Effect of weaning age on nursery pig and subsequent sow reproductive performance

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Effect of weaning age on nursery pig and subsequent sow reproductive performance

by

Alison Leah Smith

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Animal Science

Program of Study Committee:
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Iowa State University

Ames, Iowa

2006
Graduate College
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This is to certify that the master’s thesis of

Alison Leah Smith

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy
This thesis is dedicated in loving memory of my mother Roxanne J. Smith.
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ACKNOWLEDGEMENTS

I would like to thank Dr. Kenneth Stalder who has shared his patience, guidance, knowledge and many hours with me during my time at Iowa State University.

The author wishes to thank Dr. Howard Hill, Dave Moody and other personnel at H & K Enterprises for the management of the pigs and allowing me to conduct research at the facility. A special thanks to Dave for the countless hours that he spent in helping complete this research project and for his support throughout the research trials, and in completing my master's while working at the Iowa Pork Producers Association.
ABSTRACT

The objectives of this study were to: (1) quantify the effect of piglet birth weight on weaning and nursery off-test weights, (2) assess the effect of weaning age on nursery pig performance, and (3) model the effect of weaning age on subsequent sow reproductive performance. The study utilized Danbred N.A. (Columbus, NE) barrows and gilts (n=2,467) from a commercial maternal line multiplication herd. Litters were randomly assigned at birth to either a 15 d (pigs weaned at 14, 15, and 16 d of age) or a 20 d (pigs weaned at 19, 20, and 21 d of age) average weaning age group. Increasing birth weight from 0.94 to 2.06 kg improved subsequent growth performance. Improvements in growth could be seen in the initial 42 d postweaning, with birth weight and weaning weight being key indicators of end of nursery weight. Collectively, birth weight and weaning weight are important predictors of subsequent nursery growth performance. The research also defined how weaning age affects ADG, ADFI, mortality %, G:F, and feed cost/kg gain in the nursery phase of production. Pigs weaned at 20 d had greater ADG, increased ADFI, fewer pigs removed from the test, similar G:F ratios, and lower feed cost/kg gain when compared to pigs weaned at 15 d. Pigs in the 20 d weaning age group were also heavier at the end of the 42 d nursery phase of production when compared to pigs weaned in the 15 d group. Based on the differences seen in pigs weaned at 20 d and 15 d, weaning pigs at 20 d may prove advantageous in commercial operations because of the improvements in nursery growth performance. The research also analyzed the effect of lactation length on wean-to-estrus interval (WSI), wean-to-conception interval (WCI), and subsequent litter size in sows weaned at two different average weaning ages. No significant lactation length treatment differences were observed for WSI, WCI, or subsequent litter size. This study indicates that producers should be able to choose weaning ages in the range of 15 to 20 d without any negative impacts on sow reproductive performance. Thus, when producers are making weaning age decisions they must consider what the best decision is for the entire production system.
CHAPTER 1. GENERAL INTRODUCTION

The swine industry has shifted to weaning litters at earlier ages as a means to improve piglet health. However, applying this management practice has ramifications on subsequent piglet growth performance. Limited research has been conducted to determine the most appropriate weaning age which will result in optimum growth performance of the pig in its early stages of development. Increased age at weaning has been shown to result in enhanced adaptability to the post weaning environment, which results in allowing pigs to increase daily feed intake at a faster rate (Leibbrandt et al., 1975).

Not only is weaning age important, but piglet birth weight and weaning weight both greatly influence piglet growth performance throughout the remaining phases of pork production. Relative differences in body weight will tend to be perpetuated after weaning, and thus will result in the lower birth weight animals being considerably older or weighing less at eventual harvest than their heavier birth weight littermates (Campbell and Dunkin, 1982). Management of lightweight pigs is a challenge in pork production that many producers face. The number and actual weight of lightweight market hogs can directly impact production and marketing decisions, as well as disrupt pig flow in a time-sensitive management system. These lightweight market hogs represent an opportunity cost for producers, or a loss in potential income. Specifically, the opportunity cost of a dead or lightweight pig can be close to $40 in a commercial operation (Deen, 2005). The problem of managing lightweight pigs begins at birth. Pigs that have lower birth weights frequently have lower weaning weights and remain lightweight throughout the grow/finish phases of production.

The goal of the present research was to determine the mechanisms that affect the growth performance of piglets during and after lactation. Studies suggest that weaning age up to 21.5 days can be an effective management strategy to improve wean-to-finish growth performance (Main et al., 2004). Collectively, if the effect of weaning age on the piglet and the sow can be determined, this will provide the tools to decide which lactation length to utilize based on optimal sow and piglet performance. There have been many retrospective studies done comparing lactation length and the effect on the sow. The importance of manipulation of lactation length to maximize pigs/sow/year may not only have significant negative impact on sow reproductive performance, but also on piglet growth performance. The overall
The objective of this study was to wean at different ages (average of 15 and average of 20 d) and study the effects on the piglet's growth performance during the nursery phase and on subsequent sow reproductive performance. Data on piglet birth weight, weaning weight, and weaning age could be used by commercial producers to determine the most effective strategies to maximize piglet growth performance and to manage lightweight piglets at birth.

**Thesis Organization**

The following thesis is organized as a literature review followed by two papers which are in the style and format for the Journal of Animal Science, followed by a general summary of the entire thesis and a complete listing of references used throughout the thesis. The literature review examines the effect of birth weight and weaning weight on subsequent nursery performance, as well as the effect of weaning on piglet nursery performance and on subsequent sow performance. The research reported in the papers was conducted by Alison L. Smith under the direction of Dr. Kenneth J. Stalder, Dr. Thomas J. Baas, Dr. James B. Kliebenstein, Dr. John W. Mabry, Dr. Timo V. Serenius, and Dave Moody. The research was conducted at H & K Enterprises, a commercial maternal line multiplication operation.
CHAPTER 2. LITERATURE REVIEW

Swine producers face increasingly tight profit margins per pig, thus the production sector continues to identify ways to reduce cost of production (Kliebenstein et al., 1984). The significance of this research is to effectively manage piglets in order to reduce fixed and variable costs by maximizing output or weight of pigs out of the nursery. Both the piglet and the sow have variable responses to different weaning ages. Weaning poses a stressful time for both the piglet and the sow. Manipulating weaning age can maximize pigs weaned per sow per year (Main et al., 2004), but also reduce as much stress on the animal as possible (Grellner et al., 2002). As the U.S. industry has moved to increasingly younger weaning ages (Harris, 2000) and crated gestation systems, the production system has placed stress on animals which causes animals to be less able to fit in terms of disease resistance, livability and longevity (Stalder et al., 2003). The following sections review the factors that affect nursery performance, specifically how piglet weight at birth and weaning, as well as weaning age, contribute to differences in subsequent pig performance through the nursery phase of production.

Birth Weight

Piglet birth weight has a significant impact on the ability of a piglet to grow, maintain body temperature and to compete for a place to suckle. Low birth weight piglets often are born later in the birth order, take longer to first suckle and ingest smaller amounts of colostrum (Gardner et al., 1989). Low birth weight piglets have a lower level of body fat stores when compared to piglets that are heavier at birth, causing a greater sensitivity to cold. Many times these lightweight piglets do not even survive until weaning because of malnutrition or chilling. The results of a piglet receiving lower quantities of colostrum and milk intake are associated with a poorer acquisition of passive immunity and low nutritional status, causing postnatal mortality or reduced growth performance (Quiniou et al., 2002). Receiving adequate colostrum is an important consideration in survivability during lactation and in the nursery. Quiniou et al. (2002) reported the highest mortality occurred in those pigs found earlier to have low-serum immunoglobulin defenses. The piglets with high immunoglobulin levels had a significantly better average daily gain (ADG) in the nursery period (Walters, 2004).
With greater pressure on increasing number of piglets born alive per litter, smaller birth weight piglets are generally observed. Genetically, litter size is unfavorably correlated to piglet survival and vitality, and selection for litter size has a negative impact on preweaning mortality and birth weight (Roehe, 1999). Birth weight, in the trial by Roehe (1999), was reduced by 44 g per additional pig born in the litter. Not only does a large variation in the birth weight of individual piglets occur, but there also is a large impact on mortality. In a trial reported by Damgaard et al. (2003), live born piglets which died before 3 weeks of age weighed less at birth (1.17 kg) than piglets surviving the first 3 weeks (1.51 kg). Studies indicate piglets weighing less than 1 kg at birth have very little chance of being alive at weaning or producing a “standard pig” (Damgaard et al., 2003). A standard pig is one falling within a target market weight range—and not substantially discounted from an established base price or value (Baas et al., 2004). This suggests that even though benefits in number born alive are observed, the number of viable, standard piglets at weaning does not support the pressures to improve number born alive.

Birth weight impacts the piglet’s ability to grow, not only during lactation, but throughout the nursery and grow-finish periods. During suckling, higher birth weight piglets miss fewer sucklings and can compete more effectively with other littermates (Campbell and Dunkin, 1982). Quiniou et al. (2002) reported that as birth weight increased, ADG was greater during suckling, postweaning and the grow-finish period. Other research has supported this premise and has reported a significant correlation ($r = 0.65$, $P < 0.001$) between birth weight and ADG, calculated from birth until harvest (Gondret et al., 2005). Not only do advantages in ADG occur, but producers see major disadvantages of low birth weight piglets in the form of preweaning mortality (Lay et al., 2002). Preweaning mortality decreased rapidly with increasing individual birth weight from 40% for pigs with less than or equal to 1 kg birth weight to less than 7% for pigs that weighed more than 1.6 kg at birth (Roehe, 1999). Birth weight was the single most important determinant of a neonatal pig’s chance of survival (Gardner et al., 1989).

Light birth weight piglets have been defined as piglets having a birth weight of more than 2.5 standard deviations below the mean litter birth weight (Gondret et al., 2005). Other researchers have described light birth weight piglets to be piglets that are 1 kg or less at birth (Powell and Aberle, 1980). Birth weight of less than 1 kg was significantly associated with being female, with pigs born to primiparous sows, with large variability in birth weight within a litter, and with litters that had greater than
12 pigs born (Gardner et al., 1989). Time required by light birth weight pigs to catch up with standard pigs may result either in low body weight at harvest or extended stays in the finisher to reach market weight. Thus, it is very important to determine a threshold for birth weight above which saving piglets is economically feasible (Quiniou et al., 2002). Even when light birth weight piglets are reared separately, both a fatter carcass and higher muscle lipid content at market weight have been reported when compared to normal birth weight pigs (Powell and Aberle, 1980). Light birth weight piglets, if they survive until the finishing phase, take longer to reach market weight (23 days longer), their carcasses are composed of more fat, require extra facility costs, produce less pork, and complicate facility pig flow and time management (Hegarty and Allen, 1978).

Not only is individual birth weight important to growth, but within litter birth weight variation also has a significant impact on subsequent growth rate. Milligan et al. (2001) reported that litters with exaggerated birth weight variation had more variable 21-day weights when compared to litters with reduced birth weight variation. This is supported by variable weaning weights which cause problems when grouping pigs together in the nursery. The genetic correlation between within-litter standard deviation in birth weight, and within-litter standard deviation in piglet weight at 3 weeks was high (r = 0.71), indicating that genetic change in one of these traits will simultaneously result in an almost parallel increase in variation in the other (Damgaard et al., 2003).

Research has shown that cross fostering to eliminate within litter weight variation may prove beneficial by decreasing variation in weaning weights (English, 1998; Cutler et al., 1999). Cross fostering is a procedure wherein piglets are transferred from 1 litter to another to improve survivability of vulnerable piglets in a litter and to improve uniformity of piglet size within the litter (English and Bilkei, 2004). Cross fostering is also practiced to reduce maternal effects on replacement gilts (Robison, 1972). However, Milligan et al. (2001) reported only a weak tendency to improve pre-weaning survival when cross fostering was practiced. This study also reported that low birth weight piglets gained the same amount of weight during lactation, no matter what size their littermates were. This suggests that lightweight piglets are never able to compete with heavier piglets, despite being cross fostered to a litter of lightweight piglets. Another study by English and Bilkei (2004) reported that cross fostering had no effect (P > 0.05) on subsequent weight gains. However, when lightweight piglets are fostered to 1 sow, the small piglets
may not create enough stimulation of the udder to maximize lactation. Cross fostering low birth weight piglets to other litters is a difficult procedure and often fails because of the low viability of these piglets. Birth weight might be expected to not only be associated with mortality due to being born with low viability, but also may predispose the animal to being crushed by the female or to dying from starvation (English and Bilkei, 2004).

Powell and Aberle (1980) studied differences in birth weight and its outcomes at marketing. They also reported that low birth weight piglets took 23 days longer to reach 109 kg when compared to their heavier birth weight littermates. Pigs of lower birth weight have a lower number of muscle fibers, which ultimately results in a lower gain and poorer feed efficiency response throughout their growth cycle (Powell and Aberle, 1980). Wolter and Ellis (2001) concluded that birth weight has a substantially greater impact on post weaning growth rate when compared to increasing nutrient intake during lactation. This demonstrates the importance of piglet birth weight and its effect on post weaning growth performance. Pigs from heavier litters had greater ADG and average daily feed intake (ADFI), similar G:F ratios, and required seven fewer days to reach harvest weight compared to pigs having lower birth weights (Wolter and Ellis, 2001). Individual piglet birth weight is a predictor of subsequent growth performance, including muscle composition at harvest weights.

**Weaning Weight**

Previous research has demonstrated that weaning weight is predictive of overall pig performance and days to market weight (Mahan and Lepine, 1991). Weight of piglets at weaning has been shown to have a significant effect on their subsequent growth performance (Wolter and Ellis, 2001). Weaning weight has been shown to be closely related to birth weight and to the amount of sow’s milk consumed by the piglet during lactation. Tokach et al. (1998) reported that feed intake and rate of gain during the nursery period increase with weight at weaning.

Pig weaning weight increased as weaning age increased, suggesting that initial weight may be a factor in early weaned pig performance (Himmelberg et al., 1985). Heavier pigs at weaning consumed more feed, which resulted in an increase in ADG, but feed conversion ratios were similar (Mahan et al., 1998). Average daily gain was improved, but the effect decreased progressively with each incremental increase in weaning weight. Himmelberg et al. (1985) also reported that pigs that
were heavier at weaning had greater (P < 0.01) ADG and improved daily feed intake when compared to their lighter littermates. It was also noted that feed intake and rate of gain increased at a faster rate as weaning weight increased. Weaning weight is a very important predictor of nursery growth performance and feed intake.

Harvest weight is also positively correlated with weaning weight. Heavier pigs at weaning were heavier at 56 d of age and also reached harvest weight 8.6 d earlier when compared to lighter pigs at weaning (Wolter and Ellis, 2001). Mahan and Lepine (1991) reported that a initial weaning weight advantage is maintained and may widen by market weight among different weight groups. From 35 to 56 d of age, lightweight pigs had a lower ADG (8%) and ADFI (8%) and a similar G:F when compared to heavy pigs (Wolter and Ellis, 2001). Main et al. (2004) also reported linear improvements in wean-to-finish growth with increased weaning weight. Weaning weights can affect postweaning performance both in the nursery and in the grow-finish phases of production.

Diet complexity also influences postweaning performance. Mahan et al. (1998) reported that weaning heavier pigs had a greater effect on postweaning performance relative to the feeding duration of complex diets. Heavier pigs had more efficient feed utilization when compared to lighter pigs. Factors that increase sow milk production and piglet milk consumption (e.g. equalized litter size, split weaning, and longer lactation periods) result in heavier pig weaning weights, which may be of greater importance than determining the desired weaning age (Mahan et al., 1998).

Variation in weaning weights within a group of pigs under commercial conditions can be costly, particularly to producers who are practicing all-in, all-out swine production, which is important to maximize facility usage and to minimize health risks. For every 0.5 kg increase in weaning weight, a decrease in cost of $0.32 at common market weight was observed (Main et al., 2005a). Seasonal variation can be observed in weaning weights and may be dependent upon sow feed intake as it affects milk production (Azain et al., 1996). During the summer months when sow feed intake is depressed, Azain et al. (1996) found an average of a 1 kg/pig decrease in weaning weight when compared to pigs weaned in cooler months. The seasonal effect is also evident in relation to birth weight; however, a different relationship is observed. The trend during the summer months was to observe greater birth weights but lower weaning weights (Azain et al., 1996). Thus, sow feed intake during lactation is very important in early growth of piglets and subsequent growth.
during the nursery and grow-finish phases of production. Increasing weaning weight, instead of trying to influence the variation, has been extremely successful in reducing the number of lightweight nursery and grow-finish pigs (Tokach et al., 1998). A very effective strategy that is being used to increase weaning weight is to increase feed intake of the lactating sow.

All-in, all-out weaning programs and weaning groups of sows to synchronize the sows' reproductive cycle have created groups of pigs with more age and weight variation than in conventional weaning systems. For 3-wk weaning programs, pigs may range from 16 to 26 d of age and from 3.5 to 9.0 kg in body weight at weaning (Mahan and Lepine, 1991). This creates challenges for producers to group pigs together based on body weight and to abide by all-in, all-out practices. In order to compensate for younger or lighter weight pigs, producers often feed a more nutritionally dense nursery diet for a longer period when compared to the diets provided to heavier pigs in an attempt to provide a better nutritional program for the disadvantaged pigs. However, more nutritionally dense diets are very costly to the producer, and increased labor is required in order to feed multiple rations to a single group of pigs.

When comparing the effect of weaning weight on the entire nursery phase, Mahan and Lepine (1991) also reported that total nursery feed consumption was reduced when weaning weight increased. This reflects the shorter feeding duration for pigs weaned at heavier weights. Regardless of weaning age, a heavier pig at weaning may have a more developed digestive tract and is better able to transition from sow's milk to a corn/soy-based diet (Mahan and Lepine, 1991). Strategies that increase weaning weight may have a greater impact on overall pig performance than feeding and management strategies that aim to accelerate growth rate immediately after weaning (Wolter and Ellis, 2001). Thus, the initial weaning weight advantage among the different weight groups was maintained and may have widened by the time the pigs reach market weight.

**Weaning Age**

When considering nursery growth performance, it is evident that weaning age has a significant impact on the pig's ability to transition to a dry diet. As previously discussed, in order to determine the most value for the producer, a threshold weaning age must be identified that will result in optimal piglet growth performance. Leibbrandt et al. (1975) observed that weight gain and feed intake
through 4 weeks postweaning were less as weaning age decreased. Increasing age at weaning enhances the adaptability to postweaning environment, thus less severe weight gain depression (Leibbrandt et al., 1975). Nursery feed intake is influenced by age at weaning which affects rate of gain (Mahan and Lepine, 1991). Energy intake per unit of physiological size was maximized by 3 weeks after weaning and intake during the second week of the nursery phase increased with weaning age (Leibbrandt et al., 1975). The ability of pigs to transition from a liquid diet (sow’s milk) to a dry corn/soy-based diet is dependent upon the maturity of their digestive system. Poor performance of early-weaned pigs may relate to inadequate digestive development, resulting in poor utilization of the nutrients fed after weaning (Leibbrandt et al., 1975).

Due to considerable within litter variation of body weight that is frequently observed, the optimal timing for weaning may vary greatly between individual piglets (Mason et al., 2003). This suggests that every piglet weaned in commercial production systems will react differently to the weaning process. A shift to earlier weaning ages has occurred in the industry and pigs are being weaned at less than 21 days of age, which has been termed as early weaning systems. The premise behind early weaning or segregated early weaning (SEW) is that pigs are removed from the sow between 10 and 20 days of age and are moved to an off-site facility in an effort to reduce disease transmission (Corrigan, 2002). However, shifts toward earlier weaning ages presented many problems including nutrition, housing, health, behavioral, and environmental requirements of the young pig (Pluske et al., 1993). Another response to early weaning systems may be dependent on piglet health status at weaning. An antigenic challenge in young pigs suppressed growth rate but had its greatest impact on feed intake (Schinckel et al., 1995).

Response of piglets to differences in group size is interesting when looking at weaning age. Libal (2001) reported the response of pigs to group size was the same for pigs weaned greater than 20 days when compared to those weaned less than 20 days. The only significant differences between pigs weaned from 10 to 20 days and 20 to 30 days that Libal (2001) observed was in the G:F ratio. The younger pigs (10 to 20 days) had a more desirable G:F ratio when penned in groups of 24 pigs than in groups of 48 pigs. Pigs weaned at an older age (20 to 30 days) in this study had a higher survival rate. Within a weaning treatment, the lighter pigs at weaning gained slower throughout the nursery phase, regardless of group size. This suggests that no matter the stocking density, as long as pen space per pig is maintained, no
effects are observed in performance of pigs in the nursery. A majority of the differences between early and late weaned pigs is evident soon after weaning and throughout the entire nursery and grow-finish phases.

Segregated and medicated early weaning are technologies utilized by the swine industry to improve health of pigs and increase farrowings per sow per year because of shorter lactation lengths (Hohenshell et al., 1997). Increasing farrowings per sow per year is very important to the commercial swine producer because more pigs produced per sow per year increases total pigs produced from a pork operation. There are advantages and disadvantages to these early weaning systems. In addition to optimizing herd health, some other advantages that producers may also observe are improved feed efficiency and growth rate. However, Hohenshell et al. (1997) reported some disadvantages to early weaning systems which included: inconsistent growth performance throughout the finishing phase, decreased postweaning weight gain, abnormal feed intake and increased aberrant behavior. Research by Fangman et al. (1996) reported that pigs weaned between 16 and 21 days of age had greater ADG and feed efficiency when compared to pigs weaned between 11 and 16 d of age, which persisted throughout the 42-day study. More results from the Hohenshell et al. (2000) research supports inconsistent growth performance reported in other studies. Soon after weaning, early weaned pigs had a greater ADG, but ADG dropped dramatically during the last 30 d before harvest.

Main et al. (2004) reported that wean-to-finish ADG, mortality rate, average pig gain per day postweaning, and pounds sold per pig weaned improved linearly as weaning age increased from 12 to 21.5 days. Even though a majority of the benefits of weaning at a later age are observed during the early postweaning period, the effects are consistent through the finishing phase. The linear improvements that Main et al. (2004) observed in growth and throughput with increased weaning age are likely functions of both weight and physiological maturity at weaning. This study directly illustrates the importance of evaluating weaning age in a production system to measure its impact on throughput through the grow-finish phases of production. One of the major considerations in modern pork production is consistency of pig performance, such that facility usage can be optimized by the production of more uniform groups of pigs (Patience et al., 2000).

Pig flow is another consideration that must be dealt with when making decisions regarding weaning age. Pig flow is not constant; surges and delays in pig flow present challenges in managing the growth of pigs. During a surge in pig flow, pigs
in the production system that are ahead of the surge are prematurely forced to the next stage, resulting in a younger weaning age, earlier transfer from nursery to finisher, and/or lighter market weights (Greenley, 2004).

In research by Fangman et al. (1996), it was reported that the older weaning age group pigs (17-21 days of age) demonstrated significantly greater average daily gain than the younger weaning age group pigs (8-13 days of age). Feed efficiency was also significantly improved for the older weaning age group pigs when compared to the younger weaning age group pigs. Thus, the industry must weigh the benefits and costs of weaning age and choose one that is best for the piglet and the sow. The decisions of weaning age are typically driven by the cost and returns from such a weaning age. Many times weaning age decisions are also made based upon needed lactation space and meeting a specific weaned quota each week. The problems that occur are related to weaning pigs from a number of farrowing rooms and also weaning pigs from a wide age range. As the benefits of SEW are realized, we tend to see large differences in growth performance from pigs weaned at 12 days and 21 days of age. Main et al. (2004) reported that nursery ADG, ADFI, mortality rate and 42-day post-weaning weight improved as weaning age increased from 12 to 21 days.

Management of Lightweight Pigs

Management of lightweight pigs is a challenge that many swine producers face. The number and actual weight of lightweight market hogs can directly impact production and marketing decisions, as well as disrupt pig flow in a time-sensitive management system and ultimately impact the pounds of pork marketed per year by a commercial operation. The problem begins at birth; piglets that are lightweight at birth when compared to their heavier littermates will be weaned at lighter weights and remain a significant contributor to the variation in harvest weight (Morrow, 2000). Pigs weighing less than 0.9 kg at birth required 7-15 days longer to reach market weight than did pigs weighing greater than 0.9 kg at birth (Azain et al., 1998). The issue is then to decide whether it is economically to euthanize lightweight pigs at birth versus handling them throughout the subsequent phases of production because they interrupt pig flow. The difficulty with this is in deciding which pigs to euthanize because, on an individual pig basis, there is no room for error as euthanasia is a final decision at any given point in time (Morrow, 2000). If these pigs are not euthanized at birth or soon after, they will either have a high mortality rate or are usually sold as lightweight market hogs which receive an
extremely discounted price when marketed and frequently are not profitable to produce.

With the use of all-in, all out production, lightweight pigs are readily identified; however, the constraints of all-in, all out production limit what producers can do to address the problem (Deen, 2000). Not only is the disruption of pig flow important, but the risk of disease transmission is also a problem. Many farms, in order to empty a barn, transfer these lightweight pigs to another facility to add additional weight. Frequent introductions into these types of facilities place all pigs at a significant disadvantage from a disease standpoint. Additionally, it has been demonstrated that even when lightweight weaned pigs were provided a postweaning diet superior to that fed to pigs of a similar age, it took 10 to 15 days longer for them to reach market weight (Mahan, 1993).

A study by Azain et al. (1998) demonstrated that growth rate differences are evident between heavy and lightweight pigs. The difference in growth rate was greatest between birth and 14 days, with the lighter pigs growing at only 45 percent of the rate of the heavier pigs (Morrow, 2000). When lightweight pigs were fed a liquid diet postweaning, the pigs exhibited improved growth but the benefits of the liquid diet were lost when the liquid feeding was stopped (Azain et al., 1998). Not only is there a correlation between birth weight and marketing weight, weaning weight is also a predictor of end marketing weight. In the same study by Azain et al. (1998), they found that pigs weighing less than 4.5 kg at weaning (21 days) required 12 additional days to reach market weight when compared to pigs weighing greater than 6.8 kg. Even though birth weight and weaning weight are significant predictors of marketing weight, the most important predictor is superior weight gain in the week following weaning. This implies that an emphasis on improving performance in this period of growth will result in greater benefits to the producer (Azain et al., 1998).

The effectiveness of liquid milk in easing the transition from sow’s milk to a solid diet in early weaned pigs and increasing feed intake immediately after weaning has been investigated. The Azain et al. (1998) study indicated that growth and dry matter intake was greater for pigs fed the liquid diets for 4 d postweaning; however the benefits were only sustained while the pigs were on the diet. The most important thing to note from this part of the study is that growth rate of the lightweight pigs was not different from the average weight group.
Brumm et al. (2002) studied the effects of removal and remixing of lightweight pigs on performance to harvest weights. The results suggest that removal of lightweight pigs and remixing of the removed pigs into pens of similar weight pigs is ineffective in improving the overall performance of a population of pigs during the postweaning period. Tindsley and Lean (1984) reported that sorting pigs into finishing pens by uniform weight groups was not effective in improving overall performance to harvest weight. Payne et al. (1999) reported that variation in performance is a very significant problem, but it is often hidden and is very costly to the pork industry each year. Thus, the research conducted by Brumm et al. (2002) and Tindsley and Lean (1984) both suggest that sorting and remixing pigs into pens of similar sizes was not successful in decreasing days to market for lightweight pigs.

A tendency for a greater variation in pig weights at market weight has been reported when simple nursery diets were fed (Mahan et al., 2004). In another study it was reported that smaller pigs at weaning (3.6 kg or less) required more specialized management and feed, and hence were more expensive to produce (Snelson, 2000). They also observed excessively high mortality rates in small pigs. Analysis of the difference between pigs weighing below 3.6 kg and those above 3.6 kg at weaning was conducted and it was reported that lightweight pigs at weaning (<3.6 kg) were 3.2 times more likely to grow slower than pigs weaned weighing > 3.6 kg at weaning (Larriestra et al., 2002).

Although the largest effect of lightweight pigs is seen early postweaning, the industry also has seen very problematic obstacles at the packing plant and in the retail meat case. At the packing plant with harvest capacity relatively constant, fixed costs per pound of retail pork produced increased as harvest pig weight decreased (Deen, 2000). This results in lost profit potential from lightweight pigs. In the meat case, problems exist with inconsistent size or weight, increasing the cost of retail pork products. If consistency is highly valued, then lightweight pigs are nonconformists and their pork products may need to be marketed through alternate retail streams (Deen, 2000). Problems with lightweight pigs occur all throughout the production cycle, the packing plant and in the retail meat case.

In relation to weaning weight and weaning age, mortality rate is an important indicator of nursery performance. Mortality rate is the percentage of pigs entering that die before completing the nursery phase of production and is usually disease related or caused by injury (Baas et al., 2004). As discussed in a previous section, smaller pigs are disadvantaged during the nursery phase. Because they are
disadvantaged, they are less likely to endure adversity while maintaining adequate intake (Roberts, 2000). The primary cause of mean weaning weight differences is the age of piglets at weaning (Roberts, 2000). It is important to understand postweaning management and factors that influence morbidity and mortality in growing pigs (Lowe et al., 2005). Morbidity is defined as pigs appearing ill, diseased, or unthrifty, characterized by loss of body weight (Corrigan, 2002). In a report by Deen (2005), an “at risk” pig was identified as a pig entering the nursery at less than 3.6 kg he reported a strong positive correlation between the “at risk” pig being either dead or lightweight by the end of the nursery phase. This demonstrates the importance of the weight in which a pig enters the nursery and entering as a standard pig (defined previously).

Deen (2000) reported the following example: If a lightweight pig is marketed at $40 instead of $100; the loss of margin is $60 which can be reduced by the savings in feed costs of $15. Thus, the opportunity cost of a lightweight market pig is $45. Lowe et al. (2005) demonstrated that 68% of all mortalities from 10 to 20 weeks postweaning were acute losses. Over 50% of the acute losses were due to enteric disease. This suggests that half of the mortalities that occurred were due to the effects of feed restriction in animals with high feed intake on enteric health (Lowe et al., 2005). In commercial practice, floor mat feeding appears to reduce the morbidity rate in nursery pigs. The rate of piglet morbidity can increase with decreases in diet complexity during the early growth period (Lowe et al., 2005). Low birth weight pigs had a higher mortality and morbidity rate prior to weaning than did high birth weight pigs (10.03 vs. 17.79 %, P < 0.001) in the Lowe et al. (2005) study.

What is the solution to managing lightweight pigs? One solution already discussed is euthanizing lightweight piglets at birth. The advantage to producers of adopting a policy to euthanize more at risk nursery pigs on arrival is that they can immediately improve the welfare status of their farm without incurring any additional capital costs (Morrow et al., 2004). Another potential solution that has been studied is split weaning programs. If split weaning is practiced, positive results occur in improving average piglet size and reducing piglet weaning weight variation, as well as the sow's ability to rebreed and be reproducively efficient. Sows might maintain a high feed intake while nursing a small litter and restore maternal tissue losses, return to estrus sooner, and produce large litters in the subsequent farrowing when split weaning is practiced (Mahan, 1993). Although advantages have been demonstrated when split weaning is used, lightweight pigs
that nursed sows for an additional week took longer to reach market when compared to their heavier counterparts.

Nursery Pig Diets

Profound changes in piglet digestive physiology occur following weaning as the piglet gut adapts to the change in feed type (Pluske et al., 1993). As the piglet transitions from sow’s milk to dry feed, feed intake drops dramatically. During this time of decreased feed intake, the piglet’s system mobilizes significant amounts of lipid reserves and a deficit in energy intake is created (Pluske et al., 1993). The maturation of the digestive system of the pig is a process that causes sub-optimal growth. The actual amount of feed consumed is positively correlated with the development of the small intestine (Pluske et al., 1993). This is the premise behind the goal of formulating diets to stimulate feed intake, which can be accomplished by increasing the complexity of the diet (Tokach et al., 1994). Pigs weaned at 19 d of age gained faster than pigs weaned at 9 d of age, and pigs fed high and medium-complexity diet regimens gained faster ($P > 0.01$) than pigs fed the low complexity regimens (Dritz et al., 1996a). Data from the experiment tend to indicate that diet complexity is critical in the first week after weaning; however, diet complexity can be decreased more quickly without reducing performance (Dritz et al., 1996a).

Complexity of diets fed during the nursery phase can have a significant impact on growth performance of pigs. In later nursery phases, however, the objective for diet formulation changes rapidly to selecting less complex, thus less expensive, diets sufficient to optimize growth performance and protein deposition (Dritz et al., 1996a). In a study by Wolter et al. (2003), pigs fed simple versus complex diets were 2.8% lighter and had greater variation in body weight within pen 56 d postweaning. In the first 56 d postweaning, feeding pigs simple diets resulted in similar ADFI, but lower ADG and G:F ratios and lighter body weights compared to pigs fed the more complex diets (Wolter et al., 2003).

In commercial pork production operations, diet complexity and facility cost through space allocation are two important factors affecting the cost of pork production (Wolter et al., 2003). In the Wolter et al. (2003) study, the impact of diet program on pig growth decreased with increasing time postweaning, and therefore, the impact of diet complexity on body weight 56 d postweaning, although significant, was relatively small. Wolter et al. (2003) also reported that body weight within a pen at the end of week 23 of life tended to be greater for pigs fed simple
than those fed complex diets during the nursery period. Determining the importance of maximizing growth rate during the early stages postweaning on later growth is essential for evaluating the increased costs associated with increasing diet complexity (Haag et al., 2004).

Previously discussed is the effect of diet complexity on postweaning growth, but there are also effects on morbidity. Pigs fed a simple diet had a higher morbidity rate compared to pigs fed complex diets (Haag et al., 2004). In the Haag et al. (2004) study, researchers also performed necropsies on pigs fed the complex and simple diets and found that pigs fed the simple diet all had enteric lesions, but only 1/2 of the pigs fed complex diets exhibited this problem. This could predispose the pig to other enteric problems and diseases throughout subsequent phases of production. These results suggest that the simple diet program may increase the rate of morbidity after weaning, and in practice, result in an increase in therapeutic treatment of pigs (Haag et al., 2004). Studies have shown, however, that feeding complex diets postweaning may be ineffective because it has little affect on ADG and ADFI (Dritz et al., 1996b).

Research has indicated that for pigs weaned at 9 d of age, feeding nursery diets that are too simple increased lipid accretion rates and decreased protein deposition in the grow-finish period (Dritz et al., 1996b). The early-weaned pig has limited capacity to digest vegetable proteins such as soybean meal typically used in simple diets. Dried whey is a feed ingredient commonly used in weanling pig diets because of its lactose characteristics and a similarity to sow’s milk. Although high protein digestibility and high amino acid quality enhances the value of whey, lactose in this form seems to be a primary factor in achieving good performance responses from this product (Mahan, 1992). Studies by Mahan et al. (2004) suggest that pigs would probably benefit from dietary lactose to 25 kg body weight, but pigs of a lighter weight would respond more than heavier weight pigs. The inclusion of lactose throughout the nursery period may be important in maintaining a good intestinal environment and in decreasing variability in pig market weights (Mahan et al., 2004). Lactose is a major substrate that enhances the growth of *Lactobacillus* and its presence helps to suppress other pathogens that decrease pig performance and their health status (Mahan et al., 2004). Thus, lactose in the starter pig diet is essential in the pig’s transition from sow’s milk to a dry diet by allowing for adjustment of the gastrointestinal system as well as decreasing bacterial growth.
Emphasis has been placed on very gradual introduction of soybean meal into the pig’s diet to minimize the potential for immune reaction to the soy proteins, conglycinin and betacyconglycinin, and thus, generally results in excellent growth performance initially after weaning (Tokach et al., 2003). Except for the period shortly after birth and after weaning, pigs appear to have sufficient enzymatic capability to digest proteins, starch and lipids at a rate as great as the need that could possibly be presented based on physical capacity of the digestive tract (Lindemann et al., 1986). The introduction of soy proteins should be a gradual process that replaces lactose in nursery pig diets.

When studying the nutritional requirements of pigs based on weaning age, Tokach et al. (2003) reported that the youngest pigs at weaning gained the smallest amount of body weight from day 0 to 42 after weaning. Data from their study clearly show that weaning weight is important no matter which age pigs are weaned; however, the impact of weaning weight was not as important as weaning age. Pigs weaned at heavier weights and older ages are simply easier to manage and have a lower risk of developing enteric disease (Madec et al., 1998).

Providing nursery diets that will allow pigs to grow when compared to younger and/or lighter weight pigs at weaning is very important. A commercial pork producer desires uniformity in ADG for pigs in a group in order to deliver them to harvest at a similar weight at the same time (Kanis and Koops, 1990). The importance of highly palatable feeds during the first week postweaning is vital to keeping pigs growing in uniform groups.

**Immunity and Stress**

Weaning age in swine is one of the major factors that contributes to the overall level of immunity in the herd (Fangman et al., 1996). Pigs weaned at older ages have more infectious pathogens present when those infectious pathogens are present in the sow herd (Wiseman et al., 1992). Other studies have shown that lower immune function of younger pigs might render them more susceptible to reduced growth performance because of infectious challenges (Dritz et al., 1996a). Piglets must receive colostrum within 36 hours of birth in order to absorb protective factors (mostly antibodies); after 36 hours, the piglet’s gut closes and these colostral antibodies are no longer absorbed into the blood (Harris, 2000). The level of colostral immunoglobulins reaches a maximum at 36 hours and then decreases logarithmically to low levels at 3 weeks of age (Blecha et al., 1983). Thus, results
show that optimal growth performance occurs at 3 weeks of age with pigs being healthier and having a higher immune status.

Variation in the age of piglets in the farrowing room results in wide variation in the age at weaning of sows weaned in all-in, all-out farrowing systems. The variation increases the possibility of lower immunity levels and increases the chance of infection among the oldest pigs in the weaned group (Harris, 2000). In general, the younger the weaning age, the more likely the piglet will be weaned free of infectious agents. If a very high level of immunity can be created and maintained in the sows, weaning age may be increased because fewer pathogens are required to be eliminated. Over stimulation of the immune system of growing pigs due to chronic infection and poor sanitation results in poor performance. To maximize protein deposition, piglets should be reared with as little exposure to infectious agents and harmful antigens as possible to reduce antibody production (Harris, 2000).

Acute phase proteins (APP) have been studied to determine if changes in the levels of these proteins are indicators of immune stimulation or stress (Grellner et al., 2002). Changes in the level of these proteins at weaning time may be an indicator of an immune response and stress at weaning. A specific APP called 1-acid glycoprotein (AGP), when increased serum concentrations are found in the blood, indicate stress or disease (Grellner et al., 2002). Grellner et al. (2002) reported a negative correlation between AGP and weight, which suggests that an active cellular immune response adversely affects protein accretion and growth rate. Disease and other stressors such as weaning may contribute to increases in AGP in pigs that are chronically exposed to pathogens (Grellner et al., 2002). Exposure to stressors such as weaning can activate the immune system and can be a detriment to growth. In a similar study by Schinckel et al. (1995), differences between antigen-challenged pigs and a control were evaluated. It was found that, in the nursery, antigen-challenged pigs had significantly lower growth rate and feed intake than control pigs. This suggests that any challenge on a piglet’s immune system may be detrimental in terms of growth rate and days to market.

It is also vital to the viral exposure of piglets to note the importance of biosecurity in nursery rooms to minimize the introduction of new infectious agents. Age at weaning is one of the many factors that influences swine health and may serve as an unrelenting form of production stress (Francisco et al., 1996). Another factor to consider is that with increased importance of biosecurity and all-in all-out
practices, the mixing of pigs of different ages and from different farms should be avoided because of the risk of spreading disease (Francisco et al., 1996).

Weaning is a stressful event on the piglet because of separation from the sow for the first time, transition to a dry diet and changing environmental conditions. Weaning causes the pig to undergo several physiological transformations and stresses and the degree of these changes is dependent upon weaning age, weaning weight, coping ability, health status, feed intake, diet composition, digestive capability and environment (Corrigan, 2002). To evaluate the stress level, Pluske et al. (1993) measured the increase in plasma cortisol concentrations and behavioral changes in weaned and unweaned pigs and reported that levels reached 2.5 times higher in weaned pigs than in unweaned pigs. Inadequate or low feed intake, lethargy, reduced activity and fever are prevalent during stressful situations (Pluske et al., 1993). The result of the heightened period of stress and possible damage to gut integrity may lead to reduced feed intake immediately after weaning, which can then be followed by a period of over consumption, where large quantities of feed are ingested and overload of the digestive system occurs, resulting in diarrhea (Corrigan, 2002).

The major reason the swine industry has moved to SEW systems is to reduce the chance of transferring pathogens from the sow to the piglet. However, with decreasing use of antibiotics and evaluating the effects of weaning age on growth performance, the pork production industry must evaluate the potential gains from decreasing weaning ages because of pathogen transfer from sow to piglet and the growth differences that have been shown between older and younger weaning groups. It is important to make use of SEW technology to prevent pathogen transmission from sow to piglet but also to look at growth performance differences when weaning pigs at 21 days of age or less.

Behavior

Behavioral response to abrupt environmental changes can be influenced by piglet weaning age, weight and weight variation as well as pre- and post-weaning practices (Corrigan, 2002). Weaning creates a new social setting for pigs and the opportunity to combine pigs from a number of different litters. Mixing pigs appears to cause an increase in fighting that can lead to wounds that may cause infections in hot weather and even result in death (Friend et al., 1983). The behavior of pigs depends on many factors, but one may be the genetic line of the pigs. Much like any
animal, pigs must develop a hierarchy (pecking order) which occurs every time a new group of pigs is established. Typically, pigs spend the first 3 to 5 minutes in the nursery exploring the new environment and fighting tended to commence after the novelty of the pen wears off (Friend et al., 1983).

Based on the behavioral changes that take place at weaning, it is important to examine the differences between piglets weaned at different ages to help determine the most appropriate weaning age for a producer's operation. Worobec et al. (1999) reported that weaning piglets on or before 14 days of age may result in reduced performance and the development of behavior patterns that either cause, or are indicators of, reduced welfare. Specific behavior has been reported in younger weaning age systems. Oral behavior in piglets that has been observed as signs of stress include: belly-nosing, flank biting and oral manipulation of pen-mates' ears, tails and other body parts (Worobec et al., 1999). Researchers also suggested that nosing littermates in the younger piglets acted as substitutes for teat contact with the sow. Nosing and chewing of the other piglets exhibited by piglets weaned at 12 days of age persisted into the grow-finish period (Gonyou et al., 1998). Not only the original decision to wean early impact nursery behavior, but it can also continue on in subsequent phases and significantly affect the growth performance of these early weaned pigs.

Stress and discomfort are two of the many factors that have been associated with higher frequencies of tail biting. Tail biting is one of the most common problems in confinement herds (Kritas and Morrison, 2004). Tail biting is a complex behavioral condition that may cause substantial economic losses due to slow growth, carcass devaluation, and increased cost for labor and medication costs (Kritas and Morrison, 2004). Pigs that are housed in over-stocked pens immediately postweaning in wean-to-finish facilities designed for achieving optimal performance during the finishing period may require additional feeder trough space to maximize growth performance (Lowe et al., 2005). Other stressors such as high ambient temperature, reduced space allowance and regrouping decreased ADG, feed intake and G:F (Hyun et al., 1998). Removal of a stressor substantially impacts growth performance. Mason et al. (2003) studied the effects of weaning at day 21 and day 35 on piglet behavior. Distress vocalizations were found to remain at higher levels for a longer period of time in piglets weaned at 21 d compared to those weaned at 35 d. This provides further evidence that the process of weaning provokes a greater stress response on
younger piglets and occurs at the time they are removed from the sow (Mason et al., 2003).

Pigs weaned as early as 7 days had significantly more behavioral problems such as belly-nosing, more time in escape behavior and very little time at the feeder immediately after weaning compared to a pig weaned at 14 or 28 days (Worobec et al., 1999). Smaller pigs (because of age) are more stressed by weaning and thus have more behavioral challenges and growth lag during the initial days post weaning. Profound changes occur during the weaning process and cause considerably more distress to the animal the earlier the separation occurs (Mason et al., 2003). It is important to also look at feeding behavior. In a study by Bruininx et al. (2001), they found that lightweight pigs make more total daily visits to the feeder, but feed intake was not different between heavy and lightweight pigs. Bruininx et al. (2001) also reported that in pens of unacquainted pigs during the first days after weaning, heavy pigs spent more time on aggressive behavior, resulting in less feed consumption than pigs who were less aggressive. The heavier pigs experienced lower stress levels from weaning but it took longer for them to develop the social hierarchy.

Belly nosing has been found to be more prevalent in pigs weaned at earlier ages (Straw and Bartlett, 2001; Widowski et al., 2003). A study by Main et al. (2002) quantifies the effect on weaning age, reporting that weaning pigs at less than 15 days of age significantly increases belly nosing behavior and associated umbilical lesions. There are a couple of reasons that have been examined as possible theories for the reason belly nosing develops. First, belly rubbing develops because of frustrations that result from removal of the sow which may cause suckling behavior to be redirected toward pen mates (Straw and Bartlett, 2001). Secondly, nosing may be a normal rooting or exploratory behavior for swine (Dybkjar, 1992). Straw and Barlett (2001) reported that the growth rate of the belly nosing recipient was not affected, however, the perpetrators had a significantly slower growth rate. Additionally, inflammation in the umbilical region because of belly nosing due to either physical damage or localized infection is thought to be a contributing factor to umbilical hernias (Main et al., 2002). An important implication is that pigs weaned earlier are more active in stress related behaviors that affect growth rate.
Economics of weaning age

The costs and revenues associated with the breeding herd of a commercial pork operation are very influential in weaning age decisions. Increasing weaning age to 21.5 days resulted in linear increases in weaned pig value (Main et al., 2005a). Assessing a common value to acceptable quality weaned pigs, regardless of weaning age or weight, may lead to false conclusions concerning a breeding herd’s true financial performance (Main et al., 2005a). Revenue and income over cost per pig weaned increased and cost per hundred weight of weaned pigs decreased as weaning age increased from 12 to 21 days (Main et al., 2005a). Increasing weaning age increased pounds sold per pig weaned due to improvements in growth and livability (Main et al., 2005a). Overall results of this study demonstrated that weaning older pigs up to 21.5 days was more profitable. Dritz and Tokach (1998) also supported this premise that average weaning weight below or above the profit maximizing point decreases profitability.

The ability to produce a piglet that enters the finishing stage with the greatest potential to have the least cost of production should be a goal of every production system (Olsen, 2004). Weaning pigs later is a management decision that strives to meet this goal which is supported from studies in the early 80’s references and then again with the Main et al. (2005a) research. As the U.S. commercial pork industry has evolved, the importance of reducing variation in pig weights between groups of marketed pigs has become extremely important. Weaning pigs at older ages can reduce the variation in piglet weight throughout the production phases. Dependent upon finishing space, whether limited or non-limited, the income over costs reported by Main et al. (2005a) were vast; “If finishing space is limited, increasing weaning age from 16 to 19 days is predicted to improve income over cost by $2.82/pig.”

Weaning age itself is an important driver of nursery costs, but looking at mortality and morbidity within weaning age is another important factor in determining the appropriate weaning age for individual pork operations. Mortality and morbidity can be very costly to a producer. Main et al. (2004), reported a mortality rate of 2.82% for pigs weaned at 15 d of age and 0.54% for pigs weaned at 20 d of age. This presents a significant loss of income from pig mortality, but also the increased expense of feeding the pig until it died. Morbidity is also important to consider when examining lost income or increased costs of feeding these pigs. Variability in profits, ADG and G:F for lightweight pigs can be very high for
producers. Mortality and morbidity in the nursery are largely a function of entry and exit weight, and weaning age significantly impacts both of these weights.

When considering increasing the weaning age for a pork operation, there are a few implementation options to consider. Increasing the number of farrowing crates, decreasing the time between groups of sows, and more accurately or tightly controlling the breeding/farrowing schedule to reduce age variability are some of these options. Two of these three suggestions assume a change in management with relatively little investment in addition/remodeling to facilities. In a study by Lawrence (1996), alternate investments were investigated to determine the profitability of investment decisions. In the study, a continuous-flow, single site operation was considering implementing either all-in, all-out on one site or SEW with different weaning ages ranging from 11 days to 17 days on three sites. The most profitable of the decisions involved weaning at 17 d of age and breeding on the first estrus. With an initial investment of $450,000, the cash after principle was steady at $42,000 (Lawrence, 1996). This suggests that the older the weaning age (up to 21.5 d), the greater the return on investment, no matter what the investment.

When producers make the decision to increase weaning age, there are a number of alternatives to effectively manage lactation space. In a study by Main et al. (2005b), four alternatives were modeled to increase weaning age: making more efficient use of lactation space, adding lactation space, a combination of increasing efficiency and adding lactation space or reducing the number of sows farrowing per week. The study reported that increasing the efficiency of lactation space and adding lactation spaces collectively would increase net revenue by $31.63 per sow space per year (Main et al., 2005b). This increase in net revenue was greater than any of the other alternatives, suggesting that improving efficiency of lactation space and adding lactation spaces may provide opportunities to improve profitability for commercial swine producers.

Variation in weaning age is one of the biggest drivers of variation in the final market weight in many production systems. Thus, when determining the age to wean pigs, you must consider growth differences, investment options and also cost of nursery and finisher space to determine the optimal weaning age for individual pork operations. Pigs weaned earlier on medium (2,000-9,999 pigs) and large size (10,000 or more pigs) sites spent more time in nurseries on average than pigs on small sites (APHIS, 2002). Fixed costs associated with larger nurseries represent a smaller portion of the total costs because facility costs can be spread over a large
number of pigs each year. Variable costs make up a large portion of the total costs to a producer and these costs include items such as feed, veterinary costs, death loss, labor costs, any interest costs, and marketing costs. Variable costs associated with nursery production are much greater when compared to variable finishing costs, especially when you examine feed costs. In the Main et al. (2005b) study, feed costs differed by $179.7/metric ton in one trial and close to $220.5/metric ton in another trial, with the more complex nursery diets having a significantly higher amount.

**Sow Performance**

Applying early weaning management practices has effects on sow performance as well, so in order to make the best decision regarding weaning age, the sow’s performance must be evaluated. A sow’s ability to return to estrus, conceive on her first service, and subsequent litter size are all economically relevant reproductive traits to measure her performance (Mabry et al., 1996). Not only are these reproductive traits important, but alterations in skeletal muscle protein metabolism that permit a diversion of muscle protein reserves toward milk production during lactation are also important (Clowes et al., 2005). Preserving maternal protein reserves would reduce further reproductive problems, such as anoestrus.

Lactation places an enormous metabolic demand on a sow, and causes the sow to lose weight. A loss of 10 to 15% of the sow’s body weight in lactation reduces milk production and subsequent reproductive performance (Clowes et al., 2003). Even properly managed sows can potentially lose large amounts of body weight during lactation. If a sow mobilizes too much muscle protein, there will be less milk production which results in reduced litter growth as well as unfavorable subsequent reproductive performance.

The effect of lactation length is extremely influential on sow reproductive performance and productivity. In theory, reducing lactation length would decrease the interval between farrowings and increase litters per sow per year and pigs weaned per sow per year, if sow weaning-to-estrus interval, conception rate and subsequent litter size remained constant (Belstra, 1999). However, as one might expect, conception rate, wean-to-estrus interval and subsequent litter size do not remain constant as lactation length changes. Studies have shown that there is no change in pigs weaned per sow per year due to reduced sow reproductive performance and increased non-productive days associated with reducing lactation length (Xue et al., 1993). Research has shown that as lactation length drops below 21
days, there is a substantial increase in sow weaning-to-estrus interval and a decrease in conception rate and subsequent litter size. The average weaning-to-first service interval did not exceed 7 days until lactation length was less than 14 days. Sow recycling was affected by the difference in weaning age (Mabry et al., 1996). Another study demonstrated the influence of lactation length on conception rate; at lactation lengths of 14-16 days an 83% conception rate was observed and at 20-22 days an 88% conception rate was found (Dial, 1995). There is a positive relationship between lactation length and conception rate, which implies as lactation length decreases, conception rate decreases as well. A reduction in lactation length from 20 days to 15 days would appear to result in an average reduction in litter size of 0.20 pigs per litter born alive in the sow’s next litter (Mabry et al., 1996).

Inevitably, there are factors that affect reproductive response of sows to early weaning. Sows’ responses to early weaning may differ from farm to farm; however, some trends are present in reproductive responses. First parity (primiparous) gilts are often times still maturing and the demands from lactation can cause excessive loss of body reserves and reduced reproductive performance postweaning (Belstra, 1999). However, primiparous sows seem to be the most susceptible to the negative effects of short lactation lengths. Thus, it would be beneficial to allow primiparous sows to lactate a few days longer than multiparous sows.

Lactation feed intake is extremely important. Maintaining high lactation feed intake can reduce many reproductive and body conditioning problems. Studies suggest that sows that consume greater than 5.9 kg feed/day on average do not exhibit a large increase in wean-to-estrus interval or a decrease in conception rate and subsequent litter size (Dial, 1995). Whereas, sows that consume less than 1.9 kg feed/day do exhibit a large reduction in reproductive performance (Koketsu et al., 1997). Not only is lactation feed intake important, but increased maternal nutrition during early and midgestation is also extremely important in the development of the piglets. Malnutrition in utero results in low birth weight, a decrease in muscle fiber number and a reduction in postnatal growth rate of the piglets (Dwyer et al., 1994).

Depletion of maternal reserves may eventually compromise both the current lactation and subsequent reproduction. Thus, it is evident that mobilization of a sow’s body reserves to support her litter is a very important aspect of sow welfare and performance. A substantial fraction of the differences in body weight and protein at the end of lactation were attributable to skeletal muscle (Clowes et al., 2003). Additionally, multiparous sows channel extra nutrients into maternal tissue
accretion and milk production (Clowes et al., 1998). If sows fail to eat or are restricted from feed during lactation, milk output is maintained but the sows extensively mobilize their protein reserves to maintain their milk production (Clowes et al., 1998).

Skeletal muscle is the main source for protein that can be mobilized by the sow when needed. Therefore, changes in muscle mass are attributed to mobilizing protein to support lactation. In the Clowes et al. (2005) study, by the end of lactation, sows were calculated to have lost approximately 16, 20 and 36% of their muscle mass present at parturition, dependent upon feeding level during gestation (2.8, 2.5 and 2.3 kg/day, respectively). It is important to maintain energy and nitrogen intake required for maintenance and milk production in order to reduce mobilizing body reserves and ultimately, maternal losses of skeletal muscle. Mullan and Williams (1990) examined maternal weight loss. Of the 16 kg of weight lost by a sow nursing 10 piglets during her first 28-day lactation, it was predicted that 2 to 9 kg was protein and 3 to 5 was lipid. As lactation continues, muscle mobilization rate increases because during late lactation, when milk demands are the greatest and feed intake does not meet these needs, protein is mobilized from muscle (Clowes et al., 2005).

The need to find an optimal lactation length becomes very important when balancing sow reproductive performance, interval between farrowings and sow body reserves. The change in sow body reserves is negatively associated with these specific sow reproductive measures. Theoretically, as we move toward shorter lactation lengths we would expect to minimize loss of sow body reserves which in turn should improve sow welfare and reproductive performance (Belstra, 1999). It is important to examine the stresses that weaning places on the sow as well as the piglet.
CHAPTER 3. EFFECT OF PIGLET BIRTH WEIGHT AND WEANING WEIGHT ON NURSERY OFF-TEST WEIGHT

A paper to be submitted to the Journal of Swine Health and Production

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ABSTRACT

An experiment was conducted to evaluate the effect of piglet birth weight on weaning and nursery off-test weights. The study utilized Yorkshire x Landrace barrows and gilts from a commercial maternal line multiplication herd. A total of 2,467 pigs were randomly allocated to nursery pens based on weaning age group. Pigs were weaned at either a 15 d (pigs weaned at 14, 15, and 16 d) or a 20 d (pigs weaned at 19, 20, and 21 d) average age. Twenty-eight pigs were housed in each 2.44 x 3.05 m nursery pen. Feed disappearance was recorded on a pen basis through the nursery phase. Diets were fed in four phases with the total lysine content of each diet being 1.70%, 1.50%, 1.30%, and 1.20%, respectively. Individual piglet weights were recorded within 24 h of birth, on weaning day, and 42 d postweaning (off-test weight). Individual birth weight records were partitioned into nine categories. These categories incrementally increased or decreased by one-half SD (0.16 kg) from the birth weight mean (1.57 kg). Similarly, individual weaning weight records were partitioned into nine categories. These categories incrementally increased or decreased by one-half SD (0.68 kg) from the weaning weight mean (5.80 kg). To study the effect of birth weight on weight at subsequent phases, fixed effects of birth weight category and parity of dam were included in the model for weaning and off-

¹ This journal paper of the Iowa Agric. and Home Econ. Experiment Station, Ames, IA, Project No. 3600, was supported by Hatch Act and State of Iowa funds. The authors gratefully acknowledge H & K Enterprises, Inc., Nevada, IA for allowing the study to be conducted at their facility, and for technical assistance.

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test weights. A linear ($P < 0.05$) weaning age covariate was also included in the birth weight category analysis. To evaluate the effect of weaning weight on off-test weight, fixed effects of weaning weight category and parity of dam were included in the model. Percentages of piglets surviving from birth to weaning were calculated across birth weight categories with the lowest survival occurring in category 1. Birth weight category was a source of variation in the analyses of weaning ($P < 0.01$) and nursery off-test ($P < 0.01$) weight. Without exception, weaning and nursery off-test weights significantly increased with increasing birth weight category. Nursery off-test weight increased ($P < 0.05$) with increasing weaning weight category. Parity of dam was a source of variation ($P < 0.01$) for weaning and nursery off-test weights. Producers should employ management improvements in order to increase birth weights while maintaining low within litter variation, and weaning weights as a means to improve weights at the end of the nursery phase.

Keywords: Birth Weight, Pigs, Weaning Weight

INTRODUCTION

Within the swine industry, increased number born alive has been a selection objective to increase litter size at birth and at weaning. Selection for litter size is negatively correlated with birth weight (Roehe, 1999). However, with increased number born alive, average piglet birth weight and birth weight variation have contributed to higher piglet mortality (Quiniou et al., 2002). Additionally, low birth weight piglets often experience lower weight gains and survivability in subsequent phases of production (Gondret et al., 2005). Increased use of three-phase production and all-in, all-out systems has made growth rate extremely important throughout most pork operations. Slow growing and/or substandard pigs interrupt pig flow in time sensitive production systems (Harris, 2000).

At weaning, pigs weighing less than 3.6 kg require greater management and more complex diets, which increase production costs for pork producers (Damgaard et al., 2003). Studies indicate piglets weighing less than 1 kg at birth have very little chance of still being alive or of producing a standard pig at weaning (Damgaard et al., 2003). A standard pig is referred to as a pig falling within a target market weight range—and not substantially discounted from an established base price or value (Baas et al., 2004). Ultimately, light birth weight pigs have lower BW and are unable to meet ideal market weight demands of the processor or alternatively, have
extended stays in the finisher to reach a more desirable market weight. Both situations reduce profit potential for pork production operations.

Management can play a significant role in survival rates as well, and it is important to determine a threshold for birth weights above which saving piglets is economically feasible. Thus, the objectives of this study were to: (1) model the effects of birth weight on survival to weaning, and (2) assess the effect of piglet birth weight on weaning weight and nursery off-test weight.

**MATERIALS AND METHODS**

*Animals and Procedures*

The experiment was conducted using Danbred N.A. (Columbus, NE) maternal line barrows and gilts from a maternal line multiplication herd (H & K Enterprises, Nevada, IA). A total of 89 pens (7 to 8 pens per group and 12 groups) were utilized in the study, with each pen housing 26 to 28 pigs (n=2,467). Each pen consisted of approximately 50% barrows and 50% gilts. Data were from Yorkshire (Y) x Landrace (L) crossbred pigs. All pigs were produced by purebred L sows in their first to eleventh parities (Table 1). Sows in parity 6 and greater were grouped into 1 parity class for the purposes of this study. Parities greater than 6 were combined for 3 specific reasons: (1) performance between parties 6, 7, 8, 9, 10, and 11 was similar, (2) combining provided a more equal distribution, and (3) many commercial operations automatically cull at parity 6 (PigCHAMP, 2004). The experimental protocol followed the commercial production practices of the operation and met or exceeded requirements in Guidelines for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999).

Each piglet was individually identified, weighed, and sex was determined within 24 h of birth. At birth, pigs from each litter were assigned to 1 of 2 weaning age groups. The first group averaged 15 d of age at weaning and included pigs that were 14, 15, and 16 d of age. The second weaning age group averaged 20 d of age at weaning and included pigs that were 19, 20, and 21 d of age. Neonatal pigs that were cross fostered were moved before 3 d of age. By 7 d of age, all boars were castrated. On weaning day, piglets within each weaning age group were weighed and randomly assigned to nursery pens. Body weights were recorded at weaning and 42 d postweaning (off-test weight).

Pigs were housed in a mechanically ventilated, heated, thermostatically controlled, totally confined nursery with plastic slatted flooring. Pigs were raised in
2.44 x 3.05 m nursery pens, providing 0.27 to 0.29 m² of floor space per pig. Each pen was equipped with a single-sided stainless steel self-feeder (Chore-Time, Milford, IN)(76.2 cm linear trough space/pen) and 2-nipple drinkers, which provided pigs ad libitum access to feed and water. Pigs were fed a 4-phase diet regime from weaning to 42 d postweaning with feed disappearance recorded on a pen basis. A feed budget was developed which provided each pig 1.25 kg of a 1.70% lysine pellet, 6.14 kg of a 1.50% lysine meal diet, 12.57 kg of a 1.30% lysine meal diet, and the remainder was a 1.20% lysine meal diet. Pigs were removed from test pens due to mortality or if a condition existed in which the pig did not respond to medical treatment (non-ambulatory).

**Statistical Procedures**

*Birth weight category.* Data were analyzed using PROC MIXED of SAS (Cary, NC). An analysis was completed that analyzed all pigs born alive, and a body weight was recorded at birth. This analysis included all of those pigs that did not survive until weaning (pre-weaning mortalities). Within this analysis, individual piglet birth weights were partitioned into nine categories which were 1/2 SD (0.17 kg) from the birth weight mean (1.55 kg). Survival rates from birth to weaning were computed from the birth weight categories of interest. A chi-square test for proportions (SAS, 2003) was utilized to evaluate survival differences among birth weight categories using mean separation.

Individual birth weight records were partitioned into 9 birth weight categories. These categories incrementally increased or decreased by 1/2 SD (0.16 kg) from the birth weight mean (1.57 kg). In the analysis of weaning and off-test weights, fixed effects of birth weight category, parity of dam, and a linear weaning age covariate were included in the model. Only pigs that were weaned were included in this birth weight category analysis. The two way interactions between fixed effects were tested but were dropped from the models because they had little impact.

*Weaning weight category.* Similarly, individual weaning weight records were partitioned into 9 weaning weight categories. These categories incrementally increased or decreased by 1/2 SD (0.68 kg) from the weaning weight mean (5.80 kg). Fixed effects of weaning weight category, parity of dam, and the linear regression of nursery off-test age and weaning age were included in the model used to analyze off-test weight. The two way interactions between fixed effects were tested but were dropped from the models because they had little impact.
Pig was the experimental unit for all traits measured on the individual animal. Least squares means (± SE) and differences among fixed effect levels were obtained using the PDIF (SAS, 2003) option in SAS.

RESULTS AND DISCUSSION

Birth weight category

Survival to weaning. Survival patterns from the current study across birth weight categories are listed in Table 2. Although the maximum survival (97.1%) was not obtained in the heaviest birth weight group (> 2.06 kg), it is evident that the lowest survivability (71.2%) was observed in the lowest birth weight category (< 0.87 kg). Quiniou et al. (2002) reported that pigs weighing less than 1 kg at birth had very little chance of being alive at weaning. These results are similar to those reported by Gondret et al. (2005), who found that 86% of the piglets weighing less than 0.80 kg did not survive to weaning. Gardner et al. (1989) divided birth weights into 9 groups ranging from less than 601 g to greater than 2000 g. They reported that increases in birth weight category were associated with increasing odds of 7- and 21-d survival, with maximum survival being obtained in the highest birth weight group (> 2 kg).

It is possible that different outcomes could occur by operation or by genetic lines being utilized. Each commercial swine producer should determine, whether it is worth while from an economic standpoint, to euthanize lightweight piglets at birth versus handling them throughout the subsequent phases of production. Higher mortalities, higher morbidity, and increased number of substandard pigs are reasons why it may not be worthwhile to handle lightweight piglets. Variable costs may also be greater than the sales income from lightweight pigs.

Weaning weight. Birth weight category was a highly significant source of variation in the analysis of weaning weight. Without exception, weaning weight increased (P < 0.05) with increasing birth weight category (Table 3). A linear weaning age covariate (P < 0.01) states that for every 1 day increase in weaning age there is a 3.6 kg increase in weaning weight. These results agree with previous work by Damgaard et al. (2003) and Quiniou et al. (2002) who reported that piglets that are lighter at weaning have lighter body weight throughout the grow-finish phase of production. Like the present study, both studies utilized maternal line barrows and gilts.
In the present trial, parity of dam was a source of variation ($P < 0.01$) for weaning weight across birth weight category (Table 6). Previous work indicates that weaning weights increased for sows up to parity 4, then declined in subsequent parities (Baas et al., 1992; NSIF, 1997). Baas et al. (1992) demonstrated that the effects of parity increase initially and then decrease in subsequent parities. Similarly, NSIF (1997) defines parity 4 as the parity where peak production occurs. However, in the current trial, weaning weights increased until parity 4, decreased in parity 5, and increased in parity 6 and above. The present results differ from previous work and are likely due to the relatively low number of sows in each parity subclass when compared to the number of records that were used to develop the NSIF (1997) parity adjustments.

**Nursery off-test weight.** Birth weight category was a source of variation ($P < 0.01$) in the analysis of nursery off-test weight. Without exception, nursery off-test weight increased ($P < 0.05$) with increasing birth weight category (Table 4). The linear regression of weaning age ($P < 0.01$) on nursery off-test weight states that for every 1 day increase in weaning age there is a 0.7 kg increase in nursery off-test weight. Previous studies support the current findings. Campbell and Dunkin (1982) studied piglets from Large White litters and divided the piglets into heavy and light birth weight classes. They reported that relative differences in body weight will be perpetuated after weaning and result in light birth weight pigs being considerably older, or lighter at eventual slaughter than their heavier birth weight littermates. Powell and Aberle (1980) also reported similar results. They studied crossbred piglets and divided them into three birth weight groups and reported that low birth weight piglets grew slower from birth until slaughter. Whether purebred or crossbred pigs were evaluated; growth performance relationships from birth until end of nursery produced similar results.

In the present trial, parity of dam was a source of variation ($P < 0.01$) in nursery off-test weight (Table 7). Nursery off-test weights varied across parities and no consistent pattern by parity was observed. It is difficult to biologically explain the results observed considering the relatively small range of differences (19.95 kg to 21.03 kg) across the 6 parity classes.
Weaning Weight Category

Nursery off-test weight. Weaning weight category was a source of variation (P < 0.01) in the analysis of nursery off-test weight. Nursery off-test weight increased (P < 0.05) with increasing weaning weight category (Table 5). The linear regression of weaning age (P < 0.01) on nursery off-test weight indicates that for every 1 day increase in weaning age there is a 0.12 kg increase in nursery off-test weight. The linear regression of nursery off-test age on nursery off-test weight was not significant (P = 0.15). Weaning weight appears to be a better predictor of nursery off-test weight than birth weight, as the effect of 1/2 SD of weaning weight on nursery off-test weight is greater when compared to the effect of 1/2 SD of birth weight. However, in the current study, the relationship between birth weight and weaning weight categories is positively related to pig weight at the end of the nursery phase of production. Wolter et al. (2002) studied the effect of birth weight on growth performance using crossbred pigs. They reported that birth weight had a greater impact on growth performance after weaning than increasing nutrient intake during lactation. Many previous studies have reported that lightweight pigs at birth (Wolter et al., 2002; Gondret et al., 2005; Walters, 2004) or at weaning (Wolter and Ellis, 2001) require a greater number of days to reach the same market weight than their heavier littermates.

In the present study, light pigs at birth and weaning had lower body weight 42 d postweaning. These findings are in agreement with previous work (Main et al., 2004). The results of the current study focused on the initial 42 d postweaning, mainly because previous research (Main et al., 2004) indicated that improvements in growth and mortality largely occurred in the initial 42 d postweaning. Previous work (Gondret et al., 2005) demonstrated that when lightweight pigs were placed in collective pens, they competed less effectively for feed when compared to heavier pigs during the postweaning period. These findings may explain why lightweight pigs at the end of the nursery phase of production continue to be lightweight in subsequent production phases.

Low birth weight pigs continued to be lightweight in subsequent phases of production in the present study. The lightweight pigs were considered to be a health risk for their contemporaries throughout the production system. Other operations may find different results and should develop their own threshold levels for determining which pigs should be euthanized or considered substandard based on the availability of alternative markets to sell lightweight pigs. Alternatively,
different facilities could be used to rear lightweight pigs. For example, a hoop building could be a lower cost facility that could be used to raise lightweight pigs in an attempt to increase an operations income.

IMPLICATIONS

In order to increase birth weights while maintaining low within litter variation, producers should utilize management factors such as increased feeding in the last three weeks of gestation, and grouping sows by size. Research has shown that birth weight and weaning weight are good predictors of nursery off-test weight. Producers should further evaluate their lowest birth weight pigs to identify piglets that should be euthanized. Producers need to determine this threshold on an individual herd basis. Relative differences in body weight at birth were perpetuated after weaning and resulted in light birth weight pigs being lighter when weighed off test in the nursery than heavier birth weight pigs. Parity of dam also influences piglet weight in subsequent phases of production, with pigs born to primiparous sows having a growth disadvantage. A heavier pig at the end of the nursery phase will be worth more money if marketing feeder pigs or in a farrow-to-finish operation.

LITERATURE CITED


Table 1. Number of pigs by parity, from a study evaluating birth, weaning, and end of nursery weights from a maternal line of barrows and gilts

<table>
<thead>
<tr>
<th>Parity</th>
<th>No. of pigs$^a$</th>
<th>No. of litters$^a$</th>
<th>No. of pigs$^b$</th>
<th>No. of litters$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>838</td>
<td>91</td>
<td>726</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>534</td>
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<td>463</td>
<td>57</td>
</tr>
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<td>3</td>
<td>371</td>
<td>49</td>
<td>317</td>
<td>38</td>
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<td>4</td>
<td>342</td>
<td>54</td>
<td>286</td>
<td>42</td>
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<td>5</td>
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<td>40</td>
<td>201</td>
<td>33</td>
</tr>
<tr>
<td>&gt; 5</td>
<td>552</td>
<td>89</td>
<td>474</td>
<td>79</td>
</tr>
<tr>
<td>Total</td>
<td>2893</td>
<td>386</td>
<td>2467</td>
<td>339</td>
</tr>
</tbody>
</table>

$^a$All pigs were included in this analysis, including preweaning mortalities.

$^b$Pigs in this analysis consisted only of pigs that were weaned on test.
Table 2. Effect of birth weight category on survivability in a maternal line of barrows and gilts

<table>
<thead>
<tr>
<th>Birth weight category&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Number of piglets/category (n=2,893)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Minimum weight, kg</th>
<th>Maximum weight, kg</th>
<th>Mean birth weight within category, kg</th>
<th>SD</th>
<th>Survival, %&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>59</td>
<td>0.57</td>
<td>0.87</td>
<td>0.77</td>
<td>0.08</td>
<td>71.2&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>139</td>
<td>0.88</td>
<td>1.04</td>
<td>0.98</td>
<td>0.05</td>
<td>97.1&lt;sup&gt;w&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>259</td>
<td>1.05</td>
<td>1.21</td>
<td>1.14</td>
<td>0.05</td>
<td>93.8&lt;sup&gt;w&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>405</td>
<td>1.22</td>
<td>1.38</td>
<td>1.30</td>
<td>0.05</td>
<td>95.6&lt;sup&gt;w&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>617</td>
<td>1.39</td>
<td>1.55</td>
<td>1.47</td>
<td>0.05</td>
<td>79.6&lt;sup&gt;yz&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>566</td>
<td>1.56</td>
<td>1.72</td>
<td>1.64</td>
<td>0.05</td>
<td>82.5&lt;sup&gt;xy&lt;/sup&gt;</td>
</tr>
<tr>
<td>7</td>
<td>407</td>
<td>1.73</td>
<td>1.89</td>
<td>1.80</td>
<td>0.05</td>
<td>78.4&lt;sup&gt;yz&lt;/sup&gt;</td>
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<tr>
<td>8</td>
<td>273</td>
<td>1.90</td>
<td>2.06</td>
<td>1.96</td>
<td>0.05</td>
<td>87.2&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td>9</td>
<td>168</td>
<td>2.07</td>
<td>2.85</td>
<td>2.24</td>
<td>0.16</td>
<td>86.3&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> These categories incrementally increased or decreased by ½ SD (0.16 kg) from the birth weight mean (1.57 kg).

<sup>b</sup> All pigs were included in this analysis, including preweaning mortalities.

<sup>c</sup> Within a column, means without a common superscript differ (P < 0.05).
### Table 3. Effect of birth weight category on weaning weight in a maternal line of barrows and gilts$^a$

<table>
<thead>
<tr>
<th>Birth weight category$^b$</th>
<th>Number of piglets/category (n=2,467)$^c$</th>
<th>Minimum weight, kg</th>
<th>Maximum weight, kg</th>
<th>Mean birth weight within category, kg</th>
<th>Mean wean weight, kg$^d$</th>
<th>SEM</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>42</td>
<td>0.66</td>
<td>0.94</td>
<td>0.86</td>
<td>4.15$^e$</td>
<td>0.13</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>2</td>
<td>135</td>
<td>0.95</td>
<td>1.10</td>
<td>1.03</td>
<td>4.65$^a$</td>
<td>0.07</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>3</td>
<td>243</td>
<td>1.11</td>
<td>1.26</td>
<td>1.19</td>
<td>5.03$^i$</td>
<td>0.05</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>4</td>
<td>387</td>
<td>1.27</td>
<td>1.42</td>
<td>1.35</td>
<td>5.38$^{da}$</td>
<td>0.04</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>5</td>
<td>491</td>
<td>1.43</td>
<td>1.58</td>
<td>1.51</td>
<td>5.76$^y$</td>
<td>0.04</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>6</td>
<td>467</td>
<td>1.59</td>
<td>1.74</td>
<td>1.67</td>
<td>6.08$^w$</td>
<td>0.04</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>7</td>
<td>319</td>
<td>1.75</td>
<td>1.90</td>
<td>1.82</td>
<td>6.39$^x$</td>
<td>0.05</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>8</td>
<td>238</td>
<td>1.91</td>
<td>2.06</td>
<td>1.97</td>
<td>6.64$^y$</td>
<td>0.05</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>9</td>
<td>145</td>
<td>2.07</td>
<td>2.85</td>
<td>2.24</td>
<td>7.15$^z$</td>
<td>0.07</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

$^a$Pigs were weaned at either a 15 d average (pigs weaned at 14, 15 or 16 d) or a 20 d average (pigs weaned at 19, 20 or 21 d) weaning age.

$^b$Individual piglet birth weights were partitioned into 9 categories which incrementally increased or decreased by $\frac{1}{2}$ SD (0.16 kg) from the birth weight mean (1.57 kg).

$^c$Only pigs that were weaned were included in the analysis.

$^d$Within a column, means without a common superscript differ (P < 0.05).
Table 4. Effect of birth weight category on nursery off-test weight in a maternal line of barrows and gilts

<table>
<thead>
<tr>
<th>Birth weight Category</th>
<th>Number of piglets/category(n=2,391)</th>
<th>Minimum weight, kg</th>
<th>Maximum weight, kg</th>
<th>Mean birth weight within category, kg</th>
<th>Mean off-test weight, kg</th>
<th>SEM</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>39</td>
<td>0.66</td>
<td>0.94</td>
<td>0.86</td>
<td>15.52z</td>
<td>0.47</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>2</td>
<td>125</td>
<td>0.95</td>
<td>1.10</td>
<td>1.03</td>
<td>17.31s</td>
<td>0.27</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>3</td>
<td>232</td>
<td>1.11</td>
<td>1.26</td>
<td>1.19</td>
<td>18.05t</td>
<td>0.20</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>4</td>
<td>379</td>
<td>1.27</td>
<td>1.42</td>
<td>1.35</td>
<td>19.27u</td>
<td>0.16</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>5</td>
<td>475</td>
<td>1.43</td>
<td>1.58</td>
<td>1.51</td>
<td>20.00v</td>
<td>0.14</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>6</td>
<td>453</td>
<td>1.59</td>
<td>1.74</td>
<td>1.67</td>
<td>20.76w</td>
<td>0.14</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>7</td>
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<td>1.75</td>
<td>1.90</td>
<td>1.82</td>
<td>21.69x</td>
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</tr>
<tr>
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<td>1.91</td>
<td>2.06</td>
<td>1.97</td>
<td>22.72y</td>
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<td>&lt;0.0001</td>
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<tr>
<td>9</td>
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<td>2.85</td>
<td>2.24</td>
<td>23.41z</td>
<td>0.25</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

aNursery off-test weight is piglet weight 42 d post weaning.

bIndividual piglet birth weights were partitioned into 9 categories which incrementally increased or decreased by ½ SD (0.16 kg) from the birth weight mean (1.57 kg).

cOnly pigs that were weaned were included in the analysis.

dWithin a column, means without a common superscript differ (P < 0.05).
Table 5. Effect of weaning weight category on nursery off-test weight in a maternal line of barrows and gilts

<table>
<thead>
<tr>
<th>Weaning weight category</th>
<th>Number of piglets/category (n=2,467)</th>
<th>Minimum weight, kg</th>
<th>Maximum weight, kg</th>
<th>Mean weaning weight within category, kg</th>
<th>Mean off-test weight, kg</th>
<th>SEM</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>1.85</td>
<td>3.08</td>
<td>2.83</td>
<td>13.16</td>
<td>0.76</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>2</td>
<td>400</td>
<td>3.09</td>
<td>4.43</td>
<td>3.98</td>
<td>16.28</td>
<td>0.15</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>3</td>
<td>413</td>
<td>4.44</td>
<td>5.10</td>
<td>4.78</td>
<td>18.05</td>
<td>0.15</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>4</td>
<td>444</td>
<td>5.11</td>
<td>5.78</td>
<td>5.44</td>
<td>19.67</td>
<td>0.14</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>5</td>
<td>442</td>
<td>5.79</td>
<td>6.46</td>
<td>6.10</td>
<td>21.07</td>
<td>0.14</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>6</td>
<td>328</td>
<td>6.47</td>
<td>7.13</td>
<td>6.77</td>
<td>22.53</td>
<td>0.16</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>7</td>
<td>208</td>
<td>7.14</td>
<td>7.81</td>
<td>7.43</td>
<td>23.45</td>
<td>0.30</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>8</td>
<td>125</td>
<td>7.82</td>
<td>8.40</td>
<td>8.07</td>
<td>24.17</td>
<td>0.26</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>9</td>
<td>92</td>
<td>8.41</td>
<td>10.48</td>
<td>8.98</td>
<td>25.28</td>
<td>0.30</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

aNursery off-test weight is piglet weight 42 d post weaning. Pigs were weaned at either a 15 d average (pigs weaned at 14, 15 or 16 d) or a 20 d average (pigs weaned at 19, 20 or 21 d) weaning age.

bIndividual weaning weights were partitioned into nine categories which incrementally increased or decreased by ½ SD (0.68 kg) from the weaning weight mean (5.80 kg).

cWithin a column, means without a common superscript differ (P < 0.05).
Table 6. Least square means (± SE) for piglet weaning and off-test weight by parity of dam across birth weight categories from a maternal line of sows

<table>
<thead>
<tr>
<th>Parity</th>
<th>No. of sows</th>
<th>No. of pigs</th>
<th>Weaning weight, kg(^b)</th>
<th>Off-test weight, kg(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90</td>
<td>726</td>
<td>5.37 ± 0.03(^x)</td>
<td>18.91 ± 0.13(^x)</td>
</tr>
<tr>
<td>2</td>
<td>57</td>
<td>463</td>
<td>5.76 ± 0.04(^yz)</td>
<td>20.16 ± 0.15(^y)</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
<td>317</td>
<td>5.82 ± 0.05(^y)</td>
<td>19.79 ± 0.18(^y)</td>
</tr>
<tr>
<td>4</td>
<td>42</td>
<td>286</td>
<td>5.83 ± 0.05(^y)</td>
<td>19.89 ± 0.18(^yz)</td>
</tr>
<tr>
<td>5</td>
<td>33</td>
<td>201</td>
<td>5.63 ± 0.06(^z)</td>
<td>20.41 ± 0.22(^yz)</td>
</tr>
<tr>
<td>&gt;5</td>
<td>79</td>
<td>474</td>
<td>5.74 ± 0.04(^yz)</td>
<td>19.98 ± 0.15(^y)</td>
</tr>
</tbody>
</table>

\(^a\)Nursery off-test weight is piglet weight 42 d post weaning. Individual piglet birth weights were partitioned into nine categories which incrementally increased or decreased by 1/2 SD (0.16 kg) from the birth weight mean (1.57 kg).

\(^b\)Within a column, means without a common superscript differ (P < 0.05).
Table 7. Least square means (± SE) for piglet off-test weight by parity of dam across weaning weight categories from a maternal line of sows

<table>
<thead>
<tr>
<th>Parity</th>
<th>No. of sows</th>
<th>No. of pigs</th>
<th>Off-test weight, kg&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90</td>
<td>726</td>
<td>19.95 ± 0.14&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>57</td>
<td>463</td>
<td>20.57 ± 0.16&lt;sup&gt;y&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
<td>317</td>
<td>20.02 ± 0.19&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>42</td>
<td>286</td>
<td>20.24 ± 0.19&lt;sup&gt;y&lt;/sup&gt;&lt;sup&gt;y&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>33</td>
<td>201</td>
<td>21.03 ± 0.22&lt;sup&gt;z&lt;/sup&gt;</td>
</tr>
<tr>
<td>&gt;5</td>
<td>79</td>
<td>474</td>
<td>20.62 ± 0.16&lt;sup&gt;y&lt;/sup&gt;&lt;sup&gt;y&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Nursery off-test weight is piglet weight 42 d post weaning. Individual weaning weights were partitioned into 9 categories which incrementally increased or decreased by ½ SD (1.36 kg) from the weaning weight mean (5.80 kg).

<sup>b</sup>Within a column, means without a common superscript differ (P < 0.05).
CHAPTER 4. EFFECT OF WEANING AGE ON NURSERY PIG AND SOW REPRODUCTIVE PERFORMANCE

A paper to be submitted to the Journal of Swine Health and Production

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Department of Animal Science, Iowa State University, Ames, Iowa, 50011

ABSTRACT

An experiment was conducted to evaluate the effect of weaning age on nursery pig and sow reproductive performance. A total of 2,467 Yorkshire x Landrace crossbred barrows and gilts (Danbred N.A., Columbus, NE) from 339 litters from a commercial line multiplication herd were randomly allocated to pens based on weaning age treatment. Weaning age treatments were: 15 d (weaned at 14, 15, and 16 d) and 20 d (weaned at 19, 20, and 21 d) average weaning age group. Twenty-eight pigs (mixed sex) were housed in each 2.44 x 3.05 m nursery pen (0.27 m² per pig). Diets were fed in four phases with the total lysine content of each diet being 1.70%, 1.50%, 1.30%, and 1.20% (as fed basis), respectively. Growth and feed efficiency were calculated using BW on weaning day. To evaluate the effect of weaning age on ADG, fixed effects of weaning age group, parity, pen within weaning age group, and a covariate for birth weight were included in the analysis model. Similarly, fixed effects of weaning age group and pen within weaning age group were included in the model for ADFI, G:F, and feed cost/kg gain. Pigs weaned at 20 d were 3.13 kg heavier, had a greater (P < 0.01) nursery ADG (0.79 vs. 0.71 kg/d), had a 0.07 kg/d greater ADFI, and had fewer (P < 0.03) pigs removed from test (2.07, 1.01%) at the end of the 42 d nursery phase when compared to pigs

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3 This journal paper of the Iowa Agric. and Home Econ. Experiment Station, Ames, IA, Project No. 3600, was supported by Hatch Act and State of Iowa funds. The authors gratefully acknowledge H & K Enterprises, Inc., Nevada, IA for allowing the study to be conducted at their facility, and for technical assistance.

4 Correspondence: 109 Kildee Hall, Iowa State University, Ames, IA 50011-3150. (Phone: 515-294-4683; fax: 515-294-5698; Email: stalder@iastate.edu).
weaned at 15 d of age. Additionally, pigs weaned at 15 d had a $0.03 greater feed cost/kg gain when compared to pigs weaned at 20 d. The sow’s subsequent reproductive performance following the weaning age treatment was evaluated and included the following traits: wean-to-first service (WSI), wean-to-conception (WCI), total number of piglets born (TB), and total live born piglets (TLB). To evaluate the effect of lactation length on WSI, TB, and TLB, fixed effects of weaning month, parity, and weaning age treatment were included. A covariate for WSI was also included in the model analyzing WCI. No lactation length treatment differences in WSI, WCI, TB, or TLB were found. Parity was a significant source variation for WSI and TLB. Parity 2 sows had a higher WSI than sows in parities 2 and greater (P < 0.01). Parity 2 and 4 sows had a greater TLB than sows in parity 3 and those in parity 6 and higher (P < 0.01). Manipulating lactation length between 15 d and 20 d had no effect on sow reproductive traits, but had a significant impact on growth performance traits of nursery pigs.

Keywords: Pigs, Growth Performance, Sows, Weaning Age, Wean-to-First Service

INTRODUCTION

The swine industry has shifted to earlier weaning to improve farrowing crate utilization, increase pigs per sow per year, improve piglet health, and increase the operation’s throughput (Harris, 2000). Many producers and scientists are reevaluating weaning age decisions, comparing growth differences and herd health issues among pigs weaned at different ages. Lactation length (weaning age) can impact nursery growth as well as sow fertility, and should be optimized so that producers can maximize profitability of their pork operations.

Segregated early weaning (SEW) was developed to minimize transmission of pathogens from sow to piglet. This process consists of farrowing sows on the same site as the rest of the breeding herd, weaning piglets from 10 to 21 d and decreasing the amount of medication needed (Harris, 2000). Applying these management practices improves piglet health, but also impacts piglet growth and sow reproductive performance. Even though a majority of the benefits of weaning at a later age are observed during the early postweaning period, the effect has been reported to persist through the grow-finish phase (Main et al., 2004).
Sow reproductive performance is dependent upon various factors such as sow breed, parity, and environment, but management decisions such as lactation length also influence fertility. Short lactations have been shown to negatively affect measures such as WSI (Le Cozler et al., 1997). However, others have reported that lactation length has no effect on WSI and subsequent litter size (Tantasuparuk et al., 2000). Sow performance differences observed are likely the result of the range in lactation length.

Limited research has been conducted to determine the weaning age that results in optimum performance of the pig in the early stages of its development and in reproductive performance of the sow. The objective of this research was to determine the effect of weaning age on nursery pig and sow reproductive performance.

**MATERIALS AND METHODS**

*Animals and Procedures*

This experiment was conducted using Danbred N.A. (Columbus, NE) barrows and gilts from a commercial maternal line multiplication herd (H & K Enterprises, Nevada, IA). The experimental protocol followed the operation’s production practices and met or exceeded requirements in Guidelines for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999). All breeding, farrowing, and weaning information was recorded in PigWIN® (Little Canada, MN), and relevant data was extracted from that program and utilized for the analysis in this study.

**Pigs.** Yorkshire x Landrace crossbred pigs (n=2,467) were utilized in this study. All pigs were produced by purebred Landrace sows in their first to eleventh parities (Table 1), divided into 6 parity classes for the purposes of this study. Parities greater than 6 were combined for 3 specific reasons: (1) performance between parties 6, 7, 8, 9, 10, and 11 was similar, (2) combining provided a more equal distribution, and (3) many commercial operations automatically cull at parity 6 (PigCHAMP, 2004). Each piglet was individually identified, weighed, and sex was determined within 24 h of birth.

At birth, pigs from each litter were assigned to 1 of 2 weaning age (pigs) or lactation length (sows) treatments. The first weaning age (lactation length) treatment averaged 15 d of age at weaning and included pigs that were 14, 15, and 16 d of age. The second weaning age (lactation length) treatment averaged 20 d at weaning and included pigs that were 19, 20, and 21 d of age. A weighted average
weaning age was also calculated based on the number of pigs weaned at each age and the first weighted average weaning age (lactation length) treatment was 14.9 d of age. The second weighted average weaning age (lactation length) treatment was 20.2 d of age. Litter size was standardized to 10 to 11 piglets per litter by cross fostering individuals (moving piglets from large to small litters) within 3 d post farrowing. By d 7, all boars were castrated. Weaning was performed once a week (Thursday), at which time piglets in each weaning age treatment group were weighed and randomly assigned to a nursery pen. Pigs from litters that were substandard or non ambulatory were not included in the trial.

Pigs were housed in mechanically ventilated, heated, totally confined nursery rooms with plastic slatted flooring. A total of 89 pens (7 to 8 pens per group and 12 groups) were utilized in the study, each pen containing 26 to 28 pigs (n=2,467). Pigs were reared in 2.44 x 3.05 m nursery pens, providing 0.27 to 0.29 m² per pig. Each nursery room contained 8 pens, 4 for each weaning age treatment. Each pen was equipped with a single-sided, stainless steel self-feeder (Chore-Time, Milford, IN) (76.2 cm linear trough space/pen; 2.72 to 2.93 cm/pig) and 2 nipple drinkers. Pigs were provided ad libitum access to feed and water at all times. Pigs were fed a 4-phase diet regime from weaning to 42 d postweaning and feed disappearance was recorded on a pen basis. A feed budget was developed in which each pig was provided 1.25 kg of a 1.70% lysine pellet, 6.14 kg of a 1.50% lysine meal diet, 12.57 kg of a 1.30% lysine meal diet and the remainder was a 1.20% lysine meal diet (as fed basis).

Pigs remained in their pen until 42 d postweaning when they were weighed and removed from test (off-test weight). Growth and feed efficiency were calculated using BW at weaning and 42 d postweaning. Pigs were removed from test pens prior to 42 d postweaning due to mortality or if a health condition existed in which the pig did not respond to medical treatment. Morbidity is defined as pigs appearing ill, diseased, unthrifty, or characterized by loss of body weight (Corrigan, 2002).

Sows. A total of 339 purebred Landrace sows were included in this experiment (Table 2). Data was collected over the period of 1 year in a 600 sow farrow to finish operation, farrowing approximately 25 litters per week. Sows were mated using purebred semen (pooled sire) resulting in Yorkshire x Landrace crossbred pigs. Subsequent sow reproductive performance was measured following weaning.
Sows were housed in totally confined buildings and were grouped in individual stalls during mating, pens during gestation, and individual farrowing stalls during lactation. At weaning, sows were housed in 55.9 cm x 182.9 cm breeding stalls. Each breeding stall was equipped with water troughs where sows were provided ad libitum access to water, as the troughs were filled twice daily. Each sow was fed 2.7 kg/d of a 14.4 % CP, 0.7 % lysine diet (as fed basis) while in the breeding stall (Table 3).

Estrus detection began 4 d postweaning and was performed once daily at approximately 7:30 by providing weaned sows crate-line contact with a mature boar. Estrus detection occurred until each sow was mated or the decision to cull an individual sow was made. Sows were mated 24 h and 48 h post estrus detection by artificial insemination.

Approximately 2 d post mating, sows were moved from the breeding stalls into a pen of bred sows. Bred sows were grouped by size and penned with 5 to 9 other females. Pregnancy detection was performed 28 d post first mating using real-time ultrasound (Alliance Medical Inc., Montreal, Quebec, Canada). Sows detected not pregnant were moved back to the breeding area for estrus detection and mating. Pregnant sows were housed in these pens until approximately 5 d before farrowing, when they were moved to farrowing facilities.

Gestation pens provided 1.26 m² to 1.30 m² per sow. Flooring of the pens was partially slatted concrete and each pen was equipped with a nipple drinker that provided sows ad libitum access to water. Sows were fed 2.7 kg/d of the gestation diet previously described (Table 3).

Each farrowing stall was 55.9 cm x 182.9 cm and was equipped with a nipple drinker that provided the sow ad libitum access to water. Lactating sows were fed a diet containing 18.3% CP and 1% lysine (as fed basis) 3 times daily in a step up program until they reached a maximum intake (approximately 8.2 kg/d)(Table 3). The step up lactation feeding program started with 0.9 kg per feeding (three feedings per day) immediately after farrowing and was slowly increased as the sow fully consumed the feed provided in each subsequent feeding.

A measure used in this investigation to analyze a sow’s reproductive performance was WCI. This refers to the number of days from weaning until the sow conceives her next litter. If the sow conceived on the first breeding after weaning, WSI and WCI were considered the same (PigWIN®, 2005). If the sow failed to conceive on the first postweaning estrus (repeat breeder) and was bred again on
the next estrus and became pregnant, WCI was counted from the day of weaning up to the second breeding when the sow conceived.

**Statistical Procedures**

Data were analyzed using PROC MIXED of SAS (SAS, 2003) (Cary, NC). When fixed effects were a significant source of variation, differences were determined using the PDIFF option of SAS.

**Pig Data.** Records with off-test weights greater than 33.6 kg (1 pig) or less than 5.9 kg (26 pigs) or ADG greater than 1.54 kg/d (14 pigs) or less than -0.08 kg/d (15 pigs) were more likely related to management factors or errors in measurement and were excluded from the analysis. This resulted in a total of 2,411 pigs included in the statistical analysis. Pig was the experimental unit for all traits measured on the individual animal. Pen was the experimental unit for G:F, ADFI, and feed cost/kg gain. Fixed effects of weaning age treatment, parity of dam, and pen within weaning age treatment were included in the model for ADG and birth weight was included as a linear covariate. Sow ID and Group ID were initially included as random effects, however they were determined to have little impact (extremely low variance) and were excluded from the analysis model for ADG. The two way interactions between fixed effects were tested but were dropped from the models because they had little impact. Fixed effects of weaning age treatment group and pen within weaning age group were included in the model for ADFI and G:F. A chi-square test for proportions (SAS, 2003) was utilized to evaluate mortality and morbidity differences between the two weaning age treatment groups.

**Sow Data.** Sows producing abnormal records for WSI and WCI were removed according to the following criteria, WSI greater than 50 days (4 sows) and WCI greater than 100 days (8 sows). A total of 227 sows were included in the statistical analysis. A binary response variable was created for evaluation of culling rate: removed from the herd [0], or retained in the herd [1], and only sows that were culled due to reproductive failure were included in the analysis. Sows culled because of management decisions were excluded from the study. There were 60 sows that were culled for the following reasons: 31 culled for reproductive failure, 17 culled for body condition, 7 culled for old age and 5 culled for miscellaneous reasons. An additional 40 sows that farrowed during the weaning age treatment either died or were not included in the analysis. Weaning-to-first service interval was also modeled using a binary response variable, WSI greater than 10 d [2] or WSI less than or equal to 10 d [1]. A chi-square test for proportions (SAS, 2003) between
the two lactation length treatments was utilized to evaluate the number of sows removed from the herd versus those retained in the herd and the number of sows with normal WSI (WSI less than or equal to 10 d) versus those with abnormal WSI (WSI greater than 10 d).

Fixed effects of weaning month, lactation length treatment and parity of the sow were included in the analysis of WSI, WCI, TB, and TLB. A covariate for WSI was included in the model used to analyze WCI. The two way interactions between fixed effects were tested but were dropped from the models because they had little impact.

RESULTS AND DISCUSSION

Nursery Pig Performance

Weaning weight and off-test weight. In the present trial, weaning weight increased (P < 0.01) with increasing weaning age (Table 4). Pigs from the 20 d group were 1.53 kg heavier at weaning (Table 4). Furthermore, variation in weaning weight (i.e., the coefficient of variation for weaning weight) decreased as weaning age increased (Table 4). Pigs weaned in the 15 d group had a 0.95 greater variation in weaning weight than pigs in the 20 d group (Table 4). These results agree with previous work by Wolter and Ellis (2001) and Himmelberg et al. (1985), who reported a favorable correlation between weaning weight and weaning age.

Wolter and Ellis (2001) studied pigs from Pig Improvement Company (PIC) and reported that heavier pigs at weaning were heavier at birth and at 56 d of age and reached slaughter weight 8.6 d sooner. Mahan and Lepine (1991) and Roberts (2000) also reported weaning weight to be predictive of overall pig performance and days to market weight in crossbred pigs. Studies have also shown that feed intake and rate of gain during the nursery period increase with weight at weaning (Himmelberg et al., 1985; Main et al., 2004). Main et al. (2004) also reported highly favorable correlations between weaning age, ADG, and weight sold per pig weaned in a multi-site system utilizing crossbred pigs.

In the current trial, off-test weight improved (P < 0.01) as weaning age increased from 15 d to 20 d (Table 4). Pigs weaned in the 20 d group were 3.13 kg heavier than pigs weaned in the 15 d group. Main et al. (2004) studied pigs from a commercial PIC operation and also observed a significant increase (5.5 kg) in nursery off-test weight from pigs weaned at 15 d when compared to those weaned at 20 d. The results of the current study only reported on weights through 42 d postweaning,
because the production system where the trial was conducted typically sold many of the pigs at this point and further data collection was not possible. Main et al. (2004) and Powell and Aberle (1980) reported that improvements in growth and mortality largely occur in the initial 42 d after weaning, with some further improvements in growth through finishing.

**Average daily gain and average daily feed intake.** Nursery ADG and ADFI improved (P < 0.01) as weaning age increased from 15 d to 20 d (Table 4). Pigs weaned at 20 d of age gained 0.08 kg per day more than pigs weaned at 15 d of age. A linear birth weight covariate (P < 0.01) states that for every 1 kg increase in birth weight there is a 0.18 kg increase in ADG. Pigs in the 20 d group also had a greater ADFI (0.07 kg per day) when compared to pigs in the 15 d group. These results are consistent with previous studies reported by Himmelberg et al. (1985) and Leibbrandt et al. (1975), who reported that pigs that were heavier at weaning had greater (P < 0.01) ADG and improved ADFI when compared to their lighter littermates throughout the nursery and grow-finish phases of production. Hohenshell et al. (2000) also observed decreased postweaning weight gains associated with early weaning. Additionally, Main et al. (2004) and Fangman et al. (1996) reported improved nursery ADG and ADFI as weaning age increased from 12 d to 21 d.

**Mortality and Morbidity.** Weaning age itself is an important driver of nursery costs, but mortality and morbidity within weaning age is another important factor in determining the optimal weaning age for individual pork operations. In the present study, pigs weaned at 20 d had a lower (P < 0.05) morbidity (1.01% vs. 2.07%) when compared to pigs weaned at 15 d of age. However, the morbidity values from both treatments would be considered above average by current industry standards. A trend was observed (P = 0.14) in mortality rates between the two weaning age treatment groups with pigs in the 15 d weaning age group having 0.95% mortality and pigs from the 20 d weaning age group having 0.58% mortality (Table 4). Again, the mortality values for both treatments would be considered above current industry standards (PigCHAMP, 2004). These results are consistent with those reported by Main et al. (2004), who found that pigs weaned at 15 d of age had 2.82% mortality and pigs weaned at 20 d of age had 0.54% mortality. The greater mortality observed in pigs weaned at younger ages represents a substantial reduction of net income through lost revenue from pigs that died and increased expenses of feeding the pigs until they died. In a study by Deen (2005), variability in profits for cull,
dead, and lightweight pigs was greater than 50%, greater than 15% for ADG and approximately 30% for G:F. This variability in performance and profitability of cull, dead, and lightweight pigs reveals the importance of minimizing these pigs in any production system. Mortality and morbidity in the nursery are largely a function of entry and exit weight, and weaning age significantly impacts both of these weights.

**Gain to feed ratio.** Feed efficiency was similar for pigs in the two weaning age treatment groups (Table 4). Mahan et al. (1998) also reported similar feed conversion ratios for pigs with different weaning weights. The current study showed that weaning age and weaning weight are related. Main et al. (2004) reported that pigs weaned at 12 d had decreased G:F ratios when compared to pigs weaned at 21 d. Additionally, the same study found similar G:F ratios between 15, 18, and 21 d weaning ages. Schinckel and DeLange (1996) portray the relationships between pig genotype and environmental factors which are essential in order to evaluate and implement different management strategies such as weaning age. The relationship between feed efficiency and BW is similar for the two weaning age groups in the present study because their growth curves during the nursery phase of production are essentially the same.

**Feed cost/kg gain.** Feed cost/kg gain improved (P < 0.05) as weaning age increased from 15 d to 20 d (Table 4). Pigs weaned at 15 d had $0.03 greater feed cost per kg of gain when compared to pigs from the 20 d weaning age group. This reflects the increased ADG and decreased morbidity observed in the 20 d old pigs. Although not directly measured in this study, Main et al. (2005) reported that income over costs/pig weaned increased (P < 0.001) from $3.71 at 12 d to $10.28 at 21 d. The current results demonstrate the importance of ADG, morbidity, and weaning age to profitability in the nursery phase of production in a pork operation.

**Sow Performance**

**Subsequent reproductive traits.** No significant lactation length treatment differences were observed for WSI, WCI, TB, or TLB (Table 5). A linear WSI covariate (P < 0.01) states that for every 1 day increase in WSI there is a 0.7 d increase in WCI. These results are consistent with those reported by Tantasuparuk et al. (2000). Like the present study, Tantasuparuk et al. (2000) utilized purebred females and evaluated a relatively short range of lactation length. The range in lactation lengths in the two treatment groups in the present study was 14 to 21 days. Previous studies have reported that increasing lactation length decreases WSI and increases subsequent litter sizes (Xue et al., 1993; Le Cozler et al., 1997; Tummaruk et
These studies analyzed sow records retrospectively, whereas the current study was conducted with effects on sow productivity being an objective of the trial. The results of the previous studies (Xue et al., 1993; Le Cozler et al., 1997; Tummaruk et al., 2000) differ from the results of the present investigation and are likely due to differences in lactation length and also the use of purebred sows versus crossbred sows in some cases.

No differences were observed between normal (WSI less than or equal to 10 d) and abnormal (WSI greater than 10 d) WSI for sows from the 15 or 20 d lactation length groups. However, variation in WSI when comparing normal and abnormal WSI (i.e. the coefficient of variation for WSI) decreased as lactation length increased. These results agree with previous work by Le Cozler et al. (1997), who reported that sow WSI decreased with increasing lactation length.

The present study found no difference in the number of piglets born alive between the two lactation length treatments (Table 5). However, subsequent litter size was influenced by WSI in previous research (Koketsu et al., 1997; Tantasuparuk et al., 2000). These studies reported that longer lactation lengths were associated with higher subsequent litter size. Results of the previous studies (Koketsu et al., 1997; Tantasuparuk et al., 2000) differ from the present study and are likely due to the relatively small difference between the lactation length treatments. Breed is also an important source of variation in litter size as purebred sows generally have lower prolificacy (Le Cozler et al., 1997) when compared to crossbred females (Buchanan and Johnson, 1984). Since purebred Landrace females were utilized in the present study, values for some traits may be lower than expected with crossbred females.

**Parity.** When evaluating WSI, TB, and TBL, parity differences were observed in the present study (Table 6). Parity 2 sows had a greater (P < 0.01) WSI than sows in parities higher than 2. Parity 4 sows had a greater (P < 0.01) TB than sows in parity 6 sows. Parity 2 and 4 sows had a greater TLB when compared to sows from parity 3 and parity 6 and higher (P < 0.01). In this study, WSI decreased as parity increased and parities 4 and greater experienced a linear decrease in TBL. In a study by Xue et al. (1993), parity (P < 0.01) affected WSI, TB, and TBL. The same study also reported that average litter size was lower for parity 2 than for later parities. The relatively low number of observations in the parity subclasses in each weaning age treatment in the present study could explain differences between the present and previous investigations. Thus, when analyzing parity, it is important to look at the correlation between WSI, WCI, and litter size by parity.
Culling Rate. There were no differences in culling rate between sows weaned at 15 d and those weaned at 20 d (Table 5). Previous studies have reported that sow longevity is adversely affected by reducing lactation length (Pattison et al., 1980; Xue et al., 1997). Xue et al. (1997) reported that sows removed from the herd had a shorter (P < 0.01) lactation length (less than 15 d) when compared to sows that remained in the herd (greater than 16 d). In the Xue et al. (1997) study, they included sows that were culled for reasons unrelated to reproduction and thus the results may be biased because sow culling may have been a result of factors other than lactation length.

The present study evaluated the difference between 2 average lactation lengths of 15 d and 20 d, which is commonly implemented in commercial swine production systems today (Harris, 2000). A lactation length shorter than 14 d typically had a negative impact on subsequent performance and caused more variability in sow performance (Mabry et al., 1996). Lactation lengths less than 14 d were not included in the present study due to the possibility of a negative impact on subsequent sow performance.

IMPLICATIONS

Weaning pigs at 20 d may prove advantageous in commercial operations because of improvements in nursery growth performance. Pigs weaned at 20 d had a lower feed cost/kg gain than pigs weaned at 15 d. No differences were observed in sow reproductive performance when comparing those weaned at 15 d and 20 d. Consequently, producers should be able to choose weaning ages in the range of 15 to 20 d without any negative impacts on sow reproductive performance. Parity of dam influences both piglet weights in subsequent phases of production, but also subsequent reproductive performance of the sow. However, optimum weaning age corresponds to the optimization of management for any weaning age strategy and may differ from operation to operation.

LITERATURE CITED


PIGWIN. 2005. Version 5. PIGWIN INC., Little Canada, MN.


Table 1. Number of pigs and litters by parity in a study of the effects of two different weaning ages on nursery performance

<table>
<thead>
<tr>
<th>Parity</th>
<th>15 D (No. of litters)</th>
<th>15 D (No. of pigs)</th>
<th>20 D (No. of litters)</th>
<th>20 D (No. of pigs)</th>
<th>Total (pigs)</th>
<th>Totals (litters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48</td>
<td>416</td>
<td>42</td>
<td>310</td>
<td>726</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>201</td>
<td>32</td>
<td>262</td>
<td>463</td>
<td>57</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>175</td>
<td>18</td>
<td>142</td>
<td>317</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>107</td>
<td>25</td>
<td>179</td>
<td>286</td>
<td>42</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
<td>117</td>
<td>16</td>
<td>84</td>
<td>201</td>
<td>33</td>
</tr>
<tr>
<td>&gt; 5</td>
<td>36</td>
<td>228</td>
<td>43</td>
<td>246</td>
<td>474</td>
<td>79</td>
</tr>
<tr>
<td>Totals</td>
<td>163</td>
<td>1244</td>
<td>176</td>
<td>1223</td>
<td>2467</td>
<td>339</td>
</tr>
</tbody>
</table>

*a Average weaning age of 15 d included pigs weaned at 14, 15, and 16 d of age. Average weaning age of 20 d included pigs weaned at 19, 20, and 21 d of age.
Table 2. Number of sows by parity in a study of the effects of two different lactation lengths on subsequent sow reproductive performance

<table>
<thead>
<tr>
<th>Parity</th>
<th>15 D</th>
<th>20 D</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48</td>
<td>42</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>32</td>
<td>57</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>18</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>25</td>
<td>42</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
<td>16</td>
<td>33</td>
</tr>
<tr>
<td>&gt;5</td>
<td>36</td>
<td>43</td>
<td>79</td>
</tr>
<tr>
<td>Totals</td>
<td>163</td>
<td>176</td>
<td>339</td>
</tr>
</tbody>
</table>

*a Average lactation length of 15 d included sows weaned at 14, 15, and 16 d. Average lactation length of 20 d included sows weaned at 19, 20, and 21 d.*
Table 3. Calculated nutrient analysis (as-fed basis) diets fed to sows in a study of two average lactation lengths (15 d and 20 d)\(^a\)

<table>
<thead>
<tr>
<th>Calculated analysis</th>
<th>Lactation</th>
<th>Gestation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein, %</td>
<td>18.27</td>
<td>14.40</td>
</tr>
<tr>
<td>Lysine, %</td>
<td>1.00</td>
<td>0.72</td>
</tr>
<tr>
<td>Threonine, %</td>
<td>0.73</td>
<td>0.16</td>
</tr>
<tr>
<td>Tryptophane, %</td>
<td>0.23</td>
<td>0.16</td>
</tr>
<tr>
<td>Ca, %</td>
<td>0.89</td>
<td>0.86</td>
</tr>
<tr>
<td>P (available), %</td>
<td>0.72</td>
<td>0.68</td>
</tr>
<tr>
<td>Fat, %</td>
<td>2.70</td>
<td>2.97</td>
</tr>
<tr>
<td>ME, kcal/kg</td>
<td>3233</td>
<td>3242</td>
</tr>
</tbody>
</table>

\(^a\) Average lactation length of 15 d included sows weaned at 14, 15, and 16 d. Average lactation length of 20 d included sows weaned at 19, 20, and 21 d.
Table 4. Influence of weaning age on nursery performance in a study comparing two average weaning age groups (15 d and 20 d)

<table>
<thead>
<tr>
<th>Item</th>
<th>15 d</th>
<th>20 d</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of pigs, n</td>
<td>1205</td>
<td>1206</td>
<td>--</td>
</tr>
<tr>
<td>Weaning weight, kg</td>
<td>5.15±0.03\textsuperscript{x}</td>
<td>6.68±0.05\textsuperscript{y}</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Weaning weight CV, %</td>
<td>19.44</td>
<td>18.49</td>
<td>--</td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>0.71±0.04\textsuperscript{x}</td>
<td>0.79±0.01\textsuperscript{y}</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>ADFI, kg/d\textsuperscript{b}</td>
<td>0.57±0.01\textsuperscript{x}</td>
<td>0.64±0.01\textsuperscript{y}</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>G:F\textsuperscript{b}</td>
<td>0.55±0.05\textsuperscript{x}</td>
<td>0.56±0.00\textsuperscript{x}</td>
<td>0.85</td>
</tr>
<tr>
<td>Mortality, %</td>
<td>0.95</td>
<td>0.58</td>
<td>0.14</td>
</tr>
<tr>
<td>Morbidity, %</td>
<td>2.07</td>
<td>1.01</td>
<td>0.03</td>
</tr>
<tr>
<td>Off-test weight, kg\textsuperscript{c}</td>
<td>18.7±0.11\textsuperscript{x}</td>
<td>21.8±0.16\textsuperscript{y}</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Feed costs/kg gain\textsuperscript{b}</td>
<td>0.47±0.04\textsuperscript{x}</td>
<td>0.44±0.01\textsuperscript{y}</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Means with different subscripts in a row differ (P < 0.05).

\textsuperscript{b} ADFI, G:F and feed cost/kg gain were calculated on a pen basis, using 42 d weight and actual pig days.

\textsuperscript{c} Off-test weight = 42 d postweaning weight.
Table 5. Influence of lactation length on sow reproductive performance, in a study comparing two average lactation length treatments (15 d and 20 d)\(^a\)

<table>
<thead>
<tr>
<th>Item</th>
<th>Lactation Length</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15 d</td>
<td>20 d</td>
<td>SE</td>
<td>P Value</td>
<td></td>
</tr>
<tr>
<td>Number of sows</td>
<td>114</td>
<td>113</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Average parity</td>
<td>4.01</td>
<td>4.28</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>WSI, d(^b)</td>
<td>7.98</td>
<td>8.38</td>
<td>0.78</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>WCI, d(^b)</td>
<td>15.65</td>
<td>16.93</td>
<td>2.56</td>
<td>0.62</td>
<td></td>
</tr>
<tr>
<td>Total born</td>
<td>11.15</td>
<td>10.97</td>
<td>0.41</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>Total born alive</td>
<td>9.28</td>
<td>9.41</td>
<td>0.56</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>Culling rate, %(^c)</td>
<td>6.06</td>
<td>7.95</td>
<td>--</td>
<td>0.43</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Average lactation length of 15 d included sows weaned at 14, 15, and 16 d of age. Average lactation length of 20 d included sows weaned at 19, 20, and 21 d of age.

\(^b\)Wean-to-service (WSI) refers to the number of days from weaning until first mating. Wean-to-conception (WCI) refers to the number of days from weaning until the sow conceived her next litter (PigWin\(^\circledR\), 2005)

\(^c\)Culling rate was calculated using only sows that were culled due to reproductive failure. Sows culled because of management decisions were excluded from the study.
Table 6. Influence of parity on sow reproductive performance in a study comparing two average lactation length treatments (15 d and 20 d)a

<table>
<thead>
<tr>
<th>Parity</th>
<th>Weaning-to first serviceb</th>
<th>Total bornbc</th>
<th>Total live bornb</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>12.8&lt;sup&gt;w&lt;/sup&gt;</td>
<td>11.1&lt;sup&gt;xy&lt;/sup&gt;</td>
<td>10.1&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>7.2&lt;sup&gt;xy&lt;/sup&gt;</td>
<td>10.6&lt;sup&gt;xy&lt;/sup&gt;</td>
<td>9.5&lt;sup&gt;xy&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>6.7&lt;sup&gt;y&lt;/sup&gt;</td>
<td>12.2&lt;sup&gt;y&lt;/sup&gt;</td>
<td>11.0&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td>&gt; 5</td>
<td>6.0&lt;sup&gt;yz&lt;/sup&gt;</td>
<td>10.4&lt;sup&gt;x&lt;/sup&gt;</td>
<td>8.4&lt;sup&gt;y&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*<sup>a</sup>Average lactation length of 15 d included sows weaned at 14, 15, and 16 d of age. Average lactation length of 20 d included sows weaned at 19, 20, and 21 d of age.

*<sup>b</sup>Within a column, means without a common superscript differ (P < 0.05).

*<sup>c</sup>Total born includes live born and still born pigs while total live born only includes those pigs born alive.
CHAPTER 5. ECONOMIC ANALYSIS

SUMMARY
An experiment was conducted to evaluate the effect of weaning age on nursery pig costs of production. A total of 2,467 Yorkshire x Landrace crossbred barrows and gilts (Danbred N.A., Columbus, NE) from a commercial maternal line multiplication herd were randomly allocated to pens based on weaning age treatment. Weaning age treatments were: 15 d (weaned at 14, 15, and 16 d) and 20 d (weaned at 19, 20, and 21 d) average weaning age group. Economic results provided a comparison of costs and returns for the two different weaning ages. Pigs weaned at 20 d had a lower feed cost/kg gain than pigs weaned at 15 d. Weaning at 15 d and 20 d had a significant impact on feeder pig value. Weaning at 15 d of age brought in less net revenue per pig than weaning at 20 d of age. The advantages in growth performance of the pigs weaned at 20 d are the main determinants of the differences in feeder pig value and net revenue per pig.

INTRODUCTION
Methods for determining the value of weaned pigs vary by type of production system, whether under a contract, privately sold or on an independent farrow to finish operation. There are two main factors that affect the value of early weaned pigs, the weight of the pig and the potential for enhanced performance such as decreased death loss and increased ADG (Brumm and Bitney, 1995). Although most producers have individual weaned-pig quality criterion or discount programs, pigs meeting the minimum standards are commonly valued equally (Main et al., 2005). In the nursery phase of production, weight is used to derive costs and revenues. Thus, if a common value is assessed to all weaned or feeder pigs the value may not be accurate based upon weight. Weaning age impacts the weight into and out of the nursery phase of production and thus affects weaned-pig and feeder-pig value within this commercial farrow to finish operation.

Swine producers face increasingly tight profit margins per pig, thus the production sector continues to identify ways to reduce cost of production (Kliebenstein et al., 1984). The significance of this research was to effectively manage piglets in order to reduce variable and fixed costs by maximizing weight of pigs out of the nursery. Assigning a common value to acceptable quality weaned pigs, regardless of weaning age or weight, may lead to false conclusions concerning
a breeding herd's true financial performance (Main et al., 2005). Revenue and income over cost per pig weaned increased as weaning age increased from 12 to 21 days (Main et al., 2005). Thus, in this study the objective was to quantify the effects of weaning at two different ages on income and costs for swine producers.

**MATERIALS AND METHODS**

In this experiment 89 pens (7 to 8 pens per group) were utilized with each containing 26 to 28 pigs (n = 2,467). At birth, pigs from each litter were assigned to 1 of 2 weaning age treatments. Pigs were weaned at an average of 15 days (weaned at 14, 15, and 16 days of age) or at an average of 20 days (weaned at 19, 20, and 21 days of age). Diets were fed in 4 phases: phase 1 (1.25 kg/pig), phase 2 (6.14 kg/pig), phase 3 (12.57 kg/pig) and phase 4 (remainder).

Results were evaluated by using actual production efficiency values of the groups of pigs and actual feed costs incurred during the trial, while using average or typical costs for Segregated Early Weaning (SEW) pigs and variable costs. Pricing for SEW and feeder pigs was an average price over the past 6 years (1999 to 2005). This allows for comparison of expected costs and returns using normal input costs and hog price relationships.

**Productivity**

Production efficiencies are provided in Table 1. Important efficiency numbers would include the percent of pigs weighed off test, feed efficiency and average daily gain.

Pigs taken off test (death loss %) were pigs that were considered to be ill, unthrifty, diseased, characterized by loss of body weight or dead. Pigs removed from the study were considered to have zero value. The percent of pigs weighed off test was calculated by taking the pigs that were weighed off test as feeder pigs and dividing by the pigs that were placed on test (at weaning). This percentage had a direct effect on the system’s returns because the pigs weighed off test represent revenue. During the trial, of the pigs that were weaned at 15 days, 97.93% were weighed off test. Of the pigs that were weaned at 20 days, 98.99% were weighed off test.

Feed measurements were taken based upon feed consumption per pen. Feed efficiency was calculated, using the weight gain of the animals when weighed off test and total feed consumed by the group. Measurements for ADG and body weights were based on individual pigs.
RESULTS AND DISCUSSION

Economic results provided a comparison of costs and returns for the two different weaning ages. Table 2 provides a nursery production budget per pig placed based on the two different weaning ages.

**Facility and other Fixed Costs.** Related facility and fixed costs used in Table 2 and are reported on a per pig basis (May et al., 2003). Turns per year is based upon 42 days for each turn and includes downtime to wash and prepare for the next set of pigs. Total investment per turn was calculated by dividing total investment per year by turns per year. Facility cost per pig weighed off test was calculated by dividing total investment by the number of pigs included in each weaning age treatment for the 42 day nursery trial.

**Operating Costs.** Segregated Early Weaning (SEW) pigs were priced based on the University of Minnesota Livestock Enterprise Analysis. According to the summary, the average price for delivered SEW pigs from 1999 to 2005 was $48.16 per pig. Pig death loss was estimated by multiplying feeder pig price by the mortality percent for the weaning age treatment. A 6.5% interest rate was used and the interest on SEW pigs was calculated by multiplying the interest rate (6.5%) by the SEW pig price. Fuel, repairs, utilities, health costs and labor were all based on May et al. (2003) budgets and are reported on a per pig basis. Feed costs were the actual feed costs per pig that were incurred during the trial.

**Revenue.** The only revenue to this system that was considered was the sale of the feeder pigs at the end of the 42-day postweaning period. Pigs that were taken off test were considered to have zero value. To calculate revenue, feeder pig price was multiplied by the percent of pigs taken off test. Feeder pig prices were based upon livestock enterprise analysis of feeder pig prices reported by University of Minnesota (2005). The following equations were used to adjust the feeder pig price based upon the weights recorded for the two weaning age groups (Lawrence, 1993). XX kg price of the past 5 years (1999-2005)=$48.16

20 D Feeder Pig Price: 46.88 (adjusted from a 24.3 kg basis 24.3-21.8=2.5*.511=1.28)
15 D Feeder Pig Price: 45.30 (adjusted from a 24.3 kg basis 24.3-18.7=5.6*.511=2.86)

**Growth Performance.** Growth measures including, ADG and ADFI, increased with increasing weaning age (Table 1). Feed efficiency was essentially the same for both groups of pigs (Table 1). This suggests that there are no feed efficiency advantages due to weaning at an average of 15 d versus 20 d. Feed cost/kg gain improved (P < 0.05) as weaning age increased from 15 d to 20 d (Table 1). With a
difference of $0.03/kg, pigs weaned at 20 d can be fed for less per kg of gain than pigs weaned at 15 d. Total feed costs were greater for pigs weaned at 20 d, but they gained weight more efficiently. Costs associated with pig death loss were almost $1 higher for pigs weaned at 15 d versus those weaned at 20 d. Differences in net revenue reflect increased ADG and decreased morbidity observed in the 20 d old pigs. The net revenue from selling feeder pigs weaned at 20 d of age yielded $2.26 more per pig than selling feeder pigs weaned at 15 d of age. A heavier pig at the end of the nursery phase will be worth more money if selling feeder pigs or in a farrow-to-finish operation.

Research has shown that increasing weaning age up to 21.5 days can increase income over costs (Main et al., 2005). Results of this trial suggest that net revenue per pig is greater for pigs that are weaned at 20 days versus 15 days. However, the optimum weaning age corresponds to the optimization of management for any weaning age strategy and may differ from operation to operation.

**IMPLICATIONS**

Linear increases in postweaning growth rate and livability are the biological drivers of the advantages of increasing weaning age from 15 d to 20 d. Assessing a common value to weaned pigs in this commercial operation may lead to incorrect conclusions concerning the profitability of the sow herd (weaned pig value) or the nursery phase (feeder pig value).

**LITERATURE CITED**


Table 1. Productivity information for maternal line barrows and gilts weaned at two different weaning ages

<table>
<thead>
<tr>
<th>Item</th>
<th>Weaning Age&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15 day</td>
</tr>
<tr>
<td>Number of pigs&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1205</td>
</tr>
<tr>
<td>Weaning weight (SEW), kg</td>
<td>5.15</td>
</tr>
<tr>
<td>Death loss, %&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.07</td>
</tr>
<tr>
<td>Pigs weighed off-test, %</td>
<td>97.93</td>
</tr>
<tr>
<td>ADG, kg/day</td>
<td>0.71</td>
</tr>
<tr>
<td>ADFI, kg/day</td>
<td>0.57</td>
</tr>
<tr>
<td>Feed efficiency&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.55</td>
</tr>
<tr>
<td>Feeder pig weight, kg&lt;sup&gt;e&lt;/sup&gt;</td>
<td>18.69</td>
</tr>
<tr>
<td>Total days on test</td>
<td>42</td>
</tr>
<tr>
<td>Feed cost/kg gain, $&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.47</td>
</tr>
</tbody>
</table>

<sup>a</sup>Pigs were weaned at either a 15 day average (pigs weaned at 14, 15, and 16 day) or a 20 day average (pigs weaned at 19, 20, and 21 day) weaning age.

<sup>b</sup>Death loss = pigs removed from test plus mortalities.

<sup>d</sup>Feed efficiency and cost/kg gain were calculated on a per pen basis, using 42-d postweaning weight and pig days.

<sup>e</sup>Feeder pig weight = weight 42 day postweaning.
Table 2. Nursery production budget for two different weaning ages\textsuperscript{a} 
(per pig basis)

<table>
<thead>
<tr>
<th>Item</th>
<th>Weaning Age\textsuperscript{a}</th>
<th>15 d</th>
<th>20 d</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Facility Investment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building (per pig space), $</td>
<td></td>
<td>126.00</td>
<td>126.00</td>
</tr>
<tr>
<td>Feed &amp; manure handling, $</td>
<td></td>
<td>36.00</td>
<td>36.00</td>
</tr>
<tr>
<td>Total initial investment, $</td>
<td></td>
<td>162.00</td>
<td>162.00</td>
</tr>
<tr>
<td>Turns/year\textsuperscript{b}</td>
<td></td>
<td>8.10</td>
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</tr>
<tr>
<td>Total initial investment per turn, $</td>
<td></td>
<td>20.00</td>
<td>20.00</td>
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<tr>
<td>Facility cost per hog weighed off test, $</td>
<td></td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>Fixed Costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest, taxes, depreciation, $</td>
<td></td>
<td>14.00</td>
<td>14.00</td>
</tr>
<tr>
<td><strong>Operating Costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEW pigs, $</td>
<td></td>
<td>28.93</td>
<td>28.93</td>
</tr>
<tr>
<td>Pig death loss, %\textsuperscript{c}</td>
<td></td>
<td>2.53</td>
<td>1.55</td>
</tr>
<tr>
<td>Interest on SEW pig (6.5 %), $</td>
<td></td>
<td>2.45</td>
<td>2.45</td>
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<tr>
<td>Fuel, repairs, utilities, $</td>
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<tr>
<td>Feed, $</td>
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<td>6.36</td>
<td>6.66</td>
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<tr>
<td>Health costs, $</td>
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<tr>
<td>Labor, $</td>
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<td>1.58</td>
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<tr>
<td>Total operating costs, $</td>
<td></td>
<td>44.88</td>
<td>44.20</td>
</tr>
<tr>
<td>Total cost (per pig weighed off test), $</td>
<td></td>
<td>45.02</td>
<td>44.34</td>
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<tr>
<td>Feeder pigs, $</td>
<td></td>
<td>45.30</td>
<td>46.88</td>
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<tr>
<td>Net revenue, $</td>
<td></td>
<td>0.28</td>
<td>2.54</td>
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\textsuperscript{a}Average weaning age of 15 d included pigs weaned at 14, 15, and 16 d of age. Average weaning age of 20 d included pigs weaned at 19, 20, and 21 d of age.

\textsuperscript{b}Based on a 42 day stay in the nursery. Included washing and downtime between turns of pigs.

\textsuperscript{c}Pigs that either died or were weighed off before the end of the nursery phase were included in this calculation.
CHAPTER 6. GENERAL CONCLUSIONS

This experiment was conducted on a commercial maternal line multiplication operation and compared growth of animals, taking into account variation at birth, weaning, and end of nursery weights. The experiment also compared the subsequent reproductive performance of sows that were weaned at an average of 15 d and an average of 20 d. The following is a list of significant findings:

1. Consistent with other studies, pigs that had lower birth weights remained lighter throughout the nursery phase of production. As birth weight increased, linear increases in both weaning weight and nursery off-test weights were observed.

2. Weaning weight is also a significant predictor of nursery off test weight. A heavier pig at weaning was heavier at the end of the nursery period. This can have a significant impact on the value of a feeder pig.

3. Weaning age has a significant impact on growth performance of pigs in the nursery phase. As found in previous studies, ADG and ADFI increase with increasing weaning age.

4. Weaning age decisions also impact the sow’s subsequent reproductive performance. No differences were found in subsequent reproductive traits among lactation length treatments. This study indicates that producers should be able to choose weaning ages in the range of 14 to 21 d without any negative impacts on sow reproductive performance.

5. Overall, producers must consider a number of factors when making weaning age decisions. The importance of weight at weaning, herd health status, sow reproductive issues, lactation crate utilization, and pigs per sow per year, are all important considerations in weaning age decisions.
CHAPTER 7. REFERENCES


PIGWIN. 2005. Version 5. PIGWIN INC., Little Canada, MN.


