VITAMINS AND THE EARLY WEANED SOW

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Don Down

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree of

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DEDICATION

To my wife Melanie, for her endless support and encouragement.

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LIST OF ABBREVIATIONS

AA	amino acid
ADFI	average daily feed intake
ADG	average daily gain
IU	international units
RE	retinol equivalents
LH	lutenizing hormone
WEI	weaning to estrus interval.
WMI	weaning to mating interval.
ME	metabolizable energy
NPD	non-productive days.
NTD	neural tube defects
SCE	sister chromatid exchange
SEW	segregated early weaning
WSI	weaning to first service interval

ABSTRACT

An experiment was conducted within a 1500 sow farrow to wean research facility to evaluate the effectiveness of Vitamin A (retinyl palmitate) injected at the time of weaning and dietary Folic Acid on the reproductive performance of the early weaned sow. Several experiments have taken place looking at these two vitamins individually, however there is no reported literature involving both vitamins concurrently. Two hundred and forty Manor Hybrid Sows [(Landrace x York) x Large White] were randomly placed on of the four treatments. The animals were from parities one to four, with equal numbers of the four parities on each treatment. The sows were all crossed to a Duroc boar either by artificial insemination or natural service. The animals were on test for one complete gestation period (115 days) and one lactation period. All litters were weighed at birth, and again at the time of weaning. All sows were weighed and a back fat test done when they were placed on the trial, at the time of breeding, previous to subsequent farrowing and again at weaning. All litters were weighed at birth, and again at weaning. All sows were served at the completion of the trial and there wean to first service interval recorded. Vitamin A resulted in a significant difference in the total number of pigs born per litter (P=0.030). However, Folic Acid did not make a significant difference in the total number of pigs weaned (P=0.911). The interaction between Folic Acid did not result in a significant difference in the total number of pigs born (P=0.495). The increased number of pigs born due to the Vitamin A treatment did not result in a significant difference in the number of pigs weaned (P=0.526). The Folic Acid treatment groups weaned fewer pigs, which were heavier at the time of weaning. However, the interaction between Folic Acid and Vitamin A did not result in a significant difference in

the number of pigs weaned (P=0.396). Vitamin A treatment appeared to negatively impact the conception rates of the sows, with farrowing rates 10 % lower than the control group. There were a higher number of repeat services 21 days post breeding, this was more evident with the younger parities. Folic Acid resulted in a difference in the wean to first service interval approaching significance (P=0.075). The interaction between parity and Folic Acid resulted in a significant difference in the wean to first service interval (P=0.023). However the interaction between Folic Acid and Vitamin A did not result in a significant difference in the wean to first service interval (P=0.373). This study indicates that Vitamin A treatment resulted in a significant difference in the number of pigs born; however Folic Acid did not. The interaction of the two vitamins did not result in a significant difference in the number of pigs born or weaned. Further research looking into the effect of higher doses of Folic Acid in conjunction with the Vitamin A treatment will potentially wean the increased number of pigs born.

CHAPTER 1

INTRODUCTION

In recent years the trend to weaning the pig at a younger age has occurred. This trend is initiated by factors such as the need to optimize swine farrowing facilities by moving more sows through the farrowing crates each year, thereby reducing capital cost. Other factors driving early weaning include the elimination of disease transmission from sow to piglets, and improving the number of pigs weaned per sow per year.

Early weaning allows clean movement through a three-site production model. The three-site production model allows for good disease eradication as the weanlings are removed from the sow when the piglets are still relying on temporary passive immunity. Once the piglets are placed in off site nurseries and finishing barns, all in all out production efficiencies can be realized.

Lactation length or weaning age, season, parity, and feed intake during lactation are recognized as factors affecting reproductive performance, (Dial et al., 1992). Early weaning decreases the number of days used for lactation, potentially increasing the productivity of the sow, but it can also have negative effects on the reproductive performance. These can include an increase in the weaning-to-estrus (WEI) and/or smaller subsequent litter size (Foxcroft et al 1995). Early weaning or short lactation length has been suggested to be associated with suboptimal farrowing rate (Koketsu,

1994). Farrowing rate is one of the most commonly used variables indicating breeding herd productivity (Dial et al., 1992).

Nutrition plays a key role in managing the early-weaned sow. With the trend toward shorter lactation length, the productivity of sows is influenced by feed intake. The effects of shorter lactation lengths (<18 days) on weaning to service interval was much more pronounced in sows eating less than 4.2 kg/day throughout a 19 day lactation than it was for sows eating more 4.2 kg/day. (Dial et al., 1996)

The importance of nutrition for reproductive function came largely empirical studies, which laid the foundation for using good nutritional management to optimize reproductive performance (Aherne, 1998). In adult swine, vitamins and minerals are required for a variety of biochemical functions. These same nutrients are likely required by fetal pigs, but the timing and mechanism for delivery for conceptus tissue formation are not clearly understood (Mahan et al., 1997).

The main objective of this research is to provide some insight into the benefits of supplementary folic acid and retinyl palmitate on the reproductive performance of the early-weaned sow. Based on the literature reviewed it is hypothesized that sows fed supplementary folic acid will farrow larger litters. The research reviewed on Vitamin A leads to the hypothesis that the sows injected with retinyl palmitate will also farrow larger litters.

By evaluating the reproductive performance of the sows treated with these vitamins, we can gain a better understanding as to the benefit they have to the early-weaned sow. This will assist producers and animal nutritionists in developing swine diets that will help the sow to overcome some of the challenges created as a result of how the industry weans the sow today.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

Weaning the sow at an age younger age can potentially increase the productivity of the sow, however it can also have negative effects on the reproductive performance. One of the key factors in managing the performance of the early weaned sow is by providing the optimal levels of nutrition at different stages of production. Providing the required protein and energy levels for optimal reproductive performance is essential. The concept of supplementary vitamins and minerals is an area of interest, and research has been done to determine the effect of supplementary vitamins, and at what levels they are required. The fat soluble Vitamin A has been recognized as a potential opportunity to increase litter size. Understanding the function of Vitamin A and the theory behind improved litter size is developmental to designing it's application. The water soluble vitamin, Folic Acid has also been recognized as a potential opportunity to reduce embryonic mortality and to improve the strength and viability of the pigs born. The effects of these two vitamins on the reproductive performance of the early weaned sow is unclear.

Early Weaning of the Sow

Swine production systems are designed to produce ever increasing reproductive performance and efficiency from the domestic sow. The efficiency of the breeding sow can be measured in pigs per sow per year. Most often this number is reported in the literature as pigs weaned per mated female per year.

Advantages of Early Weaning

The goal of the hog producer is to maximize the number of piglets per sow per year and also have the sow productive as many days of the year as possible. One of the ways to increase the number of pigs weaned per sow per year is to decrease the sow's lactation length. Weaning the sow at 10 to 21 days has become more popular and standard practice in many countries.

By weaning the sow at a young age, producers also try to increase the efficiency of the production facilities. Batch farrowing and weaning is much easier to assemble in an early weaning system, because all in all out production is possible. The all in all out strategy helps to break the disease cycle by allowing facilities to be cleaned and disinfected between groups of farrowing sows.

A simulated computer model was developed to quantify costs and benefits of segregated early weaning (SEW) compared to standard production in a vertically integrated system (Krieter, 2001). Despite higher expenses for facilities, transportation and labour, SEW reduced the total chain production cost. Krieter maintained that SEW

may be an effective and beneficial alternative that meets some of the demands of pig producers and consumers such as effective production, good health and food safety.

Concerns of Early Weaning

While early weaning may increase the number of piglets weaned per sow per year, it can have a negative effect on the sow's reproductive performance. It is known that the weaning to estrus interval (WEI), weaning to service interval and weaning to conception interval increase with decreased lactation length (Foxcroft et al. 1995). These intervals can all be counted as non-productive days (NPD). Inadequate dietary amino acid intake in sows during early lactation results in lower lutenizing hormone secretion by day 10 postpartum and is associated with increased WEI, (Jones et al. 1999). However in a production context, the increased WEI is usually offset by increased litters per sow per year, resulting in an economic benefit to the producer.

Longevity of reproduction of the sow is best served by minimizing weight and fat loss in lactation. The ideal situation requires only a minimal restoration of weight in the following pregnancy, which would be beneficial, since the greater feed intake and weight gain in pregnancy, the greater the weight loss in lactation, Neil, (1996).

The subsequent litter from a sow or gilt with a previous short lactation length is known to be fewer in number and quite often also of a lower total birth weight. A sow with a 14-day lactation length, is 2 to 3 times more likely to mate within a 6 to 12 day weaning to mating interval (WMI). This period is known to be a less productive period,

(larger litter sizes) as compared to 4 or 5 days after weaning, more commonly seen with sows weaned after 19 days of lactation, Koketsu, (1999). In a sow herd practicing early weaning, some sows will be mated during what is considered to be the low productive period, as this period is a part of the WMI in a herd.

The low productive period can be categorized by the timing of ovulation. Sows that expressed estrus within 8 days of weaning are more likely to be ovulating (Knox et al., 2001). The percentage of sows ovulating within 8 days of weaning was significantly influenced by lactation length. Sows that lactated less than 16 days were less likely to ovulate in the productive period than the sows lactating greater than 17 days.

One of the other variables often overlooked in an early wean system is the size of the piglet born and weaned. The age and weight of the pig at the time of weaning can have an effect the growth performance and efficiency of the pig in the nursery, grower and finisher stages.

However, even though early weaning can increase overall production, other aspects must be carefully examined and manipulated in an effort to offset the negative effects on the breeding sow. Some of these factors include seasonality, housing, animal social interactions and nutrition.

Nutrition of the Early Weaned Sow

Research conducted at the University of Minnesota indicated that the impact of lactation feed intake on subsequent reproduction increases as weaning age is reduced. The use of high dietary fat levels during lactation will improve litter-weaning weights, but may actually impair subsequent reproductive performance by reducing the number of LH peaks in early lactation (Koketsu et al., 1996).

Feeding the sow for maximum reproduction involves recognizing that the nutrient requirements are different during different stages of the sow's reproductive life. Nutrient levels may immediately affect the sow or may have an affect on subsequent production.

The performance of replacement gilts has a profound influence on the total efficiency of the breeding herd. Developing gilts must be provided with the nutrition, environment, and management conditions necessary for them to attain puberty, express estrus, mate and conceive at a relatively early age.

Lactation

Many studies have shown that sows, especially primiparous sows that lose excessive amounts of weight will have extended remating intervals, a lower percentage of sows in estrus within 10 days of weaning, reduced pregnancy rate and reduced embryo survival (Neil, 1996). The voluntary feed intake of the modern primiparous sow is low and generally results in nutrient output exceeding nutrient input. With higher parity sows

the metabolic demands of lactation are more nearly met by increased feed intake and tissue catabolism may be reduced, (Neil, 1996).

Everts (1994) has suggested that breeding multiparous sows have a biological need to attain a target protein body mass of at least 35 kg but that there is no such drive for a target body fatness. Reproductive efficiency would be expected to increase as the animal approaches its target protein mass. The pattern of protein accretion leading to the attainment of this protein mass is generally made up of a series of gestation gains and lactation losses. The drive to accrete protein in the sow decreases with increasing parity. Clowes et al. (1994), suggested that increases in reproductive efficiency with parity are associated with a larger maternal protein mass.

The loss of protein during lactation may be of greater relevance to subsequent reproductive performance than loss of fat (King, 1987). When protein and amino acid intake do not meet the sow's needs for maintenance, growth and milk production, she mobilizes her protein reserves to meet such needs.

Gestation

The major objectives of nutrition during the post weaning period are to shorten the interval to fertile mating, synchronize the onset of estrus, and maximize ovulation and conception rates. King and Martin (1989) suggested that approximately 50 % of first litter sows fail to exhibit estrus within one week of weaning, whereas almost 80 % of older sows are mated within this period. Increasing the level of feed intake after weaning has

been reported to shorten the interval to service in primaparous sows and to increase the number of sows exhibiting estrus within 10 days of weaning, but it has no effect on mature sows in good body condition (Neil, 1996).

Nutrient requirements during gestation are smaller as compared to lactation, but the feed intake pattern can influence reproductive performance. Staged feeding is important to meet the specific goals of each gestation period. Timing as well as quantity of nutrients fed during each gestation period is important for optimizing subsequent lactating and reproductive performance. The gestation period contains the greatest opportunity for increasing female productivity due to the high inherent rate of embryonic mortality that can occur during the first 30 days of pregnancy.

Gestation is the longest portion of the reproductive cycle of sows. Therefore, it can be considered as the phase during which there is adequate time for management practices to have beneficial effects on the reproductive process (Flowers, 1998). Nutrient requirements during gestation can be divided into three different areas: 1) maintenance, 2) maternal growth, and 3) fetal growth. During the gestation period of day 0 to 30 several researchers have reported that higher than maintenance level feed intake will decrease embryo survival. This increased embryo mortality was attributed to a reduction in plasma progesterone concentration due to increased blood flow and hepatic clearance of progesterone caused by the high feed intake, (Flowers, 1998). The body condition or energy state of the sow also influences the response to high levels of feed intake after mating. Feeding according to body condition during the first thirty days of gestation is critical for minimizing embryo mortality.

The period of day 30 to 75 is the area of gestation that is the least understood, of the maternal growth period. The general recommendation is to feed a constant level sufficient to meet the energy requirements of the sow and maintain body condition. Some recent research indicates that this time frame is a critical period for muscle differentiation of the developing fetuses. Dwyer et al (1994) observed that by doubling feed intake (2.5 kg vs. 5.0 kg/day) from day 25 to 80 of gestation increased the number of secondary muscle fibers and improved growth rate and feed efficiency of the offspring during the 70 to 130 postnatal growth period.

Mammary development is rapid between day 75 to 100 of gestation. Excessive energy intake during this period increases fat deposits and reduces the number of secretory cells in the mammary gland. The result of this is lower milk production during lactation, (Flowers, 1998).

Feed intake should be increased by 1 to 2 kg from day 100 to 112 of gestation to prevent sows from losing weight during this period, as the sow is preparing herself for lactation and rapid fetal growth is occurring. Failure to increase feed intake during this period results in sows in an extremely catabolic state at farrowing. The catabolic state can contribute to gorging and sows going off feed during lactation.

Supplemental Vitamins and Minerals

The dietary requirement for micronutrients during development is smaller in gestation as compared to lactation, however adequate amounts are essential for both the

immediate and long-term well being of the embryo, fetus and neonate (Ashworth and Antipatis, 2001).

Studies investigating the effect of vitamins and minerals on reproduction can be categorized into two distinct categories based on the timing and duration of the supplemental period (Flowers, 1998). The time frame associated with the first strategy usually is limited to the first 30 days of gestation and often is initiated at or just prior to breeding. In this time period the assumption is made that the additional vitamins and minerals are beneficial for the development of early embryos and should have an effect on the high rate of loss that normally occurs in the first 30 days. Minerals and vitamins used in this manner usually have been shown to be present in uterine secretions or endometrial tissue during maternal recognition of pregnancy and/or the first 30 days of gestation (Flowers, 1998).

Early pregnancy is often considered a relatively safe period when nutrient demands on females are low and not particularly critical. It is now recognized that the initial half of pregnancy establishes micronutrient transport mechanisms for the conceptus, whereas during the latter half of pregnancy these and possibly other mechanisms transport larger quantities of these nutrients to fetal and mammary tissue (Mahan and Vallet, 1997).

The second strategy involves supplementation during the entire reproductive cycle over several parities. This approach addresses the possibility that nutritional requirements for certain minerals and vitamins have actually been underestimated or have

increased over time. This may be due to the development of highly prolific genotypes. Most of the vitamins and minerals used in this strategy are associated with basal metabolic functions in sows, (Flowers, 1998).

There are periods during pregnancy when sows may have a temporarily high requirement for certain vitamins and minerals. Proteins transferring retinol and iron to the developing fetus have been discovered, whereas transport mechanisms for other vitamins and minerals are probably present but have not yet been identified (Mahan and Vallet, 1997).

Folic acid, the minerals zinc, iron and copper and the antioxidant Vitamins A and E are of particular importance during pregnancy. Excesses and deficiencies of these micronutrients can have profound and sometimes persistent effects on many fetal tissues and organs in the absence of clinical signs of deficiency in the mother.

Micornutrients are involved in all stages of cell growth and differentiation including cell signaling and protein translation, and are key elements of many enzymes and cell structures. Micronutrients also effect development by modifying changes in hormones, growth factors and cell signaling pathways that affect both nutrient uptake by the conceptus and the environment in which prenatal development proceeds (Ashworth and Antipatis, 2001).

Sow body tissues can serve as a reservoir for many micornutrients, but it is not known whether these reserves can supply an adequate quantity during critical fetal

developmental periods (Mahan and Vallet, 1997). The consequences of micronutrient imbalance of the developing conceptus may not be apparent at the time of nutritional insult, but may manifest later in development. Passive transfer of some nutrients undoubtedly occurs between the maternal-fetal blood barrier, however most micronutrients are probably dependant on an active transport mechanism. A tremendous amount of metabolic activity takes place in placental and fetal tissues, requiring an ample supply of most vitamins and minerals.

The detrimental effects of many micronutrient deficiencies, particularly zinc and copper can be alleviated by supplementary antioxidants. However deficiencies of antioxidant Vitamins A and E are likely to reduce defence against free radical damage (Ashworth and Antipatis, 2001).

Vitamins Defined

The existence of nutritive factors, such as vitamins, was not recognized until about the start of the twentieth century. Typically, the value of food in nutrition was expressed solely in terms of its ability to provide energy and basic building units necessary for life, (McDowell, 1989).

The vitamin hypothesis began with gradual recognition that cause of diseases such as night blindness, scurvy, beriberi and rickets could be related to diet. In the early 1900s many scientists in the field of nutrition began to realize that diet could not be adequately defined in terms of carbohydrate, fat, protein and salts. It had become evident

that other organic compounds had to be present in the diet if health was to be maintained, (McDowell, 1989).

Casmir Funk proposed the "vitamin theory" in 1912, (McDowell, 1989). He had reviewed the literature and made the important conclusion that beriberi could be prevented or cured by a protective factor present in natural food. Funk named the distinct factor that prevented beriberi as a "vitamine." The word was derived from "vital amine." Later, when it became evident that not all "vitamines" contained nitrogen (amine), the term became vitamin, (McDowell, 1989).

Vitamins are defined as a group of complex organic compounds present in minute amounts in natural foodstuffs that are essential to normal metabolism and lack of which in the diet causes deficiency diseases. Vitamins are required in trace amounts in the diet for health, growth and reproduction. Omission of a single vitamin from the diet of a species that requires it will produce deficiency signs and symptoms. Classically, vitamins have been divided into two groups based on their solubilities in fat solvents or in water. Fat-soluble vitamins include A, D, E and K, while vitamins of the B complex and others such as C are classified as water-soluble, (McDowell, 1989).

Fat-soluble vitamins are found in feedstuffs in association with lipids. Fat-soluble vitamins are absorbed along with the dietary fats by mechanisms similar to those involved in fat absorption. Conditions favorable to fat absorption, such as adequate bile flow and good micelle formation also favor absorption of fat-soluble vitamins. The

absorption of fat-soluble vitamins can be impaired when conditions are unfavorable for normal fat absorption, (McDowell, 1989).

Water-soluble vitamins are not associated with fats and alterations in fat absorption do not affect their absorption. Fat-soluble vitamins are stored in appreciable amounts in the animal body. Water-soluble vitamins are not totally stored in the body and excesses are rapidly excreted, the only exception being vitamin B 12. A continual dietary supply of the water-soluble vitamins is needed to avoid deficiencies.

Fat-soluble vitamins are primarily excreted in the feces via the bile, whereas water-soluble vitamins are mainly excreted in urine. Water-soluble vitamins are relatively nontoxic but excesses of fat-soluble vitamins A and D can cause serious problems, (McDowell, 1989).

Vitamins originate primarily in plant tissues or via microbial processes. Fat soluble vitamins A and D differ from the water soluble B vitamins in that they occur in plant tissue in the form of a provitamin (a precursor of the vitamin), which can be converted into a vitamin in the animal body. There are no known provitamins for any of the water-soluble vitamins. Fat and water soluble vitamins also differ in that water soluble B vitamins are universally distributed in all living tissues, whereas fat soluble vitamins are completely absent from some tissues, (McDowell, 1989).

Vitamin A and β-Carotene

Vitamin A is the generic name given to compounds having the biological activities of retinol; the activities include paracrine, protein modifying, and antioxidant functions (Mahan and Vallet, 1997). Vitamin A exists in natural products in many different forms. It exists as preformed retinoids, which are stored in animal tissues, and as provitamin A carotenoids, which are synthesized as pigments by many plants and are found in green, orange and yellow plant tissues. In milk, meat and eggs, vitamin A exists in several forms, many as long chain fatty acid esters of retinol, the predominant one being retinyl palmitate.

There are estimated to be about 500 different compounds present, with about 60 of these having pro-vitamin A activity. Generally only 5 or 6 of these provitamins are commonly encountered in foods. The reporting of vitamin A activity requires some means of standardization, in which two systems are commonly used; International Units (IU) and Retinol Equivalents (RE), (Combs, 1998).

Most of the preformed vitamin A in the diet is in the form of retinyl esters. Retinyl esters are hydrolyzed in the lumen of the small intestine to yield retinol. The retinyl esters, as well as the carotenoids, are hydrophobic and thus depend on micellular solubilization for their dispersion in the aqueous environment of the small intestine lumen. The overall absorption of retinol from retinyl esters appears to be fairly high and

appears to be minimally affected by the level and type of dietary fat. Absorption is less efficient at very high vitamin A doses, (Combs, 1998).

Vitamin A is transported to the liver mainly in the form of retinyl esters. The composition of lymph retinyl esters is independent of the fatty acid composition of the most recent meal. Retinyl palmitate comprises about one half of the total esters, with retinyl stearate comprising about one quarter and retinyl oleate and retinyl linoleate being present in small amounts.

Provitamin A carotenoids, retinyl esters, retinol, and retinal can support the maintenance of healthy epithelial cell differentiation, normal reproductive performance, and visual function.

Table 1. Known Functional Forms of Vitamin A (Combs, 1998).

Active Form	**Function**
Retinol	Transport, reproduction (mammals)
Retinyl Esters	Storage
Retinal	Vision
Retinoic Acid	Epithelial differentiation, gene transcription, reproduction

Each of the above forms can be metabolized to retinol, retinal, or retinoic acid. But unlike retinol and retinal, retinoic acid cannot be reduced to retinal or retinol.

Vitamin A has an essential role in the normal metabolism of bone. It is clear that vitamin A affects osteoclasts, which are reduced in number in vitamin A deficiency, results in excessive deposition of periosteal bone by the apparently unchecked function of osteoblasts.

Chronic deprivation of vitamin A also leads to anemia. It would appear that vitamin A deficiency results in impaired re-utilization of iron stores in the spleen and bone for erythropoiesis. Research has shown that supplemental vitamin A increases iron status in anemic, vitamin A-deficient humans and animals, (Combs, 1998).

Vitamin A deficient animals and humans are typically more susceptible to infection than are individuals that are not deficient. Deficient animals show changes in lymphoid organ mass, cell distribution, histology, and lymphocyte characteristics. Retinol may be a specific growth factor for B-lymphocytes. The lymphocyte proliferation can be impaired by vitamin A deprivation and thus cell-mediated immunity may be compromised by vitamin A deficiency, (Combs, 1998).

The body stores a large amount of vitamin A and tends to mitigate the effects of low dietary intakes of vitamin A. Tissue stores are mobilized in response to low vitamin A conditions. There are two effective pools of vitamin A in the body; the rate of mobilization varies between tissues according to their respective proportions of fast turnover and slow turnover pools, (Combs, 1998).

Severe micronutrient deficiencies during pregnancy lead to high rates of spontaneous abortion, fetal malformation and late fetal death. However, more moderate reductions, which occur in clinical and agricultural situations, also compromise pregnancy outcome (Ashworth and Anipatis, 2001).

The hepatic storage of vitamin A tends to mitigate against the development of intoxication due to intakes in excess of physiological needs. Persistent large overdoses (more than 1000 times the nutritionally required amount) can exceed the capacity of the liver to store and catabolize and will then result in intoxication. Some other aspects of vitamin A metabolism tend to protect against hypervitaminosis: relatively inefficient conversion of the provitamin A in the gut, the unidirectional oxidation of the vitamin to a form (retinoic acid) that is rapidly catabolized and excreted, and the relative excess capacity of CRBP (II) to bind retinol, (Combs, 1998).

Vitamin A in Reproduction and Embryonic Development

Retinoids play an important fundamental role in morphogenesis. It has been found in studies on the regenerating amphibian limb, that retinoids have profound effects in providing positional information enabling cells to differentiate into the pattern of structures relevant to their appropriate spatial locations, (Combs, 1998). It is possible that vitamin A affects cell differentiation through the actions of three morphogens: 9-cis-retinoic acid, all-trans-retinoic acid, and all-trans-3, 4-didehydroretinoic acid.

Vitamin A is necessary for reproduction, but the biochemical basis of this function is not known. Maintenance of reproduction is discharged by retinol and not retinoic acid in mammals. Rats maintained with retinoic acid grow well and appear healthy, but lose reproductive ability. Several researchers have found that vitamin A-deficient dairy cows show reduced corpus luteal production of progesterone and increased intervals between the (LH) peak and ovulation.

Vitamin A and Swine Nutrition

Delivery of retinol to the developing conceptus is accomplished through endometrial synthesis of Retinol Binding Protein (RBP) (Adams et al., 1981). Endometrial RBP may be taken up by conceptus/placenta tissue by fluid phase pinocytosis and delivered into fetal blood (Raub et al., 1985). The correlation between the size of the embryo and the retinol content in the uterine flushings is high (r=.97) (Trout et al., 1992). Retinol in the uterine secretions may function by protecting the conceptus against the oxidizing activity of uteroferrin (Vallet, 1995).

Retinol Binding Protein may have several functions within the reproductive tracts of pigs: 1) transfer of retinol to the fetus, 2) protection of tissues against oxidative reactions, and 3) provisions of a substrate to generate retinoic acid and other biologically active metabolites of retinol (Mahan and Vallet, 1997).

The treatment of sows and gilts with Vitamin A at different stages of gestation has been reported to increase subsequent litter size. Research done on gilts, where the injection of Vitamin A was given before mating, by Whaley et al. (2000) indicated that Vitamin A may influence embryonic development by advancing resumption of ovum meiosis and altering follicular hormonal environment during follicle maturation. These gilts were given 1,000,000 IU of retinyl palmitate dissolved in 5 ml of corn oil intramuscularly in the neck area 15 days after second estrus. The animals on the control treatment were given 5 ml of corn oil intramuscularly 15 days after second estrus also.

The data suggested that treatment with vitamin A advances follicular maturation and oocyte maturation when provided during the period of final follicle maturation in gilts fed high energy diets. All gilts were fed a diet supplying 11.0 Mcal ME per gilt per day. From first estrus until 7 days after second estrous the gilts were group fed once daily to provide 5.4 Mcal ME per gilt per day. The high energy diet was used as a method to reduce embryo survival thus setting the stage for possible Vitamin A effects.

The use of Vitamin A on multiparous sows has had varying results. Pusateri et al., (1999) found that giving 1,000, 000 IU of retinyl palmitate at several different stages of gestation did not influence total litter size significantly. The Vitamin A treatment had no effect on litter weight, number of runts or the number of mummies either. No treatment vs. parity interaction was detected in the study. The retinyl palmitate was dissolved in 5 ml of corn oil, the control animals also received 5 ml of corn oil. The sows were allocated to a treatment group, therefore if the sow was treated on day ten that was her only injection.

Feeding gilts a high-energy diet before estrus has been known to reduce embryo survival. Research conducted by Whaley et al. (1997) looked at the benefit of injecting Vitamin A to gilts that were fed high-energy diets. They found that injecting Vitamin A before estrus restored embryo survival to normal levels in gilts fed high-energy diets. The high-energy diet increased variation in embryo diameter, whereas the Vitamin A reduced variation in diameter and increased average diameter. The gilts were injected with 1,000,000 IU of (Vitamin A, retinyl palmitate) dissolved in corn oil. The control animals also received an injection of corn oil intramuscularly. The high energy or flush diet

delivered 11.0 Mcal ME per gilt per day. The control diet delivered 5.5 Mcal ME per gilt per day.

The effect of Vitamin A injections on gilts that were previously on a diet free of Vitamin A and beta carotene was researched by Brief and Chew, 1985. The trial was broken into 3 treatment groups: 1) deficient in Vitamin A (received 2100 IU of Vitamin A per day, 2) fed dietary supplementation of 0, 2100 or 12,300 IU Vitamin A and (or) 0, 32.6 or 65.2 mg Beta-carotene per day, and 3) injected 0 or 12,300 IU Vitamin A and 32.6 mg Beta-carotene per day administered once weekly. All gilts were fed a diet free of vitamin A and Beta-carotene for 5 weeks previous to starting the trial. Embryonic mortality was lowest in the injected gilts and thus they had more piglets at birth. The injected gilts also had heavier litters at birth and at weaning.

Most of the research on the use of Vitamin A to increase reproductive performance of gilts and sows has focused on the effects that Vitamin A has on animals fed high energy diets, or diets deficient in the Vitamin. High energy diets, or diets deficient in Vitamin A are used to decrease embryo survival as a model for studying the effects of treatment with the Vitamin.

Folic Acid

The term folate is used as a generic descriptor for folic acid and related compounds exhibiting the biological activity of folic acid. Folic acid is closely related in

function with Vitamins B 12 and B 6, the full extent of its interrelationship with these vitamins and amino acids is not completely understood, (Combs, 1998).

Folate is present in most feedstuffs fed to swine, but reported grain values are quite variable. It is generally present in feed grains in the reduced folyl polyglutamate form, but it must be cleaved and converted to the mono- or di-glutamate form before absorption from the intestinal tract. Dietary folic acid and the cleaved folyl polyglutamates from grains are absorbed across the intestinal mucosa by an active folate-binding protein transport system that is mediated by sodium (Mahan and Vallet, 1997). Oilseeds such as soybean meal and canola meal are important sources of folate in livestock rations.

There are three main types of folate-binding receptors (α, β and γ) in various body tissues including the placenta, choproid plexus, and mammary gland (Combs, 1992). Folate derivatives function in the body as acceptors or donors of single C-units in amino acid and nucleotide metabolism. Folate is required for thymidine synthesis, which is the rate limiting step in DNA synthesis (Shane and Stokstad, 1985). Consequently, during the early stages of conceptus development, when DNA, RNA, and protein synthesis is high, the need for folic acid would be expected to be higher than at other periods of pregnancy.

Folic acid is actively transported across the jejunum, and perhaps the duodenum, by a sodium coupled, carrier mediated process that is stimulated by glucose and shows a pH maximum at about pH 6. The overall efficiency of folate absorption appears to be

approximately 50 %, (Combs, 1998). Malabsorption of the vitamin occurs in diseases affecting the intestinal mucosa. Folacin is widely distributed in tissues largely in the conjugated polyglutamate forms. Normal body stores in humans have been estimated at 5-10 mg, with approximately half of that in the liver. Body folacin stores are small at birth and are rapidly depleted, particularly in small infants. Under a condition of vitamin B12 deficiency, there are defects in the conversion of pteroylmonoglutamates to polyglutamate forms that lead to functional folacin deficiency even when folic acid intake and absorption are normal. The folates function as enzyme cosubstrates in many reactions of the metabolism of amino acids and nucleotides. Folacin is needed to maintain the immune system. The functioning of the immune system was severely inhibited by folacin deficiency in rats, which is probably mediated through a reduction in DNA synthesis, resulting in impaired nuclear division. Folate deficiency in animals is generally associated with poor growth, anemia, and lesions involving skin, hair and feathers. Swine will typically display alopecia, dermatitis, leukopenia, anemia and diarrhea when deficient in folacin. Historically folacin deficiency in swine had only been produced by the simultaneous feeding of sulfa drugs, indicating that intestinal synthesis was adequate to meet the needs. Lindemann and Kornegay (1986) reported that the combination of the antibiotic mixture ASP 250 (chlortetracycline, sulfamethazine and penicillin) and folacin to a corn-soybean meal diet increased gains and feed consumption. No effect has been seen with administration of either alone.

There are no reports of adverse effects of high oral doses of folate in animals. It has been suggested that folate may form a nonabsorbable complex with zinc, thus antagonizing the utilization of that essential trace element with high intakes of folic acid.

Folic Acid in Reproduction and Embryonic Development

Folate plays an important role in normal embryogeneis. This is thought to be due to its involvement in normal cell division. Folate status has historically been linked to reduced risks of abnormalities in early embryonic development, specifically to the risk of malformations of the embryonic brain and spinal cord, (Combs, 1998). This condition can be termed neural tube defects (NTD). In humans, high incidences of low folate status have been linked to NTD births as compared to women with normal birth outcomes. Folate deprivation has been shown to cause elevated plasma homocysteine concentrations. The use of folate containing multivitamins supplements is associated with low mean plasma homocysteine levels. Human studies have indicated that folate supplements may reduce NTD'S by correcting an abnormality in homocysteine metabolism related to methionine synthase.

Folic acid is essential for synthesis of nucleic acids and in the production of certain amino acids. Research conducted by Tremblay et al. (1989) reported modest improvements in fetal survival and greater fetal protein concentration after 30 days of gestation when sows were fed folic acid supplemented diets. Folic acid supplementation at the 15-ppm level increased prostoglandin secretions in the uterus and tended to increase protein content of blastocysts on day 12 of gestation.

Folic Acid and Swine Nutrition

Despite abundant information on folic acid, the optimal dietary requirement for folic acid in gestating sows is still not clearly established (Matte and Girard, 1999). Harper et al. (1995), reported that the supplementation of gilts and third parity sows with 2 ppm of dietary Folic Acid did not affect litter size at day 45 of gestation. However, they reported that several important physical and chemical criteria associated with placental and fetal growth were influenced by folic acid supplementation. The data suggested that folic acid supplementation can enhance fetal and/or placental development up to and near day 45 of gestation, which may be a contributing factor to improved litter size at birth.

A study conducted by Matte et al, (1996) looked at the role of folic acid in uterine environment and embryonic development during early gestation. Third parity sows received a diet supplemented with 0 or 15 mg/kg. The treatments began 2 weeks before expected estrus and lasted until slaughter on either day 12 or 15 after mating. The improvement in embryonic survival attributed to dietary supplements of folic acid might be linked to changes in the secretion of uterine prostoglandins and possibly on embryonic development.

Research conducted by Harper et al., (1994) concluded that folic acid supplementation of 1, 2, and 4 ppm had no significant effect on total pigs born, pigs born alive and litter birth and weaning weights. The number of days post weaning to estrus also was not affected by folic acid treatment. The trials however indicated that increasing

levels of folic acid in the diet had a pronounced effect in attenuating decreased serum folates concentration during gestation.

Lindemann and Kornegay (1989) investigated the use of folic acid at levels of 1 ppm. The research was conducted over three parities and indicated that the number of matings required per female farrowed was less for females fed folic acid supplemented diets. The folic acid treatment of 1 ppm improved total born. However, the numbers weaned were not significantly different. The results of this work demonstrate improved sow performance through an increase in pigs born and possibly an improved conception rate when folic acid is supplemented.

Tremblay et al. (1989) researched the use of folic acid at 5 ppm in the first 30 days of gestation in a commercial swine unit. They found that the addition of 5-mg/kg folic acid between weaning and day 30 after breeding significantly improved the survival rate of fetuses during early gestation. The supplemental folic acid tended to increase the number of embryos presumably living at 30 days of gestation when this treatment was associated with a high ovulation rate. A dramatic decrease in serum folacin concentrations was observed during early and mid- gestation that may be associated in part with embryonic mortality (Matte et al., 1984).

Folic Acid and Vitamin A Antagonism

Vitamin antagonists (antimetabolites) can interfere with the activity of various vitamins. The antagonism can occur in several ways. The antagonist could cleave the

metabolite molecule and render it inactive, for example with thiaminase and thiamin. Also, the antagonist could complex with the metabolite, which is known to happen between avidin and biotin. Structural similarity can be a problem as the antagonist could occupy reaction sites and thereby deny them to the metabolite, as with dicumarol and Vitamin K.

There are no known antagonisms between Vitamin A and folic acid, however it is documented that rancid fats can inactivate biotin and destroy vitamins A, D, and E and perhaps others.

Synergism

There is no reported research on the concurrent use of Vitamin A and Folic Acid in swine. Research on the two vitamins indicates the potential for improved sow performance and leads to the question of how well the two can work in conjunction. Vitamin A plays a key role the protection of tissues against oxidative reactions.

Human research has indicated that maternal nutrition before and during pregnancy may influence the pregnancy, fetal development and the child's health in its early and also adult life. Folic acid deficiency during the periconceptional period may cause neural tube defects in the offspring. Folic acid deficiency during pregnancy may also contribute to preterm delivery and low infant birth weight. The synergistic opportunities of antioxidant vitamins in the prevention of pregnancy hypertension is an area of importance. (Szostak-Wegierek, 2000).

Plasma levels of antioxidants as well as sister chromatid exchange rate (SCE) are good indicators of DNA damage. Human research conducted by Park et al, (1999), indicated that increased plasma levels of antioxidants could prevent an increase in SCE rates which may be induced by reactive oxygen species generated from the enhanced steroid hormones in the last trimester. Park suggested that multivitamin mineral-supplement during pregnancy may in fact prevent DNA damage due to the altered hormonal profile.

Human cancer research indicates that there is no conclusive evidence that vitamins administered in large doses have significant antineoplastic effects although large doses of vitamin A, vitamin C and vitamin B12 have been used for this purpose (Bertino, 1979). Certain vitamin analogs such as folate antimetabolites can cause tumor regression and are useful clinical treatment.

Controlled studies looking at the maternal plasma concentrations of several vitamins and minerals in malformed children did not differ from the levels in non-malformed children's maternal plasma levels (Stoll et al. 1999). The use of vitamin profiles do not appear to be a suitable means for identifying women at risk for having a child with congenital malformations.

Conclusion

Early weaning has become a standard production practice throughout the industry. While increasing overall production in terms of piglets per sow per year, early

weaning decreases the sow's reproductive performance. Some of the negative effects of early weaning are decreases in litter size, reduction of conception rate, and increases in embryonic death.

Optimal nutrition of the sow or gilt is necessary for her to maximize production and longevity. Feeding the sow for maximum reproduction involves recognizing that the nutrient requirements are different at the different stages of the sow's reproductive life. Nutrient levels may immediately affect the sow or may have an affect on subsequent production.

As the swine industry continues to move to a more efficient and fast paced model, the need for larger litter sizes and short lactation lengths will be necessary. The introduction of new genetic lines that tend to be more prolific will most likely require nutritional evaluation to determine nutrient requirements for the sow to maximize the performance she has been selected for. With production models built and in place in many countries the weaning age of sows will not likely change significantly over time and the need to maximize productivity of the early weaned sow will continue to be an area of focus.

Body tissues serve as a reservoir for many micronutrients. Understanding whether or not these reserves can supply an adequate quantity during critical fetal developmental periods is necessary. Vitamins are required in trace amounts in the diet for health, growth and reproduction. Omission of a single vitamin from the diet of a species that requires it

will produce deficiency signs and symptoms. The vitamins are divided into two groups based on their solubilities in fat solvents or in water. Fat-soluble vitamins include A, D, E and K, while vitamins of the B complex and others such as C are classified as water-soluble.

The fat soluble Vitamin A is necessary for reproduction, but the biochemical basis of this function is not known. Retinoids play a fundamental role in morphogenesis. Retinoic acid will support growth and tissue differentiation, but does appear to play a role in reproduction. Retinol binding protein is believed to play a key role in the transfer of retinol to the fetus and the protection of tissue against oxidative reactions within the reproductive tracts of swine.

Folate plays an important role in normal embryogeneis. This is thought to be due to its involvement in normal cell division. Folate status has historically been linked to reduced risks of abnormalities in early embryonic development, specifically to the risk of malformations of the embryonic brain and spinal cord. Several important physical and chemical criteria associated with placental and fetal growth have been influenced by folic acid supplementation. Folic acid supplementation can enhance embryonic and/or placental development up to and near day 45 of gestation, which may be a contributing factor to improved litter size at birth.

The concurrent use of folic acid and vitamin A in gestating swine clearly requires more work as there is no reported research in this area. The protection against

oxidative reactions and the influence on placental and fetal growth are areas of opportunity with the concurrent use of these vitamins.

CHAPTER 3

HYPOTHESES AND OBJECTIVES

Hypotheses

Alternate Hypothesis: Supplementary Folic Acid and Vitamin A will increase subsequent litter size.

Null Hypothesis: Supplementary Folic Acid and Vitamin A will not increase subsequent litter size.

Will the interaction of Folic Acid and Vitamin A at varying levels be a benefit to increased productivity of the early-weaned sow?

Objectives

The purpose of this research is to evaluate the effect of supplementary folic acid and Vitamin A on the early-weaned sow. This will be accomplished through the following objective:

To determine the effect of supplementary Vitamin A and Folic Acid on the reproductive performance of the early weaned sow.

CHAPTER 4

MATERIALS AND METHODS

General Methodology

The results of this experiment conducted at the Kelly Farms Sow Research Unit near New Bothwell, Manitoba are reported in this thesis.

Two hundred (200) Manor Hybrid (Landrace x York x Large White) Sows were placed on trial at the time of weaning. The animals were randomly placed on each of the four treatments. The treatments were evenly balanced for parity. Parities 1 to 4 were used on the trial. The distribution of parities within the trial is shown in Table 4.1.

TABLE 4.1 Allocation of sows by parity and treatment.

Parity	- Folic [1]		+ Folic [2]	
	-A	+A	-A	+A
1	15 sows	15 sows	15 sows	15 sows
2	15 sows	15 sows	15 sows	15 sows
3	15 sows	15 sows	15 sows	15 sows
4	15 sows	15 sows	15 sows	15 sows
Total	60	60	60	60

[1] Folic Acid fed at 3 mg/kg.

[2] Folic Acid fed at 7 mg/kg.

The sows were weaned from the farrowing crate at 17 +/- 2 days, and then placed into a breeding stall within the breeding section of the barn. The flooring within the stall is approximately ½ solid concrete with hot water heating, and the other half is a slatted floor.

The animals were randomly allocated to a treatment at the time of weaning. They were weighed at the time of weaning and then again at the time of breeding. The sows were then weighed again at day 112 of gestation, just before expected farrowing and at the subsequent weaning events. The distribution of sow body weight samples is indicated in Table 4.2.

TABLE 4.2 . Number of sows weighed throughout the trail.

Parameter	- Folic [1]		+ Folic [2]	
	-A	+A	-A	+A
Weight at Weaning (Start) (kg)	60 sows	60 sows	60 sows	60 sows
Weight at Breeding (kg)	60 sows	60 sows	60 sows	60 sows
Weight at Day 112 of Gestation (Kg)	56 sows	49 sows	55 sows	50 sows
Weight at Weaning (End) (kg)	54 sows	49 sows	55 sows	49 sows

[1] Folic Acid fed at 3 mg/kg.

[2] Folic Acid fed at 7 mg/kg.

Backfat measurements (P2) were taken by ultrasound (Scanmatic SM-1), (Medimatic, Copenhagen, Denmark) at the time of weaning and then again at the time of breeding. The sows were then backfat tested again at the time of the subsequent farrowing and weaning events. The distribution of sow back fat samples is indicated in Table 4.3.

TABLE 4.3 . Distribution of sow back fat samples (P2) throughout the trial.

Parameter	- Folic [1]		+ Folic [2]	
	-A	+ A	-A	+A
Back fat at Weaning (Start) (mm)	60 sows	60 sows	60 sows	60 sows
Back fat at Breeding (mm)	60 sows	60 sows	60 sows	60 sows
Back fat, Day 112 of Gestation (mm)	56 sows	49 sows	55 sows	50 sows
Back fat at Weaning (End) (mm)	54 sows	49 sows	55 sows	49 sows

[1] Folic Acid fed at 3 mg/kg.

[2] Folic Acid fed at 7 mg/kg.

Vitamin Program

The trial involved the use of two vitamins: Vitamin A and folic acid. The Vitamin A (retinyl palmitate) was injected (I.M.) and the Folic Acid was a dietary treatment. The vitamin A (Bimedia –MTC, Cambridge, ON Canada) was injected as a 2 ml dose at the time of weaning. Each 2-ml dose contains 1,000,000 I.U. of Vitamin A. The product also contained, Benzyl Alcohol 2 % w/v, Vitamin E, BHT and BHA as antioxidants in an emulsifiable base. The vitamin was injected intra muscularly in the neck muscle using a 16 gauge x 1 ½ inch needle (Monoject, Mansfield, Massachusetts USA). The syringe used for delivery was a 5-ml multi dose syringe (Socorex, Ecublens/Lausannen, Switzerland). Sows not receiving vitamin A received a 2ml

injection of a placebo (Bimedia-MTC, Cambridge, ON Canada). The placebo was the current Bimedia-MTC Vitamin AD Injectable formula with vitamin D3 and vitamin A propionate removed. Both products were filled in a 50-ml amber glass vial using 20-mm aluminum non-tear seal and 20 mm red rubber stopper.

The folic acid was manufactured as a premix by (Landmark Nutrition, Landmark, MB Canada). The premix was then incorporated into a pelleted ration (Landmark Feeds Inc., Landmark, MB Canada).

The folic acid supplemented ration was fed to treatments (+F-A) and (+F+A). The ration was hand fed to the animals while the animals were housed in the breeding and dry sow sections of the barn. The folic acid supplemented ration was fed one time per day throughout from weaning, throughout gestation until the animals were moved into the farrowing rooms at approximately day 112 of gestation.

Feeding Program

The basal diets were formulated to meet or exceed National Research Council nutrient requirements for breeding swine.

Breeding and Gestation

The sows were fed a 15 % Hog Breeder Ration (Landmark Feeds Inc.) from the day of weaning into the breeding stall until 35 days post breeding. At this point two pregnancy tests were completed and the sows were moved to the gestation barn. Once the

sows were moved to the gestation barn, they were placed on a 13.5 % protein pelleted dry sow ration, (Landmark Feeds Inc., Landmark, MB Canada). The amount of feed delivered each day was determined by the feeding schedule routinely incorporated in the barn (Elite Swine Inc., Landmark, MB Canada), (Figure A3). Treatment groups (+F-A) and (+F-A) were hand fed the pelleted ration in the breeding and dry sow barns. Treatment groups (-F+A) and (-A-F) were fed through the automatic feed system. The feed is delivered at 7 am each morning into a stainless steel trough containing 1-2 inches of water remaining from the night before. Once all the feed was consumed the troughs were filled with fresh water and then topped up a few times throughout the day.

Breeder Diets

The sows were fed a breeder diet until placed in the gestation barn at approximately 30 days post breeding. There were two breeder diets used on the trial. Both diets were 15 % protein and 2800 Kcal/kg ME. The vitamin A was standardized at 8000 IU/Kg for both diets as the vitamin A treatment was by intra muscular injection. The folic acid levels were 3.0 mg/kg for the treatments (-A-F) and (+A-F). The treatment groups (-A+F) and (+A+F) both were on the diet with folic acid at 7.0 mg/kg. The diet specifications for the breeder diets are summarized in Table 4.4. The components and the controls used in the development of the diets are listed in the appendix.

Dry Sow Diets

Once in the dry sow barn the sows were on the dry sow diets until they were moved into the farrowing crates. There were two main dry sow diets used on the trial.

Both diets were 13.5 % protein and 2750 Kcal/kg ME. The vitamin A was consistent at 8000 IU/Kg for both diets as the vitamin A treatment was by intra muscular injection. The folic acid levels were 3.0 mg/kg for the treatments (-A-F) and (+A+F). The treatment groups (-A+F) and (+A+F) both were on the diet with folic acid at 7.0 mg/kg. The diet specifications for the dry sow diets are summarized in Table 4.4.

Farrowing

Once the sows were moved into the farrowing area, they were fed an 18 % protein pelleted lactation ration. All sows were fed the same diet across all treatments. The sows were fed 2 times per day to appetite using a feed intake card (Elite Swine Inc., Landmark, MB Canada) illustrating minimum requirements (Figure A4). The feed was hand delivered into a hopper style feeder. Water was supplied by a nipple adjacent to the feeder, with a flow rate of 2 litres per minute.

Lactation Diet

As there were no treatments delivered during lactation, here was only one diet fed to all the animals during the trial. The lactation diet was an 18 % protein diet with energy levels of 3125 Kcal ME. There were no treatments in the farrowing section of the barn, therefore all of the sows across all of the four treatment groups received the same diet. The Folic Acid levels were 3.0 mg/kg and the Vitamin A was formulated at 8000 IU/kg. The diet specifications are summarized in Table 4.4. The components and controls used in the development of the diets are listed in the appendix.

Table 4.4. Comparison of Diet Specifications

Diets	ME Kcal/kg (min)	Lysine Total % (min)	Lysine App. Dig % (min)	Crude Fat % (min)	Crude Fibre % (min)	Calcium % (act)	Phos % (act)	Sodium % (act)	Vit A (Iu/KG) (act)	Folic Acid IU/KG (act)	Biotin (mg/Kg) (act)
Control Diets											
13.5 % Dry Sow	2750	0.60	0.45	2.00	5.00	1.10	0.80	0.22	8000	3.0	0.40
15 % Breeder	2800	0.85	0.67	2.50	5.00	1.00	0.80	0.20	8000	3.0	0.60
18 % Lactation	3125	1.00	0.80	5.00	4.75	1.10	0.80	0.20	8000	3.0	0.40
Folic + Diets											
13.5 % Dry Sow	2750	0.60	0.45	2.00	5.00	1.10	0.80	0.22	8000	7.0	0.40
15 % Breeder	2800	0.85	0.67	2.50	5.00	1.00	0.80	0.20	8000	7.0	0.60

Lighting Program

All sows were maintained under 16 hours of light and 8 hours of darkness. The lights run on an automatic timer. The light is given off by fluorescent bulbs located on the ceiling of the barn.

Estrus Detection and Breeding

The sows were exposed to the boar from day 3 after weaning until breeding occurred. Boar exposure was done in a fence line method, with the boar being tethered to the stall in front of the sow. Sows were exposed to the boar twice per day for 10 minutes each time. All estrus checks were done by three technicians familiar with the signs of estrus and standing estrus. Signs of estrus included swelling of the vulva, redness of the vulva, mucous secretion, restlessness, and willingness to stand to back pressure by a technician. Standing estrus was defined as the time at which the sow stood to back pressure by a technician. When the sow was determined to be in standing estrus she was inseminated artificially with a golden pig artificial insemination rod (Insemination Technics and Supplies, Walworth, Wisconsin). The fresh semen was contained in a plastic bottle containing 2 billion live sperm cells of pooled Duroc semen (Carlo Genetics Inc., St. Anne MB, Canada). Each sow was inseminated twice as per an AM, AM sequence. The sows were left in the stall where they were bred until 35 days post breeding. They were checked for a return to estrus between 17 and 23 days. They were then ultrasound checked for pregnancy at 24 days post service and again at 35 days. They were again checked for return to estrus from 38-44 days post service, while in the gestation section of the barn.

Statistical Analysis

The sows were completely randomly assigned to one of the four treatments (-A-F), (+A-F)), (-A+F) or (+A+F) using a stratified random sampling procedure with respect to parity. The levels of folic acid as well vitamin A in the base and treatment diets as well as the amount of vitamin A or placebo injected by treatment is summarized in Table 4.5.

The model used for analysis included the effects of treatment, as well as the trial effects and interactions of trial with treatments. The data will be summarized using a 2 x 2 factorial arrangement of treatments.

Model $\mathbf{Y}_{ijk} = \mu + \mathbf{F}_i + \mathbf{A}_j + \delta_{ij} + \mathbf{e}_{ijk}$

- Where $_i$ and $_j$ refer to the levels of Folic Acid and Vitamin A.
- Where $_k$ refers to the experimental unit with the treatments.

Chi-Square analysis was completed on the frequency of still born and mummified piglets.

Significance level will be tested at the .05 level. P-values ranging from .05-.10 will not be considered significant, however will be considered as a trend towards significance.

Table 4.5. Comparison of Vitamin Levels by Treatment

Vitamin Level	Treatment			
	- Folic		+ Folic	
	-A	+A	-A	+A
Folic Acid (mg/kg)	3.0	3.0	7.0	7.0
Vitamin A (Diet) (IU)	8000	8000	8000	8000
Vitamin A Injected (IU)	-	1,000,000 (2 ml)	-	1,000,000 (2 ml)
Placebo Injected	2 ml	-	2 ml	-

CHAPTER 5

RESULTS

Dry Sow Feed Provided

Dry Sow Feed –Total Dry Sow Feed Provided/Sow (kg)

The dry sow feed was delivered according to recommended feeding program attached in Figure A3. Therefore the total dry sow feed provided was very consistent amongst the four treatments. The least square means ranged from (290.20 – 290.79) with standard errors very low and consistent, ranging from (0.12 – 0.13). The dry sow feed provided data is summarized in Table 5.1. All values reported in the results are least square means ± standard error of the means, unless otherwise stated.

Dry Sow Feed - Dry Sow Feed Provided/Sow/Day (kg)

As with the total dry sow feed provided the dry sow feed provided per day was very consistent among the four treatments. The least square means ranged from (2.52 – 2.53) with standard errors very low and consistent at (0.001) for all four treatments. The very consistent feed disappearance per sow is important to allow any differences in performance to be due to the treatment effects. The dry sow feed provided per sow per day is summarized in Table 5.1.

Table 5.1. Comparison of Dry Sow Feed Provided

Parameter	- Folic		+ Folic	
	-A n=56	+A n=49	-A n=55	+A n=50
Total Dry Sow Feed Provided. (kg)	290.20 (0.12)	290.34 (0.13)	290.79 (0.12)	290.56 (0.13)
Dry Sow Feed Provided/Sow/Day (kg)	2.52 (0.001)	2.53 (0.001)	2.53 (0.001)	2.53 (0.001)
Folic Acid/Sow/Day (mg)	7.57 (0.006)	7.57 (0.007)	17.70 (0.006)	17.69 (0.007)
Vit A/Sow/Day (IU)	20187.36 (8.39)	20197.50 (8.97)	20228.49 (8.46)	20212.60 (8.88)

Dry Sow Feed – Folic Acid/Sow/Day (mg)

The diets were formulated to deliver 3.0 or 7.0 mg/kg according to treatment protocols. The treatment groups (-A-F) and (+A-F) were very consistent in the amount of Folic Acid delivered per sow per day with least square means being the same (7.57). The treatment groups (-A+F) and (+A+F) were also very consistent with least square means being similar from (17.69 – 17.70). The Folic Acid provided per sow per day data is summarized in Table 5.1. Targeted folic acid per treatment was accomplished with very low standard errors reported (0.006 – 0.007).

Dry Sow Feed – Vitamin/Day (IU)

The diets were formulated to deliver 8000 IU/kg to all off the four treatment groups, as the Vitamin A treatment was by intra muscular injection. The amount of Vitamin A delivered per sow per day was very consistent with least square means ranging from (20187.36 – 20228.49). The targeted Vitamin A per sow per day for the trial protocol was accomplished with very low standard errors reported (8.39 – 8.97). The Vitamin A per sow per day provided data is summarized in Table 5.1.

Nursing Sow Feed Disappearance

Nursing Sow Feed – Total Nursing Sow Feed Provided During Lactation (kg)

The nursing sow feed disappearance was very consistent among the four treatments with least square means ranging from 84.57 and 87.34. The standard errors

were very consistent ranging from 2.28 to 2.41. The treatment group (+A+F) had the most feed provided (87.34 ± 2.41). During lactation the nursing sows are fed to appetite. The nursing sow feed provided data is summarized in Table 5.2. A feed card indicating the minimum feed requirements per sow per day is used a guide. (See Figure A4)

Table 5.2. Comparison of Nursing Sow Feed Provided by Treatment

Parameter	- Folic		+ Folic	
	-A n= 54	**+A** n=49	**-A** n=55	**+A** n= 49
Total Nursing Sow Feed Provided/Sow (kg)	84.57 (2.29)	85.11 (2.41)	86.63 (2.28)	87.34 (2.41)
Lactation Length (Days)	16.02 (0.28)	16.20 (0.29)	16.31 (0.28)	16.27 (0.29)
Nursing Sow Feed Provided/Sow/Day (kg)	5.26 (0.08)	5.24 (0.08)	5.30 (0.08)	5.34 (0.08)

Nursing Sow Feed – Lactation Length

The weaning age or lactation length was very consistent amongst the four treatments with the least square means ranging from (16.02 – 16.33) days. The standard errors of the means ranged from (0.28 – 0.29). With the lactation length being very consistent across the treatments, this should not have been a factor in weaning weights of the pigs, sow body weight loss and sow back fat loss. The least square means and standard errors for lactation length are shown in Table 5.2.

Nursing Sow Feed – Nursing Sow Feed Provided/Day (kg)

The nursing sow feed disappearance per sow per day was very consistent amongst the four treatments on the trial with least square means ranging from (5.26 – 5.34). The standard errors ranged from (0.08 – 0.08). The treatment group (+A+F) had the highest feed disappearance (5.34 ± 0.08). The nursing sow feed disappearance per sow per day data is summarized in Table 5.2.

Reproductive Performance

Farrowing Performance – Total Litter Size Born

Vitamin A resulted in a significant difference in the total number of pigs born per litter (P=0.030). However, Folic Acid supplementation did not make a significant difference in the total numbers of pigs born per litter (P=0.911). The total number of pigs born per litter is defined as the number of pigs born alive plus the number of mummified piglets plus the number of piglets stillborn. This number is reflective of the total number of fetuses implanted and potentially available as live born piglets. The treatment group (-F+A) had the highest total born per litter (11.92 ± 0.38). However, the interaction of Folic Acid and Vitamin A did not have a significant difference in the total number of pigs born per litter (P=0.495), suggesting that the two factors Vitamin A and Folic Acid are acting independently with respect to total pigs born. The farrowing performance data is summarized in Table 5.3.

Farrowing Performance – Total Litter Size Weight (kg)

Vitamin A did not make a significant difference in the total litter weights (P=0.338). As well the Folic Acid did not make a significant difference in the total litter weights (P=0.339). The total litter size weight (kg) is defined as the weight of the pigs born alive plus the weight of the mummified piglets + the weight of the stillborn piglets. The treatment group (+A+F) had the highest total born weight (16.25 ± 0.50). However, the interaction of Folic Acid and Vitamin A did not result in a significant difference in the total litter size born weight (P=0.737). The total litter weights are summarized in Table 5.3. With the interaction not being significant we can infer that the two factors, Vitamin A and Folic Acid are acting independently with respect to total litter weight.

Table 5.3. Comparison of Litter Size Born (Parity and Treatment Interactions)

Parameter	- Folic		+ Folic		P-Values						
	-A n= 56	+A n=49	-A n=55	+A n= 50	Folic	Vit A	Interact F*A	Parity	Interact (Parity *F)	Interact (Parity*A)	Interact (Parity*A*F)
Number Total Born	10.88 (0.36)	11.92 (0.38)	11.16 (0.36)	11.71 (0.38)	0.911	0.030	0.495	0.042	0.021	0.593	0.689
Total Born Weight (kg)	15.32 (0.47)	15.95 (0.50)	15.95 (0.47)	16.25 (0.50)	0.339	0.338	0.737	0.434	0.504	0.742	0.979
Total Born Wt/Pig (kg)	1.44 (0.03)	1.37 (0.03)	1.45 (0.03)	1.40 (0.03)	0.445	0.059	0.723	0.302	0.099	0.824	0.119
Number Born Alive	9.80 (0.37)	10.94 (0.40)	10.33 (0.37)	10.98 (0.40)	0.462	0.021	0.523	0.020	0.044	0.683	0.827
Born Alive Weight (kg)	14.47 (0.51)	15.21 (0.54)	15.09 (0.51)	15.48 (0.52)	0.394	0.282	0.747	0.507	0.260	0.965	0.770
Born Alive Weight/Pig (kg)	1.51 (0.09)	1.42 (0.10	1.53 (0.09)	1.50 (0.05)	0.368	0.273	0.597	0.046	0.483	0.643	0.057

Farrowing Performance – Total Born Weight/Pig (kg)

There was a trend toward higher total born weights per pig due to the Vitamin A treatment (P=0.059). Folic Acid did not result in a significant difference in the total born weight per pig (P=0.445). The treatment group (-A+F) had the heaviest total born weight per pig (1.45 ± 0.03). The interaction of Folic Acid and Vitamin A did not result in a significant difference in the total born weight per pig (P=0.723). The total born weight per pig data is summarized in Table 5.3.

Farrowing Performance – Born Alive Litter Size.

The injected Vitamin A made a significant difference in the number of pigs born alive per litter (P=0.021). Consistent with the total pigs born result, Folic Acid did not make a significant difference in the number of pigs born alive per litter (P=0.462). The number of pigs born alive per litter is defined as the total number of pigs born minus the number of mummified piglets minus the number of piglets stillborn. This number is reflective of the number of piglets available to potentially be weaned. The treatment group (+A+F) had the highest number of pigs born alive per litter (10.98 ± 0.40). The interaction of Folic Acid and Vitamin A did not result in a significant difference in the total number of pigs born per litter (P=0.523), suggesting that the two factors, Vitamin A and Folic Acid are acting independently with respect to the number born alive per litter. The born alive litter size data is summarized in Table 5.3.

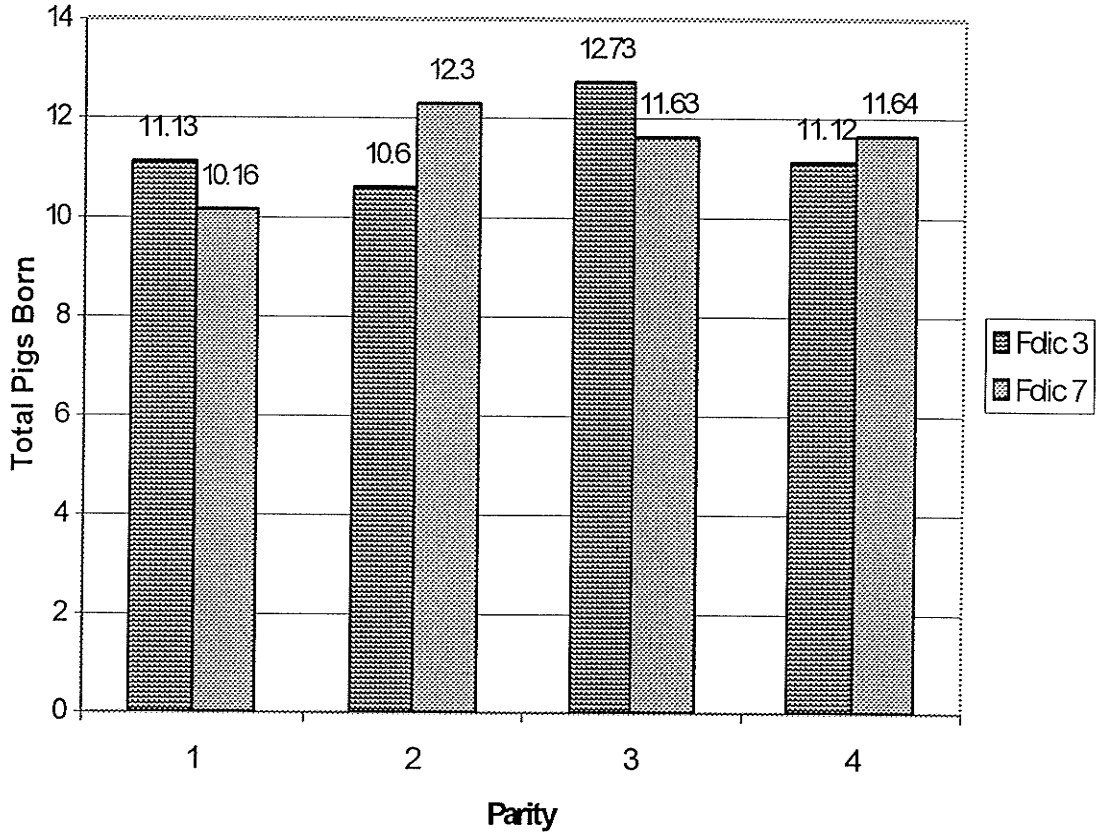
Farrowing Performance – Born Alive Weights

Vitamin A and Folic Acid did not make a significant difference on the born alive litter weights or weights per pig. The born alive litter weight is summarized in Table 5.3. With the interaction not being significant we can infer that the two factors, Vitamin A and Folic Acid are acting independently with respect to born-alive litter weight.

Farrowing Performance – Parity Effects (Total Born Litter Size)

Not surprisingly parity made a significant difference in the number of pigs total born (P=0.042). As the sow matures we expect the performance to improve. The parity and treatment interactions are summarized in Table 5.3. The parity three sows had the highest number total born of all four parities (12.18 ± 0.37 piglets per litter). The standard errors were very similar for all parities. The interaction of Parity and Folic Acid resulted in a significant difference in the total number of pigs born (P=0.021). The total born numbers by parity are summarized by Folic Acid level in Figure 5.1. The interaction of parity and Vitamin A did not result in a significant difference in the total number of pigs born (P=0.593). The interaction of parity, Folic Acid and Vitamin A did not result in a significant difference in the total number of pigs born (P=0.689). The farrowing performance parity data is shown in Table 5.4.

Figure 5.1. Total Pigs Born By Parity (Folic Treatment)



Farrowing Performance – Parity Effects (Total Born Litter Weights)

There was no significant difference in the total pigs born litter weight amongst the four parities on the trial (P=0.434). The parity and treatment interactions are summarized in Table 5.3. The parity three sows had the highest total born weight of all four parities (16.38 ±0.50). The standard errors were very similar for all parities. The interaction of parity and Folic Acid did not result in a significant difference in the total born litter weight (P=0.504). As well there was not a significant difference in the total born litter weight with the interaction of Folic Acid and Vitamin A (P=0.742). The interaction of parity, Folic Acid and Vitamin A did not result in a significant difference in the total born litter weight (P=0.979). The parity effects total born litter weights data is summarized in Table 5.4. With the interactions not being significant we can suggest that the factors are acting independently.

Table 5.4. Comparison of Litter Size and Weights By Parity

Parameter	**Parity**			
	Parity 1 n= 50	Parity 2 n= 55	Parity 3 n=51	Parity 4 n=54
Number Total Born	10.64 (0.38)	11.45 (0.36)	12.18 (0.37)	11.38 (0.36)
Total Born Litter Weight (kg)	15.32 (0.50)	16.12 (0.47)	16.38 (0.50)	15.65 (0.48)
Total Born Wt/Pig (kg)	1.45 (0.03)	1.44 (0.03)	1.38 (0.03)	1.40 (0.03)
Number Born Alive	9.75 (0.40)	10.60 (0.37)	11.46 (0.39)	10.25 (0.38)
Born Alive Litter Weight (kg)	14.80 (0.54)	15.63 (0.51)	15.21 (0.53)	14.61 (0.51)
Born Alive Wt/Pig (kg)	1.56 (0.05)	1.54 (0.05)	1.37 (0.05)	1.47 (0.05)

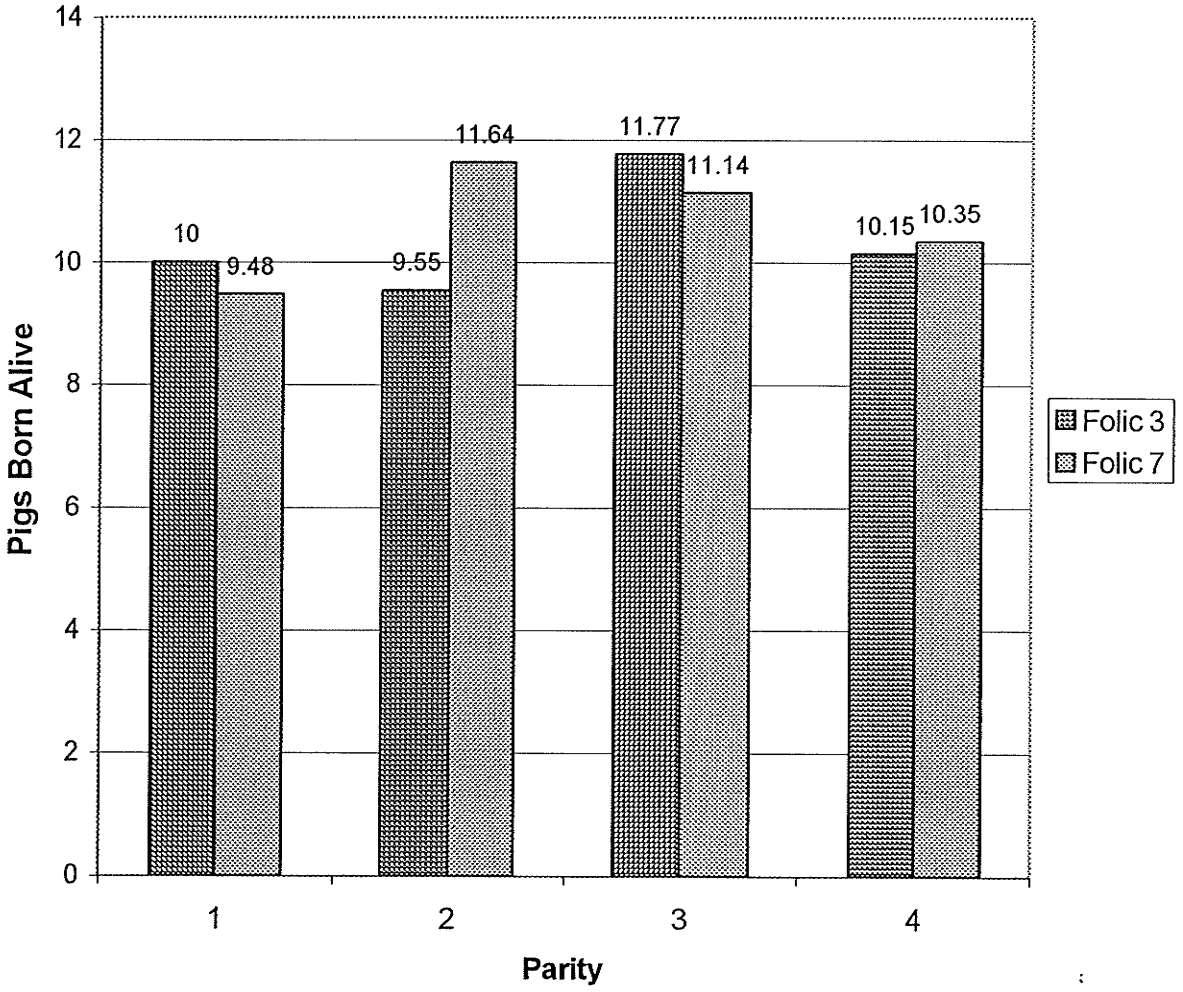
Farowing Performance – Parity Effects (Total Born Wt/Pig) (kg)

There was no significant difference in the total born weight per pig amongst the four parities on the trial (P=0.302). The parity and treatment interactions are summarized in Table 5.3. The parity 1 animals had the heaviest total born weight/pig (1.45 ± 0.03). As the parity increased the total born weight per pig decreased slightly. Standard errors were very consistent (0.03) for all four parities. The Vitamin A and parity interaction did not make a significant difference in the total born weight per pig (0.824). The interaction of Folic Acid and parity did not result in a significant difference in the total born weight per pig (P=0.099). The parity effects total born weight per pig data is summarized in Table 5.4.

Farrowing Performance – Parity Effects (Born Alive Litter Size)

Consistent with the total pigs born, parity made a significant difference in the number of pigs born alive (P=0.020). The parity and The parity three animals had the highest number born alive per litter of all four parities (11.46 ± 0.39). The standard errors ranged from (0.37 - 0.40) over the four parities. The interaction of parity and Folic Acid resulted in a significant difference in the number of pigs born alive per litter (P=0.044). The born alive numbers by parity are illustrated by Folic Acid level in Figure 5.2. The interaction of parity and Vitamin A did not result in a significant difference in the number of pigs born alive (P=0.683). The interaction of parity, Folic Acid and Vitamin A did not result in a significant difference in the number of pigs born alive per litter (P=0.827). The parity effects born-alive litter size data is summarized in Table 5.4.

Figure 5.2. Pigs Born Alive By Parity (Folic Treatment)



Farrowing Performance – Parity Effects (Born Alive Litter Weight) (kg)

Parity did not make a significant difference in the born alive litter weight (P=0.507). The parity 2 sows had the highest born alive litter weight (15.63 ± 0.51). The standard error of the means ranged from (0.51 to 0.54). The interaction of parity and Folic Acid did not result in a significant difference in the born alive litter weight (P=0.260). As well the interaction of parity and Vitamin A did not result in a significant difference in the born alive litter weight (P=0.965). The interaction of parity, Folic Acid and Vitamin did not result in a significant difference in the born alive litter weight (P=0.770). The parity effects average born-alive weight per pig data is summarized in Table 5.4.

Farrowing Performance – Parity Effects (Born Alive Weight/Pig) (kg)

There was a significant difference in the born alive weight per pig amongst the four parities on the trial (P=0.046). The parity 1 had the heaviest born alive weight per pig (1.56 ± 0.10). The parity 1 animals actually had fewer numbers born alive but individually they were heavier. The parity and Vitamin A interaction did not result in a significant difference in the born alive weight per pig (P=0.643). As well, the interaction of Folic Acid and parity did not result in a significant difference in the born alive weight per pig (P=0.483). The interaction between parity, Vitamin A and Folic Acid did not make a significant difference in the born alive weight per pig (P=0.057). It appears that the interaction between parity, Vitamin A and Folic Acid showing a level close to significance is due to the difference in the born alive weight per pig between the parities and not due to either of the treatments.

Farrowing Performance - (Mummified Piglet Results)

The results of the mummified piglets per treatment group have been summarized into a frequency and probability table, see table 10. The total number of mummified piglets ranged from 10 to 19 per treatment group or .21 to .35 per litter farrowed. The probability of the litter farrowed having no mummified piglets was best for the treatment group (-A+F) at (0.86). This Folic Acid supplemented group farrowed an average of 0.21 mummified piglets per litter. The treatment group (+A+F) had the lowest probability of having a litter farrowed with no mummified piglets at (0.74). The number of mummified piglets per litter ranged from a minimum of 0 to a maximum of 3 within the treatment groups. The treatment group (+A+F) however did not have a litter with anymore than 2 mummified piglets per litter despite having the lowest probability of having zero mummified piglets. The Pearson Chi-Square analysis indicated that there was no significant difference in the frequency of mummies amongst the treatments (P=0.488).

Table 5.5. Comparison of Mummified Piglets by Treatment Group.

Parameter	**Treatment ***			
	- Folic		**+ Folic**	
Frequency Mummified Level	**-A** n= 56	**+A** n=49	**-A** n=55	**+A** n= 50
0	44 (0.79)	37 (0.76)	47 (0.86)	37 (0.74)
1	6 (0.11)	9 (0.18)	5 (0.09)	10 (0.20)
2	5 (0.09)	2 (0.04)	1 (0.02)	3 (0.60)
3	1 (0.02)	1 (0.02)	2 (0.04)	0
Totals Mummified Piglets/Treatment	19	16	10	16
Average/ Litter	0.35	0.33	0.21	0.33
Mummified %/Litter	3.24	2.74	1.90	2.79

* Values are the number of sows with mummified piglets and (probabilities) of occurrence at that level within the treatment.

Farrowing Performance - (Stillborn Piglet Results)

The results of the stillborn piglets per treatment groups have been summarized into a frequency and probability table, see Table 5.6. The total number of stillborn piglets ranged from (19 – 41) per treatment group, or (0.39 to 0.76) per litter farrowed. The probability of a litter farrowed having no stillborn piglets was best for (+A+F) treatment group at (0.68). The treatment group (+A-F) had the lowest probability of having a litter farrowed with no stillborn piglets at (0.55). The number of piglets stillborn per litter farrowed ranged from a minimum of 0 to a maximum of 5. The treatment group (+A+F) had the lowest total number of stillborn piglets per litter at 0.39; this number was less than half of the control group. The treatment group also did not have anymore than 2 stillborn piglets per litter farrowed. The treatment group (-A+F) was the only treatment group to have more than 3 stillborn piglets per litter. This group had one litter with four and one litter with five piglets stillborn per litter. The Pearson Chi-Square analysis indicated that there was no significant difference in the number of stillborn piglets across the treatments (P=0.428).

Table 5.6. Comparison of Stillborn Piglets By Treatment Group.

Parameter	**Treatment ***			
	- Folic		**+ Folic**	
Frequency Stillborn Level	**-A** n= 56	**+A** n=49	**-A** n=55	**+A** n= 50
0	32 (0.57)	27 (0.55)	35 (0.64)	34 (0.68)
1	11 (0.20)	14 (0.29)	13 (0.24)	13 (0.26)
2	9 (0.16)	6 (0.12)	4 (0.07)	3 (0.60)
3	4 (0.07)	2 (0.04)	1 (0.02)	0
4	0	0	1 (0.02)	0
5	0	0	1 (0.02)	0
Total Stillborn Piglets/Treatment	41	30	33	19
Average Stillborn Piglets/Litter	0.76	0.61	0.60	0.39
Stillborn %/ Litter	6.98	5.13	5.38	3.31

* Values are the number of sows with stillborn piglets at that level and (probabilities) of occurrence at that level within the treatment.

Weaning Performance – Pigs Weaned Per Litter

Vitamin A did not result in a significant difference in the number of pigs weaned per litter (P=0.526). As well Folic Acid treatment did not result in a significant difference in the number of pigs weaned per litter (P=0.524). The total number of pigs weaned per litter is defined as the number of pigs born alive minus the number of piglets that were accidentally killed or were euthanized in lactation. This number is reflective of the total number of saleable piglets from the sow farm. The treatment group (+A-F) weaned the most number of pigs per litter (9.64 ± 0.23). The interaction of Folic Acid and Vitamin A did not show a significant difference in the total number of pigs weaned per litter (P=0.396), suggesting that the two factors, Vitamin A and Folic Acid are acting independently with respect to pigs weaned per litter. Total pigs weaned data is summarized in Table 5.7.

Table 5.7. Comparison of Pigs Weaned (Parity and Treatment Interactions)

Parameter	- Folic		+ Folic		P-Values						
	-A n= 54	+A n=49	-A n=55	+A n= 49	Folic	Vit A	Interact F*A	Parity	Interact (Parity *F)	Interact (Parity*A)	Interact (Parity*A*F)
Number Pigs Weaned	9.01 (0.22)	9.64 (0.23)	9.35 (0.22)	9.60 (0.23)	0.524	0.526	0.396	0.213	0.309	0.860	0.912
Litter Weight (kg)	46.58 (1.47)	49.45 (1.54)	50.02 (1.45)	49.54 (1.56)	0.244	0.424	0.263	0.868	0.570	0.432	0.759
Wean Weight/Pig	5.25 (0.13)	5.17 (0.14)	5.37 (0.13)	5.21 (0.14)	0.567	0.368	0.753	0.059	0.914	0.608	0.660
Pig Deaths/Litter	0.87 (0.34)	1.30 (0.35)	0.98 (0.33)	1.34 (0.36)	0.822	0.260	0.921	0.037	0.057	0.448	0.687

Weaning Performance – Litter Wean Weights

The litters were weighed individually as they were weaned and prepared for shipping to the off-site nursery. Folic Acid and Vitamin A did not result a significant difference in the litter wean weights or wean weight per pig. The interaction of Folic Acid and Vitamin A did not result in a significant difference in the litter wean weights or wean weight per pig. With the interaction not being significant we can suggest that the two factors are acting independently with respect to litter wean weights. The weaning performance data is summarized in Table 5.7.

Weaning Performance – Pig Deaths/Litter

The number of pig deaths per litter ranged from (0.87 – 1.34). Vitamin A did not result in a significant difference in the number of pig deaths per litter (P=0.260). As well Folic Acid did not result in a significant difference in the number of pig deaths (P=0.822). The treatment group (+A+F) had the most pig deaths per litter (1.34 ± 0.36). Interestingly, this treatment group had the most pigs total born and born alive, however they suffered the most piglet deaths. The interaction of Vitamin A and Folic Acid did not result in a significant difference in the number of pig deaths per litter (P=0.921).

Weaning Performance – Total Pigs Weaned (Parity and Treatment Interactions)

There was no significant difference in the number of pigs weaned per litter amongst the four parities on the trial (P=0.213). The parity and treatment interactions are summarized in Table 5.7. The parity 3 sows weaned more pigs per sow than the other

parities (9.72 ± 0.23). The interaction between Folic Acid and Parity did not show a significant difference in the number of pigs weaned per litter (P=0.309). As well the interaction between Vitamin A and Parity did not show a significant difference in the number of pigs weaned per litter (P=0.860). The interaction between Folic Acid, Vitamin A and Parity also did not show a significant difference in the number of pigs weaned (P=0.912). The pigs weaned by parity data is summarized in Table 5.8.

Weaning Performance – Litter Wean Weights (Parity and Treatment Interactions)

There was no significant difference in the litter wean weights or the wean weight per pig among the four parities on the trial. The interactions between Folic Acid as well the interaction between Vitamin A and Parity did not show a significant difference in the litter wean weights. The interaction between Folic Acid, Vitamin A and Parity also did not show a significant difference in the litter wean weights. With no significance being present within all of the interactions we can suggest that the factors are acting independently The litter wean weights by parity data is summarized in Table 5.8.

Weaning Performance – Pig Deaths Litter (Parity Effects)

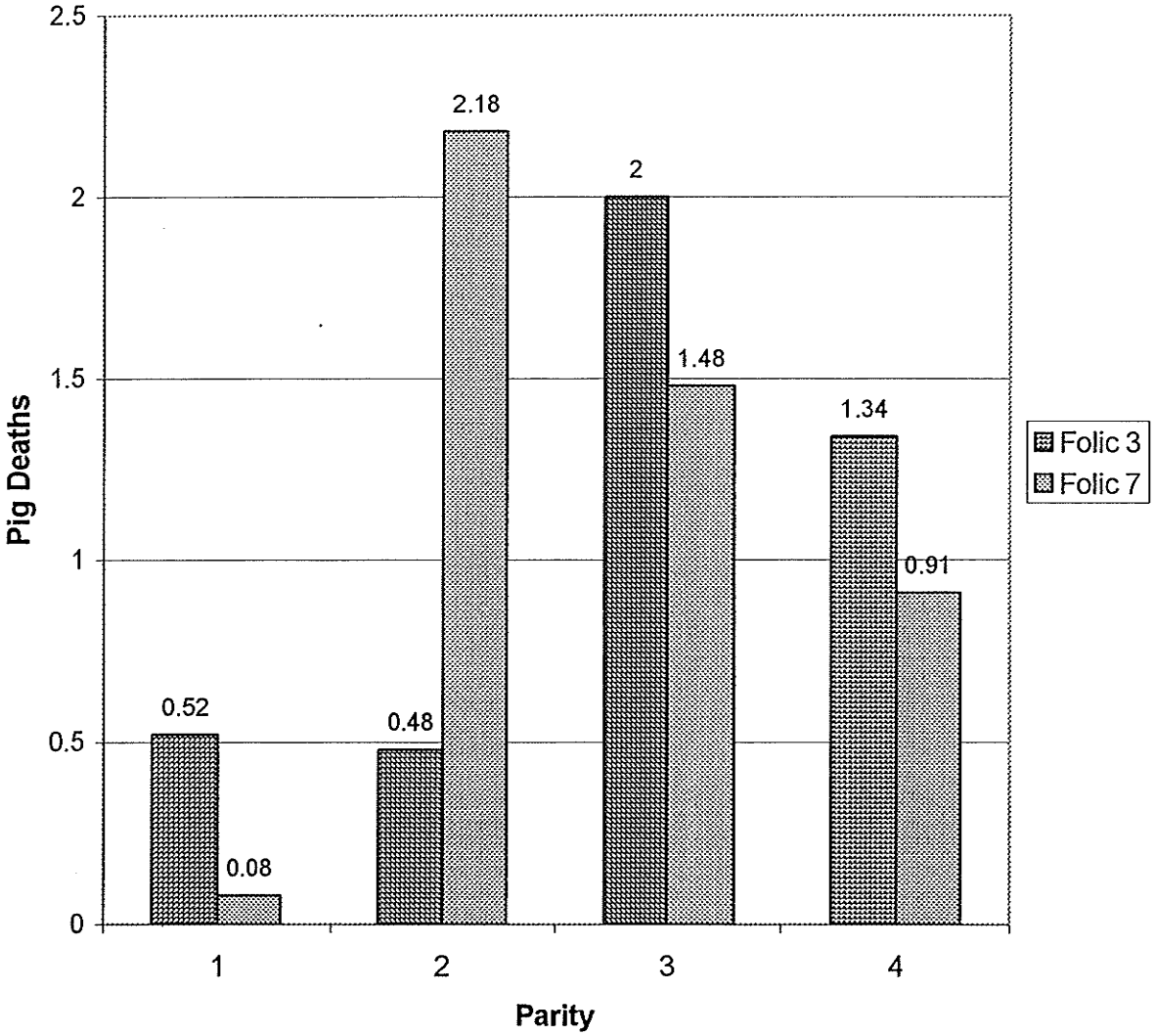
There was a significant difference in the number of pig deaths per litter across the four parities (P=0.037). The parity and treatment interactions are summarized in Table 5.7. The parity three animals had the most pig deaths (1.74 ± 0.35). The parity 1 animals had the least number of post natal pig deaths per litter (0.30 ± 0.36) of all the four parities. The parity 1 sows had the least number of pigs born alive but they were the heaviest amongst the parities. With more suckling space on the sow and a heavier pig at

Table 5.8. Comparison of Pigs Weaned by Parity.

Parameter	**Parity**			
	Parity 1 n= 48	Parity 2 n= 54	Parity 3 n=51	Parity 4 n=54
Number Weaned	9.53 (0.24)	9.22 (0.22)	9.72 (0.23)	9.12 (0.22)
Litter Wean Weight (kg)	47.90 (1.57)	49.68 (1.46)	48.86 (1.52)	49.16 (1.47)
Wean Weight/Pig (kg)	5.06 (0.14)	5.42 (0.13)	5.07 (0.13)	5.44 (0.13)
Pig Deaths/Litter	0.30 (0.36)	1.33 (0.34)	1.74 (0.35)	1.13 (0.34)

birth the parity 1 sows were able to wean a higher percentage than the other parities. The parity interactions with Vitamin A and Folic Acid did not result in a significant difference in the number of pig deaths per litter. However there was a trend towards significance in the number of pig deaths per litter from the interaction between Parity and Folic Acid. The pig deaths per litter by parity are illustrated by Folic Acid level in Figure 5.3. The data on pig deaths per litter by parity is summarized in Table 5.8.

Figure 5.3. Pig Deaths By Parity (Folic Treatment)



Pregnancy Failure Results

Each treatment group began with 60 animals per treatment. Within the treatment groups there were 15 animals for each of the four parities on the trial. The animals were allocated to the trial as they were weaned from the farrowing rooms. The reasons for pregnancy failure were recorded beginning from the allocation to treatment at the time of weaning throughout the trial to the final weaning of the piglets. The treatment group (-A+F) had the lowest number of pregnancy failures at 5. The control group (-A-F) or the control group had the next least at six pregnancy failures. Both Vitamin A treatment groups had the highest number of failures at 11 each. The main reason for failure was the sows that repeated at 21 days. The treatment group (+A+F) had 6 fall out at this time period most of all four treatment groups. The lowest number of failures at 21 days was the control treatment group (-A-F) with 2. The treatment groups (+A-F) and (-A+F) each had 4 failures at 21 days. There were 2 abortions on the trial, treatment groups (-A-F) and (+A-F) each had one abortion at 43 and 56 days respectively.

There were 4 deaths on the trial, three in lactation and one in gestation. Two out of the four deaths occurred on the treatment group (-A-F) or control. The farrowing rate percentage ranged from 81.6 to 93.3 %. Interestingly, the lowest farrowing rates occurred on the Vitamin A treatment groups (+A-F) and (+A+F) at 81.6 % and 83.3 % respectively, indicating that perhaps the injected Vitamin A may have had an impact on the number of sows staying pregnant throughout the trial. The pregnancy failures appear to be distributed across all of the parities within the four treatment groups on the trial. The exception however is the treatment group (+A+F) where more than 50 % of the

failures were from parity 1 sows. The question as to the relationship between the Vitamin A injected dose versus body weight of the animal needs to be discussed. The pregnancy failure data is summarized in Table 5.9.

Sow Conditioning Performance

Sow Body Weights – Start Weights (kg)

All of the sows were weighed at the time of weaning to begin the trial and were allocated to one of the four treatments. The least square means start weights of the four treatment groups ranged from 214.12 – 222.04 kg, and standard errors were from 2.57 – 2.64. The trial was set up balanced by parity, however some variation in body weights on the animals is expected given the phenotypic variation within the sow herd. The starting sow body weights are shown in Table 5.10.

Sow Body Weights – Breed Weights (kg)

The sows were again weighed at the time of their first service. Folic Acid and vitamin A did not make a significant difference in the sow body weight at the time of breeding. The interaction group of Folic Acid and Vitamin did not result in a significant difference in the body weight of the sows at the time of breeding (P=0.924). It would however not be expected to see any treatment effects on body weights of the sows this early in the trial. The sow body weight data at breeding is located in Table 5.10.

Table 5.9. Comparison of Pregnancy Failures by Treatment Group

Parameter	Treatment *			
	- Folic		+ Folic	
	-A n= 60	+A n= 60	-A n=60	+A n=60
Total Failures	6	11	5	11
Parity 1 Failures	1	3	2	6
Parity 2 Failures	1	2	1	2
Parity 3 Failures	4	4	1	0
Parity 4 Failures	0	2	1	3
Anestrous [2]	0	3	0	0
21 Day Repeats	2	4	4	6
42 Day Repeats	0	1	0	0
Abortions	1 (43 days)	1(56 days)	0	0
Preg Check Negative	0	1	1	3
Not In Pig	1	0	0	1
Dead in Gestation	0	1	0	0
Dead in Lactation [1]	2	0	0	1
Farrow Rate %	93.3	86.0	91.7	83.3

[1] Note: Sows that died in lactation are included in the farrowing rate %.

[2] Note: Sows that fell out due to anestrous reasons are not included in the farrowing rate %.

* Values are count data for each parameter.

Table 5.10. Comparison of Sow Body Weights (Parity and Treatment Interactions)

Parameter	- Folic		+ Folic		P-Values						
	-A n= 60	+A n=60	-A n=60	+A n= 60	Folic	Vit A	Interact F*A	Parity	Interact (Parity *F)	Interact (Parity*A)	Interact (Parity*A*F)
Sow Start Weight (kg)	214.12 (2.57)	215.29 (2.64)	222.04 (2.58)	218.45 (2.57)	0.034	0.641	0.360	<0.0001	0.749	0.183	0.844
Sow Breed Weight (kg)	209.69 (2.29)	206.17 (2.35)	211.15 (2.29)	208.07 (2.28)	0.467	0.154	0.924	<0.0001	0.408	0.156	0.897
Wean to First Service [1]	6.02 (0.505)	7.09 (0.518)	5.77 (0.507)	5.97 (0.504)	0.177	0.213	0.392	0.027	0.432	0.751	0.503
Sow Wean-Breed Weight Loss (kg)	7.55 (0.92)	9.12 (0.95)	10.89 (0.93)	10.38 (0.92)	0.014	0.574	0.267	<0.0001	0.921	0.871	0.481
	- Folic		+ Folic								
	-A n= 56	+A n=49	-A n=55	+A n= 50							
Sow Farrow Body Weight (kg)	259.29 (2.69)	262.80 (2.81)	268.83 (2.66)	262.78 (2.85)	0.086	0.646	0.085	<0.0001	0.356	0.193	0.543
Sow Wean Weight (kg)	226.88 (2.78)	230.04 (2.90)	231.20 (2.75)	228.13 (2.95)	0.671	0.987	0.257	<0.0001	0.179	0.053	0.667
Sow Farrow-Wean Weight Loss (kg)	32.42 (2.09)	32.76 (2.18)	37.63 (2.06)	34.65 (2.21)	0.099	0.539	0.438	0.950	0.491	0.521	0.975
Wean to First Service (End)	6.44 (0.61)	7.71 (0.63)	5.88 (0.61)	6.05 (0.64)	0.075	0.247	0.373	0.023	0.020	0.989	0.361

[1] Three sows on treatment group (-F+A) were anestrous and were not bred.

Sow Body Weights – Wean –Breed Weight Loss (kg)

The amount of body weight loss from weaning to breeding is not a frequently reported number. The least square means ranged from (7.55 – 10.89). The standard errors of the mean are small and consistent ranging from (0.92 – 0.95). Interestingly the Folic Acid treatment had an effect on the wean to breed weight loss (P=0.014). The Vitamin A did not significantly effect the weight loss (P=0.574). The interaction of Vitamin A and Folic Acid did not make a significant difference in the weight loss from weaning to breeding (P=0.267). The sow body weight loss from weaning to breeding data is located in Table 15.

Sow Body Weights – Weaning to First Service Interval (Days)

The number of days until the sow is bred back after weaning is important to measuring non-productive sow days, which if not managed well can be costly to the farm. The average WEI ranged from 5.77 to 7.09 days. The standard errors were small and consistent across the treatment groups. Folic Acid and Vitamin A did not make a significant difference in the weaning to first service interval. The weaning to first service data is shown in Table 5.10

Sow Body Weights – Farrowing Body Weight (kg)

The sows were again weighed as they entered the farrowing crates from the gestation barn. The Folic Acid and Vitamin A did not make a significant difference in the

body weight of the sows entering farrowing. The interaction of Folic Acid and Vitamin A did not make a significant difference in the sow body weights entering farrowing (P=0.085). Sow body weights at farrowing are shown in Table 5.10.

Sow Body Weights – Sow Wean Weights (kg)

The sows were again weighed as they were weaned and placed in the breeding barn. The Folic Acid and Vitamin A treatment did not result in a significant difference in the body weight of the sows at the time of weaning or in the amount of body weight loss during lactation. Sow wean weight and body weight loss in lactation data is shown in Table 5.10.

Sow Body Weights – Weaning to First Service Interval (End)

The weaning to first service interval at the end of the trial is the number of days from the time the sows were weaned out of the farrowing rooms at the completion of the trial until they were again served. The wean to first service interval can be a reflection of the sow body condition as they are weaned. Higher than expected body weight and back fat losses can result in an extended wean to first service interval. The least square means ranged from 6.05 – 7.71 kg. The standard errors were consistent ranging from (0.61 – 0.64). Folic Acid did not result in a trend towards significance in the wean to first service interval at the end of the trial (P=0.075). Vitamin A did not make a significant difference in the wean to first service interval (P=0.247). As well the interaction of Folic Acid and Vitamin A did not result in a significant difference in the wean to first service at the end

of the trial (P=0.373). The wean to first service interval at the end of the trial data is summarized in Table 5.10.

Sow Body Weights – Start and Breeding Weights (Parity and Treatment Interactions)

As would be expected, there was a significant difference in the starting and breeding body weights of the sows by parity (P=<0.0001). The sow body weights parity and treatment interactions are summarized in Table 5.10. The parity four sows were the heaviest at the start of the trial (246.50 ± 2.57). The sow body weights at the start of the trial and at the time of breeding by parity are summarized in Table 5.11.

Sow Body Weights – Weaning to First Service Interval (Parity and Treatment Interactions)

There was a significant difference in the weaning to first service interval amongst the four parities on the trial (P=0.027). The parity and treatment interactions are summarized in Table 5.10. The parity 1 sows had the highest wean to first service interval (7.53 ± 0.50 days). This finding is consistent with most production data. The interactions between Folic Acid and Vitamin A, between Parity and Folic Acid and between Parity, Folic Acid and Vitamin A were not significant. The wean to first service intervals by parity are summarized in Table 5.11. All values reported in the results are least square means ± standard errors of the means.

Table 5.11. Comparison of Sow Body Weights By Parity

	Parity			
Parameter	**Parity 1 n= 60**	**Parity 2 n= 60**	**Parity 3 n=60**	**Parity 4 n=60**
Sow Start Weight (kg)	176.13 (2.57)	212.38 (2.55)	234.88 (2.67)	246.50 (2.57)
Sow Breed Weight (kg)	172.32 (2.29)	204.08 (2.27)	225.68 (2.37)	233.01 (2.28)
Wean to First Service	7.53 (0.50)	5.57 (0.50)	5.95 (0.52)	5.80 (0.50)
Sow Wean-Breed Weight Loss (kg) [1]	6.94 (0.92)	8.30 (0.92)	9.21 (0.96)	13.49 (0.92)
	Parity 1 n= 49	**Parity 2 n= 55**	**Parity 3 n=49**	**Parity 4 n=54**
Sow Farrowing Body Weight (kg)	233.77 (2.85)	257.16 (2.66)	276.91 (2.83)	285.86 (2.68)
Sow Weaning Body Weight (kg)	199.40 (2.95)	222.03 (2.74)	242.38 (2.19)	252.44 (2.77)
Sow Farrow-Wean Weight Loss (kg)	34.37 (2.21)	35.13 (2.06)	34.53 (2.19)	33.42 (2.08)
Wean to First Service (End)	8.21 (0.64)	5.81 (0.59)	5.90 (0.65)	6.15 (0.60)

[1] Three sows were anestrous and were not bred.

Sow Body Weights – Wean to Breed Weight Loss (kg) (Parity and Treatment Interactions)

There was a significant difference in the body weight loss from weaning to breeding (P=<0.0001). The parity and treatment interactions are summarized in Table 5.10. The parity four sows lost the most weight amongst all four parities (13.49 ± 0.92 kg). As with the sow body weights at breeding, the interactions between Folic Acid and Vitamin A, between Parity and Folic Acid and between Parity, Folic Acid and Vitamin A were not significant. Again, as this was early in the trial we may not expect to see any interaction effects and the differences may be due to biological factors. The sow body weight loss from weaning to breeding by parity data is shown in Table 16.

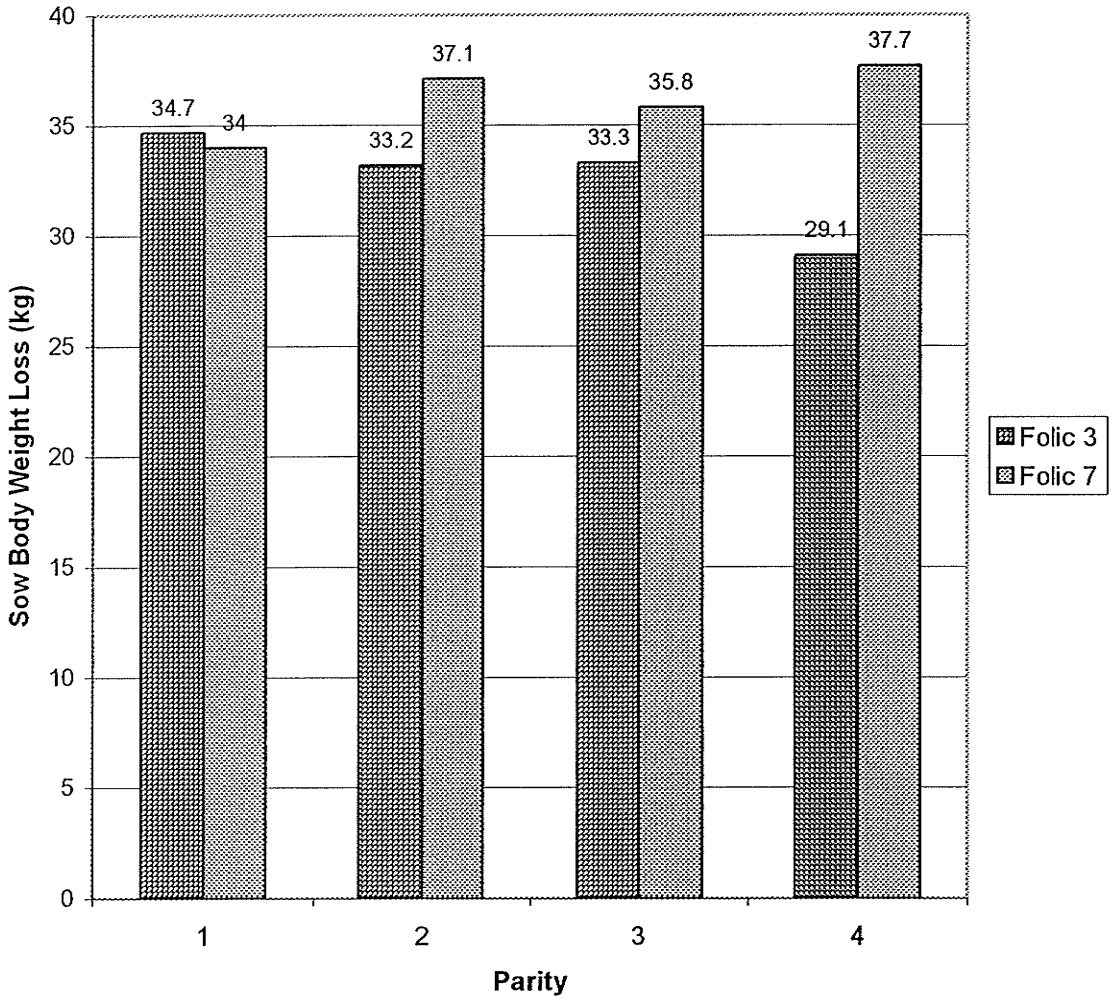
Sow Body Weights – Farrowing and Weaning Body Weights (kg) (Parity and Treatment Interactions)

There was a significant difference in the sow body weights of the sows by parity as the time of farrowing and at weaning (P=<0.0001). This is an expected result due to the age and according size of the animals. The parity and treatment interactions are summarized in Table 5.10. As expected the parity four animals were the heaviest. The interactions between Folic Acid and Vitamin A, between Parity and Folic Acid and between Parity, Folic Acid and Vitamin A were not significant. The sow body weights at farrowing and the time of weaning data by parity is summarized in Table 5.11.

Sow Body Weights – Farrow-Wean Weight Loss (kg) (Parity and Treatment Interactions)

There was no significant difference in the sow body weight loss in lactation by parity (P=0.950). The parity and treatment interactions are summarized in Table 5.10. Somewhat surprisingly, the parity two sows lost the most weight in lactation (35.13 ± 2.06 kg). The interaction between Parity and Vitamin A did not result in a significant difference in the body weight loss in lactation. The interaction of Folic Acid and Parity was not significant, however close (P=0.099). The body weight loss in lactation by parity for the Folic Acid treatment is illustrated in Figure 5.4. The interaction of Folic Acid, Vitamin A and Parity was not significant. The lack of significance within these interactions leads us to assume that the factors are acting independently. The data for sow body weight loss in lactation by parity is summarized in Table 5.11.

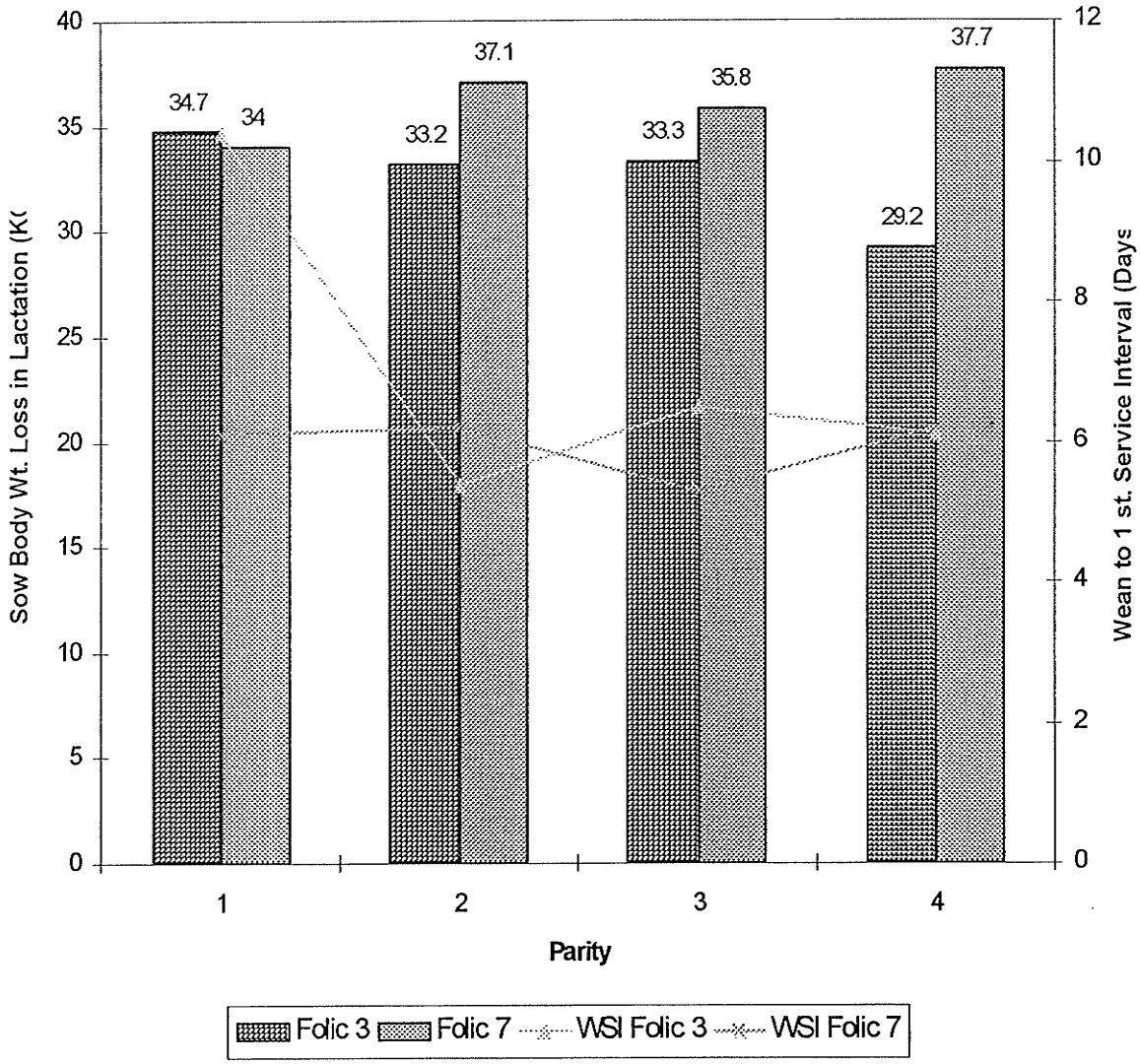
Figure 5.4. Sow Body Weight Loss in Lactation By Parity (Folic Treatment)



Sow Body Weights – Weaning to First Service Interval (End)
(Parity and Treatment Interactions)

The wean to first service interval at the end of the trial is the time period between when the sows were weaned from the farrowing crates at the completion of the trial and again served. There was a significant difference in the wean to first service interval amongst the four parities on the trial (P=0.023). The parity and treatment interactions are summarized in Table 5.10. The parity two animals (three after farrowing) had the lowest WSI (5.81 ± 0.59). The parity 1 animals (two after farrowing) had the longest WSI (8.21 ± 0.64 days), which is typical within a herd. However, the interaction between Folic Acid and Parity was also significant posing the question of the effect of Folic Acid has on the wean to first service. A prolonged wean to first service interval is normally due to a larger than expected body weight loss in lactation, this however is not the case. The Folic Acid treatment resulted in the largest body weight loss in lactation but surprisingly had the better wean to first service interval. The wean to first service interval as is compared with the body weight loss by parity for the Folic Acid treatment in Figure 2. It appears that the supplementary Folic Acid may have made an impact on the wean to first service interval of the parity 1 animals (2 after farrowing). The wean to first service interval by parity data is summarized in Table 5.11.

Figure 5.5. Sow Body Weight Loss in Lactation and Corresponding Wean to First Service Interval



Sow Back Fats – Starting and Breeding Back Fat Readings (mm)

The back fat measurements were taken on all of the sows at the beginning of the trial. The sows were then allocated to one of the four treatments. The least square means back fat measurements of the four treatment groups ranged from (21.7 to 22.1). The standard errors were very consistent ranging from (0.33 – 0.34). The starting back fat levels are shown in Table 5.12. All values in the results are listed as least square means ± standard errors of the means.

Sow Back Fats – Breeding Back Fats (mm)

The sows were again measured for back fat depth at the time of their first service. Folic Acid and vitamin A and there interaction did not make a significant difference in the back fat at the time of breeding. The sow back fat data at breeding is located in Table 5.12.

Table 5.12. Comparison of Sow Back Fats (Parity and Treatment Interactions)

Parameter	- Folic		+ Folic		P-Values						
	-A n= 60	+A n=60	-A n=60	+A n= 60	Folic	Vit A	Interact F*A	Parity	Interact (Parity *F)	Interact (Parity*A)	Interact (Parity*A*F)
Sow Start Back Fat (mm)	21.7 (0.33)	22.1 (0.34)	22.1 (0.33)	21.9 (0.33)	0.811	0.793	0.359	0.070	0.810	0.607	0.995
Sow Breed Back Fat (mm)	21.9 (0.30)	22.2 (0.30)	21.8 (0.30)	21.7 (0.30)	0.322	0.750	0.349	0.246	0.650	0.349	0.934
Wean to First Service	6.02 (0.51)	7.09 (0.52)	5.77 (0.51)	5.97 (0.50)	0.177	0.213	0.392	0.027	0.432	0.751	0.503
Sow Wean-Breed Back Fat Gain/ Loss (mm)	-0.13 (0.14)	-0.12 (0.14)	0.27 (0.14)	0.23 (0.16)	0.008	0.956	0.854	0.248	0.421	0.135	0.881
	- Folic		+ Folic								
	-A n= 56	+A n=49	-A n=55	+A n= 50							
Sow Farrow Back Fat (mm)	24.3 (0.38)	24.6 (0.40)	24.6 (0.38)	24.3 (0.40)	0.910	0.893	0.422	0.042	0.764	0.862	0.960
Sow Wean Back Fat (mm)	22.1 (0.30)	21.6 (0.32)	21.7 (0.30)	21.7 (0.32)	0.674	0.481	0.396	0.236	0.083	0.278	0.608
Sow Farrow-Wean Back Fat Loss (kg)	2.3 (0.34)	3.0 (0.35)	2.9 (0.33)	2.5 (0.36)	0.801	0.629	0.095	0.251	0.261	0.718	0.887
Wean to First Service (End)	6.4 (0.61)	7.7 (0.63)	5.9 (0.61)	6.1 (0.64)	0.075	0.247	0.373	0.023	0.020	0.989	0.361

[1] Three sows on treatment group (-F+A) were anestrous and were not bred.

Sow Back Fats – Start – Breed Back Fat Loss (mm)

The least square means ranged from (-0.13 to 0.27) with small and consistent standard errors of the mean. Interestingly, the treatment groups (-A-F) and (+A-F) reported a loss of back fat from the start to breeding, whereas the treatment groups (-A+F) and (+A+F) actually gained. Folic Acid made a significant difference in the back fat loss from the start of the trial to breeding (P=0.008). Vitamin A however did not make a significant difference in the back fat loss (P=0.956). The interaction of Folic Acid and Vitamin A did not make a significant difference in the back fat loss (P=0.854). With the interaction not being significant we can conclude that the two factors are acting independently. The sow back fat loss from weaning to breeding data is summarized in Table 5.12.

Sow Back Fats – Farrowing and Weaning Back Fats (mm)

The sows were again measured for back fat at the P2 location as they entered and were weaned from the farrowing crates. The Folic Acid and vitamin A treatments and there interaction did not make a significant difference in the back fat levels as the time the sows entered farrowing or at the time of weaning, or in the amount of back fat lost during lactation. The sow back fat data during lactation is located in Table 5.12.

Sow Back Fats – Starting and Breeding Back Fats (mm)
(Parity and Treatment Interactions)

A total of 60 sows per parity were measured for back fat thickness at the P2 location at the beginning of the trial and were randomly placed onto one of the four treatments. There was no significant difference in the starting back fats amongst the four parities on the trial (P=0.070). The parity and treatment interactions are summarized in Table 5.12. As well there was no significant difference in the back fat measurements between the parities at the time of breeding (P=0.246). The back fat measurements by parity at the start of the trial are summarized in Table 5.13.

Sow Back Fats – Start – Wean Back Fat Loss/Gain (Parity and Treatment Interactions)

There was no significant difference in the back fat loss or gain amongst the four parities on the trial (P=0.248). The parity and treatment interactions are summarized in Table 5.12. The interactions between parity, Folic Acid and Vitamin A did not result in a significant difference in the back fat loss or gain from weaning to breeding. The sow back fat loss or gain by parity is summarized in Table 5.13.

Sow Back Fats – Farrowing Back Fats (Parity and Treatment Interactions)

There was a significant difference in the back fat measurements by parity at the time the sows were moved into the farrowing area (P=0.042). The parity and treatment interactions are summarized in Table 5.12. The interactions between parity Folic Acid and Vitamin A did not make a significant difference in the back fat levels at the time of farrowing. We can infer that these factors are acting independently in terms of back fat

Table 5.13. Comparison of Sow Back Fat Measurements By Parity

	Parity			
Parameter	**Parity 1 n= 60**	**Parity 2 n= 60**	**Parity 3 n=60**	**Parity 4 n=60**
Sow Start Back Fat (mm)	21.3 (0.33)	21.8 (0.32)	22.1 (0.34)	22.6 (0.33)
Sow Breed Back Fat (mm)	21.5 (0.30)	21.8 (0.29)	22.0 (0.31)	22.3 (0.30)
Wean to First Service	7.53 (0.50)	5.57 (0.50)	5.95 (0.52)	5.80 (0.50)
Sow Wean-Breed Back Fat Gain/Loss (mm) [1]	-0.14 (0.14)	-0.01 (0.14)	+0.16 (0.14)	+0.23 (0.14)
	Parity 1 n= 49	**Parity 2 n =55**	**Parity 3 n=49**	**Parity 4 n=54**
Sow Farrowing Back Fat (mm)	23.7 (0.40)	24.2 (0.38)	24.5 (0.40)	25.3 (0.38)
Sow Weaning Back Fat (mm)	21.2 (0.32)	21.9 (0.30)	21.9 (0.32)	22.05 (0.30)
Sow Farrow-Wean Back Fat Gain/Loss (mm)	2.5 (0.36)	2.4 (0.33)	2.5 (0.35)	3.24 (0.34)
Wean to First Service (End)	8.21 (0.64)	5.81 (0.59)	5.90 (0.65)	6.15 (0.60)

[1] Three sows on treatment group (-F+A) were anestrous and were not bred.

deposited during gestation and measured at farrowing. The sow back fats by parity at the time of farrowing are summarized in Table 5.13.

Sow Back Fats – Weaning and Back Fat Loss (Parity and Treatment Interactions)

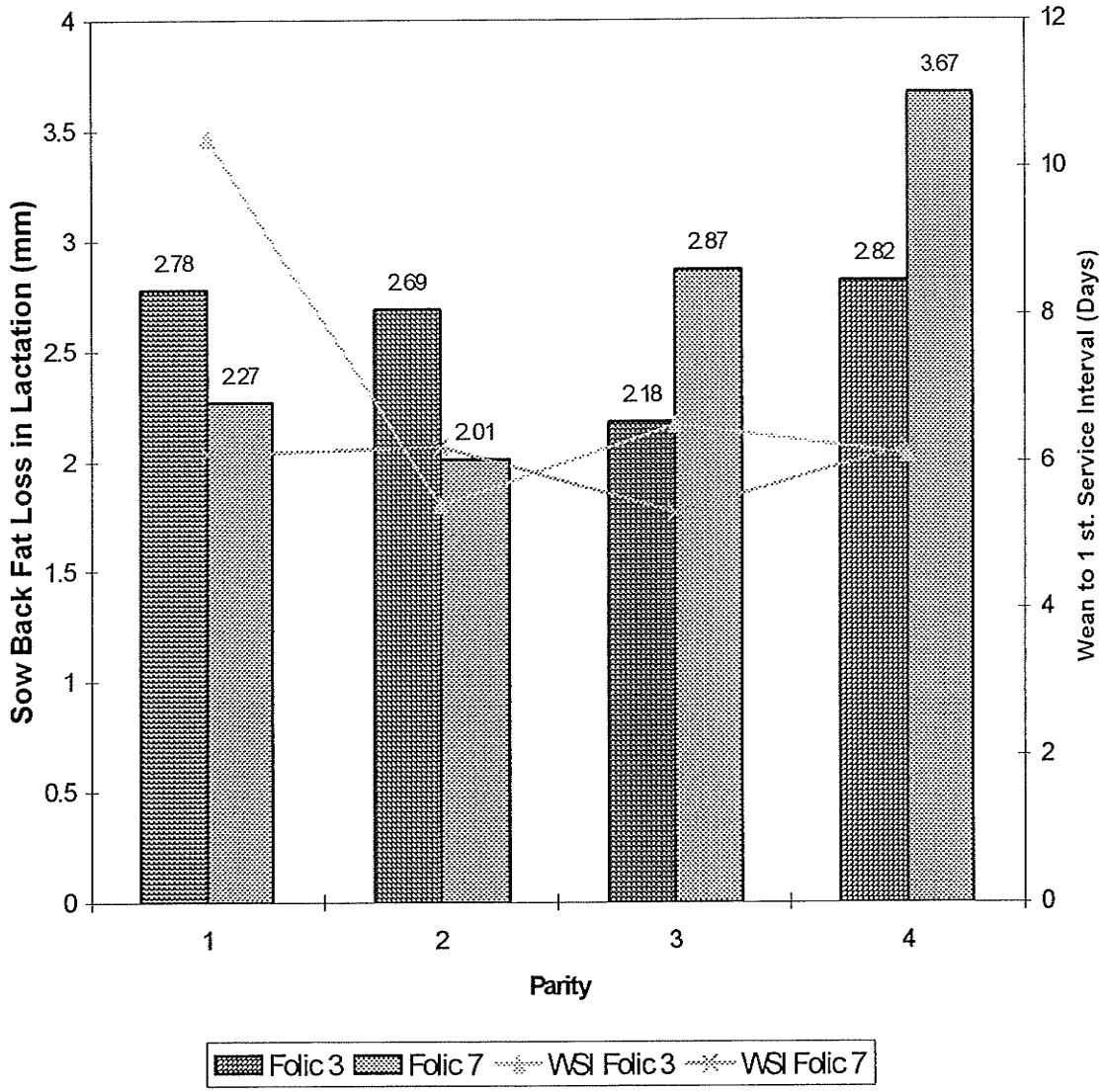
There was no significant difference in the back fat of the sows at the time of weaning or in the back fat loss in lactation among the four parities. The parity and treatment interactions are summarized in Table 5.12. Consistent with the back fat levels at the time of farrowing the interactions between parity and Folic Acid or Vitamin A are not significant. The sow back fats at the time of weaning are summarized in Table 5.13.

Sow Back Fats – Weaning to First Service Interval (End)
(Parity and Treatment Interactions)

The wean to first service interval at the end of the trial is the time period between when the sows were weaned from the farrowing crates at the completion of the trial and again served. There was a significant difference in the wean to first service interval amongst the four parities on the trial (P=0.023). The parity and treatment interactions are summarized in Table 5.12. The parity two animals had the lowest WSI (5.81 ± 0.59 days). The parity one animals had the longest WSI (8.21 ± 0.64 days), this is typical within a herd to see the youngest animal having the longest wean to first service interval. There was a trend towards significance from the interaction between Folic Acid and parity. The relationship between back fat loss in lactation and wean to first service

interval is illustrated in Figure 5.2. The wean to first service interval by parity data is summarized in Table 5.13.

Figure 5.6. Sow Back Fat Loss in Lactation and Corresponding Wean to First Service Interval



CHAPTER 6

DISCUSSION

Improving the reproductive performance of the early-weaned sow through manipulation of the diet in terms of essential fat and water-soluble vitamins remains an area with many possibilities. Research into the use of folic acid and vitamin A independently has been well documented, however the concurrent supplemental use of these two vitamins is untested. In this study four treatment groups were established at the time of weaning and placed on a 2 x 2 factorial arrangement of the two vitamins to investigate and better define the role and the possible interactions of Folic acid and Vitamin A (retinyl palmitate).

Optimal feeding of the early-weaned sow is critical to maximizing performance of the current parity and also to her longevity within the sow herd. The feeding program designed for this trial was based on considerable modeling completed within this research farm. The feeding guidelines used are illustrated in the appendix. The breeder diets used were 15 % protein and 2800 Kcal/kg ME. The Vitamin A was standardized at 8000 IU/Kg for both breeder diets as the Vitamin A treatment was by intra muscular injection. The Folic acid base level was 3 mg/kg and the treatment level was 7 mg/kg. The sows were then placed on the dry sow diets. Both diets were 13. 5 % protein and 2750 Kcal ME. The Vitamin A was again standardized at 8000 IU/Kg. The Folic acid levels were the same as the breeder diets with 3 mg/Kg base levels and 7 mg/Kg treatment level. The average intakes were very consistent between all four treatments and the small standard

errors illustrates that the feeding guidelines were met as laid out in the protocol providing consistency in the amount of the nutrients consumed. The nursing sow feed provided was very consistent with small standard errors. Staged feeding in gestation is important to meet the specific goals of the gestation period. As noted by (Flowers, 1998), timing as well as quantity of nutrients fed during each gestation period are important for optimizing subsequent lactating and reproductive performance.

The number of total pigs born on the control group (-A-F) is lower than typically expected based on historical production from the sow farm conducting the research. There is not a complete understanding for this response. The Vitamin A treatment alone resulted in a significant increase in the total litter size born. This finding was consistent with the work done by Whaley et al. (1997). However the total born weight was not significantly different amongst the treatment groups indicating that the increased number of pigs also resulted in smaller individuals. This finding was not consistent with the research conducted by Brief and Chew, (1985). The hypothesis put forward by Whaley et al, (1997) was that the retinyl palmitate would result in a decreased variation in the diameter of the fetuses and an increased average diameter. Although the diameter of the fetuses was not recorded on this trial similarity in the weight of the litters may be an indication that the fetal size was not affected. Folic acid however did not result in a significant difference in the total number of pigs born, which agrees with the research of Harper et al, (1994), using 4 mg/kg Folic acid. An increase in total weight born from sows treated with Folic acid would not have been surprising. Matte et. al, (1996) suggested that Folic acid supplementation may accelerate early embryonic development

through increased secretion of prostoglandin in the uterus. The potential for increased birth weights would most likely be realized by the increase in fetal and placental tissue development during early pregnancy. Placental growth during early pregnancy is particularly important based on the theory that beyond day 60 the porcine fetus continues to grow but placental growth is minimal (as reviewed by Harper et al., 1995).

There was a significant difference in the total pigs born across the four parities within the trial. This is not a surprising finding, as normally a sows performance improves with advancing parity, with the parity three animals producing the highest total born. The interaction between parity and Folic Acid resulted in a significant difference in the number of pigs total born. There was no consistent pattern occurring among the parities with the two levels of Folic Acid treatment as illustrated in Figure 5.1.

The significant increase in the total born resulting from the Vitamin A treatment sows carried through to the number of piglets born alive. Chi-Square analysis indicated that there was no significant difference in the frequency of mummified piglets across the four treatments. The frequency of stillborn piglets across the four treatments also was not significantly different. However, the treatment groups receiving the Vitamin A injection had the lowest % stillborn piglets per litter. The interaction between Vitamin A and Folic Acid did not improve the total born, born alive or weights. However the treatment group (+A+F) had the lowest stillborn %, nearly half that of the other treatments. The clear difference is that the treatment group (+A+F) did not end up with any litters having more than 2 stillborn piglets per litter. There was again a significant difference in the number

of pigs born alive within the four parities on the trial. The parity three sows produced the largest number of pigs born alive per litter, however the parity 1 animals produced smaller litters than expected which added to the level of significance. The interaction between Folic Acid and parity resulted in a significant difference in the number of pigs born alive per litter. There was no consistent pattern among the parities in regards to pigs born alive from the two levels of Folic Acid as illustrated in Figure 5.2. The parity two animals (three after farrowing) produced more pigs total born and born alive (2.09 pigs) on the supplemented Folic Acid, however this did not occur with other parities. Harper et al., (1995) reported that there tended to be fewer corpora lutea and live fetuses among Folic Acid supplemented sows and this affect appeared most pronounced in third parity sows. It appeared that Folic Acid supplementation had a reducing effect on ovulation. This requires more study as reviewed Harper et al., (1995), it seems unlikely that minor changes in ovulation would have a major effect on litter size because fetal survival rate increases as ovulation rate decreases in swine. There were no interaction effects between parity and Vitamin A, consistent with the findings of Pusateri et al., (1999).

Vitamin A and Folic Acid did not result in a significant difference in the born alive litter weights; the interaction of the two treatments did not result in any significant litter weight differences. The theory that Folic Acid supplementation will potentially increase the size of the piglet born did not show up here. There was a significant difference in the born alive weight per pig amongst the four parities within the trial. The parity three sows had the most pigs born alive but also had the lowest born alive weight per pig. The parity 1 sows had the lowest number of pigs born alive but also had the

heaviest born alive weight per pig. It appears that the increased number of pigs within treatments and within parities results in lower individual weights of the pigs. Although these numbers were not greatly different among the treatment there was a slight significant difference among the parities. The parity three sows had the lowest average born alive weight per pig at 1.37 kg, however from a production management perspective pigs of this weight should not be a challenge to keep alive and be weaned as strong pigs.

The greater number of pigs total born and born alive from the Vitamin A treatments did not result in a significant difference in the number of pigs weaned. This is consistent with the research conducted by Brief and Chew (1985). A large amount of the research completed on the potential effects of Vitamin A on litter size has not looked closely at the number of pigs weaned and has paid more attention to the litter sizes born. Folic Acid treatment did not result in a significant difference in the number of pigs weaned.

Vitamin A and Folic Acid did not make a significant difference in the wean weights of the pigs. The interaction of Folic and Vitamin A did not result in a significant difference in the wean weights of the pigs and indicating that the two Vitamins are acting independently. There was a trend towards significance in the wean weights per pig among the four parities on the trial.

Neither Vitamin A nor Folic Acid resulted in a significant difference in the number of post natal pig deaths per litter. There was a significant difference in the number of post natal pig deaths per litter. The parity three sows had the most post natal pig deaths, perhaps due to the larger litter sizes and slightly smaller born alive weights. There was a trend towards significance in the number of post natal pig deaths per litter from the interaction of Folic Acid and parity. The Folic Acid supplemented parity two sows had the highest number of post natal piglet deaths among treatments and parities leading the trend towards significance. The birth weights of the pigs born from this treatment and parity were very similar and standard errors consistent. We can suggest that the higher number of pig deaths from this treatment and parity have resulted from sow management factors.

There was a wide spread in farrowing rates across the four treatments. The Vitamin A treatment groups had lower farrowing rates with most of the pregnancy failures coming from 21 and 42 day repeats and negative pregnancy checks. It appears that the Vitamin A injection may have had a negative effect on the farrow rates. The treatment group (+A-F) had three sows that did not return to estrus after weaning to start the trial which were not included in the farrowing rate calculation. However the two Vitamin A treatment groups had nearly twice as many sows fallout as compared to the control and Folic Acid treatment groups. There is no clear understanding as to the lower farrowing rate on the sows injected with Vitamin A. Literature on Vitamin A toxicity eludes to potential loss of appetite, slow growth, loss of weight and reduced function of the liver and kidneys (as reviewed by McDowell, 1989). The sows treated with the

Vitamin A that farrowed had larger litters and showed no signs of the toxicity symptoms discussed. The aspect of Vitamin A toxicity at the dose given within this trial was not reported in other research. One hypothesis proposed by (McDowell, 1989) is that excess Vitamin A can affect the metabolism of other fat-soluble vitamins with competition for absorption and transport. If the sows were receiving barely adequate levels of Vitamins D, E and K, a marked increase in Vitamin A may cause a reproductive challenge due to a deficiency of one or more of the other fat-soluble vitamins, as opposed to a toxic effect of Vitamin A. It is unlikely, however that there the sows would be receiving barley adequate levels of other fat soluble Vitamins, as the control group showed very strong farrowing rates.

The sows on the Folic Acid treatment groups were heavier at the start of the trial. The sows were again weighed at the time of breeding. There was more weight loss on the Folic Acid treatment groups from the start of the trial to the time of breeding, resulting in a significant difference from the Folic Acid. There is no clear understanding of this and one might suspect that there would not be a true treatment effect this early in the trial. Typically, heavier sows will have greater weight swings in lactation and after weaning. The trial was balanced by parity however, the variation in body weights within the treatments will occur due to naturally occurring phenotypic variation.

The Folic Acid treatment groups sows started with slightly heavier sows and typically heavier sows will lose more weight from weaning to breeding and in lactation. Vitamin A and Folic Acid did not result in a significant difference in the body weights of the sows as they entered the farrowing crates, at the time of weaning or the body weight loss in lactation. The theory (as reviewed by Lindemann and Kornegay, 1989) that sows with the lowest weight gain in gestation resulted in the lowest body weight loss in lactation was a consistent finding in this study, with the exception of the treatment group (+A+F). However there was a not a linear response to body weight loss in lactation by parity as there was from the weaning at the beginning of the trial to the time of breeding. This is not consistent with the Folic Acid research reported by (Harper et al., 1994).

There was a trend towards significance in the Wean to First Service Interval from the Folic Acid treatment. There was a significant difference in the wean to first service interval among the four parities on the trial. As well, there was the interaction of parity and Folic Acid resulted in a significant decrease in the wean to first service interval. The parity effect appears to be with the parity 1 animals as illustrated in Figure 5.6. The wean to first service on the parity 1 animals was on average 2 days shorter. This is a very significant finding with huge implications to the swine producer. The ability to breed these younger sows back 2 days sooner will dramatically reduce non-productive sow days within the herd. The interaction of Vitamin A and parity did not result in a significant difference in the wean to first service interval. As well, the interaction of parity, Folic Acid and Vitamin A did not result in a significant difference in the wean to first service interval.

The sows started with a very similar back fat thickness at the beginning of the trial. The sows were again measured for back fat thickness at the time of breeding. The Folic Acid treatment reported a significant difference in the back fat loss from the beginning of the trial to the time of breeding. There is not a clear understanding as to the reason for this occurrence as it is early in the trial, and the deposit of back fat would presumably take some time.

Vitamin and Folic Acid did not make a significant difference in the body weight and there were no interactions present. There was a significant difference in the sow back fat thickness among the four parities at the time of farrowing. However, the interactions between parity and Folic and Vitamin A were not significant indicating that the parity significance is most likely due to the phenotypic variations within the animals at different ages.

Vitamin A and Folic Acid and the interaction did not result in a significant difference in the back fat loss during lactation. There was no significance in the back fat loss during lactation among the four parities.

CHAPTER 7

CONCLUSIONS

In this study Vitamin A injection resulted in a significant difference in the total number of pigs born per litter, however dietary Folic Acid did not. The interaction of the two vitamins did not result in a significant difference indicating that they are acting independently with respect to litter size born.

The increased total number of pigs born from the Vitamin A treatment carried through to the number of pigs born alive. The Vitamin A treatment did not appear to have an effect on the number of mummified or stillborn piglets. The interaction of Folic and Vitamin A did not result in a significant difference in the born alive weight of the piglets. The larger litters saw higher post natal piglet deaths, perhaps due to the sows ability to raise the larger litter or perhaps sow management factors within the farm.

The Vitamin treatments did not make a significant difference in the number of pigs weaned. The interaction of Vitamin A and Folic Acid did not result in a significant difference in the number of pigs weaned or in the weight of the pigs weaned.

Vitamin A treatment appeared to make a difference in the farrow rate of the sows. There were a higher number of repeat services at 21 days post breeding on the younger parity animals. There is not a complete understanding as to this response. The same dose

of Vitamin A was given to all of the sows on the Vitamin A treatment groups. The question of the accurate dose per kilogram of body weight needs to be reviewed. The drop in farrow rate can have a significant impact on overall farm performance. The Vitamin A treatment resulted in a significant increase in the total number of pigs born, however in light of the farrow rate concerns more research should be done before a recommendation could be made to a swine producer to inject Vitamin A at this level.

Folic Acid appeared to make a difference in the wean to first service interval despite losing the most weight in lactation. The interaction between parity and Folic Acid resulted in a significant difference in the wean to first service interval, and it would appear that the supplemented Folic Acid had an effect, most notably with the younger parity sows. The opportunity for reduced non productive days on the parity 1 animals would be very beneficial to the swine producer. The interaction between Vitamin A and Folic Acid did not result in a significant difference in the sow body weight and back fat loss in lactation. The interaction between the two vitamins did not result in a significant difference in the wean to first service interval.

From this research it would appear that Vitamin A and Folic Acid are acting independently on all parameters measured.

CHAPTER 8

FUTURE RESEARCH

Through the research conducted within this trial it was determined that Vitamin A (retinyl palmitate) has the opportunity to improve the total litter size born. However, there appears to be a concern with the large dose of the Vitamin given at day 0 or at weaning due to the increased number of repeat services. Further research can be done to determine the effect of a smaller dose at weaning or perhaps small doses spread out through the gestation period. Since all sows received the same dose regardless of body weight, administering a determined dose per kilogram of body weight may have opportunity.

Folic Acid appeared to improve the wean to first service interval, particularly with the younger animals. Research into supplementary levels of Folic Acid fed to younger animals will help to determine the benefits, as every day that is non productive within a sow herd is costly to the producer.

Vitamin A and Folic Acid both have illustrated some opportunities, however in an independent fashion. This research was completed over one complete gestation and lactation period. The question as to long term benefits from the treatment of Vitamin A and Folic Acid to a young animal could be researched further.

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APPENDIX

Table A1. Diet Components and Controls

Diets	Corn (Kg/T)	Wheat (Kg/T)	Barley (Kg/T)	Mill Run (Kg/T)	Peas (Kg/T)	Soy Meal (Kg/T)	Canol a Meal (Kg/T)	Oat Hulls (Kg/T)	Av. Fat (Kg/T)	Faba Beans (Kg/T)
13.5 % Dry Sow	0-300	0-125	0-150	0-150	75-150	NC *	0-80	0-100	5-20	0-50
15 % Breeder	0-100	50- 400	0-150	0-150	0-75	25-NC *	0-80	0-100	10-20	0-50
18 % Lactation	0-200	200 - 400	NC *	0-150	0-75	50-230	0-50	0-50	20-45	NA *

* NC = No Controls

* NA = Not Allowed

Figure A1. Sow Back Fats At Weaning By Parity (Folic Treatment)

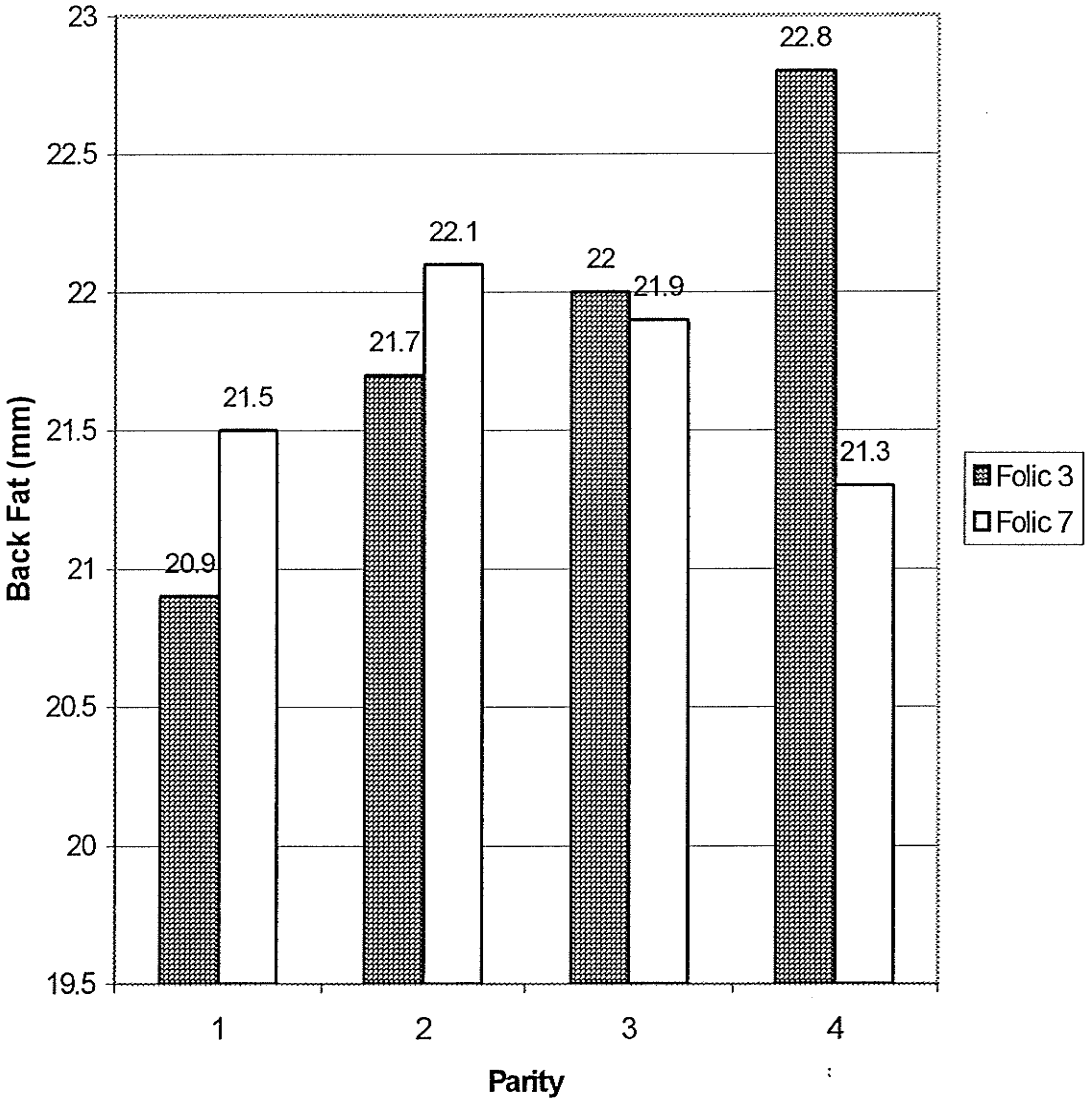


Figure A2. Sow Back Fats Entering Farrowing (Folic Treatment)

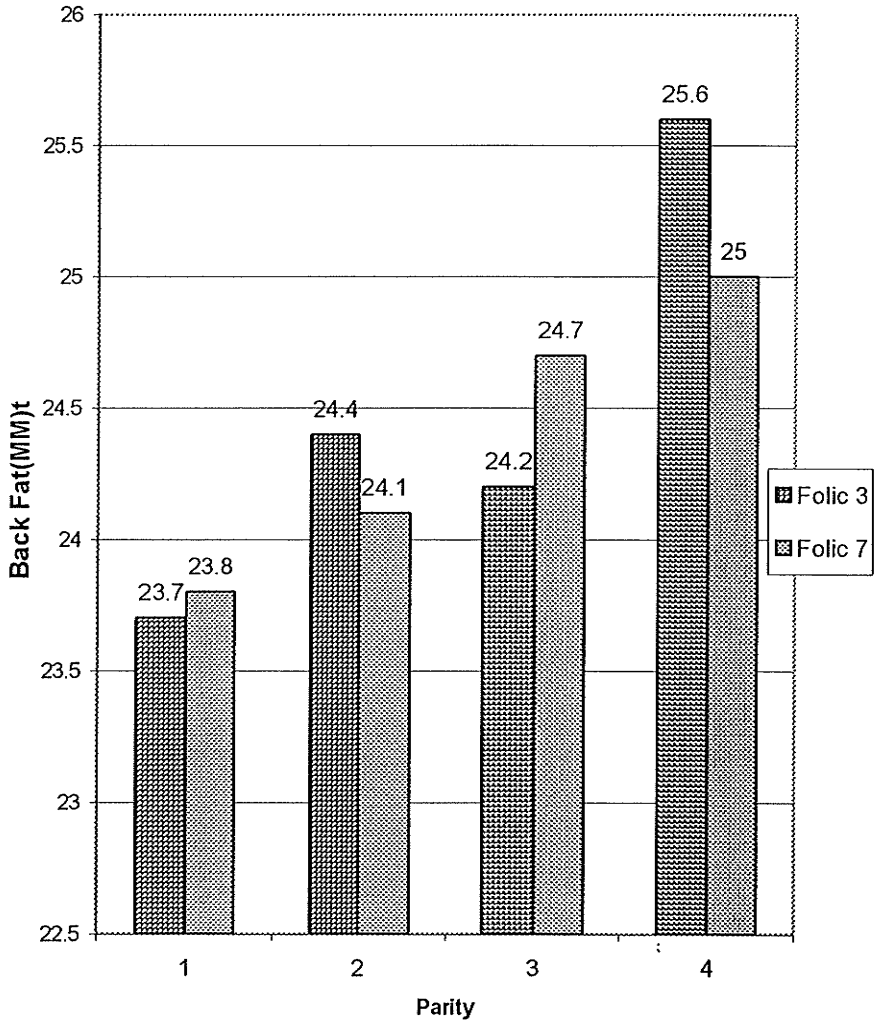
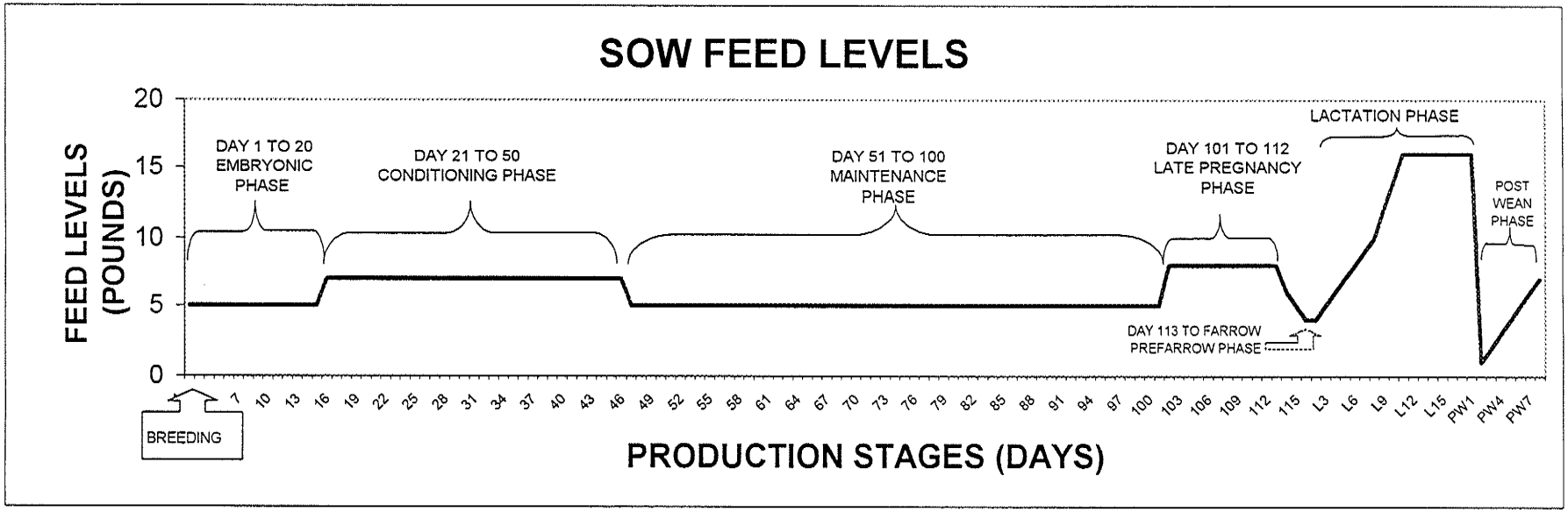


Figure A3. Sow Feeding Guidelines



Guidelines

Day 1 to 14 - Embryonic Phase- Goal to restrict intakes to maintenance levels to maximize embryo survival. This interval can be as short as 12 days and extend to 21 days in length if facility logistics don't allow a convenient feed change at the recommended time.

Day 15 to 49 Conditioning Phase - Goal is to increase the feed levels on all sows. The feed levels required, and the length of time the higher levels are needed, will depend on the conditic score of the individual sows. Higher feeding levels in this phase may also improve birth weights.

Day 50 to 100 - Maintenance Phase - Maintain sows at about 5 - 5.5 pounds/day.

Day 100 to Day 112 - Late Pregnancy Phase - The goal is to maintain sow condition in the rapid growth phase of the litter. Do not start this phase too soon as it will disrupt milking and feed intake in the lactation phase.

Day 113 to farrowing - Prefarrowing Phase - The goal is to maintain the sow at the highest level of feed intake possible without having hard udder problems or feed . intake problems in the lactation phase.

Lactation Phase - Duration averages 17 days - Goals are to maintain the sows protein and energy reserves and to maximize milk production.

Post Weaning Phase (Wean to Breeding Interval) - Duration is about 6 days - Goal is to maximize feed intake to ensure maximum ovulation.

the sows protein and energy reserves and to maximize milk production.

Note: Feed target levels are in pounds. Divide by 2.2046 to calculate kg of feed targets.

Figure A4. Nursing Sow Feeding Guideline