exogenous globulins may inhibit the production of the globulin by the pig's own system. Production of

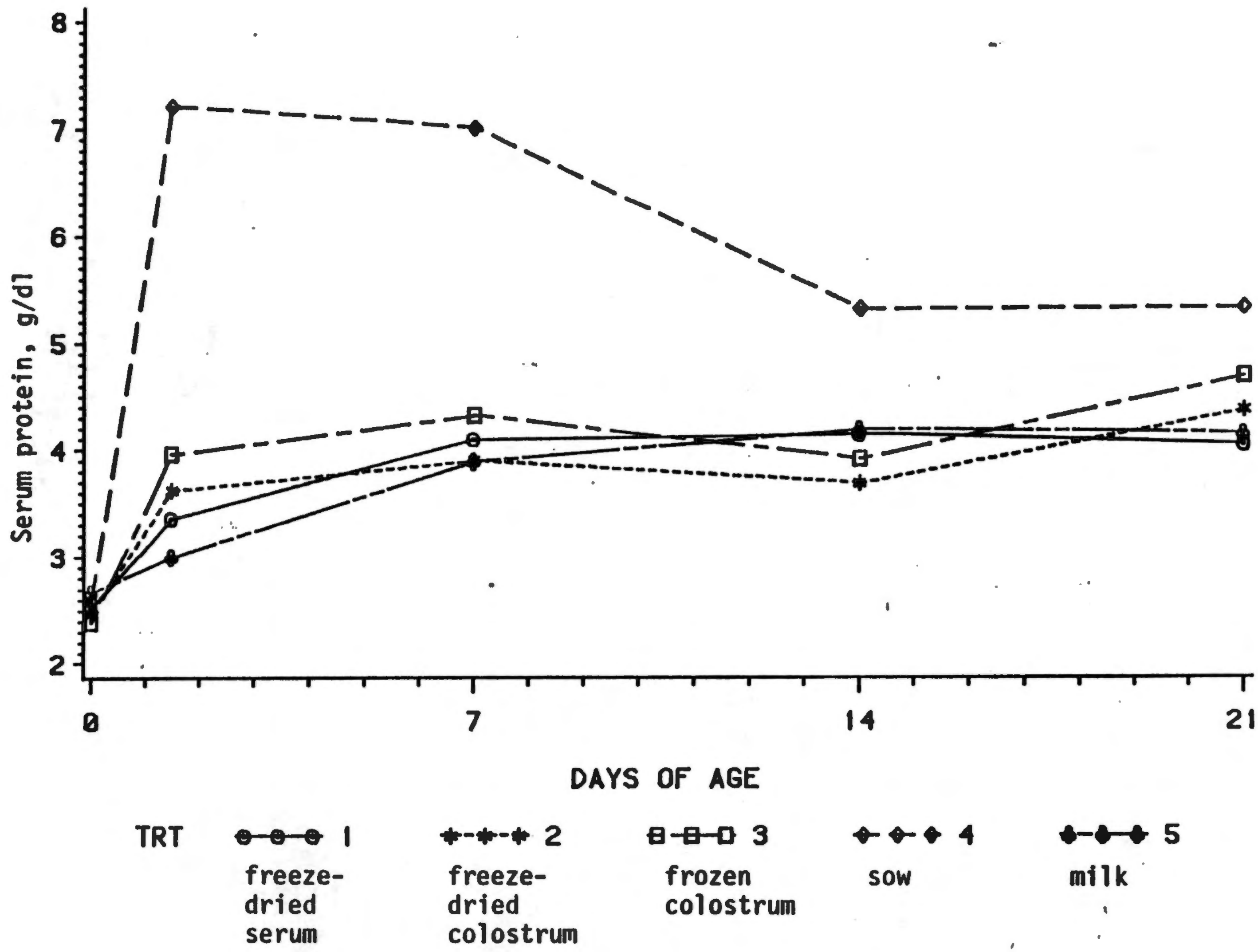

Figure 3. Serum Protein vs Time

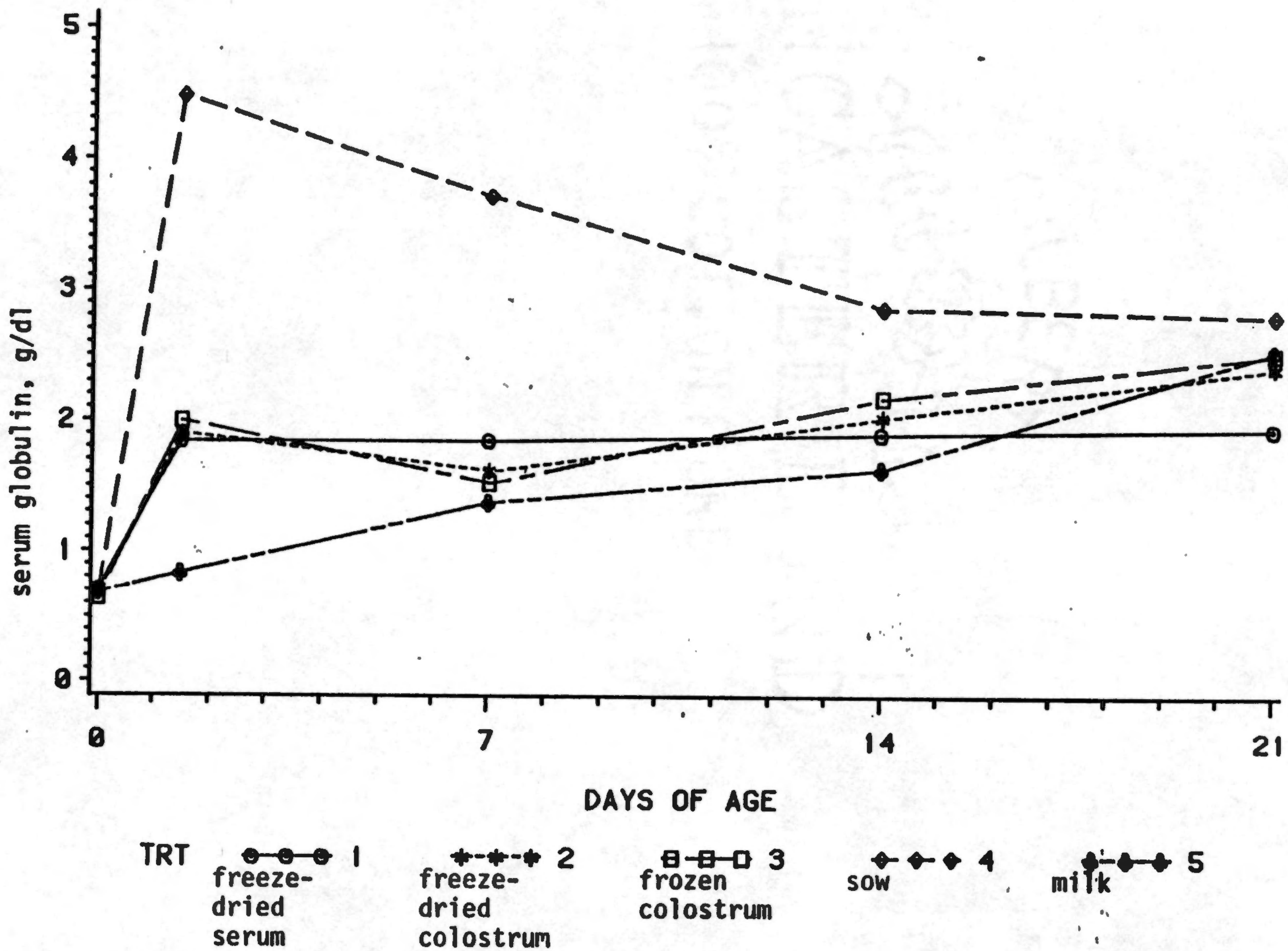

Figure 4. Serum Globulin vs Time

immunoglobulins by pigs which have received colostrum is generally not detectable until approximately 10 to 14 days of age (Wilson, 1974). This is noticeable in the current work where the decrease in globulin levels of sow-reared pigs slowed substantially between 14 and 21 days.

CHAPTER V

SUMMARY

A preliminary study (Study 1) utilizing 145 orphaned pigs was conducted to evaluate the feasibility of artificially rearing pigs which were colostrum-deprived or allowed to nurse 4, 48 or 72 hours. Pigs were derived by cesarean section (118) or natural birth (27) on days 112 (36), 113 (57) or 114 (52) of gestation. Survival of colostrum-deprived pigs and pigs which were allowed to nurse for 4, 48 or 72 hours was 16 and 83.3, 94 and 94%, respectively. Pigs consumed approximately 9.8 lbs. of dry milk replacer between birth and 21 days of age. Daily gains of all pigs averaged .31 lb to 21 days and .55 lb to 42 days.

Two additional studies were conducted to assess the value of feeding lyophylized porcine serum and bovine colostrum to orphaned pigs reared in a "practical" environment. Each study included 5 treatments, among which were positive (sow-reared) and negative (milk replacer only) controls. Study 2 pigs were fed lyophylized serum combined with milk replacer for 36 hours, 5 days or allowed to nurse for 36 hours (treatments 1,2 and 3, respectively). Study 3 pigs were intermittently dosed with a total of 160 ml of reconstituted lyophylized serum, colostrum or previously frozen colostrum (treatments 1,2 and 3, respectively). Eight (Study 2) and 5 (Study 3) newborn pigs averaging 3.1 lbs. were assigned to each treatment. Blood samples were obtained at birth, 36 hours postpartum and weekly thereafter to obtain hematological data. In Study 2, survival of

nursed pigs (36h vs. sow-reared) did not differ (87.5%). Both nursed groups had improved ($P < .05$) survival as compared to pigs on treatments 1 and 2 (37.5 and 37.5%), which was better ($P < .05$) than that of negative control pigs (12.5%). In Study 3, survival of sow-reared pigs (100%) also was greater than that of pigs in other groups. Survival rates of pigs on treatments 1,2 and 3 were (40, 60 and 40%, respectively) and was an advantage over survival of negative control pigs (20%). In Study 3 total globulin and serum protein levels were higher ($P < .001$) at 36 hours

in nursed pigs (4.5 and 7.2 g/dl, respectively) than in treated pigs (1.9 and 3.6 g/dl, respectively). Treated pigs had higher ($p < .001$) globulin and protein levels than did negative control pigs (0.83 and 3.0 g/dl, respectively). There were no significant differences in weight gains for pigs on any of the treatments. Feed: gain ratios varied among treatments but were not significantly different and averaged 1.1 lb. of dry milk replacer per lb. of gain.

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APPENDIX

TABLE 14. LENGTH AND WEIGHT OF PRENATAL PIGS

GEST. AGE (days)	SEX	WEIGHT (lb.)	STD ERROR of MEAN	LENGTH (in.)	STD ERROR of MEAN
90	F	1.5	.37	8.9	.25
90	M	1.6	.23	9.0	.21
100	F	1.8	.28	9.8	.22
100	M	1.9	.15	9.9	.13
105	F	2.4	.19	10.4	.15
105	M	2.4	.19	10.4	.15
110	F	2.6	.19	10.9	.15
110	M	2.7	.26	10.9	.18
111	F	2.8	.68	10.9	.35
111	M	2.7	.37	11.3	.30
112	F	2.7	.19	11.2	.24
112	M	2.7	.22	11.3	.14
113	F	3.2	.31	11.8	.17
113	M	3.4	.52	11.7	.09
114	F	3.1	.29	11.5	.15
114	M	3.3	.26	11.8	.16

TABLE 15. PRENATAL HEMATOCRIT AND HEMOGLOBIN VALUES

Gest. Age (days)	Sex	HCT (%)	SEM	Hb (g/dl)	SEM
90	F	32.8	.65	9.63	.14
90	M	32.5	1.81	9.73	.27
100	F	30.1	1.10	8.95	.13
100	M	30.2	1.06	8.53	.31
105	F	29.8	.79	9.07	.18
105	M	28.6	1.05	8.75	.35
110	F	31.8	.77	9.83	.22
110	M	29.8	1.02	9.46	.26
111	F	29.5	.83	8.80	.27
111	M	27.2	1.12	8.19	.36
112	F	31.5	1.09	9.80	.30
112	M	32.8	1.10	10.02	.28
113	F	30.5	.46	9.00	.16
113	M	29.1	.55	8.70	.17
114	F	32.5	.99	9.50	.31
114	M	32.3	.97	9.71	.36

VITA

Jerry A. McClain was born in Hohenwald, Tennessee on February 23, 1952, the son of Edward and Jennie McClain. He graduated from Lewis County High School in May, 1970. The following July he entered the United States Army. He received his basic training at Fort Campbell, Kentucky, advanced training at Fort Knox, Kentucky and paratrooper training at Fort Benning, Georgia prior to a tour of duty in Vietnam.

Following his discharge from the Army, he worked for the Goodyear Tire and Rubber Company in Union City, Tennessee and attended classes at The University of Tennessee at Martin. He received a Bachelor of Science degree in Education in 1976. Beginning in the fall of 1977 he taught in the McNairy County, Tennessee school system for a period of five years.

In the fall of 1983, he began work on a degree in Animal Science at The University of Tennessee, Knoxville. He received a Bachelor of Science degree in March, 1986 and the Master of Science degree in June. 1988. The author is married to the former Trudi Counce of Counce, Tennessee. They have two daughters, Itaska (Snookey) and Laura.