

## ABSTRACT

BISHOP, JOCELYN ALLIENE. Effects of Cross Fostering in Swine. (Under the direction of Dr. M. Todd See and Dr. Joe Cassady).

The objective of this project was to evaluate cross fostering as a management tool by estimating its effect on growth and survival from birth through slaughter. Cross fostering is a common practice in swine production to balance number of pigs nursed per sow. Litters were farrowed from multiparous Large White x Landrace females mated to Duroc boars. For study 1, data were recorded from farrowings during a 4 wk ( $n = 411$ ) period. For study 2, data were taken from a subset of these animals, representing farrowings from 2 wks ( $n = 178$ ). Prior to farrowing, sows were randomly assigned to one of 2 treatments, cross fostered group (CFG) or non-cross fostered group (NFG). Within 24 h of birth pigs were weighed and individually identified before cross fostering occurred. Pigs were weaned in 4 weekly groups at  $20 \pm 0.03$  d of age; 2 d before weaning, pigs were weighed and nurse sow identification was recorded. During the nursery phase (56 d), pigs were inventoried at placement and exit. All finisher data represented a subset of data collected from birth through nursery exit. Initial finisher weight was recorded at placement at  $74 \pm 1.9$  d of age. Final measurements included: live weight, back fat depth (BF) and loin eye area (LEA), and were measured at  $172 \pm 2.0$  d of age and fat-free lean gain per day (FFL) was calculated from these measurements. Hot carcass weight (HCW) (litter  $n = 133$ ) was obtained at slaughter at  $197 \pm 16.2$  d of age. Treatment effect on survival was calculated at weaning, nursery exit, and final measurements. Due to chance, sows assigned to NFG had a tendency for greater number born alive and lighter mean birth weight.

In the first study, CFG had higher mortality during the first 3 d of lactation. There was a tendency for CFG to have higher pre-weaning survival. Nursery survival did not differ between treatments and survival from birth through nursery had a tendency to be higher in CFG. Cross fostering had no effect on weaning weight, pre-weaning average daily gain (ADG), or variation of weights within a litter at weaning. It was concluded that cross fostering may benefit survival from birth through nursery but did not affect pre-weaning growth.

In the second study, cross fostering had no effect on survival from birth to finisher placement, finisher placement to exit, or birth to finisher exit. There was a higher variation of weights within litter at final measurements for NFG, but no difference between treatments for final weight, finisher ADG, BF, FFL, HCW, or slaughter age. However, there was a tendency for NFG to have larger LEA. It was concluded that cross fostering is of little to no benefit to finisher performance.

Effects of Cross Fostering on Growth and Survival in Swine

by  
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## BIOGRAPHY

Jocelyn Bishop was born on December 9<sup>th</sup>, 1986 in Atchison, Kansas. Jocelyn was an avid 4-H member through elementary and high school which also led to involvement in FFA. These activities began a passion for rabbit production, which sparked an interest in genetics. She attended Troy High school where she graduated in 2005 as valedictorian and then went on to attend Friends University of Central Kansas in Wichita, Kansas. After completing one year, she then transferred to Kansas State University in Manhattan, Kansas, where she was involved with Alpha of Clovia, a women's 4-H scholarship house. She completed an undergraduate honors project on the effects of sire by implant interactions in carcass traits in hereford cattle. She also completed internships at the University of Missouri and Progressive Swine Technologies. She graduated *summa cum laude* in 2009 with a bachelors in animal science with a focus on bioscience and biotechnology. The summer following graduation, Jocelyn spent the summer working as an intern for Smithfield Premium Genetics Group in Rose Hill, North Carolina. Her work there was then used for her Master's thesis, working with Dr. M. Todd See and Dr. Joe Cassady.

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**CHAPTER 1**  
**LITERATURE REVIEW**

## *Introduction*

Cross fostering is a common management technique used on commercial farms. Straw et al. (1998b) reported data from 300 farms in the Midwestern United States and Ontario, Canada and found that cross fostering was used on 98% of farms, with an average of 8.6% of pigs cross fostered. Cross fostering is believed to help minimize pre-weaning mortality and improve pre-weaning growth by equalizing number and size of piglets within litters. This is due to a decrease in competition for food by piglets which would be at a disadvantage in their original birth litter (English and Morrison, 1984). This advantage is needed piglet survival and growth. Giving piglets an advantage is especially important immediately after parturition, since this is when the majority of pre-weaning mortality occurs. It has been reported that 54 – 80% of pre-weaning mortality occurs within the first three days of life (Pettigrew et al., 1986; Roehe and Kalm, 2000; Straw, 1997; Svendsen et al., 1986). In addition to production needs, increased care of piglets is also important from a social and ethical perspective.(Knol, 2003; Roehe and Kalm, 2000).

## *Increasing Number Born Alive*

Meeting the needs of large litters has become of increased importance since emphasis has been placed on selection for increased number born alive. From 2000 to 2010, average number of pigs born alive per litter in the United States increased 14% from 10.1 to 11.5 (PigCHAMP, 2000, 2010). This increase of an average of 1.4 pigs per litter could translate into an increase in the amount of labor per sow (Knol, 2003).

Selection for increased number born has been associated with a decrease in mean piglet birth weight (English and Smith, 1975; Hermesch et al., 2000; Milligan et al., 2002b; Quiniou et al., 2002; Winfield et al., 1974; Wolf et al., 2008). It has also been associated with an increase amount of within-litter variation in weight at birth (Milligan et al., 2002b; Pettigrew et al., 1986; Quiniou et al., 2002; Wolf et al., 2008) and weaning (Milligan et al., 2002b). An increase in number born alive has been reported to have a negative, unfavorable genetic correlation with growth rate from 3 – 18 weeks of age, 18 - 22 weeks of age, and 21 day litter weight (Hermesch et al., 2000). In addition, a higher percentage of pre-weaning mortality has been associated with increased number born (Knol, 2003; Milligan et al., 2002b).

### *Fostering Purposes*

The main goals of cross fostering include trying to counter the effect of increased number of low birth weight piglets, increased birth weight variation, and increased mortality. Some strategies of cross fostering include: accommodating variation by assessing rearing capacity of individual sows, reducing variation within litters, and eliminating extremely a large or small number of piglets nursed by sows.

### *Rearing Capacity*

Before cross fostering piglets, rearing capacity of the sow should be assessed (English, 1993). This includes traits such as number and size of functional teats (Aherne, 1998; Beynon, 1997; Wattanaphansak et al., 2002b) and number of teats that are exposed during suckling (Aherne, 1998; English, 1977). English (1998) advised assigning one to two pigs less than the

number of teats available, in order to give room for error in case some teats that seem fully functional are not. It has been speculated that one of the main reasons for pre-weaning mortality of piglets that are seemingly healthy, without any abnormalities, is due to litters not having an adequate number of functional or exposed teats (English and Smith, 1975).

### *Litter birth weight variation*

One of the possible goals of cross fostering pigs is to reduce the amount of variation in weights within a litter at the beginning of lactation. English (1977) and English and Morrison (1984) noted that the most effective way to increase litter uniformity and to insure adequate and regular nutrition for low birth weight piglets is to cross foster piglets soon after birth. Some authors have also commented on the importance of minimizing weight variation of nursing litters (English, 1993; Wattanaphansak et al., 2002b). Smaller within-litter variation of weaning weights has also been found when litters begin lactation with smaller within-litter weight variation. However, this study also found that the weight variation at weaning decreased in litters with higher weight variation at the beginning of lactation, and almost doubled in uniform litters (Milligan et al., 2001a). Milligan (2002a) conducted a study at a farm where cross fostering was practiced, but within-litter weight variation was still present at the beginning of lactation, after cross fostering was performed. There have been some discrepancies in past studies as to whether reducing variation of weights within a litter at the beginning of lactation has an effect on mortality or growth of piglets.

Many studies have reported that an increase in birth weight variation within litters is associated with an increase in pre-weaning mortality (English and Bilkei, 2004; English, 1977;

English and Smith, 1975; Milligan et al., 2002b; Pettigrew et al., 1986). Some authors have noted that variation of birth weights within a litter is more important than individual birth weight with regard to piglet survival (English and Bampton, 1982). Lamberson and Johnson (1984) also found an increase in mortality as variation within-litter increased; however, they reported that less than 5% of variation in survival was accounted for by differences in birth weight variation. This led to a recommendation that fostering, to decrease variation, would have little effect on survival due to reduction of weight variation, but could help increase survival by decreasing the amount of stress due to competition.

Milligan et al. (2001a) found a tendency ( $P = 0.09$ ) for pre-weaning survival to decrease with decreasing litter birth weight variation. However, English and Bampton (1982) found that with the same mean litter size and birth weights, litters that were more variable had a 9.5% higher pre-weaning mortality than less variable litters. Other studies found no effect of variation within litters on pre-weaning mortality (Fix et al., 2010a; Milligan et al., 2001b). Kirkwood et al. (1998) also found that eliminating variation within litters by creating light and heavy litters did not improve pre-weaning survival. One study that saw no decrease in mortality due to birth weight variation noted that while survival of low birth weight piglets was higher, it was offset by the increase in mortality of other piglets in the litter (Milligan et al., 2001b).

Few studies have found an effect on growth due to increased birth weight variation. English and Bilkei (2004) found an increase in pre-weaning gain when low birth weight piglets were grouped with high birth weight litter mates compared to average birth weight piglets. This was attributed to a decrease in desire to fight with piglets that were heavier. However, Milligan et al. (2002a) found an increase in weaning weights at 28 days of age when litters had lower birth

weight variation. Milligan et al. (2002b) also found that variation in weaning weights was lowest when litters had lower variation in birth weights. In other studies, variation in litter birth weights has been reported to have no effect on pre-weaning weight gain (Fix et al., 2010a; Milligan et al., 2001a; Milligan et al., 2001b; Pettigrew et al., 1986), body weight, average daily gain, back fat, or loin muscle area (Fix et al., 2010a).

#### *Interaction between Litter variation and Birth weight*

While Roehe and Kalm (2000) found that both average birth weight and variation within litters independently affect pre-weaning mortality, average litter birth weight had a closer relationship to pre-weaning mortality than variation of birth weights within a litter. They also found that if individual birth weight was included in the logistic model, then variation of birth weight was no longer significant. English and Smith (1975) noted a relationship between birth weight and litter variation. They found that the lowest mortality was obtained when litters had a high average birth weight and low birth weight variation. However, no difference in mortality was found when litters with high average birth weights and high birth weight variation were compared to litters with low average birth weights and low or high birth weight variation. This led to the proclamation that having a higher average birth weight will not be advantageous to pre-weaning survival unless birth weight variation is reduced as well.

#### *Low birth weight piglets*

Although one author noted that small birth weight piglets have the potential to grow as effectively as larger littermates (English, 1977), most studies have reported that low birth weight

piglets are at a disadvantage for both survival and growth. Because of this, many authors advise to cross foster with the best interest of smaller, weaker piglets in consideration (English, 1993) or to foster only piglets with the highest birth weights, and never light birth weight piglets (Muirhead, 1998). For this reason, many studies have focused on giving extra assistance to low birth weight piglets.

An increase in pre-weaning mortality has been associated with low birth weight piglets (Bereskin et al., 1973; English, 1977; English and Smith, 1975; Fix et al., 2010b; Kerr and Cameron, 1995; Kirkwood et al., 1998; Lamberson and Johnson, 1984; Milligan et al., 2002a; Milligan et al., 2002b). Arango et al. (2006) claimed that individual birth weight is the most important factor for pre-weaning survival. Roehe and Kalm (2000) also found that individual birth weight accounted for the greatest amount of unexplained variation in pre-weaning mortality. However, Lamberson and Johnson (1984) reported greater than 80% of the variation in pre-weaning survival was unexplained by differences in birth weight. Some studies have found that maximum birth weight is not optimal for survival to 28, 42, or 56 days of age (Bereskin et al., 1973; Lamberson and Johnson, 1984); however, maximum survival for live born piglets has been found to be two standard deviations above mean birth weight. This demonstrates that above normal birth weight was not detrimental to survival to 56 days of age (Bereskin et al., 1973). Low birth weights and weaning weights have also been associated with increased nursery mortality (de Grau et al., 2005; Fix et al., 2010b).

Low birth weight has been associated with a decrease in pre-weaning growth rate or low weight at weaning (de Grau et al., 2005; Fix et al., 2010a; Gondret et al., 2005; Powell and Aberle, 1980; Quiniou et al., 2002). Wattanaphansak et al. (2002a) observed piglets weighting

less than 1 kg at birth had increased odds of being light weight at weaning. However, Kirkwood et al. (1998) found no difference in average daily gain from day three until weaning between litters that contained high birth weight pigs versus litters that contained low birth weight pigs. Few studies have followed low birth weight pigs past weaning, but of those that have, Fix et al. (2010a) and Powell and Aberle (1980) found that low birth weight pigs had a lower rate of gain through nursery and finishing phases. Hermesch et al. (2000) also found a positive, favorable genetic correlation between average birth weight and growth rate from 3-18 and 18-22 weeks of age. Gondret et al. (2005) only found a difference in rate of gain during the nursery phase. Even though they found no difference in rate of gain during the finishing phase, overall gain from birth to slaughter was 8% lower for light birth weight pigs. This resulted in light birth weight pigs being 12 days older at slaughter. A similar result was observed by Quiniou et al. (2002) who found that 1 kg birth weight pigs reached 105 kg two weeks later than pigs born at 2 kg.

#### *Litter size*

Because one of the goals of cross fostering is to eliminate extremely large litters nursed by sows, it is no surprise that English (1977) noted that cross fostering would be more useful in herds with high number born alive. Eliminating large litters is believed to be beneficial by decreasing the amount of competition for teats, thus increasing growth and decreasing mortality.

Knol et al. (2002) found that pre-weaning mortality is higher in very small litters of less than five. Kerr and Cameron (1995) also found that pre-weaning mortality was highest when litters contained one to four piglets, but that for litter sizes of five and greater, mortality increased with increasing litter size. This is supported by studies showing that an intermediate

litter size of six to eleven piglets has an increased pre-weaning survival over litters of less than five piglets, litters of twelve to fourteen piglets, or litters of greater than fifteen piglets (Cecchinato et al., 2008; Cecchinato et al., 2007). Many other studies have found that mortality increases along with litter size (Arango et al., 2006; Stewart and Diekman, 1989). Stewart and Diekman (1989) found that litters of six piglets had a 7% increase in pre-weaning survival when compared to litters of twelve piglets. Arango et al. (2006) found that pre-weaning mortality did not differ for litters of five to twelve piglets, but increased for litters over twelve piglets. Still other studies have found that an increased litter size had no effect on mortality either during lactation (Pettigrew et al., 1986) or during nursery and finisher stages (Stewart and Diekman, 1989).

While there are some studies showing that an increase in litter size had no effect on pre-weaning gain (Milligan et al., 2001b; Stevenson and Britt, 1981) or gain during the three weeks following weaning (Stevenson and Britt, 1981), a greater number of studies have reported that a decreased litter size has a positive effect on weight at weaning (English and Bilkei, 2004; Milligan et al., 2002a; Milligan et al., 2001a; Stewart and Diekman, 1989) and days to reach slaughter weight (Stewart and Diekman, 1989). Winfield et al. (1974) found that growth rate from birth to nine days of age was 87 grams per day higher for litters of six piglets compared to litters of eight piglets. No significant difference in growth was found between litters of ten piglets when compared to litters of six or eight piglets. However, this study had an extremely low sample size of one litter per litter size grouping. In another study by Winfield et al. (1974), no difference was seen in growth rates between large and small litters for growth rate from birth to five days of age or from five to twenty days of age, showing little relationship between litter size

and growth rate. Rzasas et al. (2002) recommended keeping larger litters on sows to increase the total litter weaning weight even though they suspected a decrease in average weaning weight, hypothesizing compensatory gain after weaning.

### *Disease Control*

While some studies have advised against fostering sickly pigs (Beynon, 1997; Muirhead, 1998) or observed more intensive diarrhea in transferred piglets soon after cross fostering (Grudniewska et al., 1986), few studies have looked at how cross fostering influences the spreading of diseases at farms and have focused on farms with active PRRS outbreaks (McCaw, 2000; McCaw and Derosiers, 1997; McCaw et al., 1996). However, it was also noted that many of the clinical signs and mortality associated with PRRS are due to secondary infections from bacteria (McCaw, 2000). Reports by McCaw et al. (1996), McCaw and Derosiers (1997), and McCaw (2000) focused on the effect of limiting the incidence and timing of cross fostering and its affect on mortality through lactation and in the nursery. Cross fostering was limited to the first twenty-four hours after birth which reduced the incidence of cross fostering from greater than 85% to 15% (McCaw, 2000). McCaw (2000) found a decrease in pre-weaning mortality when limited cross fostering was implemented. This agrees with McCaw et al. (1996) who noted that holding back sick pigs decreased survival during a PRRS outbreak, and with de Grau et al. (2005) who found that farms with higher mean wean ages were associated with an increase in the incidence of health problems. Higher weaning ages were attributed to delayed weaning of lightweight pigs. Kingston (1989) noted that all-in, all-out management, which helps control disease, is jeopardized by poor cross fostering and delayed weaning. McCaw (2000) found the

effect of limited fostering also carried on to the nursery, reducing mortality and increasing piglet weight at ten weeks of age. The study by McCaw and Derosiers (1997) was conducted at a farm already limiting cross fostering to within 24 hours of birth before a PRRS break. However, within these 24 hours, farm staff were extensively cross fostering to match sizes and sexes within litters. By changing the cross fostering protocol and limiting cross fostering to only filling available teat spaces, improvements were made during a PRRS break in both growth and mortality from birth through nine weeks of age. Pre-weaning mortality decreased by 6.9% and nursery mortality decreased by 4.4 %. Average end weight at nine weeks of age also increased by seven pounds. The new cross fostering protocol was continued after the PRRS outbreak had passed and improvements in survival and growth were maintained.

### *Continuous Cross Fostering*

Effects of limiting the incidence of cross fostering have been reviewed in other studies. Continuous cross fostering is intended to decrease variation and competition within litters throughout lactation. This decrease in variation is a benefit when sorting piglets into pens of equal sizes at placement following weaning and growth in later stages. While Rzasz (2002) recommended repeated cross fostering to decrease number of starvelings, many other studies have found that continuous cross fostering has detrimental effects on pre-weaning growth (Straw, 1997; Straw et al., 1998a).

Although one author found that within-litter variation was higher in continuously cross fostered litters during lactation, at weaning, and at 56 days of age (Robert and Martineau, 1998), most studies have found that continuously cross fostering piglets throughout lactation decreased

variation in weaning weights (Straw, 1997; Straw et al., 1998a). It has also been reported to decrease pre-weaning growth, resulting in lighter piglets at 13 and 16 days of age (Robert and Martineau, 2001) , 17 days of age (Larriestra et al., 2006; Wattanaphansak et al., 2002a), 18 days of age (Robert and Martineau, 2001), and 19 days of age (Straw, 1997; Straw et al., 1998a). A decrease in pre-weaning average daily gain has also been associated with continuous cross fostering (Wattanaphansak et al., 2002a). Authors of some of these studies noted that this reduction in variation is not helpful if piglets are smaller at weaning (Straw, 1997; Straw et al., 1998a). Cross fostering at any time except day one has been found to disrupt pre-weaning behavior of piglets and sows (Robert and Martineau, 2001). Continuous cross fostering has also been reported to affect not only piglets that are being cross fostered, but also resident piglets. Resident piglets of continuously cross fostered litters and piglets that were continuously cross fostered were lighter at weaning than piglets in litters where no cross fostering occurred. Also, continuously cross fostered piglets were lighter than resident piglets at sixteen and eighteen days of age and had a lower growth rate on days four through eighteen (Robert and Martineau, 2001). Continuous cross fostering has also been found to be associated with an increase in the mean number of failed nursing attempts during lactation when compared with litters that are only cross fostered on day zero (Robert and Martineau, 1998). Larriestra et al. (2006) found that continuous cross fostering did not have a direct impact on being light weight at ten weeks of age once birth weight and weaning weight were considered. No difference has been found for mortality between continuous cross fostering and limited cross fostering (Larriestra et al., 2006; Straw, 1997; Straw et al., 1998a).

### *Age at Cross Fostering*

One aspect of continuous cross fostering is that piglets are being moved at older ages. Even movement only once, at later ages has been reported to affect not only piglets being moved, but also resident piglets that are originally in the litter. Many authors advise cross fostering to be done soon after farrowing (Aherne, 1998; English, 1998; Kingston, 1989; Price et al., 1994; Vaillancourt and Tubbs, 1992).

It is well known that colostrum intake is important for the health of newborn piglets, improving resistance to diseases, and reducing risk of chilling and malnutrition (English, 1998). Because of this, cross fostering should not occur before an adequate amount of colostrum has been ingested (Beynon, 1997; English, 1993). One author even suggested that colostrum should be available for up to twelve hours after farrowing (Muirhead, 1998). Cross fostering should occur promptly as soon as colostrum intake has occurred (Beynon, 1997; English, 1993). However, Aherne (1998) noted that because of antibody specificity in colostrum for each sow, a piglet that is transferred to a sow but does not have a chance to ingest colostrum from that sow will not have protection from diseases that might be specific to that sow. Another method to ensure adequate colostrum intake is to practice “colostrums sharing” or “split suckling”. This method involves shutting away the larger half of the piglets in the litter for approximately two hours to allow smaller piglets a better chance to get a fair share of colostrum (English, 1993).

Piglets develop a teat preference very early in life. McBride (1963) proposed that teat order is established within one hour of birth and possibly even before the last piglet of the litter is born. They also found that 75% of teat positions observed at twelve hours after birth were the same teat positions observed at two weeks of age. Other authors have observed a slightly longer

latency to teat order development. English (1998) noted that some piglets have a teat preference at six hours after birth, and many at twelve hours after birth. Straw (1997) observed that teat order was established during the first few days of life and was stable after one week. Winfield et al. (1974) found an even longer time period, noting that teat order was not stable at twenty days of age in most litters and that this delay was larger for slower growing and larger litters. Teat order was found to be established by recognized sights and smells, and recognition of neighbors (McBride, 1963), all of which are possibly disrupted during fostering. McBride (1963) also noted that a loss of a preferred teat at a few hours of age is not as serious as a loss of a preferred teat at about twenty-four hours of age. By cross fostering later in life, multiple piglets which have a preference for a teat in the same location may be fostered onto the same sow. Horrell and Bennett (1981) observed slower growth when multiple piglets had preference for the same teat. They also found that when piglets were cross fostered at one week of age the teat relationships were disrupted mostly in cross fostered piglets, but were also disrupted in the resident piglets that were previously in the litter. This disruption resulted in cross fostered pigs only gaining 79% of the weight that non-cross fostered piglets gained during the second week of lactation. Winfield et al. (1974) has also reported that low growth rates were associated with less stable teat orders, regardless of litter size. Another study showed that when piglets were cross fostered at four to seven days, cross fostered piglets were less likely to be present at milk letdown when compared to resident piglets. However, sows of cross fostered litters were also observed to have fewer milk letdowns even though they were more likely to initiate suckling (Horrell, 1982), affecting not only cross fostered piglets, but also resident piglets.

Giroux et al. (2000) found pre-weaning growth was reduced for litters that were cross fostered at 6 days of age compared to litters that were only standardized after birth. Within cross fostered litters, it was found that adopted piglets had lower pre-weaning growth than resident piglets. Differences in weaning weights of piglets continued after weaning at 17 days of age through the nursery phase at 45 days of age; however, no additional effects of late cross fostering were found on post-weaning growth. Straw (1997) observed similar results when piglets were cross fostered at nine to eleven days of age. He found that not only did 69% of the cross fostered piglets have lower growth rates following relocation, but 25% of resident piglets, that were not moved, had lower growth rate. Combining growth losses of both cross fostered and resident piglets, there was a net loss of 0.23 kg per pig one week after cross fostering. Stevenson and Britt (1981) reassigned comingled litters five days before weaning. They found that piglets that were reassigned to their own dam weighed more at weaning than piglets reassigned to foster sows, but that body weights were similar three weeks after weaning. When comparing farms grouped into either early-move farms or late-move farms, Straw et al. (1998b) found that late-move farms had a 1.5% higher pre-weaning mortality than early-move farms, along with moving a larger number of piglets throughout lactation.

### *Early, Single Cross Fostering*

#### *Pre-weaning*

Most studies designed to test the effects of cross fostering do not include post-weaning performance. However pre-weaning performance is important for future performance. For example, greater weaning weights allow piglets to grow more predictably during the nursery

period (Wattanaphansak et al., 2002b). McConnell et al. (1987) found that piglets with lighter weaning weights had lower average daily gain through 28 days after weaning than heavy weaning weight piglets. They also found that while all pigs doubled their weights in 28 days, low weaning weight piglets did not exhibit compensatory gain. Wolter and Ellis (2001) reported similar results where piglets that were lighter at weaning were also lighter at 35 and 56 days old compared to piglets that were heavier at weaning. They also found that lower weaning weight piglets had decreased performance from 35 days of age to 56 days of age when compared to piglets with heavier weaning weights. Lighter weaning weight piglets had lower average daily gain and average daily feed intake from 35 to 56 days of age, though both groups had similar feed to gain ratios. This weaning weight affect was not extended from 56 days of age until slaughter, when weaning weight showed no effect on average daily gain, average daily feed intake, gain to feed ratio, loin eye area, backfat, or predicted lean content. However, the growth advantage in nursery resulted in light weaning weight piglets taking 8.6 days longer to reach slaughter than heavier weaning weight piglets.

### *Survival*

While Stewart and Diekman (1989) and Kirkwood et al. (1998) found that survival to weaning did not differ between cross fostered piglets and piglets raised on their own dam, many other authors have found that cross fostering has improved pre-weaning mortality. With equal litter sizes, litters that were cross fostered have been reported to have improved pre-weaning survival by 2.8% (1977) to 40 % (English and Bampton, 1982) when compared to litters that were not cross fostered. When litter size was larger for litters cross fostered, cross fostered litters

were still found to have an increase in pre-weaning survival for maternal (4.7%) and paternal (2.8%) lines when compared to litters that were not cross fostered (Knol et al., 2002). Marcatti (1986) also observed a difference in mortality, with cross fostered litters having 6.7% higher survival. When analyzed as individuals instead of litters, Cecchinato et al. (2007) found that cross fostering increased pre-weaning survival, cross fostered piglets having a 40% greater chance of survival than piglets that were left on their own dam. Even with no difference in individual birth weights between cross fostered and non-cross fostered pigs, a 10% decrease in pre-weaning mortality was observed for cross fostered piglets (Arango et al., 2006). Marcatti (1986) observed that cross fostering was beneficial by decreasing mortality for piglets weighing less than 0.8 kg. It was noted by English (1977) that cross fostering between litters to standardize weights has improved pre-weaning survival by decreasing competition among piglets.

However, there are other studies with conflicting results, where it has been reported that cross fostering piglets results in an increase in mortality. Holtcamp (1998) found that when cross fostering was reduced over three years, pre-weaning mortality also decreased, even as number of piglets born alive was increasing. Grudniewska et al. (1986) saw higher mortality in transferred piglets, compared to non-cross fostered and resident piglets. They also found that mortality was higher in cross fostered litters that were comprised of all cross fostered piglets than for cross fostered litters comprised of some cross fostered piglets and some resident piglets. This is supported by other studies that have found that piglets fostered into litters had a 9.4% decrease in survival compared to piglets originally in the litters (Neal and Irvin, 1985) and that a higher survival was observed when piglets had similar birth vigor scores (Neal and Irvin, 1991). Rzasza et al. (2002) found that mortality was lowest when litters were not standardized, compared to

being standardized to eight or twelve piglets. Even when average number of pigs per litter for un-standardized litters was only 0.18 greater than litters standardized to eight piglets, mortality was decreased 0.55 percent.

### *Growth*

There are also contradicting reports as to the effect of cross fostering on pre-weaning growth. In some instances there was no difference in growth throughout lactation between litters that were cross fostered and litters that were not cross fostered (English and Bilkei, 2004; Kirkwood et al., 1998; Milligan et al., 2001b) or from three days of age until weaning (Milligan et al., 2001a). However, Milligan et al. (2001a) excluded any piglets with birth weights less than 0.60 kg or physical abnormalities. Kirkwood et al. (1998) created light and heavy birth weight litters by cross fostering and leaving some litters intact as controls. Number of piglets per litter nursed were similar, and there was no difference in average daily gain from day three to weaning for cross fostered versus non-cross fostered litters. There was also no difference in weight gain from birth to 21 days of age between piglets that were cross fostered and resident piglets in cross fostered litters (Neal and Irvin, 1985; Neal and Irvin, 1991).

However, others have found that cross fostering has a positive effect on pre-weaning growth. Piglets in cross fostered litters had, on average, 0.3 kg higher weaning weights than piglets in non-cross fostered litters (Marcatti, 1986). Powell and Aberle (1980) reported that cross fostered runt piglets, defined as weighing 900 – 1000g at birth and at least 1/3 less than the average birth weight within their litter, had the same pre-weaning growth as high birth weight

piglets. Pre-weaning gain was greatest when litters were standardized to eight piglets, compared to non-standardized or litters standardized to twelve piglets (Rzasa et al., 2002).

Still, other results show that cross fostering, even when done only once, early in life, has a negative effect on pre-weaning gain. In the first three days of life, there is a tendency ( $P < 0.1$ ) for cross fostered piglets to gain less weight than non-cross fostered piglets (Milligan et al., 2001a). However, this study excluded any piglets with birth weights less than 0.60 kg or physical abnormalities. Hermesch et al. (2001) observed that cross fostering reduces individual piglet weights at fourteen days of age, and that high birth weight pigs were affected more by cross fostering than light or medium birth weight piglets. Grudniewska et al. (1986) also found that litters that were not cross fostered had higher pre-weaning gain and higher average body weight at weaning (28 days of age) than litters that were cross fostered. They also reported that within cross fostered litters, piglets cross fostered into the litters had lower pre-weaning rates of gain and lower weaning weights at 28 days than resident piglets. Fix et al. (2010a) reported an interaction between cross fostering and birth weight, with cross fostering resulting in lower pre-weaning gain and lower weaning weight at eighteen days of age regardless of birth weight, but that piglets with higher birth weights were more negatively affected by cross fostering than low birth weight piglets. Stewart and Diekman (1989) found that when piglets were raised by their own dams, they gained an average of 0.21 kg more by 21 days of age.

### *Nursery*

#### *Survival*

Stewart and Diekman (1989) found no difference in nursery survival between piglets that were cross fostered and piglets that were not cross fostered and raised on their own dam. However, Neal and Irvin (1991) observed that within cross fostered litters and piglets with similar birth vigor scores, piglets that were cross fostered into litters had lower survival during the nursery phase than resident piglets that were originally in the litters.

#### *Growth*

Neal and Irvin (1991) found no difference in weight at 42 days of age in pigs that were cross fostered into litters compared to resident piglets. However, Powell and Aberle (1980) found that when cross fostered runts were compared to non-cross fostered runts, the cross fostered runts were younger at a fixed weight of 26 kg.

### *Finisher*

#### *Survival*

No difference was observed in finishing survival between cross fostered piglets and piglets that were original residents of cross fostered litters (Stewart and Diekman, 1989). However, this study also lacked evidence of any difference in pre-weaning or nursery survival between cross fostered and non-cross fostered piglets.

### *Growth*

Neal and Irvin (1991) found no difference in rate of gain during the finishing phase between piglets that were cross fostered into litters and resident piglets of those litters. Powell and Aberle (1980) observed similar results with runt piglets, finding no difference in daily gain between cross fostered runts and non-cross fostered runts.

However, other studies have noted cross fostering as having a negative effect on growth performance during the finishing period. Neal and Irvin (1985) found that within cross fostered litters, resident piglets gained 13.5% faster in the first half of the finishing period. The cross fostered piglets then achieved slightly higher gain during the second half of the finishing period, gaining 2.8% faster than the resident piglets. However, when off test weights were taken, resident piglets were heavier. It has also been noted that when runt piglets were cross fostered and compared to non-cross fostered runts, cross fostered runts were 84 % less efficient (Powell and Aberle, 1980). They also found that when runt piglets that were cross fostered were compared to runt piglets that were not cross fostered, cross fostered runts had a decrease in loin eye area and an increase in back fat. Overall this led to a decrease in the amount of separable lean for the cross fostered runt piglets.

### *Days to Slaughter*

There are contradicting results as to the effect of cross fostering on days to reach slaughter. Stewart and Diekman (1989) found that cross fostered pigs reached a market weight of 105 kg four days later than piglets that were not cross fostered and raised by their own dam.

However, Powell and Aberle (1980) found that cross fostered runts were younger at 96 kg than their non-cross fostered runt counterparts.

### *Summary*

Cross fostering is a common management practice on commercial swine farms (Straw et al., 1998b). It is used to evenly distribute the number and size of piglets (English and Morrison, 1984) among sows. This management practice provides the possibility for farms to better balance the differences among rearing capacities of individual sows. These variations include number of functional and exposed teats and amount of milk production for each sow (Beynon, 1997; English, 1977).

With selection for increased litter size, mean piglet birth weight has decreased and litter variation has increased (Wolf et al., 2008). Cross fostering is believed to be especially beneficial to low birth weight piglets (Deen and Bilkei, 2004). These low birth weight piglets are already at a risk of higher mortality and decreased growth (Fix et al., 2010a; Fix et al., 2010b). The effect of increased birth weight variation in litters has had contradicting results. In previous studies it has been concluded that higher variation of weights within a litter has a negative effect on pre-weaning mortality (English and Bilkei, 2004; Milligan et al., 2002b; Pettigrew et al., 1986), although some studies have reported no effect (Fix et al., 2010b; Milligan et al., 2001a; Milligan et al., 2001b). The majority of studies report no effect of birth weight variation on pre-weaning growth rate (Fix et al., 2010a; Milligan et al., 2001a; Milligan et al., 2001b; Pettigrew et al., 1986). Redistributing piglets to equalize litter sizes strives to decrease the negative effects of extremely large or small litters on both pre-weaning mortality and growth (Arango et al., 2006;

Cecchinato et al., 2008; Cecchinato et al., 2007; Kerr and Cameron, 1995; Knol et al., 2002; Stewart and Diekman, 1989).

Limiting the amount of cross fostering performed at farms to only moving piglets within the first 24 hours after farrowing and moving the minimum amount needed to fill available teat spaces has been reported to decrease mortality and increase growth rates during PRRS outbreaks (McCaw, 2000; McCaw and Derosiers, 1997; McCaw et al., 1996). Little research has been done over the effect of cross fostering on other diseases; however, many clinical signs and mortality associated with PRRS are due to secondary infections from bacteria (McCaw, 2000).

Much work has been done to determine the most effective way to cross foster piglets, demonstrating advantageous timing and incidence of cross fostering. These studies emphasize the importance of colostrum (Aherne, 1998; Beynon, 1997; English, 1998) and teat order stability for performance and piglet growth (Horrell and Bennett, 1981; Winfield et al., 1974). Many of these studies have found that fostering piglets after teat order preference has been developed, within the first 24 hours after birth, can be detrimental to growth and survival of not only piglets moved (Giroux et al., 2000; Straw et al., 1998a), but also of resident piglets that are originally in the litters (Giroux et al., 2000; Straw, 1997). Continuously cross fostering piglets includes moving piglets after this teat preference is established, and has also been found to have a negative impact on growth and no impact on survival (Straw, 1997; Straw et al., 1998a).

Very few studies on cross fostering have been reported during the past ten years within the United States, during which time number of pigs born alive has increased by 1.37 pigs per litter (PigCHAMP, 2000, 2010). This increase in number of pigs born alive could change the magnitude of the effect of cross fostering. Other studies that are more recent have been

conducted in other countries where management and facility differences could make results non-transferrable to U.S. farms.

When piglets were cross fostered once, within 24 hours of birth, there are contradicting results as to its effect on pre-weaning growth and survival. Results range from cross fostering having a positive effect on growth (Marcatti, 1986; Powell and Aberle, 1980; Rzasz et al., 2002) and survival (1977; Arango et al., 2006; Cecchinato et al., 2007; English, 1977; Knol et al., 2002; Marcatti, 1986), to having a negative effect on growth (Fix et al., 2010a; Grudniewska et al., 1986; Hermesch et al., 2001; Milligan et al., 2001a; Stewart and Diekman, 1989) and survival (Grudniewska et al., 1986; Rzasz et al., 2002), and even having no effect on survival (Neal and Irvin, 1991; Stewart and Diekman, 1989) and growth (English and Bilkei, 2004; Milligan et al., 2001b; Neal and Irvin, 1991). The studies also differ in that the objective of some is the effect on the individual piglets, and others the entire litter. There are very few studies that have followed these cross fostered piglets past weaning. Those that have, also have contradicting results about the effects of cross fostering on growth and survival (Neal and Irvin, 1991; Powell and Aberle, 1980; Stewart and Diekman, 1989). No studies were found that have studied the effect of cross fostering on lean growth in all birth weight categories.

Many studies involving cross fostering only occurring once during the first twenty-four hours after birth were done in other countries, where management practices and facilities differ from those in the United States, were done more than ten years ago, when number born alive was much lower, or a combination of both. Due to these circumstances, along with contradicting results in current US studies, additional research is needed to make conclusions about effects of cross fostering in current, US swine production.

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## **CHAPTER 2**

### **EFFECT OF CROSS FOSTERING ON GROWTH AND SURVIVAL IN SWINE:**

#### **BIRTH THROUGH NURSERY**

**ABSTRACT:** Cross fostering is a common practice in swine production to balance number of pigs nursed per sow. The objective of this study was to evaluate cross fostering as a management tool by estimating its effect on growth and survival from birth through nursery exit. Multiparous Large White x Landrace females (n = 411) mated to Duroc boars were farrowed during a 4 wk period. Prior to farrowing, sows were randomly assigned to one of 2 treatments, cross fostered group (CFG) or non-cross fostered group (NFG). Within 24 h of birth pigs were weighed and individually identified before cross fostering occurred. Pigs were weaned in 4 weekly groups at  $20 \pm 0.03$  d of age; 2 d before weaning all pigs were weighed and nurse sow identification was recorded. A model with fixed effects of treatment and covariate of parity group was fit using the Mixed Procedure of SAS to estimate effect of treatment on litter growth traits. To estimate effect of treatment on survival, the Glimmix procedure of SAS was used with a model including fixed effect of treatment and covariate of parity group. Treatment effect on survival was calculated at weaning and nursery exit. Due to chance, sows assigned to NFG had a tendency for greater number born alive (NBA) (CFG =  $11.1 \pm 0.26$ , NFG =  $11.7 \pm 0.28$ ;  $P = 0.14$ ) and lighter mean birth weight (CFG =  $1.50 \pm 0.018$  kg, NFG =  $1.45 \pm 0.019$  kg;  $P = 0.07$ ). No treatment differences were found in mean weaning weight, variation of weaning weights within litters, or pre-weaning ADG. Although CFG had higher mortality during the first 3 d of lactation ( $P < 0.05$ ), there was a tendency for CFG to have higher pre-weaning survival (CFG =  $76.6 \pm 0.91$ , NFG =  $74.3 \pm 0.98$ ;  $P = 0.08$ ). In the nursery there was a tendency ( $P = 0.09$ ) for CFG to have 4.17% higher mortality in week 1 and NFG had 10.42% higher mortality during week 2 ( $P < 0.02$ ); however, overall nursery survival did not differ between treatments. Survival from birth

through nursery had a tendency to be higher in CFG (CFG =  $65.3 \pm 1.03$ , NFG =  $62.8 \pm 1.08$ ; P = 0.08). Cross fostering had no effect on pre-weaning growth performance, but tended to increase survival of CFG pigs during lactation. Cross fostering also had an impact on the timing of deaths between treatments. It was concluded that cross fostering may benefit survival from birth through nursery but did not affect pre-weaning growth.

**Keywords:** pigs, survival, cross fostering, growth

## INTRODUCTION

From 2000 to 2010, average NBA per litter in the United States increased by 1.37 pigs per litter (PigCHAMP, 2000, 2010). An increase in NBA has been associated with decreased piglet birth weight and increased variation of birth weight within litters (Quiniou et al., 2002). These traits have been linked to an increase in pre-weaning mortality (Bereskin et al., 1973; English and Bampton, 1982) and decreased pre-weaning growth (Milligan et al., 2002b; Powell and Aberle, 1980). There is contradicting evidence as to the effects of cross fostering on pre-weaning mortality. While in some studies it was concluded that cross fostered pigs have lower pre-weaning mortality (Knol et al., 2002), in others an increase was reported (Grudniewska et al., 1986). Similar conflicting results have been reported for pre-weaning growth. The reported effects of cross fostering on pre-weaning growth vary from none (Neal and Irvin, 1991), to a positive effect (Marcatti, 1986), and even a negative effect (Grudniewska et al., 1986). Reports on the effect of cross fostering on growth and survival during the nursery phase are also contradicting (Neal and Irvin, 1991; Powell and Aberle, 1980; Stewart and Diekman, 1989). Many cross foster studies were either conducted in other countries, where management practices

and facilities differ from those in the United States, were conducted more than 10 years ago, when NBA was much lower, or a combination of both. The majority of cross foster studies only follow piglets through weaning, limiting results on extended effects of cross fostering. The objective of this study was to evaluate cross fostering as a management tool by estimating the effects on growth and survival from birth through nursery exit.

## **MATERIALS AND METHODS**

### ***Animals***

Data were collected at a commercial swine farm in eastern, North Carolina. Data were collected from sows which farrowed within a 4 week period. Females (n = 425) consisted of Large White x Landrace crosses and were mated to Duroc boars. The herd from which the data were collected was a PRRS positive herd that was not experiencing an active outbreak. Fourteen sows were removed from the data set due to not producing a live pig (n = 3), treatment applied incorrectly (n = 9), or litters becoming comingled (n = 2).

Treatments applied include: cross foster group (CFG) (n = 215) and non-cross foster group (NFG) (n = 196) (Table 2.1). In CFG, piglets were eligible to be cross fostered by farm staff within 24 hours of birth. In NFG, piglets were not allowed to be cross fostered. Farrowing facilities consisted of 4 farrowing houses, each divided into 2 rooms. Each room contained 3 rows of 16 crates per row. Sows were assigned randomly to treatment and then grouped by treatment into alternating rows of crates in the farrowing room. Grouping of treatments into rows was done for ease of management and to minimize errors in treatment application by farm staff. In CFG, piglets were cross fostered among sows which farrowed within the same day, at the

discretion of farm staff. Amount of cross fostering that occurred each day varied based on average NBA and variation among sows for NBA each day (Table 2.1); however, cross fostering did occur in CFG each day of farrowing. If a litter in NFG had a piglet cross fostered into or out of that litter, the entire litter was excluded from the study. In the event that a sow in NFG became ill or died and her piglets were moved to a nurse sow, this litter was excluded from the analysis.

### ***Farrowing***

Litter processing occurred within 24 hours of farrowing. Sow data recorded included: farrowing date, treatment group, parity, NBA, number still born, and number of mummified fetuses (Table 2.1). All piglets were weighed and double tagged with barcode tags prior to cross fostering (Table 2.1). Additional information recorded for piglets includes: sex, birth sow, date born, and treatment group. Piglets in NFG were also ear notched to aid in identification of treatment groups. Piglets had unlimited access to water through a low set water nipple. Weaning weight was taken two days prior to weaning ( $18 \pm 2.0$  days of age). At this time, sow treatment was recorded and piglet data included: Sex, treatment group, wean sow, and weaning date (Table 2.1). Number weaned ( $20 \pm 2.0$  days of age) was obtained from farm records. Within CFG, cross foster status of piglets was determined by comparing birth sows and wean sows, with piglets having different birth and wean sows deemed cross fostered. If a piglet died prior to weaning, its cross foster status was unknown and it was assumed to be not cross fostered. In CFG, 30% of piglets that survived to weaning were cross fostered, affecting 70% of litters in this treatment group (Table 2.1). Throughout lactation, date of piglet mortality was recorded by farm staff. Pre-weaning survival was determined by placement at nursery and only pigs placed at nursery were included in weaning weights.

## *Nursery*

After weaning, piglets were placed into nursery facilities. Four nursery placements were made, each consisting of piglets farrowed within a week's time period. Treatments were comingled at nursery placement. Piglets were inventoried and pen location recorded within 24 hours of placement. In each subsequent week of the nursery phase, pen counts were recorded. Piglets remained at nursery facilities for 56 days and were inventoried with pen locations recorded prior to leaving nursery facilities. Farm staff collected ear tags from mortalities, with week of mortality noted. Survival during the nursery phase was determined by comparing nursery placement and exit inventories.

## *Analysis*

Experimental unit for this study is litter, but data were recorded on individual piglets. Due to tendencies for NBA to differ between treatments ( $P = 0.14$ ), data were averaged for litter traits. Data were averaged over birth sow for farrowing and survival data and nurse sow for weaning data to acquire a litter trait. Parities were assigned groups; with parity 1 in group 1, parities 2 through 5 in group 2, and parities 6 and greater in group 3. Piglet weaning weights were adjusted by sex to 21 days of age prior to being averaged within litter.

Where:

Y = adjusted individual BW at weaning

W = individual BW at birth

ADG = average daily gain (ADG) during lactation

Z = individual animal's age at weaning

S = fixed effect of sex, barrow or gilt, for BW at weaning

Survival analysis was done with the GLIMMIX procedure of SAS. Fixed effects were treatment and a covariate of parity group. Percentage of pre-weaning mortality per day and nursery mortality per week was also analyzed with the GLIMMIX procedure of SAS. This was done by comparing the percentage of piglets that died each day or week out of the total number of piglets that died during lactation or nursery phase. Pre-weaning death days were grouped into 3 day increments and censored at 16 d, the lowest wean age. Nursery death weeks were not censored as all piglets were moved in and out of nursery buildings after the same number of days. Pre-weaning death date was known for 87% of all pre-weaning deaths. Nursery death week was known for 45% of all nursery deaths. Growth traits were analyzed with the MIXED procedure in SAS. Fixed effects were treatment and a covariate of parity group. Degrees of freedom for all analysis were adjusted with Kenward-Rodgers adjustment.

## **RESULTS**

### ***Survival***

Pre-weaning survival had a tendency ( $P = 0.08$ ) to be higher for CFG. Pre-weaning timing of death did not differ between treatments except for 0 – 2 d ( $P = 0.05$ ) (Figure 2.1). In days 0 – 2, 42.6% of total pre-weaning mortalities for CFG occurred, but only 36.3% of total pre-weaning mortalities for NFG. Nursery timing of death tended to differ during week 1 ( $P = 0.09$ ) and was different between treatments during week 2 ( $P < 0.02$ ) (Figure 2.2). During week 1, 7.09% of total nursery mortalities occurred for CFG and 2.91% of total nursery mortalities for NFG. During week 2, 19.35% of total nursery mortalities occurred for NFG and 8.93% of total nursery

mortalities for CFG. However, overall nursery survival did not differ between treatments. Combined survival from birth through nursery exit had the same tendency ( $P= 0.08$ ) as pre-weaning survival to be higher for CFG (Table 2.2).

### ***Growth***

Mean birth weight had a tendency ( $P = 0.07$ ) to be higher for CFG (Table 2.3). This difference in birth weight could be due to differences in NBA between treatments. Average NBA was 0.55 higher per litter for NFG and mean birth weight was 0.05 kg lower. However, no difference was found in mean weaning weights between treatments. There was also no significant difference in average pre-weaning ADG between treatments. Variation for BW within litters was not different between treatments at either birth or weaning (Table 2.3).

## **DISCUSSION**

### ***Survival***

The tendency for CFG to have a higher pre-weaning survival compared to NFG supports reports from previous studies (1977; Arango et al., 2006; Cecchinato et al., 2007; English and Bampton, 1982; Knol et al., 2002; Marcatti, 1986). Results for increase in survival more closely resemble those of Knol et al. (2002), who reported a 4.7% increase in a maternal line and a 2.8% increase in a paternal line for survival of litters that were cross fostered compared to litters that were not cross fostered. However, NBA was lower for their study, 10.31 and 9.37 respectively for maternal and paternal lines. With larger mean litters sizes of 11 and 10.9 for cross fostered litters of light piglets and non-cross fostered litters, it has been reported that litters of light cross fostered piglets had 2.8% higher survival than non-cross fostered piglets (1977). However, with

the same litter sizes English and Bampton (1982) reported a 40% increase of cross fostered litters when compared to litters that were not cross fostered.

Other studies have reported contradicting evidence of survival being higher in litters that were not standardized, compared to litters that were standardized to 8 or 12 piglets. Mean litter size was only 0.18 greater than litters standardized to 8 piglets, but survival increased by 0.55 percent (Rzasa et al., 2002). Grudniewska et al. (1986) also observed an increase in survival when piglets were either in litters that were not cross fostered or were resident piglets of a cross fostered litter, compared to piglets that were cross fostered into the litter.

Tendency for a difference in NBA and mean piglet birth weight between treatments may have had an impact on the difference in pre-weaning survival. Milligan et al. (2002b) reported a small (-0.272) correlation between NBA in a litter and percent survival to weaning and a moderate (0.429) correlation between mean piglet birth weight and percent survival to weaning, both significant at  $P < 0.001$ . Given that NFG tended to have a higher NBA with lower birth weight, it might be expected that survival would be lower in that group.

Similar results for nursery survival were found by Stewart and Diekman (1989) who, while observing individual piglets instead of litters, reported no difference in nursery (35 – 70 d) survival between piglets that were cross fostered and piglets that were residents of the sows onto which piglets were cross fostered. This indicates that the effect of cross fostering on survival is limited to pre-weaning. This could be due to the sow being a limiting factor for the nutrition of piglets during lactation.

Higher mortality for CFG within the first 3 d of lactation could give an additional benefit to piglets within the CFG group. By eliminating increased competition from additional litter

mates earlier in life and increasing resources available to each piglet, the CFG could be expected to have higher weaning weights. No difference was found between treatments for survival through nursery phase. However, difference in timing of deaths during the nursery phase does not give the same advantage as during lactation. During the nursery phase, increased death in one treatment group does not result in piglets within that group receiving additional resources due to treatment groups being comingled in nursery pens. However, there is a financial motivation not to input resources into animals that will not survive until slaughter. The difference in number of piglets that die during the first few weeks of nursery placement between treatments could also indicate that piglets from litters that are not cross fostered need to be managed differently. Examples of different management strategies could include weaning piglets later or providing more supplemental feed, such as milk replacer, at either the end of the lactation period or beginning of the nursery phase. The lack of overall effect of treatment in nursery phase resulted in the 2.23% increase in pre-weaning survival being seen at the end of the nursery phase as well (2.48%). While no studies have observed the combined survival from birth through nursery, most of the effect seen here can be attributed to differences in pre-weaning survival.

### ***Growth***

An increase in NBA has been associated with a decrease in mean piglet birth weight (English and Smith, 1975; Milligan et al., 2002b; Quiniou et al., 2002; Winfield et al., 1974; Wolf et al., 2008). This tendency for higher mean BW was not maintained throughout lactation, resulting in no difference between treatments for mean weaning weight. However, no difference was found in ADG from birth to weaning. This supports previous studies reporting no difference in growth from birth to 21 d (English and Bilkei, 2004; Milligan et al., 2001b) or from 3 -21 d

(Milligan et al., 2001a) between litters that were cross fostered and litters that were not cross fostered. However, in past studies, positive (Marcatti, 1986; Powell and Aberle, 1980; Rzasas et al., 2002) or negative (Fix et al., 2010; Grudniewska et al., 1986; Hermes et al., 2000; Milligan et al., 2001a; Stewart and Diekmann, 1989) effects of cross fostering on pre-weaning growth have also been reported.

### ***Weight Variation***

An increase in NBA has also been associated with an increase in variation of birth weights within a litter (Milligan et al., 2002b; Pettigrew et al., 1986; Quiniou et al., 2002; Wolf et al., 2008). However, no difference was found for within litter birth weight variation in this study. Decreasing variation of birth weights within litter has been reported to decrease variation in weaning weights (Milligan et al., 2001a), and cross fostering is believed to be an effective way to increase litter uniformity at birth (English, 1993; Wattanaphansak et al., 2002). This decrease in variation of BW at weaning is desirable from a management standpoint. When piglets are more uniform, less labor is needed at nursery placement to sort the piglets into pens according to size. However, in other studies it has been observed that after cross fostering, variation in BW was still present at the beginning of lactation (Milligan et al., 2002a). With no significant difference in variation of BW within litters at weaning, cross fostering piglets did not increase or decrease amount of variation within litters at weaning. The absence of treatment effect on variation of BW at weaning, mean weaning weight, and pre-weaning ADG leads to cross fostering having no impact on pre-weaning growth.

## **CONCLUSION**

Pre-weaning growth was not affected by cross fostering. Even though CFG had a tendency for higher mean birth weight; weaning weights, pre-weaning ADG, and BW variation within litter at birth and weaning were not different between treatments. Although there are confounded influences within treatment of NBA and mean litter birth weight, which are known to affect survival, there was a tendency for CFG to have higher pre-weaning survival and for this difference to be sustained through the nursery phase. Out of all of the pre-weaning mortalities per treatment group, a larger percentage of mortalities occurred within the first 3 d of life for CFG than NFG. This translates into less resources being exploited by piglets that are not going to survive until nursery placement. In the nursery phase higher mortality was seen in NFG during week 2. Overall, cross fostering did not have a detrimental effect on performance of piglets from birth through the nursery phase and tended to give an increase in survival during this time period.

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**Table 2.1.** Descriptive statistics and standard errors

Trait	CF <sup>b</sup>	NF <sup>c</sup>
Litters	215	196
Parity	3.7 ± 0.14	3.7 ± 0.14
NBA <sup>a</sup>	11.4 ± 0.27	12.0 ± 0.26
Stillborns	1.2 ± 0.10	1.4 ± 0.13
Mummified fetuses	0.5 ± 0.10	0.4 ± 0.06
Mean birth weight, kg	1.5 ± 0.02	1.5 ± 0.02
Variation in birth weight	0.09 ± 0.005	0.09 ± 0.004
Pigs fostered, % <sup>d</sup>	30.38	0
Litters affected, % <sup>d</sup>	70.05	0
Wean age, d	20.1 ± 0.05	20.0 ± 0.04

<sup>a</sup> NBA = Number born alive

<sup>b</sup> CF = Cross foster treatment

<sup>c</sup> NF = Non-cross foster treatment

<sup>d</sup> Determined at weaning

**Table 2.2.** Least squares survival percentages

Trait	CF <sup>b</sup>	NF <sup>c</sup>	P - value
Pre-weaning	76.6 ± 0.91	74.3 ± 0.98	0.08
Nursery	83.6 ± 0.92	84.2 ± 0.94	0.61
Overall <sup>a</sup>	65.3 ± 1.03	62.8 ± 1.08	0.08

<sup>a</sup> Overall = Birth through nursery exit

<sup>b</sup> CF = Cross foster treatment

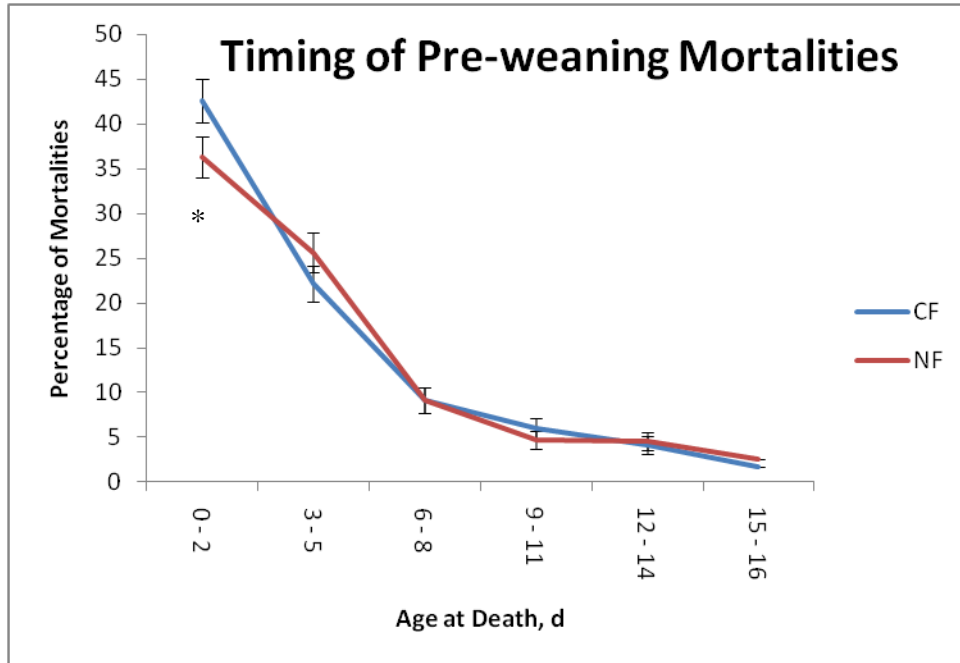
<sup>c</sup> NF = Non-cross foster treatment

**Table 2.3.** Least squares means and standard errors for growth traits

Trait	CF <sup>a</sup>	NF <sup>b</sup>	P - value
Number of pigs per litter			
At birth	11.1 ± 0.26	11.7 ± 0.28	0.14
At weaning	8.5 ± 0.22	8.7 ± 0.23	0.59
At nursery exit	7.3 ± 0.21	7.4 ± 0.22	0.74
Mean weight, kg			
At birth	1.50 ± 0.018	1.45 ± 0.019	0.07
At weaning	5.9 ± 0.06	5.9 ± 0.07	0.34
Weight variance within litter			
At birth	0.08 ± 0.005	0.08 ± 0.005	0.46
At weaning	1.2 ± 0.06	1.1 ± 0.06	0.42
Average daily gain, kg/ d			
Pre-weaning	0.21 ± 0.003	0.20 ± 0.003	0.21

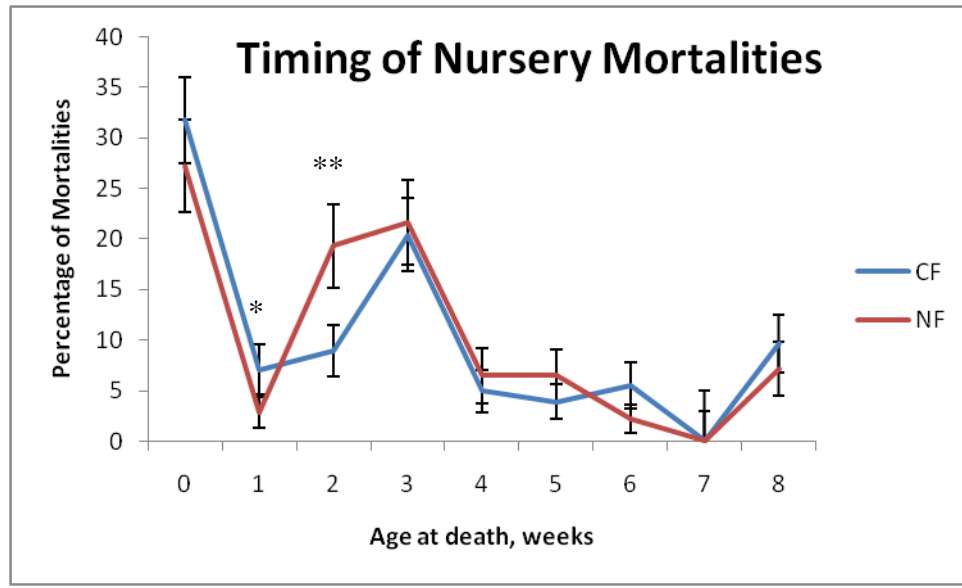
<sup>a</sup> CF = Cross foster treatment

<sup>b</sup> NF = Non-cross foster treatment



**Figure. 2.1.** Timing of pre-weaning mortalities, expressed as percentage of total pre-weaning deaths, per day

\*  $P < 0.05$



**Figure. 2.2.** Timing of nursery mortalities, expressed as percentage of total nursery deaths, per week

\* Tendency at  $P = 0.09$

\*\*  $P < 0.02$

## **CHAPTER 3**

### **EFFECT OF CROSS FOSTERING ON GROWTH AND SURVIVAL IN SWINE:**

#### **FINISHING**

**ABSTRACT:** Cross fostering is a common practice in swine production to balance number of pigs nursed per sow. The objective of this study was to evaluate cross fostering as a management tool by estimating its effect on growth and survival in a commercial finisher. During a 2 wk period, litters (n = 178) were farrowed from multiparous Large White x Landrace females mated to Duroc boars. Prior to farrowing, sows were randomly assigned to 1 of 2 treatments, cross fostered group (CFG) or non-cross fostered group (NFG). Within 24 h of birth, pigs were weighed and individually identified before cross fostering occurred. Piglets were weaned in 2 weekly groups; 2 d before weaning all pigs were weighed and nurse sow identification recorded. Nursery placement and exit inventories were recorded. Pigs were then moved to a finishing building where weight was recorded. Final live weight, back fat depth (BF), and loin eye area (LEA) were recorded 98 days later. Fat-free lean gain per day (FFL) was calculated from these measurements. Hot carcass weight (HCW) (litter n = 133) was obtained at slaughter. Mean ages and standard deviations for pigs were  $20 \pm 1.8$ ,  $74 \pm 1.9$ ,  $172 \pm 2.0$ , and  $197 \pm 16.2$  days of age at weaning, finisher placement, final live weight, and slaughter, respectively. To determine the effect of treatment on survival the Glimmix procedure of SAS was used with model including fixed effect of treatment and covariate of parity group. A model with fixed effect of treatment and covariate of parity group was fit using the Mixed procedure of SAS for growth and carcass traits. No difference was found for finishing survival between treatments. No difference was found between treatments for average BW at finisher placement or final live weight, variation of BW within litter at finisher placement, finisher ADG, average FFL, BF, HCW, or age at slaughter. Variation of BW within litter at final live weight was lower for CFG than NFG (CFG

=  $136.4 \pm 11.12$ , NFG =  $171.0 \pm 11.57$ ;  $P < 0.03$ ). There was a tendency ( $P = 0.10$ ) for CFG to have smaller average LEA (CFG =  $41.9 \pm 0.26 \text{ cm}^2$ , NFG =  $42.5 \pm 0.27 \text{ cm}^2$ ). There were minimal differences between treatments for growth and meat characteristics and no difference for survival during finishing. It was concluded that cross fostering was of little or no benefit to finishing performance.

**Keywords:** pigs, survival, cross fostering, growth

## INTRODUCTION

From 2000 to 2010, average NBA per litter in the United States increased by 1.37 pigs per litter (PigCHAMP, 2000, 2010). An increase in NBA has been associated with decreased mean piglet birth weight and increased variation of birth weight within litters (Quiniou et al., 2002). These traits have been linked to an increase in pre-weaning mortality (Bereskin et al., 1973; English and Bampton, 1982) and decreased pre-weaning growth (Milligan et al., 2002; Powell and Aberle, 1980). One management strategy to compensate for the effects of increased NBA is to cross foster piglets soon after birth. There is contradicting evidence as to the effects of cross fostering on pre-weaning (Grudniewska et al., 1986; Knol et al., 2002; Marcatti, 1986; Neal and Irvin, 1991) and nursery (Neal and Irvin, 1991; Powell and Aberle, 1980; Stewart and Diekman, 1989) performance. Very few studies have followed effects of cross fostering past the nursery phase. Those studies reported no effect of cross fostering on finishing survival (Stewart and Diekman, 1989) and contradicting effects on finisher growth and age at slaughter (Neal and Irvin, 1985; Powell and Aberle, 1980). Many cross foster studies were either conducted in other countries, where management practices and facilities differ from those in the United States, were

conducted more than 10 years ago, when NBA was much lower, or a combination of both. Also, the majority of cross foster studies only follow piglets through weaning, limiting results on extended effects of cross fostering. The objective of this study was to evaluate cross fostering as a management tool by estimating its effect on growth and survival in a commercial finisher.

## **MATERIALS AND METHODS**

### ***Animals***

Data were collected at a commercial swine farm in Eastern, North Carolina. Data were collected from sows which farrowed within a 2 week period. Females (n = 196) consisted of Large White x Landrace crosses and were mated to Duroc boars. The herd from which the data were collected was a PRRS positive herd that was not experiencing an active outbreak. Eighteen sows were removed from the data set due to not producing a live pig (n = 1), treatment applied incorrectly (n = 5), litters becoming comingled (n = 2), or a portion of the litter being weaned in a week not included in the study (n = 10).

Treatments applied include cross foster group (CFG) (n = 89) and non-cross foster group (NFG) (n = 89) (Table 3.1). In CFG, piglets were eligible to be cross fostered within 24 hours of birth. In NFG, cross fostering was not allowed. Farrowing facilities consisted of 4 farrowing houses, each divided into 2 rooms. Each room contained 3 rows of 16 crates per row. Sows were assigned randomly to treatment and then grouped by treatment into alternating rows of crates. Grouping of treatments into rows was done for ease of management and to minimize errors in treatment application by farm staff. In CFG, piglets were cross fostered among sows which farrowed within the same day, at the discretion of farm staff. Amount of cross fostering that

occurred each day varied based on average NBA and variation among sows for NBA each day (Table 3.1); however, cross fostering did occur in CFG each day of farrowing. If a litter in NFG had a piglet cross fostered into or out of that litter, the entire litter was excluded from the study. In the event that a sow in NFG became ill or died and her piglets were moved to a nurse sow, these piglets were excluded from the analysis.

### ***Farrowing***

Litter processing occurred within 24 hours of farrowing. Sow data recorded included: farrowing date, treatment group, parity, NBA, number still born, and number of mummified fetuses. All piglets were weighed and tagged with barcode tags prior to cross fostering (Table 3.1). Additional information recorded for piglets includes: sex, birth sow, date born, and treatment group. Piglets in NFG were also ear notched to aid in identification of treatment groups. Piglets had unlimited access to water through a low set water nipple. Weaning weight was taken two days prior to weaning (mean age: 18, standard deviation: 1.9). At this time, sow treatment was recorded and piglet data recorded included: sex, treatment group, wean sow, and weaning date. Number weaned (mean age: 20, standard deviation: 1.8) was obtained from farm records. Within CFG, cross foster status of piglets was determined by comparing birth sow and wean sow, with piglets having different birth and wean sows deemed cross fostered. If a piglet died prior to weaning, its cross foster status was unknown and assumed to be not cross fostered. In CFG, 29% of piglets that survived to weaning were cross fostered, effecting 65% of litters in this treatment group (Table 3.1). Throughout lactation, date of piglet mortality was recorded by farm staff. Pre-weaning survival was determined by placement at nursery and only pigs placed at nursery were included in weaning weights.

### ***Nursery***

After weaning, piglets were placed into nursery facilities. Two nursery placements were made, each consisting of piglets farrowed within a week's time period. Treatments were comingled at nursery placement. Piglets were inventoried and pen location recorded within 24 hours of placement. In each subsequent week of the nursery phase, pen counts were recorded. Piglets remained at nursery facilities for 56 days and were inventoried with pen locations recorded prior to leaving nursery facilities. Farm staff collected ear tags from mortalities, with week of mortality noted. Survival during the nursery phase was determined by finisher placement.

### ***Population Description***

Although these pigs are a subset of the data used in chapter 2, there were differences in performance of this subset during lactation and nursery phases. The tendency ( $P = 0.13$ ) for NBA to be larger for NFG continued through to finisher placement where NFG had significantly ( $P < 0.05$ ) more pigs per litter than CFG. However, survival from birth through finisher placement was not different between treatments. Average BW at birth differed between treatments ( $P < 0.05$ ) and tended to differ at weaning ( $P = 0.08$ ). Treatments did not differ in BW variance within litter at birth or weaning. Average BW at finisher placement and the variation of BW within litter at finisher placement did not differ between treatments. There was also no difference in ADG from birth through finisher placement (Table 3.2).

### ***Finisher***

From the nursery, pigs were transferred to finishing facilities and were comingled at placement. Data recorded for pigs (mean age: 74 d, standard deviation: 1.9) received at the

finisher include weight and pen location. Before the first graded load was removed from the barn, final data (mean age: 172 d, standard deviation: 2.0) were recorded. These final data included: weight, back fat depth (BF), and loin eye area (LEA). From finisher data, amount of acceptable, standardized, fat-free lean gain per day was calculated (Berg, 2000). Three graded loads were sent from the finisher to a commercial abattoir every 2 weeks. At the final week, all pigs that were not culls were sent to the same slaughter plant. Tags from mortalities were removed by farm staff with week of mortality noted. Survival during the finishing phase was determined by being present at final measurements. At slaughter (mean age: 197 d, standard deviation: 16.2), HCW was obtained. Only litters with at least 75% of pigs with recorded final weight and recorded HCW (n = 133) were used in HCW or age to slaughter analysis.

### ***Analysis***

Experimental unit for this study is litter, but data were recorded on individual piglets. Due to tendencies for NBA and number of pigs per litter at finisher placement to differ between treatments (Table 3.2), data were averaged for litter traits. Data were averaged over birth sow for farrowing and survival data and nurse sow for all other traits. Parities were assigned groups; with parity 1 in group 1, parities 2 through 5 in group 2, and parities 6 and greater in group 3. Weaning weights, finisher placement weights, final weights, and HCW were adjusted by sex to a set age prior to being averaged within litter.

Where:

Y = individual BW at weaning, finisher placement, final measurements, and slaughter

W = individual BW at birth, weaning, finisher placement, and birth

ADG = ADG during lactation, nursery, finisher, and birth to slaughter

X = 21 days of age, mean finisher placement age (74), mean final measurement age (172), and mean slaughter age (197)

Z = individual animal's age at weaning, finisher placement, final measurements, and slaughter

S = fixed effect of sex, barrow or gilt, for weaning, finisher placement, final measurements, and HCW

Average LEA and BF were adjusted by sex to 110 kg prior to being averaged within litter.

Where:

Y = LEA or BF

W = individual LEA or BF

Z = individual final live weight

$\beta$  = regression coefficient for fixed effects of BW at final measurement, pen location, wean week, and sex

Survival analysis was done with the GLIMMIX procedure of SAS. Fixed effects were treatment and a covariate of parity group. All other traits were analyzed with the MIXED procedure in SAS. Fixed effects were treatment and a covariate of parity group. Degrees of freedom for all analysis were adjusted with Kenward-Rodgers adjustment.

## RESULTS

Finisher survival did not differ between treatments. Combined survival, from birth to final measurements, also did not differ between treatments (Table 3.3). Half of the total mortalities from birth to final measurements can be accounted for by 50% of the sows (not shown). While survival was not significant, the number of pigs per litter at finisher placement and final measurements were different ( $P < 0.05$ ) between treatments (Table 3.4). This difference was attributed to the tendency for NBA to differ between treatments (Table 3.2). There was also no difference between treatments for finisher ADG. No difference was found in average BW at final measurements; however, NFG had a higher variation of BW within litter at final measurements ( $P < 0.05$ ) (Table 3.4). There was no difference between treatments for average FFL or BF, but NFG had a tendency ( $P = 0.11$ ) to have a larger LEA. Average age to slaughter did not differ between treatments, nor did HCW (Table 3.4).

## DISCUSSION

### *Pre-finishing*

Results for survival from birth through nursery exit support other studies which reported no difference in survival during lactation (Kirkwood et al., 1998; Stewart and Diekman, 1989) or nursery phases (Stewart and Diekman, 1989). However, these results disagree with other, more recent studies which report a trend that cross fostered piglets have higher pre-weaning survival (Arango et al., 2006; Cecchinato et al., 2007), and also disagreed with results from chapter 2.

An increase in NBA has been associated with a decrease in mean piglet birth weight (English and Smith, 1975; Milligan et al., 2002; Quiniou et al., 2002; Winfield et al., 1974).

Higher BW of CFG at birth was not maintained through lactation, as demonstrated by only a tendency for CFG to be heavier at weaning. This supports previous studies that have reported no difference in growth from birth to 21 d (English and Bilkei, 2004; Milligan et al., 2001b) or in weight at 42 d of age (Neal and Irvin, 1991) between litters that were cross fostered and litters that were not cross fostered. However, in past studies, positive (Marcatti, 1986; Rzasa et al., 2002) or negative (Fix et al., 2010; Hermesch et al., 2000; Milligan et al., 2001a) effects of cross fostering on pre-weaning growth have also been reported. Positive effects of cross fostering on age of piglets at 26 kg have also been reported (Powell and Aberle, 1980).

An increase in NBA has also been associated with an increase in variation of birth weights within a litter (Milligan et al., 2002; Quiniou et al., 2002; Wolf et al., 2008). However, no difference was found in within litter birth weight variation. Decreasing variation of beginning weights within a litter has been reported to decrease variation in weaning weights (1977; Milligan et al., 2001a), and cross fostering is believed to be an effective way to increase litter uniformity at birth (English, 1993; Wattanaphansak et al., 2002). This decrease in variation of BW at weaning is desirable from a management standpoint. When piglets are more uniform, less labor is needed at nursery placement to sort the piglets into pens according to size. With no significant difference in variation of BW within litters at weaning, cross fostering piglets did not decrease amount of variation within litters at weaning.

The lack of differences between treatments for survival and average daily gain from birth through nursery put piglets from both treatment groups at the same starting point for these traits when they entered the finisher. While average BW at weaning tended to be higher for the CFG, when finisher placement weight was recorded, no difference was found between treatments.

Variation of BW within litter at finisher placement was also not different between treatments, supporting the evidence of no difference between treatments for traits recorded at finisher placement.

### ***Finisher***

Separately, there was no difference in survival from birth through finisher placement or during the finishing phase. Therefore, it was expected that there would be no difference in survival from birth to final measurements. Stewart and Diekman (1989) also reported no difference in finishing survival when comparing cross fostered piglets and piglets that were original residents of cross fostered litters. Even though survival was not different between treatments, number of pigs per litter at finisher placement and final measurements were higher for NFG. This is most likely due to the tendency for NBA to be higher for NFG and for that difference to be maintained throughout the study. No effect of cross fostering on finisher ADG supports findings by Powell and Aberle (1980) who reported no difference in daily gain from 26 to 96 kg between runt piglets that were cross fostered and runt piglets that were not cross fostered. No effect of cross fostering on final weights contradicts earlier findings by Neal and Irvin (1985) who reported that resident piglets were heavier at final weights than cross fostered piglets. The difference in variation of BW within litter at final measurements has not been previously reported, but could be beneficial if an all-in, all-out system is utilized at a finishing facility. If pigs are less uniform when arriving at the packing plant, this increases the chance of growers being discounted for animal weights that are too large or too small. A finishing facility that is sending pigs to the packing plant in graded loads would not benefit as much from a decrease in variation of weights at final measurements. This is due to lighter pigs having additional time until slaughter in this

system. An increase in LEA for non-cross foster pigs was also found by Powell and Aberle (1980); however, they were comparing runt piglets that were cross fostered or not cross fostered. They also found that non-cross fostered pigs had a decrease in BF which resulted in an overall increase in the amount of separable lean for the non-cross fostered run piglets. This disagrees with current findings of no difference in BF or FFL between treatments. There are contradicting results as to the effect of cross fostering on days to reach slaughter. Stewart and Diekman (1989) reported that cross fostered pigs achieved a market weight of 105 kg 4 days later than pigs that were not cross fostered. However, Powell and Aberle (1980) reported that cross fostered runts were younger at 96 kg than their non-cross fostered run counterparts. Both of these studies disagree with current results of cross fostering not affecting age at slaughter, which would have been intensified by graded loads going to the slaughter plant every 2 weeks. Reports of effects of cross fostering on HCW have not been previously reported; however this trait is as important as live weight at final measurements due to HCW being a better estimate of amount of final product available.

## **CONCLUSION**

Finisher survival and survival from birth through final measurements were not affected by cross fostering. Even though CFG had higher average birth weight; finisher placement weights, final live weights, finisher ADG, and HCW were not different between treatments. Variation of BW within litter at final measurements was lower for CFG which could be beneficial for producers utilizing all-in, all-out management of finishing facilities. The only difference in lean growth measurements was a tendency for NFG to have larger LEA. At slaughter, no difference for age at

slaughter or HCW was found between treatments. In summary, cross fostering only resulted in minimal differences for growth and meat characteristics. It was concluded that cross fostering was of little to no benefit to finishing performance.

### **ACKNOWLEDGEMENTS**

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**Table 3.1.** Descriptive statistics and standard errors

Trait	CF <sup>b</sup>	NF <sup>c</sup>
Litters	89	89
Parity	3.8 ± 0.23	3.5 ± 0.21
NBA <sup>a</sup>	10.8 ± 0.42	11.8 ± 0.37
Stillborns	1.2 ± 0.16	1.2 ± 0.18
Mummified fetuses	0.4 ± 0.17	0.3 ± 0.07
Pigs fostered, % <sup>d</sup>	29.4	0
Litters affected, % <sup>d</sup>	65.6	0

<sup>a</sup> NBA = Number born alive

<sup>b</sup> CF = Cross foster treatment

<sup>c</sup> NF = Non-cross foster treatment

<sup>d</sup> Determined at weaning

**Table 3.2.** Pre-Finishing performance

Trait	CF <sup>a</sup>	NF <sup>b</sup>	P- value
Number of pigs per litter			
At birth	10.6 ± 0.40	11.4 ± 0.41	0.13
At weaning	8.4 ± 0.31	8.8 ± 0.32	0.30
At finisher placement	7.1 ± 0.29	8.0 ± 0.30	0.03
Average weight, kg			
At birth	1.5 ± 0.03	1.4 ± 0.03	0.02
At weaning	6.0 ± 0.10	5.7 ± 0.10	0.08
At finisher placement	22.4 ± 0.31	22.3 ± 0.32	0.92
Weight variance within litter			
At birth	0.08 ± 0.008	0.08 ± 0.008	0.74
At weaning	1.1 ± 0.08	1.1 ± 0.09	0.90
At finisher placement	13.4 ± 0.93	14.5 ± 0.96	0.39
Birth through finisher placement			
Average daily gain, kg/ d	0.28 ± 0.004	0.28 ± 0.004	0.98
Survival, %	67.3 ± 1.58	69.8 ± 1.52	0.23

<sup>a</sup> CF = Cross foster treatment

<sup>b</sup> NF = Non cross foster treatment

**Table 3.3.** Least squares survival percentages

Trait	CF <sup>a</sup>	NF <sup>b</sup>	P- value
Finisher	92.7 ± 1.07	92.8 ± 1.02	0.95
Overall <sup>c</sup>	62.4 ± 1.63	64.8 ± 1.59	0.27

<sup>a</sup> CF = Cross foster treatment

<sup>b</sup> NF = Non-cross foster treatment

<sup>c</sup> Overall = birth through final live weight

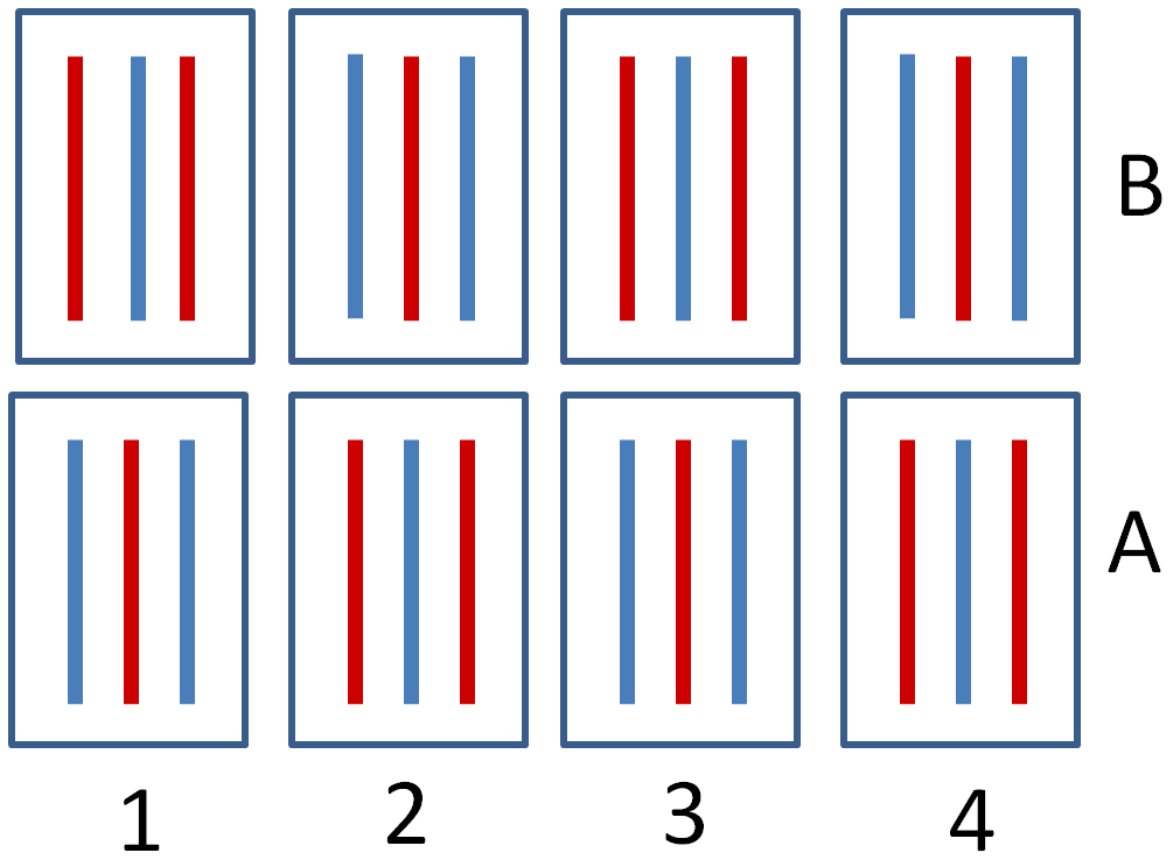
**Table 3.4.** Least squares means and standard errors for traits

Trait	CF <sup>a</sup>	NF <sup>b</sup>	P - value
At final live weight			
Number of pigs per litter	6.6 ± 0.29	7.4 ± 0.30	0.05
Average weight, kg	101.3 ± 1.02	99.7 ± 1.05	0.27
Weight variance within litter	136.4 ± 11.12	171.0 ± 11.57	0.03
Ultrasound measurements			
Fat free lean gain, kg/d	0.34 ± 0.003	0.34 ± 0.003	0.45
Back fat, cm	1.8 ± 0.02	1.8 ± 0.02	0.56
Loin eye area, cm <sup>2</sup>	41.9 ± 0.26	42.4 ± 0.27	0.11
Finisher			
Average daily gain, kg/d	0.84 ± 0.009	0.83 ± 0.009	0.2
Slaughter			
Age, d	201.6 ± 1.95	203.8 ± 2.01	0.42
Hot carcass weight	88.3 ± 0.85	87.8 ± 0.87	0.73

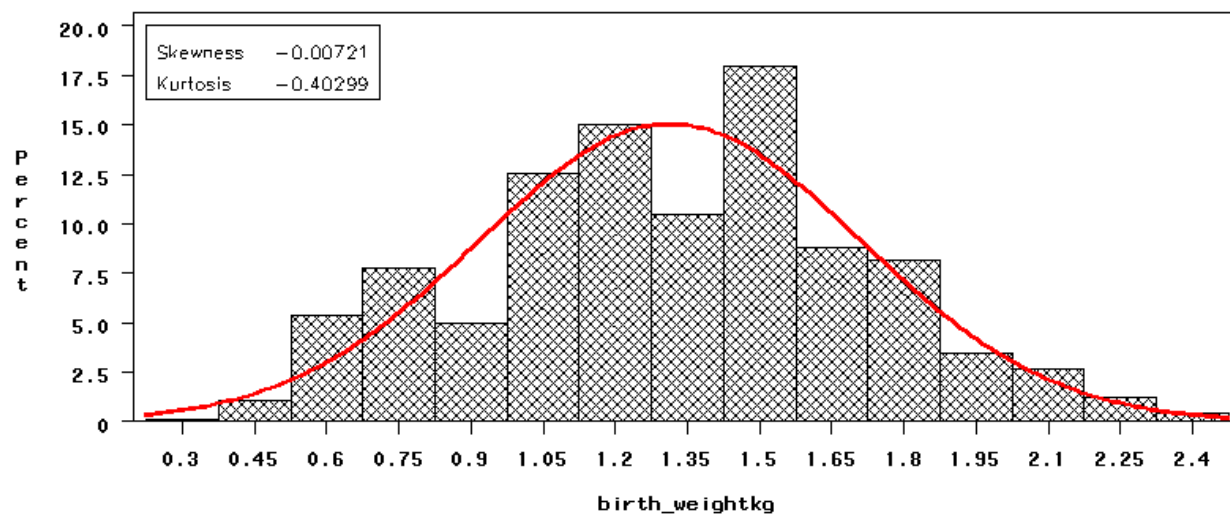
<sup>a</sup> CF = Cross foster treatment

<sup>b</sup> NF = Non-cross foster treatment

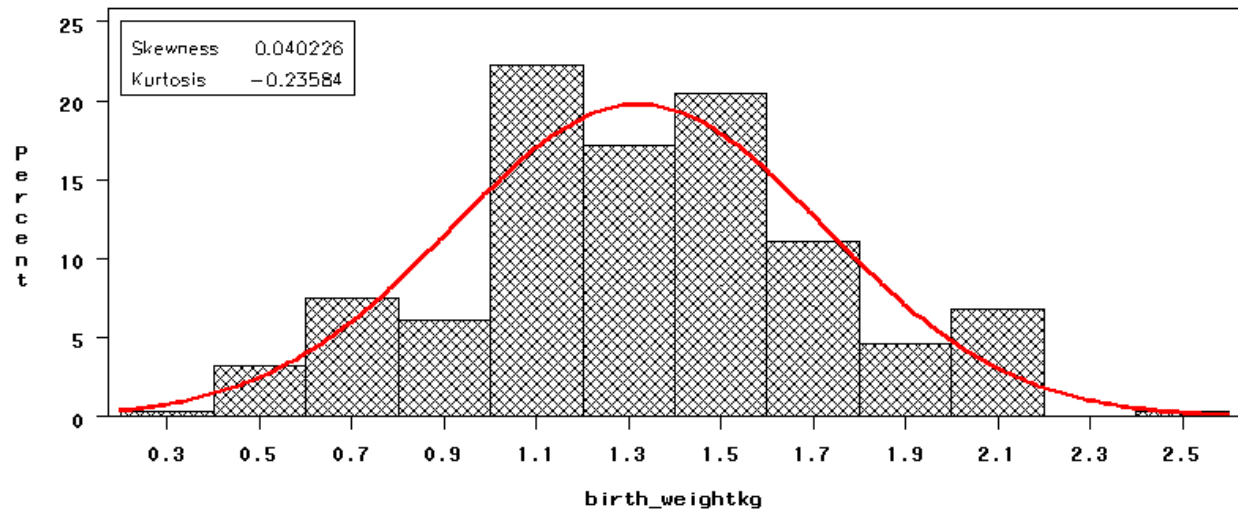
## APPENDIX



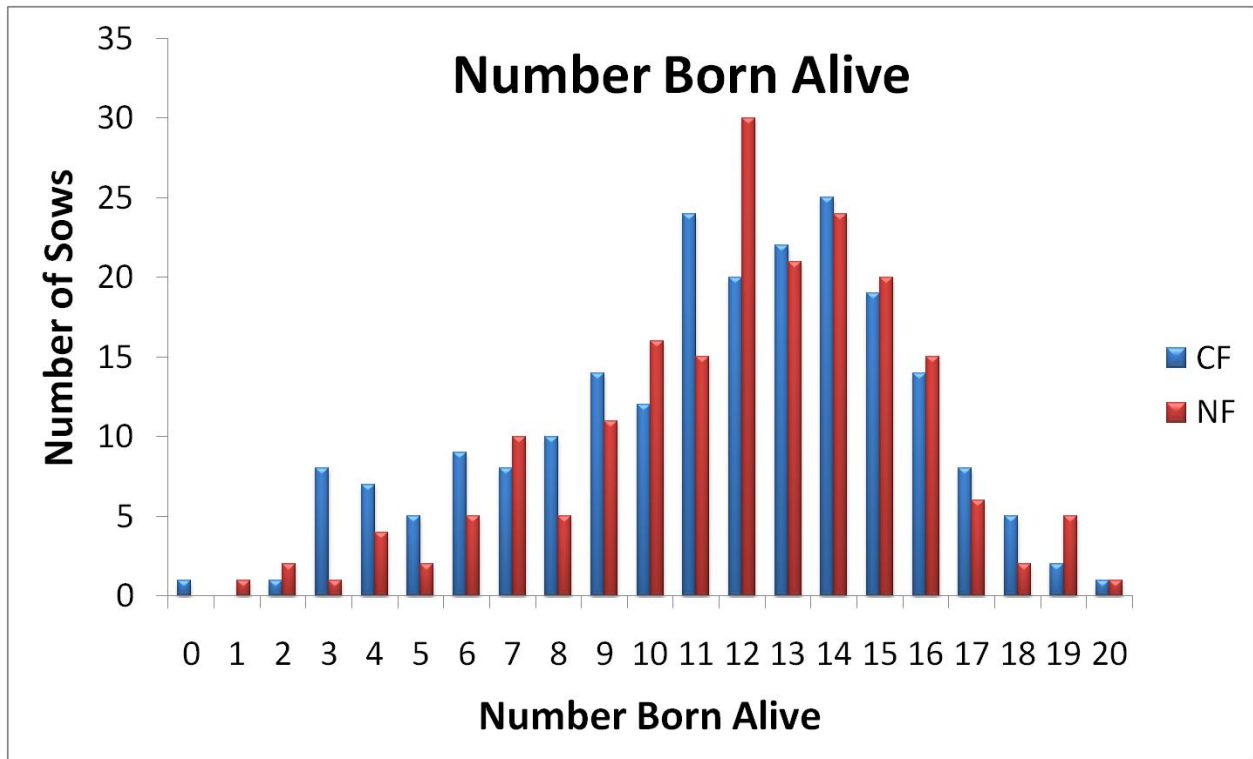
**Figure A.1.** Treatments applied to alternating rows within rooms (A and B), between rooms and among buildings (1-4). Each room contained three rows of 16 crates per row.



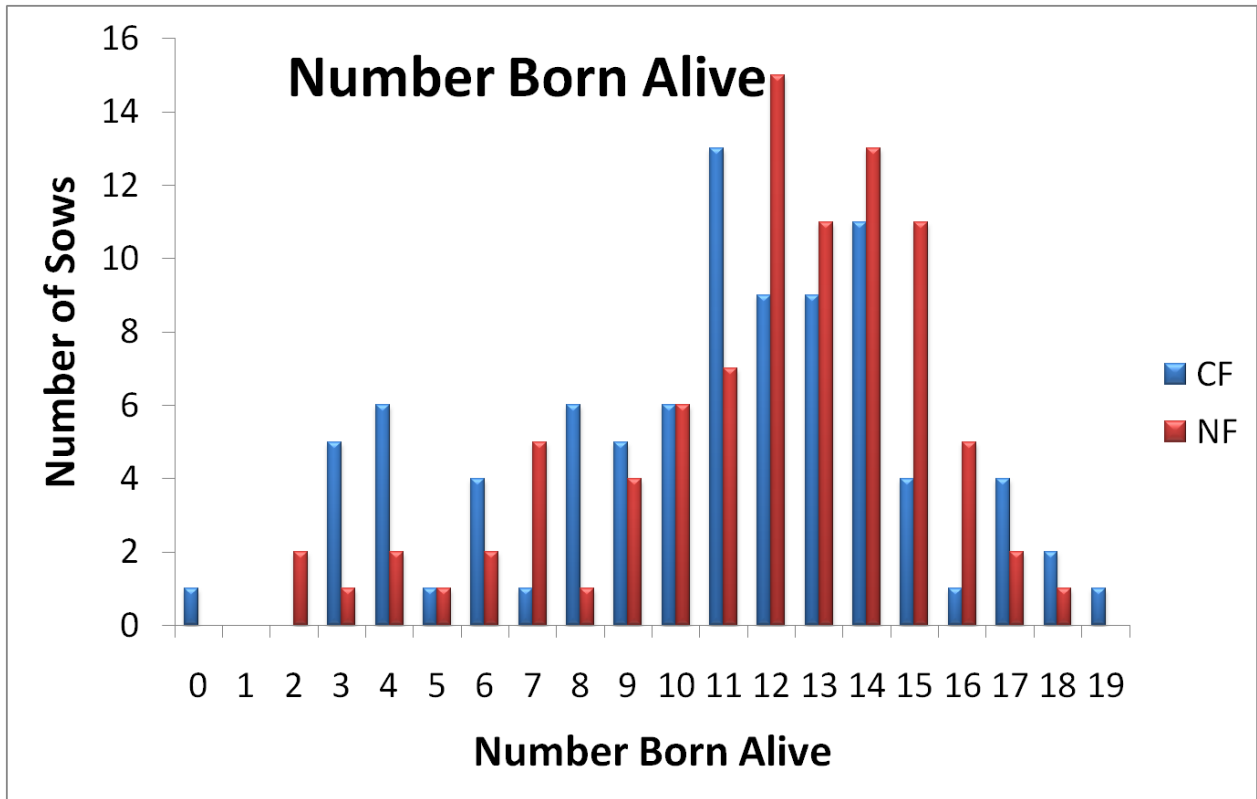
**Figure A.2.** Distribution of birth weights for piglets identified as cross fostered at weaning; Chapter 2.



**Figure A.3.** Distribution of birth weights for piglets identified as cross fostered at weaning; Chapter 3.



**Figure A.4.** Distribution of number born alive across treatments; Chapter 2.



**Figure A.5.** Distribution of number born alive across treatments; Chapter 3.