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Effects of oral versus intra-muscular iron on the preweaning performance and hematology of swine

John Andrew MacGuire

To the Graduate Council:

I am submitting herewith a thesis written by John Andrew MacGuire entitled "Effects of oral versus intra-muscular iron on the preweaning performance and hematology of swine." 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.

Frank B. Masincupp, Major Professor

We have read this thesis and recommend its acceptance:

John P. Hitchcock, George M. Merriman, Sally Prater

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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We have read this thesis and recommend its acceptance:

J.P. Hitchcock

G.M. Merriman

Accepted for the Council:

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Vice Chancellor
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EFFECTS OF ORAL VERSUS INTRAMUSCULAR IRON ON THE PREWEANING PERFORMANCE AND HEMATOLOGY OF SWINE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

John Andrew MacGuire

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ABSTRACT

Sixteen Duroc sows bred to Yorkshire boars and their litters (127 York x Duroc piglets) from the winter farrowing, January, 1976, were used during this study. Hematological and performance data were collected on the piglets and analyzed to determine the effectiveness of the administration of iron, either orally or parenterally. At the beginning of the trial, the sows were randomly allotted to one of four different treatments: (1) control; (2) Crete Koate; (3) iron-dextran, and (4) a combination of treatments (2) and (3). All the piglets remained in confinement throughout the study.

The piglets were bled at birth, seven, 14, 21, and 35 days of age. Blood analyses were performed on all procedures requiring whole blood on the day the blood was drawn, and at a later date for all tests requiring serum. Each piglet was weighed, checked for knee abrasions, and the pen condition was scored at each bleeding and at 56 days of age. The total amount of creep feed consumed per litter was recorded.

The results of this study indicated that there was very little difference between iron-dextran and Crete Koate supplementation in preweaning swine. The hematological parameters and performance traits tested during the study confirmed this fact.

In regard to hematological parameters, there were significant differences ($P<.05$) demonstrated by both types of supplemental iron

for hematocrit, hemoglobin, serum iron, total and unsaturated iron-binding capacity, percent saturation of transferrin, mean corpuscular volume and hemoglobin. There were no significant differences in erythrocyte and leukocyte counts or mean corpuscular hemoglobin concentration.

Of the performance traits tested, those pigs receiving Crete Koate demonstrated a significantly higher ($P<.05$) total creep feed consumption, average weaning weight per pig, and weekly weights throughout the study. However, there was no significant difference in pen condition or knee abrasions. All those pigs receiving iron-dextran were not significantly different from the controls, with regard to any of the performance traits tested.

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CHAPTER I

INTRODUCTION

The incidence of anemia in suckling pigs reared in confinement has for years presented a major problem to swine producers. Since McGowan and Crichton (1923) discovered that this anemic condition was caused by an iron deficiency, much time and effort has been expended in developing improved oral and parenteral methods of administering iron to the suckling pig.

Until approximately twenty years ago, numerous laborsome, often ineffective, methods of preventing anemia were tried. Then, in the middle 1950's, English workers developed injectable iron compounds which effectively prevented anemia and which have been widely accepted by swine producers (Harmon, 1969).

The development of injectable iron generated renewed interest in methods of preventing anemia in pigs. Particular attention has been given to finding new and efficient methods of administering iron orally.

The objective of this study was to determine the effectiveness of two different forms of iron administration in alleviating anemia in suckling swine and in influencing certain other traits. The two forms of iron administration used during the study were oral (Crete Koate) and intramuscular injection (iron-dextran).

In order to accomplish this objective, many hematological parameters and performance traits were measured and analyzed.

CHAPTER II

LITERATURE REVIEW

I. GENERAL INTRODUCTION

Iron is one of the most abundant elements on our planet. It is also a metal of remarkable biologic versatility. Since its presence in the tissue was first demonstrated in 1713 and related to tissue combustion thirty years later, we have constantly added to out knowledge of it (Finch, 1969). Iron, although present in most living organisms in only minute amounts, participates in a number of biologic processes essential to life. It exists not in the free state, but as part of several compounds necessary for oxygen transport and oxidative processes. In man, as well as in many other species of animals, the most common derangement in iron metabolism is iron-deficiency anemia. The seriousness of this disorder has lead to the accumulation of extensive information on the various roles iron fulfills in the body (Bothwell and Finch, 1962). For example, iron is complexed with a variety of protein molecules. The way it combines with each of the various proteins confers a specific function to that protein. If the protein is globin, the resultant molecule is hemoglobin. Other proteins give rise to such important enzymes as catalase, peroxidase, Warburg's respiratory enzyme, and the cytochromes which, by virtue of their iron content, perform the essential function of electron transport in tissue respiration (Finch, 1969).

A study of Granick (1949) stated that in contrast to the traces of iron that are needed to satisfy the enzyme requirements of simple forms like yeast, one may place a relatively enormous iron requirement on the mammal. This high iron requirement is due to the high content of hemoglobin in the mammal. In man, the iron contained in the hemoglobin of the red cells is about three gm. This is about one thousand times more iron than is used for the manufacture of all the heme catalysts of the body combined. In order to obtain an adequate amount of iron for hemoglobin synthesis, mechanisms had to be developed by the vertebrates for accumulating and regulating these biologically high quantities of iron. Swine have not developed an adequate mechanism as such, and consequently, according to Furugouri (1974), the amount of iron accumulated in the pig during fetal development cannot meet the daily iron requirements of a piglet.

Many compounds have been discovered in which iron plays an integral part. Bothwell and Finch (1962) reported that a number of iron-containing compounds other than hemoglobin have been identified, but there is still confusion concerning the functions of some of them. This is especially true of the iron-containing enzymes; however, it is clear that their unique capacity for oxygen and hydrogen ion exchange is of fundamental biologic importance. A few other iron-containing complexes of significant importance include: hemoglobin, which transports oxygen to the cells, transferrin, which carries iron through the plasma, and ferritin, which stores iron in tissues.

Over several centuries the therapeutic use of iron has evolved into one of the best understood and most effective treatments available to man. The basic objectives of treatment are to supply optimal amounts of iron for use by the bone marrow in the production of erythrocytes and at the same time, to avoid toxic reactions from the iron itself (Hebbert, 1950). The therapeutic use of iron was mentioned in Greek mythology in the story of Iphyelus, who was cured of impotence by drinking iron rust dissolved in wine (Wintrobe, 1974). Much of the iron therapy used by ancient physicians had its origin in such sympathetic magic, the sufferer hoping to assume something of the strength of steel by drinking water or wine in which a sword had been rusted. The specific use of iron salts is credited to Sydenham, who, in the early 1700's recommended iron for treatment of chlorosis (a disorder in which iron-deficiency anemia plays a prominent role). Iron deficiency is used to designate a condition in which the total body iron content has been depleted. It comes about either as a late manisfestation of prolonged negative iron balance, or because of failure to meet an increased physiologic need for iron (Wintrobe, 1974).

Nutritional anemia due to a dietary shortage of iron in housed piglets was first recognized by McGowan and Crichton in 1923, and since then efforts at prophylaxis have been concentrated on overcoming the difficulties occasioned by the necessity to repeat iron treatment at fairly frequent intervals (Brownlie, 1955).

Miller (1973) stated that the need for supplemental iron by the nursing pig to prevent anemia continues to be one of the most important facets of confinement rearing of swine. It has been over forty years since Wisconsin researchers recognized that one could prevent anemia in baby pigs by access to the iron in soil. It has been nearly twenty years since British researchers introduced an effective injectable iron preparation. Still, the search goes on for better ways of meeting the iron needs of the nursing pig.

II. THERAPEUTIC USES OF IRON

A great deal of research has been done on the effects of iron in various species of animals since the early 1700's. It is not my intention to cover this vast subject in its entirety, but rather to relate more specifically to pertinent material involved in the effects of different iron treatments, primarily on swine, in recent years.

The effectiveness of single or infrequently repeated doses of oral, as well as parenteral, iron administration in protecting baby pigs against anemia has been open to question for quite some time. Bunge realized in 1889 that milk contained very little iron, and he believed that animals which depended entirely upon it for some time after birth were born with a store in their livers to tide them over the suckling period (McCance and Widdowson, 1950). These conclusions of McCance and Widdowson were based upon species other than swine, and the essential points of their generalizations were: (1) milk is a negligible source of iron, and (2) the liver contains enough iron at birth to supply the needs of the growing animal during suckling. It follows, if the theory is true, that suckling animals should have little, if any, more iron in their bodies at the end of suckling than they had at the beginning, and that unless the store is adequate, a state of physiological anemia is inevitable towards the end of suckling.

Fontès and Thivolle (1925) first showed that this theory required modification by demonstrating that the the total amount of iron in puppies increased considerably during suckling, and they concluded that the source of this iron was the milk. The increase in total body iron, moreover, was so much greater than the amount which the liver could have contributed to the rest of the body that the value of this "store" to the puppy was clearly a relatively small one. Smythe and Miller (1929) drew similar conclusions from a study of the rat. Lintzel, Rechenberger, and Schairer (1944) published an important paper on this subject in which they discussed Bunge's theory in light of the iron metabolism of suckling rats, mice, dogs, cats, pigs, guinea pigs, goats, and humans. They developed the idea that some animals (e.g., cats and humans) are born with a great excess of circulating hemoglobin, and that in these animals, bone rather than liver acts as the store of iron. They considered, however, that some animals (e.g., rats) must absorb iron freely from milk.

Everyone connected with the swine industry recognized that there was a tremendous loss in pig raising due to the large number of deaths which so often occurred during the early growing period (Hart *et al.*, 1930). Data showed that about 35% of the pigs farrowed were lost during the nursing period in the 1920's. Hart went on to say that many factors probably influenced this excessive death rate, but undoubtedly one factor was the large prevalence of anemia in suckling pigs. McGowan and Crichton (1923) were pioneer investigators in this field. These workers noted that anemia was exceedingly prevalent in British pig breeding establishments where the sows were brought into houses, put in pens with concrete floors, and fed a dry ration during the farrowing period. The sows were farrowed normally, but when the pigs were from three to four weeks old, they took on a "stocky" appearance due to oedema of the skin and appeared to be in generally poor health. The blood was extremely watery and pale, the hemoglobin often being as low as 15% of the normal. In the cases which continued to live, the animals became very emaciated, ceased to grow, and lost their appetites.

McGowan and Crichton believed the chief cause of this disease to be an iron deficiency. When the sows were out of doors, they obtained abundant iron from the grass and the soil, but when they were kept indoors, owing to the concrete floors and the nature of the food, the supply of iron decreased. Excellent results were obtained, both in the amelioration of the anemia from which the pigs were already suffering, and in its prevention in the younger pigs when large doses of ferric oxide were fed to the sow. The British workers were in doubt as to whether the beneficial effect noted in the young pigs when the sows were fed ferric oxide was due to a more abundant source of iron in the refuse and feces of the sow, or to an increased iron content of the sow's milk. They suggested that the effect was probably not due to any change in the composition of the milk. Hart *et al.* (1930) later showed that increasing the iron content of the rations fed to cows and goats did not increase the iron content of their respective milks, and they felt this could also be applied to the pig. Doyle *et al.* (1928) observed the same condition reported by McGowan and Crichton in young suckling pigs reared by sows kept indoors. They concluded that the anemia was not influenced by the vitamin supply in the ration, nor by the addition of ferric lactate, but it was markedly affected by some factor in outside conditions--probably a lack of iron. Also, the feeding of considerable amounts of iron and copper to the sow did not delay the development of anemia.

There was some controversy for many years as to whether supplementing the sow's diet with iron helped in the prevention of anemia by increasing the iron content of the milk. The alternative was to provide iron sources which the young piglets could ingest directly. Venn, McCance, and Widdowson (1947) conducted a study of piglet anemia. They showed that the amount of iron found in the pig's liver at birth was totally inadequate for the requirements of the rest of the body during the next three weeks, and the most that such a piglet could expect from its mother's milk in this time was about 23 mg. Therefore, the piglet depends entirely upon the milk of the mother for all its organic requirements in the first three weeks of its life, although it relies upon its surroundings, chiefly the soil, for its iron. In this study and many others since the late 1940's, it became evident that suckling pigs received little iron from the sow's milk, and some other method of supplementation was necessary. Various treatments have been advocated to supplement the iron intake of piglets. These supplements range from placing dirt in the creep feed with or without soaking the earth with a solution of ferrous sulfate, dosing piglets with ferrous sulfate tablets, introducing reduced iron powder into the piglets' mouths, painting a mixture of molasses and ferrous sulfate on the sow's teats, to treating the sows with ferrous sulfate. The latter treatment does not increase the body reserves of the fetus (Hart *et al.*, 1930). Most of the treatments have been found to have some effect, but they are messy and time consuming, and it is impossible to ascertain how much each pig ingests, absorbs, and utilizes. Hart *et al.* (1929), Doyle (1932), and Kernkamp (1935) found that oral treatments of iron and copper salts provided the missing factor in hemoglobin production, thus minimizing the anemic condition. However, most of the oral treatments must be repeated, and providing for ingestion of the correct dosage is often difficult. Zimmerman *et al.* (1959) found similar results, in that the major limitation in using oral supplements was the necessity for repeated applications throughout the suckling period. For this reason, they said field application of iron treatments has seldom been completely satisfactory.

London and Twigg (unpublished data) working in England succeeded in producing an iron-dextran complex designed for intramuscular use in the treatment of hypochromic anemia in man. McDonald *et al.* (1955) decided to see if this iron-dextran complex would be effective in the treatment of pig anemia. They knew young piglets became anemic in their first few weeks of life if an adequate supply of iron was not provided. They thought this deficiency was due to two main factors: the rapid growth of piglets with the concurrent increase in blood volume, and the low amount of iron available from the sow's milk to supply a full complement of hemoglobin to the increased number of red blood cells. They felt this iron-dextran complex would be beneficial to the young pig and their results showed it was absorbed and utilized for hemoglobin regeneration when injected intramuscularly into anemic pigs. Subsequent investigators (Barber *et al.*, 1955; Brownlie, 1955; Kernkamp, 1957; and Martin *et al.*, 1955) indicated that this complex was very useful in preventing and treating baby pig anemia. For this reason, many experiments were conducted in a search for forms of iron adaptable to parenteral administration (Holly, 1951; Horrigan *et al.*, 1950; Sinclair and Duthie, 1950; and Scott and Govan, 1951). The ideal compound would be non-toxic and capable of releasing iron to the hematopoietic system at a rate commensurate with normal hemoglobin formation (Ullrey *et al.*, 1959). Many researchers found the form of iron administered was of critical importance. Barber *et al.* (1955) and Brownlie (1955) found that an intramuscular injection of a suspension of ferric phosphate provided little to no iron for hemoglobin formation and was essentially worthless in the treatment of pig anemia. A study by Harmon *et al* (1969) showed that ferrous carbonate was ineffective as an oral hematinic supporting no higher hemoglobin levels than found in pigs receiving an unsupplemented purified diet.

Once it was established that there were many oral, as well as injectable, methods of administering iron to young swine, a multitude of studies was conducted to determine which methods would provide the best results in arresting anemia. Rydberg *et al.* (1959) and Ullrey *et al.* (1959) reported that pigs injected with iron-dextran maintain higher hemoglobin levels than pigs given oral iron. Maner *et al.* (1959) found similar results and also demonstrated that a second iron shot (100 mg.) produced significantly higher hemoglobin and hematocrit levels than a single injection of 100 mg. or oral treatments. A study by Lidvall and Griffin (1967) utilized three different sources of iron: (1) sod was placed in the pens, (2) a commercial iron supplement pellet was put on the floor of the pens, and (3) the pigs were given injectable iron-dextran (100 mg.) at three and 11 days of age. The results indicated that all three treatments were adequate and provided enough iron to insure good performance at weaning and at market weight.

Harmon (1969) stated that a single iron injection (100 mg. of iron) would provide enough iron to sustain hemoglobin levels until pigs are consuming iron-adequate dry diets. He went on to say that two methods of oral administration worked just as well as intramuscular injections of iron. One method is to mix iron sulfate with the lactation diet (10% sulfate and 90% lactation diet) and distribute about six ounces of the mixture on the floor twice a week. The other oral method consisted of mixing ferric ammonium citrate in with the pigs' drinking water. In a later study, Harmon *et al.* (1974) demonstrated that iron-dextran was effective as a hematinic for the first four weeks of life, whether injected intramuscularly or administered orally.

In summary, there are basically four reasons why anemia rapidly develops in nursing pigs reared in confinement unless they receive supplemental iron. These are: (1) low body storage of iron in the newborn pig, (2) low iron content of sow's colostrum and milk, (3) elimination of contact with soil iron, and (4) the tremendous growth rate of the nursing pig.

The daily seven mg. of absorbed iron requirement of the newborn piglet has been determined to be greater than the one mg. per liter provided by sow's milk (N.R.C., 1968). The result of this finding has been an effort to provide supplemental iron, either orally or by injection. Both routes of administration have been proven satisfactory, depending on the form of iron used, to compensate for the deficiency of iron in sow's milk in the prevention of iron-deficiency anemia in young swine. However, the search goes on to find out which method of iron administration would be the best in alleviating anemia in piglets.

III. IRON METABOLISM

The welfare of the baby pig is closely associated with its iron metabolism. Limited iron stores and low iron intake predispose the animal to the development of anemia. The normal function of certain heme-containing enzymes is also affected by iron deficiency (Ullrey, 1960).

Venn *et al.* (1947) estimated that the body of the pig at birth contains approximately 50 mg. of iron, of which the pig must retain about seven mg. per day to grow at a normal rate without becoming anemic. It is well recognized that the efficiency of utilization of orally administered iron is dependent upon many exogenous factors, as well as the state of iron depletion, and that much more iron must be supplied per os than is necessary for normal metabolic functions. For example, iron absorption is affected by the size of the dose (Granick, 1949; Stewart *et al.*, 1950), the state of iron repletion (McCance and Widdowson, 1937), the presence of phosphates (Hegsted *et al.*, 1949) and reducing substances (Powell, 1944; Thompsett, 1940). At best, absorption efficiency is very low.

The iron compounds of the body may be divided into two groups: The iron porphyrin or heme compounds, and the nonheme-iron compounds. The heme compounds consist primarily of blood hemoglobin (60-70% of the total body iron), myoglobin (3-5%), and heme enzymes (0.1%). Of the nonheme-iron compounds, ferritin is the most significant, accounting for 15% of the total iron in the body. The essential function of the heme compounds when they are associated with particular proteins is to make oxygen available to the cell, while nonheme compounds primarily function as storage forms for iron (Granick, 1949).

According to Wintrobe (1974), incorporation of iron into the protoporphyrin ring is necessary for heme synthesis, and aberrations in iron metabolism affect hemoglobin formation directly and other organs and systems indirectly. Seven to 8% of the alimentary iron is absorbed mainly in the duodenum, with some absorbed in the jejunum. In the stomach, alimentary iron, most of which is in the ferric state, is then reduced to ferrous iron by food substances such as ascorbic acid, cysteine, and sulfhydryl groups of food proteins. Ferrous iron is absorbed by the mucosal cells. Fifty percent of the iron is bound to amino acids and is rapidly released into the plasma, whereas the remaining portion is linked to an intracellular acceptor protein, apoferritin, to form an iron-protein complex called ferritin. Ferritin is stable and represents one of the mechanisms of iron storage in the body. The iron is released from the duodenal mucosa into the plasma, where it circulates as ferric iron and is bound to an iron-binding B_1-globulin called transferrin. This protein is normally only 1/3 saturated with iron. Most of the iron is utilized for hemoglobin synthesis, while small amounts are incorporated into myoglobin and emzymes. Once iron is incorporated into the body, either through normal intestinal absorption or by means of parenteral administration, it is almost totally retained. The body is able to excrete or lose only minimal amounts of iron in the urine, feces, blood, sweat, and in shed cutaneous and mucosal cells.

A study by Miller (1973) showed that most of the oral iron is not absorbed across the intestinal wall and is excreted in the feces. That which is absorbed from the small intestine appears first as plasma iron (transferrin) which is transported to the bone marrow for the production of red blood cell hemoglobin, muscle myoglobin which aids in muscle metabolism, iron enzymes in many tissues, and storage iron in the liver, spleen, and bone marrow. Intramuscularly injected iron is rapidly picked up from the muscle by nearby lymph nodes and more slowly released to the plasma and tissues.

The chemical form of iron administered is very important, as far as iron metabolism and utilization are concerned. Miller (1973) showed that ferric oxide and ferrous carbonate have frequently been used in commercial trace mineral mixes, but they are almost totally unavailable to the pig. Ferrous sulfate, however, is now the most frequently used form, and it has good availability. Brownlie (1955) stated that a 100 mg. injection of ferric phosphate was essentially worthless in alleviating anemia in swine, while the same amount of an iron-dextran complex was very beneficial. Barber *et al.* (1955) demonstrated that the oral dosing of pigs with iron pyrophosphate, or the intramuscular injection of iron-dextran, were equally effective in arresting the fall in the hemoglobin content of the blood after birth and raising it to a normal level by the fourteenth day of life. On the other hand, the blood hemoglobin content of the pigs that had been given an intramuscular injection of ferric phosphate continued to decline after treatment, so that on the twenty-first day of life their blood picture did not differ significantly from that of the negative control pigs that received no supplementary iron.

Bothwell and Finch (1962) stated that iron deficiency is the result of an imbalance between iron assimilation and iron loss. In normal circumstances, it is assumed that physiologic demands are within the scope of normal iron balance, and iron-deficiency can be expected to develop only when intake or losses are outside the physiologic range. At the same time, it must be stressed that iron-deficiency is the result of an interaction between the processes of absorption and loss, and both processes often contribute to the development of the anemic condition.

In pigs, the amount of iron accumulated in the liver during fetal development cannot meet even the daily iron requirement of a piglet, and the iron content of sow's milk is remarkably small (Furugouri, 1973). Accordingly, due to the increases of the iron-releasing enzymes and plasma transferrin, the ferrous-to-ferric cycles in the liver and plasma are activated, and the rate of transport iron from storage cells to the erythropoietic organ is accelerated still more. Eventually, as a result of storage iron depletion, hemoglobin synthesis slows down, and overt iron-deficiency anemia appears (Furugouri, 1974).

Although anemia in neonatal piglets is due primarily to hemodilution caused by the increase in plasma volume resultant from the ingestion of maternal colostrum into the vascular system, the absorbed colostral constituents, in turn, accelerate the production of the iron-releasing enzymes and plasma transferrin. Therefore, in growing piglets, an iron-utilizing ability to meet the great iron demand in the nursing period develops rapidly in the early stage of growth. After this stage, iron administration if very effective in arresting the anemia (Furugouri, 1974).

CHAPTER III

EXPERIMENTAL PROCEDURES

It is well known throughout the hog industry that young suckling swine are very susceptible to contracting iron-deficiency anemia. This study was designed to determine the effectiveness of two different forms of iron administration in alleviating this anemic condition. The two forms of iron administration used during the study were oral (Crete Koate) and intramuscular injection (iron-dextran). Both forms were administered in a practical manner, i.e., one which is applicable to the average hog farmer. All sows were farrowed in a farrowing barn, and the piglets remained in confinement throughout the course of the study, from birth to eight weeks of age.

I. GENERAL PROCEDURE

Sixteen Duroc sows bred to Yorkshire boars and their litters (127 York x Duroc pigs) from the winter farrowing, January, 1976, were used during the study. At the beginning of the trial, the sows were randomly allotted to one of four different treatments. Treatment (1) consisted of a negative control in which no supplemental iron was given to the piglets. Treatment (2) involved the oral administration of iron; two pounds of Crete Koate were spread on the floors of each pen every other day until the pigs were

21 days of age. Treatment (3) consisted of the intramuscular injection of 200 mg. of an iron-dextran complex at three days of age. Treatment (4) involved a combination of treatments (2) and (3); thus, Crete Koate, as well as the iron-dextran complex, was administered to the piglets. Half of the pigs in treatments (3) and (4) were given an additional iron shot intramuscularly at three weeks of age to check the effect of a second iron shot. All the piglets remained in the farrowing barn throughout the entire study.

The baby pigs were bled from the anterior vena cava at birth, seven, 14, 21, and 35 days of age. Approximately one ml. of blood was immediately placed in heparinized tubes, and all the hematological parameters involving whole blood were tested on the day the blood was drawn. About eight ml. of blood were placed in empty test tubes, allowed to clot, and the serum was withdrawn, frozen, and various tests were performed on it at a later date. Each piglet was weighed, checked for knee abrasions, and the pen condition was scored at each bleeding and at 56 days of age. Creep feed consumption was checked throughout the trial, and the total amount of creep feed consumed per litter was recorded. The pigs were weaned as near 56 days of age as possible, based on all the litter ages.

II. FACILITIES

The farrowing barn had 24 farrowing crates that were seven feet long and six feet wide, with two and a half feet of aluminum slats at one end. The sow's portion of the crate was two feet wide and enclosed with steel bars. The piglets were provided with two feet of space on each side of the sow's enclosure. The slat openings were one inch wide behind the sow and three-eighths inch wide on the piglet's side of the crate. A 25 pound capacity aluminum creep feeder was attached to the side partition of the piglet's portion of the crate. Creep was provided *ad libitum*, beginning at 14 days of age and maintained throughout the course of the study. An automatic waterer and feed trough were located in front of the sow.

The crates were not cleaned daily, a normal management procedure, because one of the treatments claimed to act as an absorbant and thus provide a better pen condition. Consequently, all the pens were scored for pen condition at each bleeding. The water troughs were cleaned once a week. The study was conducted during the winter, so the farrowing barn was heated by heat lamps, suspended about 18 inches above the floor in each crate.

III. MANAGEMENT

The sows were placed in farrowing crates approximately three days before farrowing, washed and disinfected with an iodine solution. After farrowing, the pigs had their needle teeth clipped, teat count recorded for possible later replacement boars and gilts, birth weight taken, and they were earnotched for identification. Litters number 2 and 17 had two pigs each moved to litters number

4 and 14 respectively. This was done because these particular litters (2 and 17) had more piglets than the sows could adequately nurse.

Routine management practice at the University of Tennessee Blount Farm normally requires that all the pigs receive an intramuscular iron injection at approximately three and 21 days of age. Since this study involved iron administration, only those pigs in treatments (3) and (4) received iron injections at three days of age, and only half of the pigs in these treatments received a second iron shot.

The pigs were vaccinated against erysipelas, and all the males were castrated at approximately four weeks of age. Each pig was given two ml. of Swinenex (Semed Veterinary Pharmaceuticals, Bristol, Tennessee) orally whenever scours was noted to be present in a litter. All the pigs were weaned at 56 days of age.

IV. FEEDING

All the sows were fed a 16% protein ration during the trial and remained on this ration until the pigs were weaned. The composition of this ration is listed in Table I. The sows were not fed for approximately 12 hours before or 24 hours after farrowing in order to curtail the stress involved with delivery. The sows were hand fed twice daily.

At 14 days of age, the baby pigs were put on a 20% protein ration. The composition of this ration is listed in Table II. They

TABLE I

SOW LACTATION RATION

Ingredient	Pounds
No. 2 Yellow Corn (9%)	580.0
SBOM (44%)	100.0
Meat Scraps (50%)	50.0
Dehydrated Alfalfa Meal (17%)	150.0
Wheat Bran	100.0
Dicalcium Phosphate	14.0
Salt	5.0
Limestone	5.0
Vitamin-Mineral Premix[a]	7.5
Antibiotics	2.0
TOTAL	1013.5

[a]Provides an addition to the ration of the following vitamins and minerals per pound of premix: 400 mg. riboflavin, 1 g. d-pantothenic acid, 2 g. niacin, 20 g. choline chloride, 1.5 mg. vitamin B-12, 100 mg. vitamin K (MSBC), 400,000 USP units vitamin A, 100,000 IC units vitamin D-3, 500 Int. units vitamin E, 1.2% Zn, 1.2% Fe, 0.8% Mn, 0.12% Cu, 0.02% Co, 0.008% I, and 0.001% Se.

TABLE II

CREEP RATION

Ingredient	20% Baby Pig Feed Pounds
No. 2 Yellow Corn (9%)	621.0
SBOM (44%)	250.0
Meat Scraps (50%)	60.0
Dehydrated Alfalfa Meal	50.0
Dicalcium Phosphate	10.0
Salt	5.0
Vitamin-Mineral Premix[a]	10.0
Antibiotics	1.5
TOTAL	1007.5

[a]Provides an addition to the ration of the following vitamins and minerals per pound of premix: 400 mg. of riboflavin, 1 g. d-pantothenic acid, 2 g. niacin, 20 g. choline chloride, 1.5 mg. vitamin B-12, 100 mg. vitamin K (MSBC), 400,000 USP units vitamin A, 100,000 IC units vitamin D-3, 500 Int. units vitamin E, 1.2% Zn, 1.2% Fe, 0.8% Mn, 0.12% Cu, 0.02% Co, 0.008% I, and 0.001% Se.

were fed *ad libitum* every other day at the beginning of the study, and daily once they began to consume considerable quantities of feed. The creep feed was weighed at each feeding for all the litters, so that creep feed consumption could be measured. The creep feeders were checked daily, and all feces, urine, and debris were removed to insure that the pigs had access to fresh feed at all times. The pigs remained on this creep ration until the experiment was completed.

V. PROCEDURES AND METHODS OF ANALYSES

The following observations were made at birth, seven, 14, 21, and 35 days of age: weight, hemoglobin concentration, hematocrit, erythrocyte and leukocyte counts, serum-iron concentration, total and unbound iron-binding capacity of the serum, percent saturation of transferrin with iron, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, knee abrasion, pen condition, and creep feed consumption.

All the glassware and equipment used were washed free of iron with repeated applications of 50% hydrochloric acid and double-distilled water. Blood was obtained from the anterior vena cava, and one ml. was placed in heparinized tubes to be used in all the procedures requiring whole blood. The remainder of the blood collected, approximately eight ml., was placed in clean test tubes, allowed to clot, and the liquid portion was removed for use in all methods requiring serum. After each litter was bled, the pigs were weighed and returned to their pens.

Hemoglobin concentration was determined using the cyanomethemoglobin method of Crosby *et al.* (1954).

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

Erythrocyte and leukocyte counts were performed on each pig in duplicate with a Fisher Autocytometer II. The leukocyte and erythrocyte samples were diluted 1:250 and 1:62,500 respectively with isotonic saline prior to counting. During the first bleeding, the blood cell counts obtained using this method were compared to counts using a hemocytometer with Neubauer ruling. There was no significant difference between the two methods; consequently, all subsequent counting was performed with the Fisher Autocytometer II.

The methods used for the determination of serum-iron concentration, total and unbound iron-binding capacity, and percent saturation of transferrin with iron were adapted from Olson and Hamlin (1969).

Three parameters tested during the study were calculated by using the quantitative values obtained from the hematocrit, hemoglobin concentration, and erythrocyte count. The mean corpuscular volume was determined by dividing the hematocrit by the erythrocyte count. Mean corpuscular hemoglobin was calculated by dividing the hemoglobin concentration by the erythrocyte count. Mean corpuscular hemoglobin concentration was obtained by dividing the hemoglobin concentration by the hematocrit.

All the pigs in a litter were checked for knee abrasions at each bleeding. The litter was given a score depending upon how bad the knee abrasions were in the litter. The litters were scored as follows: one indicated all pigs had open abrasions; two indicated all pigs had scabs; three indicated some abrasions on all pigs; four indicated some abrasions on a few pigs; and five indicated none of the pigs had abrasions. The pen condition was also checked at each bleeding and scored on a scale from one to three. A score of one represented a wet pen, two a normal pen, and three a dry pen.

The amount of creep feed fed to each litter was weighed; thus creep feed consumption per litter was tabulated.

VI. STATISTICAL ANALYSIS

The experimental data were analyzed by the Statistical Analysis System (SAS). Significant differences with regard to a second iron injection were determined by the use of orthagonal contrast. All the other parameters studied were tested by analysis of variance and regression. Significant differences between the means were determined by significant F values (Stell and Torrie, 1960). Whenever interactions were significant ($P<.05$), Duncan's New Multiple-Range Test was employed to determine which means were significantly different.

CHAPTER IV

RESULTS AND DISCUSSION

I. EFFECT OF TREATMENT ON HEMATOLOGICAL PARAMETERS

Hematocrit and Hemoglobin Levels

Measurements of hematocrit and hemoglobin were performed at each bleeding. These parameters were utilized as early indicators of the state of iron repletion in the piglets. The effect of added iron or Crete Koate on hematocrit and hemoglobin levels is illustrated in Table III. By one week of age, the hematocrit and hemoglobin measurements of those pigs which received an iron-dextran injection at three days of age were significantly higher ($P<.01$) than those animals which received no injection. Similar results were found by Maner *et al.* (1959), Rydberg *et al.* (1959), Ullrey *et al.* (1959), and Ullrey *et al.* (1960). The increase in these parameters due to the addition of Crete Koate was small because the animals were apparently not ingesting appreciable amounts at this early age.

By two weeks of age, the hematocrits of both the iron-dextran and Crete Koate treated pigs were significantly higher ($P<.05$), while only the hemoglobin level of the iron-dextran injected pigs was elevated significantly ($P<.05$). The hematological status changed dramatically by the time the animals were three weeks of age. Those animals receiving Crete Koate had significantly higher ($P<.05$) hematocrit and hemoglobin levels, while those pigs which received

TABLE III

EFFECT OF IRON AND CRETE KOATE ADMINISTRATION
ON HEMATOCRIT AND HEMOGLOBIN

	Treatment			
	FE		CK	
Weeks of Age	(+) N=20	(-) N=20	(+) N=20	(-) N=20
	Hematocrit, %			
Birth	24.7	23.6	24.4	23.9
1	24.4**	20.8	23.6	21.6
2	22.9*	19.9	23.0*	19.8
3	24.3	22.1	25.5**	21.0
5	28.0**	23.9	27.4*	24.5
	Hemoglobin, g./100 ml. blood			
Birth	8.00	7.92	7.85	8.06
1	8.39**	6.99	7.96	7.41
2	9.44*	7.71	9.29	7.86
3	9.99	8.72	10.39**	8.32
5	11.50*	9.82	11.35	9.96

Note: N stands for number of pigs; (+) indicates iron or Crete Koate was administered; (-) indicates iron or Crete Koate was not administered.

*P<.05 level.

**P<.01 level.

an iron-dextran injection did not differ significantly from pigs which had not received an injection. This dramatic change can be explained by the fact that those pigs ingesting Crete Koate were old enough, by three weeks of age, to have consumed appreciable quantities, i.e., enough Crete Koate to maintain a good blood picture. On the other hand, those pigs on the iron-dextran treatment may have already utilized the iron provided by their inital injection at three days of age. These pigs had probably depleted their iron supply by three weeks of age, and their hematocrit and hemoglobin levels seemed to reflect this. Ullrey *et al.* (1959) found similar results in a study comparing iron-dextran and iron-copper-cobalt tablets with non-supplemented pigs.

By five weeks of age, the pigs on iron-dextran had a highly significant ($P<.01$) elevation in their hematocrit and significant ($P<.05$) increase in their hemoglobin level. This sudden elevation can be attributed to the fact that half the pigs on this treatment received a second iron injection and by this time were consuming considerable amounts of feed. Those pigs on the Crete Koate treatment had a higher hematocrit ($P<.05$), but not significantly higher hemoglobin level. Other investigators (Rydberg *et al.*, 1959; Ullrey *et al.*, 1959, and Ullrey *et al.*, 1960) indicated essentially the same results. However, they did obtain slightly higher quantitative values. A difference in laboratory techniques employed during the study could explain these slight variations.

As revealed in Table XI in the Appendix, there is no question that some form of iron supplementation is beneficial to young swine.

Injectable iron-dextran seems to yield slightly higher (but not significantly different) hematocrit and hemoglobin levels. The combination of the two treatments is not warranted, because it does not yield appreciably higher hematocrit and hemoglobin levels than either treatment administered by itself.

Erythrocyte and Leukocyte Counts

Erythrocyte and luekocyte counts were performed in duplicate at each bleeding, and the results are depicted in Table IV. There were no significant differences observed with the addition of iron-dextran or Crete Koate in either the erythrocyte or leukocyte counts. As shown in Table XI in the Appendix, there was a general trend of higher counts in supplemented, as opposed to non-supplemented pigs (particularly with regard to the erythrocyte counts). Once again, however, no statistically significant differences were observed. Ullrey *et al.* (1959) reported practically the same results with regard to erythrocyte and leukocyte counts. The only differences were they had slightly lower leukocyte counts, and their erythrocyte counts were statistically different between supplemented and non-supplemented pigs.

Serum Iron Levels

The serum iron levels are presented in Table V. As one would expect, the serum iron levels correlated well with the previous data on hematocrits and hemoglobins. Pigs that received an iron-dextran injection, as opposed to no injection, had significantly higher

TABLE IV

EFFECT OF IRON AND CRETE KOATE ADMINISTRATION
ON ERYTHROCYTE AND LEUKOCYTE COUNTS

	Treatment			
	FE		CK	
Weeks of Age	(+) N=20	(-) N=20	(+) N=20	(-) N=20
	---------Erythrocytes, millions/cubic mm----------			
1	4.51	4.32	4.47	4.36
2	5.14	5.00	5.22	4.92
3	6.04	5.94	5.16	5.81
5	7.23	6.91	7.14	7.00
	----------Leukocytes, thousands/cubic mm----------			
1	11.24	9.60	11.21	9.63
2	7.22	8.30	8.00	7.51
3	10.06	10.49	11.51	9.05
5	13.12	12.57	12.66	13.04

Note: N stands for number of pigs; (+) indicates iron or Crete Koate was administered; (-) indicates iron or Crete Koate was not administered.

TABLE V

EFFECT OF IRON AND CRETE KOATE ADMINISTRATION
ON SERUM IRON

Weeks of Age	Treatment: FE (+) N=20	FE (-) N=20	CK (+) N=20	CK (-) N=20
	------------Serum iron, ug/100 ml serum------------			
Birth	230.9	246.4	237.7	239.5
1	440.1**	260.6	401.9*	298.8
2	382.1**	298.8	417.1**	263.8
3	466.5	319.5	485.7	300.3
5	509.0**	307.9	495.1**	321.8

Note: N stands for number of pigs; (+) indicates iron or Crete Koate was administered; (-) indicates iron or Crete Koate was not administered.

*P<.05 level.

**P<.01 level.

(P<.01) serum iron levels at one, two, and five weeks of age. These highly significant levels at one and two weeks of age were the result of the initial iron injection given these pigs. This iron was depleted by three weeks of age, and thus there was not a significant difference between injected and non-injected pigs at that time. Since half the pigs in the iron-dextran treatment received a second iron shot (at three weeks of age), and they had begun to consume large amounts of feed, they consequently attained significantly higher serum iron levels at five weeks of age.

The serum iron levels of those pigs which received Crete Koate, as opposed to no Crete Koate, were significantly higher (P<.05) at one week of age and showed a highly significant increase (P<.01) at two and five weeks of age. This increased serum iron level at one week of age can be explained by the fact that these pigs were eating very little, but consuming enough Crete Koate to elevate their serum iron level significantly. The highly significant serum iron levels at two and five weeks of age were possibly a result of two things: continued Crete Koate consumption and increased creep feed ingestion.

As shown in Table XII of the Appendix, there was very little difference in the serum iron levels of pigs on iron-dextran or Crete Koate treatments. However, the combination of these two treatments did provide higher serum iron levels, even though they were not statistically significant. It was impossible to compare the data presented in this study with that of other workers because the literature contained either unrelated studies or those performed on species other than swine. However, Furugouri (1971), working with swine, obtained plasma iron values which were approximately one-third of the values presented here. The fact that Furugouri worked with plasma rather than serum, a different breed of pigs in another country, etc., could explain the difference in results.

Total and Unsaturated Iron-Binding Capacity and Percent Saturation of Transferrin

Data relevant to the total and unsaturated iron-binding capacity and percent saturation of transferrin is illustrated in Table VI. The total iron-binding capacity of pigs that received iron-dextran or Crete Koate was significantly lower ($P<.01$ and $P<.05$ respectively) than untreated pigs at two weeks of age.

These decreases in the total iron-binding capacity were a result of increased serum iron levels provided by the iron-dextran complex and Crete Koate respectively. In general, as demonstrated in Table XII, Appendix, neither treatment (Crete Koate nor iron-dextran), nor a combination of the two treatments, appreciably affected the total iron-binding capacity in the piglet. However, all three supplemental treatments did provide a general decrease in total iron-binding capacities when compared to those piglets that were not supplemented at all.

The data related to unsaturated iron-binding capacity is shown in Table VI. The only significant differences with regard to unsaturated iron-binding capacity were evident at one and two

TABLE VI

EFFECT OF IRON AND CRETE KOATE ADMINISTRATION ON TOTAL AND UNSATURATED IRON-BINDING CAPACITY AND PERCENT SATURATION OF TRANSFERRIN

	Treatment			
	FE		CK	
Weeks of Age	(+) N=20	(-) N=20	(+) N=20	(-) N=20
	------Total iron-binding capacity, ug./100 ml. serum-----			
Birth	770.9	813.4	786.2	798.0
1	1292.8	1332.0	1348.1	1276.7
2	1153.8**	1273.4	1164.1*	1263.1
3	1202.3	1343.6	1231.3	1314.6
5	1496.3	1513.5	1448.3	1561.5
	---Unsaturated iron-binding capacity, ug./100 ml. serum--			
Birth	240.0	273.3	274.2	240.2
1	379.0*	516.3	473.1	420.6
2	342.9*	469.7	373.5	429.8
3	327.0	493.5	372.8	436.2
5	438.8	581.0	476.6	533.2
	----------Percent saturation of transferrin, %----------			
Birth	30.9	31.7	31.9	30.7
1	62.3*	33.3	56.7	38.8
2	53.2	39.1	57.8**	34.5
3	60.2	39.0	61.2*	38.0
5	70.5**	38.2	67.3*	41.5

Note: N stands for number of pigs; (+) indicates iron or Crete Koate was administered; (-) indicates iron or Crete Koate was not administered.

*P<.05 level.

**P<.01 level.

weeks of age by iron-dextran injected pigs. This significant decrease in the unsaturated iron-binding capacity correlated well with the high serum levels at this age. Although the Crete Koate treated pigs similarly demonstrated high serum iron levels at three and five weeks of age, they did not have a significantly decreased unsaturated iron-binding capacity. Even though the Crete Koate treated pigs did not differ significantly, there were decreases in their unsaturated iron-binding capacity, as illustrated in Table VI. Table XII of the Appendix depicts the fact that those pigs on Crete Koate, iron-dextran, or a combination of the two treatments, have a considerably decreased unsaturated iron-binding capacity when compared to those piglets that received no supplemental iron.

Data related to the percent saturation of transferrin is shown in Table VI. Those pigs which received an iron-dextran injection had a significant ($P<.05$) percent saturation of transferrin at one week of age and a significant ($P<.01$) level at five weeks of age. This is easily explained, in that an iron injection was administered at three days of age, thus elevating the percent saturation of transferrin with iron at one week of age. The significant ($P<.01$) level at five weeks of age was the result of increased creep feed consumption, as well as the fact that half the pigs in this treatment received a second iron shot.

Those pigs on the Crete Koate treatment had a significant ($P<.01$) percent saturation of transferrin at two weeks of age and a significant ($P<.05$) level at three and five weeks of age. These increases in the percent saturation of transferrin with iron were the result of increased Crete Koate and creep feed consumption with time. Table XII, Appendix, indicates that there was very little difference between Crete Koate and iron-dextran supplementation with regard to the percent saturation of transferrin. However, a combination of the two treatments had an additive effect, and all three supplemental treatments had higher values than the non-supplemented group.

According to Bothwell and Finch (1962), plasma transferrin is normally about one-third saturated with iron. Similar results were demonstrated in this study for pigs lacking either iron-dextran or Crete Koate (Table VI). However, those pigs on either the iron-dextran or Crete Koate treatment obtained much higher values, approximately 56% saturation of transferrin. Thus, the supplemented pigs had a more readily available supply of iron to disperse to the tissues.

Mean Corpuscular Volume, Hemoglobin, and Hemoglobin Concentration

The mean corpuscular volume, hemoglobin, and hemoglobin concentration levels are illustrated in Table VII. All pigs treated with either Crete Koate or iron-dextran, as opposed to no supplemental iron, had a significantly increased (P<.01) mean corpuscular volume at one, two, three, and five weeks of age. When compared to normal mean corpuscular volume values, this indicated that those pigs receiving either iron-dextran or Crete Koate had normal sized erythrocytes. Conversely, those pigs

TABLE VII

EFFECT OF IRON AND CRETE KOATE ADMINISTRATION ON MEAN CORPUSCULAR VOLUME, MEAN CORPUSCULAR HEMOGLOBIN, AND MEAN CORPUSCULAR HEMOGLOBIN CONCENTRATION

	Treatment			
	FE		CK	
Weeks of Age	(+) N=20	(-) N=20	(+) N=20	(-) N=20
	Mean corpuscular volume, fl.			
1	54.5**	48.3	53.0**	49.6
2	44.6**	39.9	44.3**	40.1
3	40.3**	37.1	41.4**	36.0
5	38.7**	34.6	38.5**	34.9
	Mean corpuscular hemoglobin, pg.			
1	18.6**	16.2	17.8	17.0
2	18.3**	15.4	17.8	16.0
3	16.5*	14.6	16.8**	14.3
5	15.9*	14.2	16.0*	14.2
	Mean corpuscular hemoglobin concentration, %			
1	34.6	33.8	33.9	34.4
2	41.2	38.6	40.3	39.5
3	41.1	39.3	40.8	39.5
5	41.1	41.0	41.7	40.5

Note: N stands for number of pigs; (+) indicates iron or Crete Koate was administered; (-) indicates iron or Crete Koate was not administered.

*P<.05 level.

**P<.01 level.

not supplemented with iron had significantly (P<.01) smaller erythrocytes, indicating these pigs were in a state of microcytic anemia.

Table XIII of the Appendix illustrates that there was very little difference between the three supplemental treatments with regard to the mean corpuscular volume. However, those pigs which received no supplementation had considerably lower mean corpuscular volumes and were in a state of microcytic anemia.

The mean corpuscular hemoglobin values, which express the amount of hemoglobin per red blood cell, are depicted in Table VII. Those pigs on the iron-dextran treatment had significant (P<.01) levels at one and two weeks of age and significant (P<.05) levels at three and five weeks of age. This indicated that the iron-dextran complex provided enough iron for hemoglobin synthesis and incorporation into the erythrocytes throughout the study. The pigs that received the Crete Koate treatment had significant (P<.01) mean corpuscular hemoglobin levels at three weeks of age and significant (P<.05) levels at five weeks of age. This indicated that for the first two to three weeks of life, the pigs that received Crete Koate did not differ significantly from those receiving no supplementation, in so far as hemoglobin synthesis and incorporation into erythrocytes is concerned. However, from three weeks of age until the end of the study, an adequate supply of iron was provided for these functions.

Table XIII, Appendix, illustrates the fact that there was little difference between the three supplemental treatments with regard to mean corpuscular hemoglobin levels. However, there was a difference between the supplemented and non-supplemented pigs.

The mean corpuscular hemoblogin concentration values, which express the amount of hemoglobin as a percentage of the volume of an erythrocyte, are shown in Table VII and in Table XIII, Appendix. There was no significant difference between any of the treatments with regard to this parameter. This indicated that regardless of treatment, weeks of age, etc., there was no difference in the amount of hemoglobin expressed as a percentage of the volume of an erythrocyte throughout the study.

Schalm *et al.* (1975) established normal values for mean corpuscular volume, hemoglobin, and hemoglobin concentration in swine. Compared to these values, all those pigs receiving either iron-dextran or Crete Koate fell into the normal range and would be considered normocytic, normochromic, or normal. On the other hand, all the non-supplemented pigs' values fell below the normal range and would be considered to be in a state of microcytic, hypochromic anemia.

II. EFFECT OF TREATMENT ON PERFORMANCE TRAITS

Pen Condition and Knee Abrasions

The data related to pen condition and knee abrasions is shown in Table VIII and in Table XIV, Appendix. There were no

TABLE VIII

EFFECT OF IRON AND CRETE KOATE ADMINISTRATION ON PEN CONDITION AND KNEE ABRASIONS

	Treatment			
	FE		CK	
Weeks of Age	(+) N=20	(-) N=20	(+) N=20	(-) N=20
	Pen condition*			
1	2.28	2.35	2.38	2.24
2	1.96	1.66	2.14	1.49
3	1.96	1.79	1.94	1.81
5	1.63	1.75	1.59	1.78
	Knee abrasions**			
1	3.09	3.16	3.31	2.94
2	3.00	3.12	3.20	2.93
3	3.05	3.07	3.21	2.92
5	2.72	2.90	2.78	2.85

Note: N stands for number of pigs; (+) indicates iron or Crete was administered; (-) indicates iron or Crete Koate was not administered.

*Pen condition was scored as follows: 1=wet pen, 2=normal pen, and 3=dry pen.

**Knee abrasions were scored as follows: 1=all pigs and open abrasions, 2=all pigs and scabed, 3=some abrasions on all pigs, 4=some abrasions on a few pigs, and 5=no abrasions.

significant differences observed with the addition of iron or Crete Koate as revealed in Table VIII. Furthermore, there were no significant differences between supplemented and non-supplemented treatment groups with regard to pen condition and knee abrasions.

Since both of these traits were scored on a subjective basis, it was very difficult to obtain accurate and quantitative results. The scores should not be taken at face value, and a more systematic and reliable system should be devised to account for these traits. The literature contained no data relevant to pen condition or knee abrasion scoring. Consequently, no comparison with previous results could be made.

Total Creep Feed Consumption and Average Weaning Weight Per Pig

Total creep feed consumption and average weaning weight per pig are illustrated in Table IX. Total creep feed consumption was significantly higher ($P<.01$) for those pigs on the Crete Koate treatment, while those pigs that received iron-dextran did not differ significantly from non-supplemented pigs.

The average weaning weight per pig (42.1 lbs.) for those pigs on the Crete Koate treatment was increased significantly ($P<.05$), while the pigs on iron-dextran treatment, once again, did not differ significantly from non-supplemented pigs (39.4 lbs. vs. 38.1 lbs.).

The results indicated that the Crete Koate treated pigs ate more creep feed and gained more weight during the preweaning period

TABLE IX

EFFECT OF IRON AND CRETE KOATE ADMINISTRATION ON TOTAL CREEP FEED CONSUMPTION AND AVERAGE WEANING WEIGHT PER PIG

Treatment			
FE		CK	
(+) N=4	(-) N=4	(+) N=4	(-) N=4
Total creep feed consumption, lbs./litter			
237.8	234.7	275.5**	197.0
Average weaning weight per pig, lbs.			
39.4	38.1	42.1*	35.4

Note: N stands for number of litters; (+) indicates iron or Crete Koate was administered; (-) indicates iron or Crete Koate was not administered.

*P<.05 level.

**P<.01 level.

(birth to eight weeks of age). Table XV, Appendix, also demonstrates similar results. Pigs on the Crete Koate treatment ate more feed, but in turn, gained more weight.

According to Ligon (1975), the average weaning weight per pig on confinement at the University of Tennessee Blount Farm was approximately 37 lbs. Similar results were obtained in this study, except that those pigs on the Crete Koate treatment had higher values (averaging 42 lbs.). Thus, the pigs consuming Crete Koate gained more weight in the first eight weeks of life.

Weekly Weights

The results of weekly weights are shown in Table X. There were no significant differences between those pigs on the iron-dextran treatment and pigs which received no supplemental iron throughout the study. Those pigs which received the Crete Koate treatment, however, had significantly higher ($P<.05$) weights at one week of age and significant ($P<.01$) weekly weights at two, three, five, and eight weeks of age. These results correlate well with the results found for total creep feed consumption and average weaning weight per pig. Table XV, Appendix, reaffirms this point and demonstrates that those pigs on the Crete Koate treatment gained more weight by weaning than either the iron-dextran treatment or the unsupplemented pigs. These results are similar to the results obtained by Ligon (1975).

TABLE X

EFFECT OF IRON AND CRETE KOATE ADMINISTRATION ON WEEKLY WEIGHTS

	Treatment			
	FE		CK	
Weeks of Age	(+) N=68	(-) N=59	(+) N=61	(-) N=66
Birth	3.13	3.23	3.21	3.14
1	5.80	5.77	6.11*	5.45
2	8.86	8.81	9.52**	8.16
3	12.60	12.58	13.32**	11.86
5	19.29	18.75	20.30**	17.74
8	38.83	38.94	41.19**	36.58

Note: N stands for number of pigs; (+) indicates iron or Crete Koate was administered; (-) indicates iron or Crete Koate was not administered.

*P<.05 level.

**P<.01 level.

CHAPTER V

SUMMARY

Data were collected on 16 litters (127 York X Duroc piglets) at the University of Tennessee Blount Farm. The effectiveness of two forms of iron administration (oral and parenteral) was determined by analyzing various hematological parameters and performance traits. The litters were randomly allotted to one of four different treatments: control, Crete Koate, iron-dextran, and a combination of Crete Koate and iron-dextran. All the piglets remained in confinement throughout the study.

The piglets were bled at birth, one, two, three, and five weeks of age, and various hematological analyses were performed on each blood sample. Each piglet was weighed, checked for knee abrasions, and the pen condition was scored at each bleeding and at eight weeks of age. The total amount of creep feed consumed per litter was also recorded.

The overall results indicated that there was very little difference between iron-dextran or Crete Koate supplementation in young swine. The hematological parameters and performance traits tested confirmed this fact.

Of the hematological parameters tested, there were no significant differences in erythrocyte and leukocyte counts or mean corpuscular hemoglobin concentration. Significant differences ($P<.05$) were obtained by both types of supplemental iron for hematocrit, hemoglobin, serum iron, total and unsaturated iron-binding capacity, percent saturation of transferrin, mean corpuscular volume, and hemoglobin.

In regard to performance traits, all those pigs receiving iron-dextran revealed no significant differences. However, those pigs receiving Crete Koate had a significantly higher ($P<.05$) total creep feed consumption, average weaning weight per pig, and weekly weights, while no significant difference in pen condition or knee abrasions was observed.

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LITERATURE CITED

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APPENDIX

TABLE XI

HEMATOCRIT, HEMOGLOBIN, ERYTHROCYTE, AND LEUKOCYTE MEANS

Weeks of Age	Treatment (1) N=20	(2) N=20	(3) N=20	(4) N=20
	Hematocrit, %			
Birth	23.2	24.0	24.6	24.8
1	19.2	22.4	24.0	24.8
2	17.4	22.4	22.1	23.7
3	18.8	25.5	23.1	25.5
5	21.1	25.7	28.0	28.0
	Hemoglobin, g./100 ml. blood			
Birth	7.98	7.85	8.14	7.86
1	6.52	7.46	8.30	8.47
2	6.24	9.19	9.49	9.38
3	6.85	10.59	9.78	10.20
5	8.25	11.38	11.67	11.32
	Erythrocytes, millions/cubic mm.			
1	4.33	4.31	4.39	4.63
2	4.74	5.25	5.09	5.19
3	5.71	6.17	5.92	6.16
5	6.80	7.03	7.20	7.25
	Leukocytes, thousands/cubic mm.			
1	8.19	11.01	11.08	11.40
2	8.74	7.85	6.28	8.15
3	10.44	10.55	7.66	12.47
5	12.52	12.63	13.55	12.69

Note: Treatments were as follows: (1) no supplemental iron; (2) Crete Koate; (3) iron-dextran; (4) Crete Koate and iron-dextran. N stands for number of pigs.

TABLE XII

SERUM IRON, TOTAL IRON-BINDING CAPACITY, UNSATURATED IRON-BINDING CAPACITY, AND PERCENT SATURATION OF TRANSFERRIN MEANS

Weeks of Age	Treatment (1) N=20	(2) N=20	(3) N=20	(4) N=20
	--------------Serum iron, ug./100 ml. serum-------------			
Birth	251.9	240.8	227.2	234.6
1	185.9	335.3	411.7	468.5
2	203.6	393.8	323.9	440.3
3	199.8	439.3	400.9	532.2
5	206.8	409.0	436.9	581.1
	-----Total iron-binding capacity, ug./100 ml. serum-----			
Birth	815.1	811.7	781.0	760.8
1	1209.6	1454.4	1343.7	1241.9
2	1337.1	1209.6	1189.1	1118.5
3	1401.4	1285.8	1227.8	1176.9
5	1578.6	1448.3	1544.3	1448.3
	--Unsaturated iron-binding capacity, ug./100 ml. serum--			
Birth	274.7	271.8	213.0	276.9
1	499.4	532.9	358.4	407.1
2	552.9	388.5	332.8	356.9
3	586.2	403.1	318.0	339.4
5	669.2	494.9	425.9	456.4
	----------Percent saturation of transferrin, %---------			
Birth	32.3	31.2	29.1	32.7
1	23.6	42.9	54.0	70.5
2	26.3	51.8	42.7	63.7
3	25.0	53.0	51.0	69.4
5	26.0	50.5	56.9	84.1

Note: Treatments were as follows: (1) no supplemental iron; (2) Crete Koate; (3) iron-dextran; (4) Crete Koate and iron-dextran. N stands for number of pigs.

TABLE XIII

MEAN CORPUSCULAR VOLUME, MEAN CORPUSCULAR HEMOGLOBIN, AND MEAN CORPUSCULAR HEMOGLOBIN CONCENTRATION MEANS

Weeks of Age	Treatment (1) N=20	(2) N=20	(3) N=20	(4) N=20
	Mean corpuscular volume, fl.			
1	44.5	52.1	54.8	54.0
2	36.9	42.9	43.4	45.7
3	32.9	41.3	39.1	41.5
5	31.0	38.2	38.7	38.7
	Mean corpuscular hemoglobin, pg.			
1	15.1	17.4	19.0	18.2
2	13.3	17.6	18.7	17.9
3	12.0	17.2	16.5	16.5
5	12.1	16.4	16.2	15.6
	Mean corpuscular hemoglobin concentration, %			
1	34.1	33.4	34.8	34.3
2	35.9	41.2	43.1	39.4
3	36.7	41.8	42.3	39.8
5	39.2	42.8	41.8	40.5

Note: Treatments were as follows: (1) no supplemental iron; (2) Crete Koate; (3) iron-dextran; (4) Crete Koate and iron-dextran. N stands for number of pigs.

TABLE XIV

PEN CONDITION AND KNEE ABRASIONS ADJUSTED MEANS

Weeks of Age	Treatment (1) N=4	(2) N=4	(3) N=4	(4) N=4
	Pen condition*			
1	2.50	2.18	1.99	2.57
2	1.17	2.15	1.80	2.13
3	1.83	1.75	1.79	2.14
5	1.97	1.53	1.59	1.66
	Knee abrasions**			
1	2.81	3.50	3.07	3.12
2	2.78	3.47	3.08	2.92
3	2.63	3.52	3.21	2.89
5	2.76	3.04	2.93	2.51

Note: Treatments were as follows: (1) no supplemental iron; (2) Crete Koate; (3) iron-dextran; (4) Crete Koate and iron-dextran. N stands for number of litters.

*Pen condition was scored as follows: 1=wet pen, 2=normal pen, and 3=dry pen.

**Knee abrasions were scored as follows: 1=all pigs and open abrasions, 2=all pigs and scabed, 3=some abrasions on all pigs, 4=some abrasions on a few pigs, and 5=no abrasions.

TABLE XV

TOTAL CREEP FEED CONSUMPTION AND AVERAGE WEANING WEIGHT PER PIG MEANS

Treatment			
(1) N=4	(2) N=4	(3) N=4	(4) N=4
Total creep feed consumption, lbs.			
215.7	253.7	178.2	297.4
Average weaning weight per pig, lbs.			
35.7	40.6	35.2	43.6

Note: Treatments were as follows: (1) no supplemental iron; (2) Crete Koate; (3) iron-dextran; (4) Crete Koate and iron-dextran. N stands for number of litters.

TABLE XVI

WEEKLY WEIGHT MEANS

	Treatment			
Weeks of Age	(1) N=29	(2) N=30	(3) N=37	(4) N=31
Birth	3.28	3.17	3.01	3.25
1	5.43	6.11	5.48	6.11
2	7.88	9.74	8.44	9.29
3	11.55	13.61	12.17	13.02
5	17.10	20.39	18.38	20.21
8	36.62	41.25	36.54	41.12

Note: Treatments were as follows: (1) no supplemental iron; (2) Crete Koate; (3) iron-dextran; (4) Crete Koate and iron-dextran. N stands for number of pigs.

VITA

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After spending three years in the United States Air Force, he entered The University of Tennessee, Knoxville, in January, 1974. While completing preveterinary medicine requirements and working at the University of Tennessee Memorial Research Center, he entered Graduate School in January, 1975. In August, 1977, he received the Master of Science Degree in Animal Science.