Effect of lactation length on ovulation rate and embryo survival in swine

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Summary

Objective: *To evaluate the impact of early weaning on ovulation rate and embryo survival in sows.*

Methods: *A 900-sow commercial breeding herd was depopulated. During depopulation, sows were either early weaned (EW; 8-12 day lactation length) or conventionally weaned (CW; 18-21 day lactation length). Data from 72 early-weaned and 52 conventionally weaned sows were analyzed. Sows were mated during their first postweaning estrus. Sows were subsequently slaughtered at 33-51 days of pregnancy and reproductive tracts were collected. Ovarian, uterine, and embryo measurements were made.*

Results: *Ovulation rate in EW sows was not significantly different (20.3) from that of CW sows (20.7) (*$P = .646$*). Early-weaned sows had a significant decrease in embryo survival compared with CW sows (53% versus 67%;* $P < .001$*), and thus had significantly fewer live embryos compared with CW sows (10.4 versus 13.0;* $P < .001$*). Live embryo weights (average individual embryo weight) in EW sows were also significantly decreased compared with CW sows (7.88 g versus 9.52 g;* $P = .006$*). Weaning-to-first-service interval was significantly increased in the EW group (7.0 days versus 5.2 days;* $P < .001$*). Conception rate was also significantly decreased in EW sows (68%) compared with CW sows (87%) (*$P < .001$*).*

Implications: *In our study, embryo survival was a more important factor than ovulation rate in the decreased live embryo numbers found in pregnancies of EW sows (mean lactation length of 9.7 days). Further research is needed to explore management opportunities that might improve embryonic survival in early-weaned sows and to investigate the apparently decreased embryo weight in early-weaned sows.*

Keywords: *swine, reproduction, early weaning, ovulation rate, embryo survival*

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The primary goal of early weaning is to improve the health status of the weaned pig relative to the breeding herd.[1] As early weaning has become more widespread in the swine industry, many studies have been conducted to determine the efficacy of this strategy in disease control or growth performance improvement.[2-9] However, there have been relatively few studies to assess the impact of early weaning on reproductive parameters. Recently, a retrospective study of reproductive indices that involved 13 herds evaluated the effects of lactation length on weaning-to-first-service interval, first-service farrowing rate, and subsequent litter size.[10] The study found that:

- a lactation length of <14 days was associated with subsequent weaning-to-service intervals of >7 days;
- a lactation length of <12-14 days was associated with decreased first-service farrowing rates; and
- subsequent liveborn litter size decreased by 0.40 pigs per litter when the lactation length was reduced from 20 days to 10 days.

Litter size in swine is determined by ovulation rate, embryo survival, and uterine capacity.[11-20] Previous lactation length studies have indicated that embryo survival is a more important factor than ovulation rate in decreasing the number of viable embryos in early-weaned sows.[16,17] The greatest porcine embryo loss occurs before gestation day 20.[11-20] Our prospective study was designed to investigate the reported reduction in liveborn pigs in early-weaned sows,[10] by measuring ovulation rate, embryo survival, and uterine capacity (Figure 1).

Materials and methods

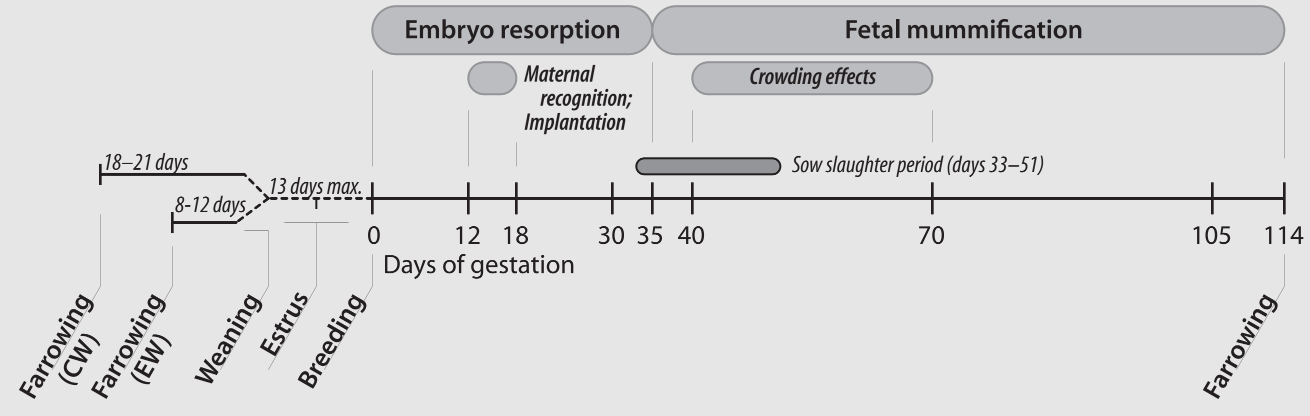
Trial schedule

The trial schedule was chosen to minimize seasonal influences on sow reproductive parameters.[21,22]

Sows

The trial was conducted in a commercial sow herd that was undergoing a complete breeding herd depopulation due to respiratory disease. The parity distribution of the trial sows was not a typical parity distribution for a commercial herd (Table 1).[23] This farm was serologically and clinically negative for porcine respiratory and reproductive syndrome virus (PRRSV) before and during the study. No evidence of other clinical reproductive diseases was noted during the study.[24] All sows selected for the trial had been on the farm site during their previous gestation period. The farm's farrowing barns, breeding barn, and gestation barns were on one site.

Figure 1



Study timeline. Note that all sows in this study were slaughtered during days 33-51.

Table 1

Parity distribution of sows

	Parity									
	1	2	3	4	5	6	7	8	9	Total
EW	11	21	11	12	7	4	2	2	2	72
CW	8	11	10	8	7	3	4	1	0	52
Total	*19*	*32*	*21*	*20*	*14*	*7*	*6*	*3*	*2*	*124*

Sows were randomly assigned by parity to either an early weaning (EW) treatment (weaning at 8-12 days) or a conventional weaning (CW) treatment (weaning at 18-21 days) so that both treatment groups contained sows of all parities (Table 1). One hundred and sixty-three sows were bred, and 124 were pregnant at slaughter. By design there were more animals in the EW group due to concerns of increased reproductive failure in this group.[10] Treatment group sample size was based on the assumption that there would be one less live embryo per litter in the EW group, and on the coefficient of variation in previous ovulation and embryo survival studies.

All animals were induced to farrow with a prostaglandin injection (Figure 1). Sows received no other medication or hormonal therapy during the trial period. Cross-suckling of pigs was allowed within treatment groups.

During lactation, sows were fed according to the farm's normal sow feeding program. Daily lactation feed intake was recorded on all sows. Sows were weighed the day after farrowing and at weaning. Sow production data were collected by farm personnel.

Sow production data (analyzed retrospectively) included:

- sow postfarrowing weight,
- liveborn number, and
- stillborn number.

Sow production data (analyzed prospectively) included:

- lactation length,
- sow weaning weight,
- sow weight gain and average daily gain from postfarrowing to weaning,
- number of weaned pigs,
- litter weaning weight,
- mean daily feed offered,
- total feed offered, and
- sow slaughter weight.

Breeding

Sows were allowed ad libitum access to feed after weaning until breeding. After weaning, the sows were group housed in pens inside the farm's environmentally controlled breeding barn.

Boars were housed in crates and interacted with sows twice daily until estrus was detected (up to 14 days postweaning). Those sows not exhibiting estrus by 14 days postweaning were removed from the trial. All breeding data were collected by farm personnel.

A mature boar pool was used for breeding. To ensure the best breeding results, all sows were handmated at the first sign of standing estrus.[25] Boars were allowed to rest after five consecutive daily matings. Sows were bred every 12 hours either naturally or by AI (based on boar availability) after the first handmating until the sows no longer exhibited estrus.[26,27]

To remove boar influence on embryo survivability, pooled semen from the six boars in the on-farm boar pool was used in all AI matings. Five billion pooled sperm per dose were used in each AI mating. Individual boar and pooled semen source were equalized across treatment groups. Sows that did not conceive or that returned to estrus were removed from the trial to prevent any second estrus effect on ovulation rate and embryo survival.[28]

The following breeding parameters were calculated and analyzed:

- mean weaning-to-first-service interval, and
- percentage of sows with weaning-to-first-service interval ≤ 7 days versus 8-13 days.

Sows were moved to another environmentally controlled gestation barn soon after breeding. Ten sows were grouped per 14' × 8' (4.3m × 2.4 m) pen across treatments, by breeding date and body condition score at breeding. During gestation, all sows were hand fed to body condition.

Reproduction

Conception rate

Conception rate was measured by ultrasound examination on the farm at day 25-30 postbreeding. Pregnancy was validated at slaughter.

Slaughter

Sows determined to be pregnant were shipped to slaughter in groups of 15-20, depending upon their day of gestation (Table 2).

The sows were weighed and slaughter procedures completed at the University of Illinois Meats Laboratory, Champaign-Urbana, Illinois. We collected reproductive organs at slaughter. The reproductive tracts with ovaries intact were examined and tagged with the sow identification number. Ovaries were separated from the uterus, tagged, and placed into a plastic bag filled with physiological saline. Ovaries were kept in saline solution and placed on ice for approximately 24 hours. The uteri were placed in separate plastic bags and allowed to stand at room temperature for approximately 6 hours until uterine muscle contractions ceased, then were frozen for 12 hours. The following day, uteri and ovaries were transported to Elanco Animal Health Research and Development, Greenfield, Indiana. Uteri were stored frozen until measurements were taken.

Ovulation rate

Ovulation rate was determined by counting corpora lutea in ovaries approximately 24 hours after animal slaughter. Ovaries were individually placed on a paper towel to remove any excess saline solution, rolled over twice, and weighed. Ovulation rate was determined by first counting the external corpora lutea, then slicing each ovary to identify presence of any buried corpora lutea. Number of corpora lutea on both the left and right ovaries was recorded.

Uterine data

Uterine length was measured by methods previously described.[29] Each uterus was also weighed. Both uterine horns and the uterine body were cut open longitudinally. Embryos were exposed by rupturing the chorion allantois, but leaving the amnion intact with the embryo. Embryo uterine positions were measured. After embryo data were collected, the embryos and placenta were removed from the uterus. Remaining uterine liquids were removed from the uterus. The empty uterus was weighed.

Embryo data

Embryos in both uterine horns were then identified, so that, e.g., in the left horn the first embryo closest to the left uterotubal junction was designated as embryo L1, followed by L2, L3, etc., down to the uterine body (Figure 2). Live embryos were judged to be those that were opaque with a bright red liver and heart. Dead embryos were judged to be those that were pink to deep red, with a depleted blood supply surrounding the embryo, and a dull red or white liver. Dead embryos frequently showed signs of necrosis, such as brown placenta.

Embryo uterine position was then determined by placing a meter stick against the opened uterus and recording the measurement of each embryo. Each embryo was measured from the uterotubal junction to the umbilical cord (uterotubal junction = 0 cm). Embryos were removed from the amnion and each placed in a designated petri dish and covered with a lid. Embryos were weighed after being placed on a paper towel and rolled over once.

The following parameters were measured and/or calculated:

- embryo weight,
- average live embryo weight per uterine horn per sow,
- embryo spacing per uterine horn per sow,
- total number of embryos per sow,
- number of live embryos per sow,
- percentage of live embryos,
- number of mummified embryos per total number of embryos per sow,
- number of live embryos per number of total embryos, and
- number of live embryos divided by corpora lutea.

Statistical analysis

Mixed-model analysis methods based on restricted maximum likelihood estimation were used to analyze live embryo weight and embryo spacing. The between-subject fixed classificatory factors included treatment group, parity group, and treatment × parity group. Parity groups were used in the statistical model instead of individual parities to eliminate factor and balance and spareness of individual parity. Days of gestation was considered a continuous regression variable, and was entered into the model as linear, quadratic, and treatment group by linear and quadratic interaction terms. The within-subject fixed factors included the side of the uterus and the treatment × side interaction. Sow was included as a random factor. The Satterthwaite approximation was used to calculate the denominator degrees of freedom for the evaluation of P values.

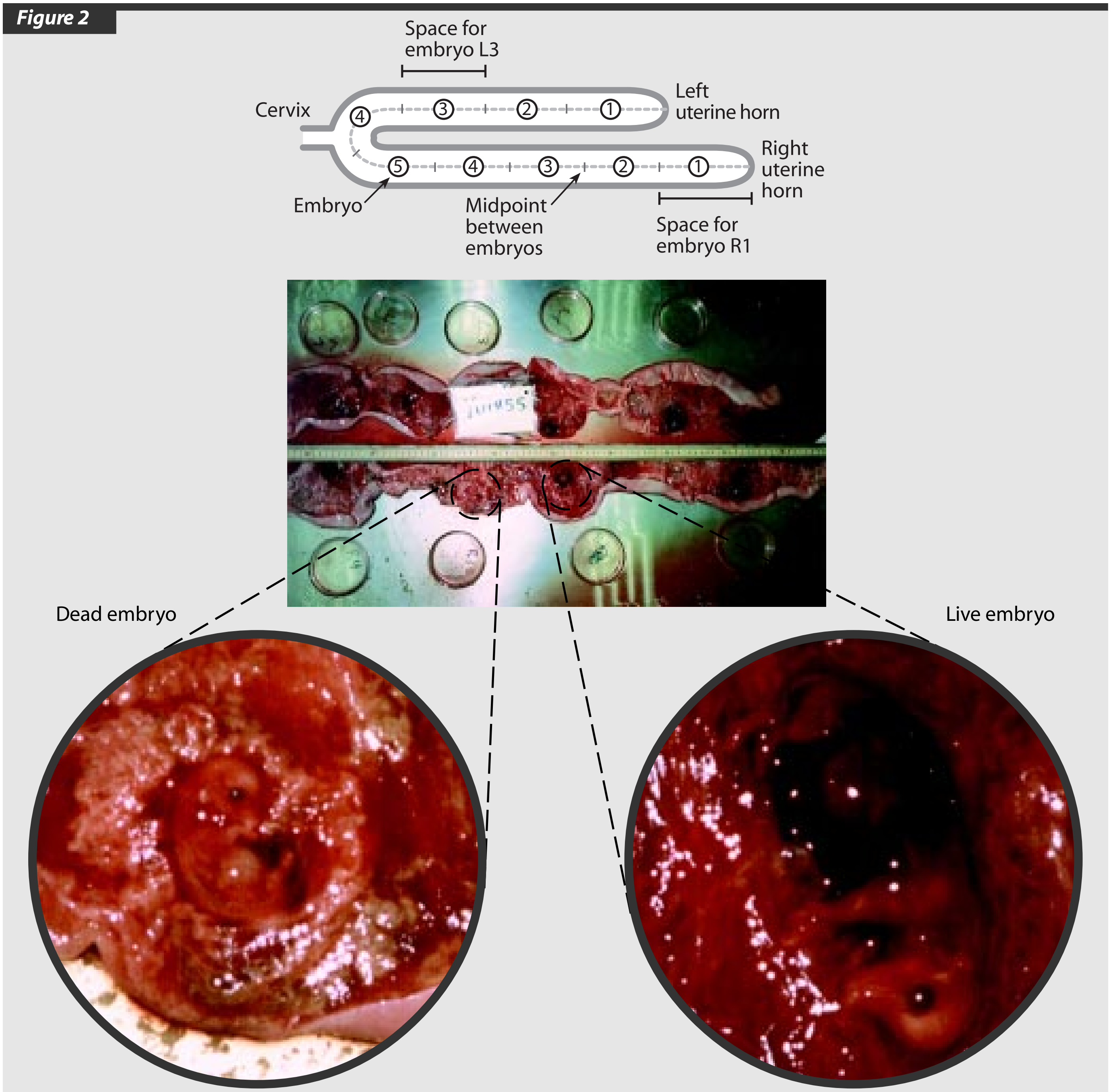
A χ^2 analysis was used to test for an association between frequency of mating and treatment group. Association between treatment group and type of mating (i.e., at least one AI mating versus all natural mating) was also

Table 2

Sampling of days of gestation at which sows were sent to slaughter

	Gestation length (days)													
	33	34	35	36	37	38	39	40	41	42	43	44	51	Total
EW	2	1	1	12	14	11	5	5	9	2	6	2	2	72
CW	0	0	0	4	21	12	2	4	3	5	0	1	0	52
Total	*2*	*1*	*1*	*16*	*35*	*23*	*7*	*9*	*12*	*7*	*6*	*3*	*2*	*124*

Figure 2



Uterine and embryo measurement and analysis

analyzed using a χ^2 analysis.

Quantitative results for other lactation, breeding, and reproduction parameters determined once per sow were analyzed using ANOVA which included treatment group, parity group, and treatment × parity group as sources of variation.

Logistic regression was used to assess the effects of early weaning on the conception rates at day 25 and at necropsy, embryo survival (as a percent of total embryos), and on the percent of sows with a weaning-to-first-service interval < 7 days (as a percent of all sows). All models included treatment group, parity group, and treatment × parity group as sources of variation. Additionally, the model for the analysis of embryo survival included a coefficient for the linear regression on days to gestation. Weaning-to-first-service interval was also used as a covariant in the model when analyzing percent embryo survival. This model also included an overdispersion estimate to account for animal-to-animal variation.

All references to statistical significance refer to P values $\leq .05$.

Results

Sow performance

Previous litter and lactation

During the study lactation period, the liveborn and stillborn pig numbers did not significantly differ between the EW and CW treatment groups (liveborn: 10.5 EW versus 11.0 CW, $P > .1$; stillborn: EW 0.71 versus 0.67 CW, $P > .1$). The lactation period lasted for a mean of 9.7 days for the EW sows and 19.6 days for CW sows. Sows in the EW group weaned a mean of 9.2 pigs and CW sows weaned a mean of 8.9 pigs ($P > .1$). Mean litter weights at weaning for EW sows were significantly lower at 35.9 kg (79.0 lb) than those for CW litters at 43.1 kg (94.8 lb) ($P = .002$).

Sow weight

Postfarrowing weight, weaning weight, and weight gain of sows during the lactation period did not differ significantly between treatment groups ($P > .1$). Mean lactational weight gain was 0.64 kg (1.42 lb) for EW sows and 2.6 kg (5.8 lb) for CW sows ($P > .1$). Weight at slaughter did not differ significantly between sows of the EW and those of the CW treatment groups ($P > .1$).

Lactation feed offered

Mean daily feed offered was significantly lower for EW sows (4.54 kg, 9.9 lb) compared with CW sows (5.83 kg, 12.82 lb)($P < .001$) (Figure 3). Total feed offered was significantly lower for EW sows (45.7 kg, 100.5 lb) than for CW sows (112.3 kg, 247.1 lb) ($P < .001$).

Breeding

There was no significant difference between AI versus natural mating and treatment group ($P > .1$). Weaning-to-first-service interval was extended in EW sows (7 days) compared with CW sows (5.2 days) ($P < .001$). Significantly fewer EW sows (68%) had weaning-to-first-service intervals of ≤ 7 days compared with CW sows (94%) ($P < .001$).

Reproduction

Conception rate

Conception rate determined at slaughter was significantly decreased in EW sows (68%) compared with CW sows (87%) ($P \leq .001$) (Figure 4).

Ovulation rate

Ovulation rates were not significantly different (EW = 20.3 and CW = 20.7) between treatments ($P = .65$) (Figure 4).

Uterine measures

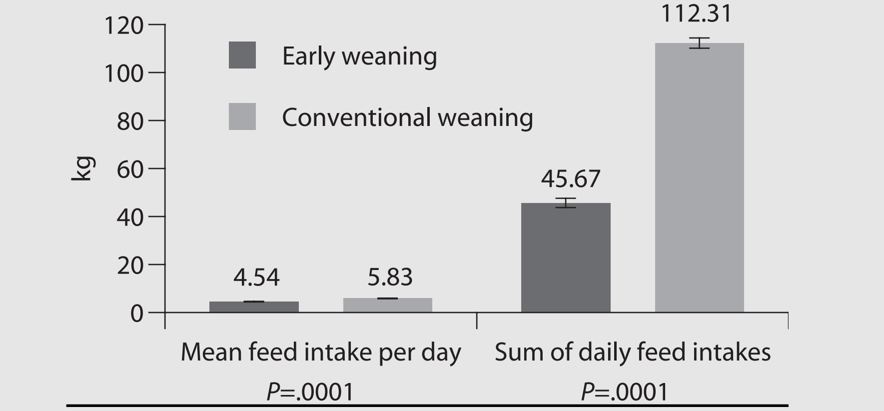
Uterine length tended to be decreased in the EW sows (325 cm, 128 inches) compared with CW sows (344 cm, 135 inches) ($P = .059$); however, the live embryos in the EW sows' uteri had significantly increased uterine space (34.7 cm [13.7 inches] per embryo) compared with embryos in the CW sows' uteri (28.8 cm [11.3 inches] per embryo) ($P = .02$) (Figure 5).

Embryo data

EW sows had decreased embryo survival compared with CW sows (EW = 53% and CW = 67%) ($P < .001$) (Figure 5). EW reduced the number of live embryos (2.56 embryos per litter) in early gestation when compared with CW ($P < .001$; Figure 5). There was no difference between treatments ($P = .93$) in percentage of live embryos in utero at gestation day 51.

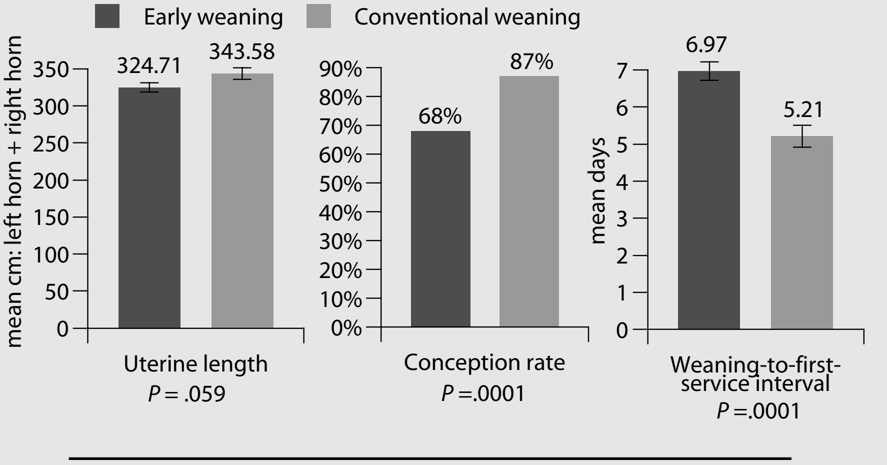
The mean individual live embryo weight was significantly less for sows in the EW group (7.88 g [0.28 oz]) compared with those in the CW group (9.52 g [0.34 oz]) ($P = .006$). Mean gestation lengths in this study were the same ($P = .46$).

Figure 3



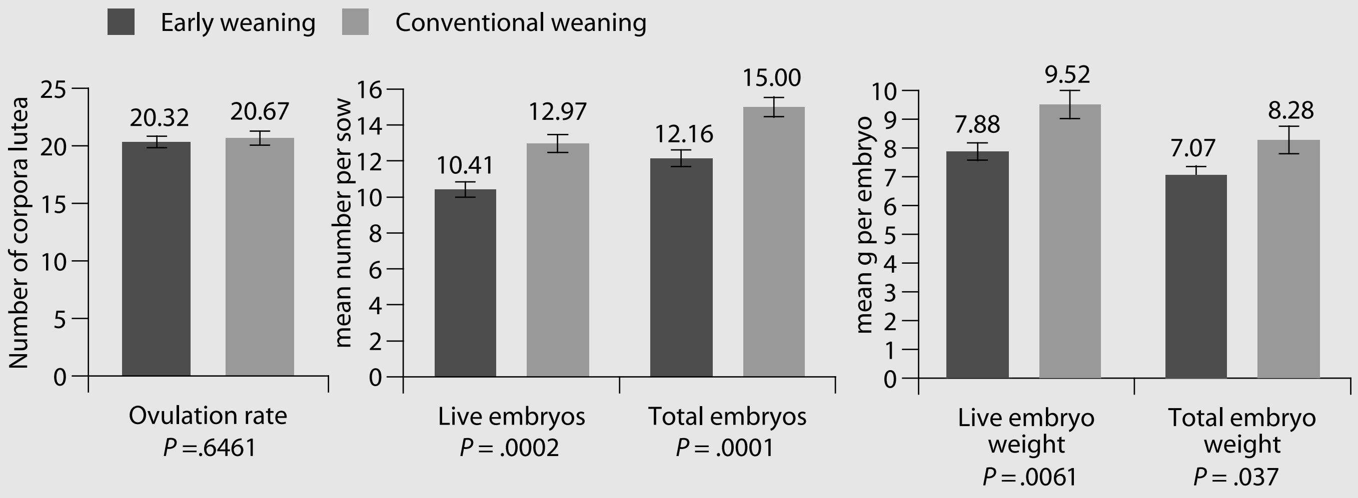
Comparison of feed intake

Figure 4



Comparison of breeding parameters

Figure 5



Comparison of ovulation rate and embryo data

Discussion

Sow performance

Previous litters and lactation

Given that previous litter sizes did not differ significantly between treatment groups, it is unlikely that previous litter performance had an effect on differences between the treatment groups. Differences in litter weaning weight could be attributed to the effect of lactation length, because litter size at weaning was similar.

Sow weight

The numerical difference in mean sow weight gain could be attributed to the lactation length differences. Management of lactation sow feeding was excellent,[30,31] and allowed both treatment groups to gain weight during lactation. With similar mean animal weight gain between treatment groups, one would not expect the animal weight changes during lactation to have any effect on the reproductive parameters measured.

Sow lactation feed offered

The feeding management of sows during this study prevented mean weight loss from occurring in either treatment group during lactation. Therefore, lactation feeding effect should have had little impact on our findings.

Sows were housed in pens in the breeding and gestation areas, and therefore we were unable to collect daily gestating sow feed intake data. However, because slaughter weight did not differ significantly between treatments, it is unlikely that gestational feed intake had an influence on the reproductive parameters measured in this study. Future study designs should accurately measure individual sow postweaning feed intake to determine its effect on embryo survival in early-weaned sows.[31]

Breeding

The weaning-to-first-service interval data agree with previous studies that as lactation length decreases below 14 days, weaning-to-first-service interval will increase.[10,12]

An interaction between weaning-to-first-service interval and embryo survival was not found in this data set. However this study was not designed to investigate the effect of weaning-to-first-service interval on embryo survival. One would need to block animals by weaning-to-first-service interval to appropriately test this interaction.

Reproduction

Conception rate

We assumed the accuracy of the ultrasound pregnancy examination was the same across treatment groups. Early weaning reduced the conception rate in our study, which is consistent with findings reported in previous literature.[10]

Ovulation rate

Our findings agree with previous studies, which found that early weaning had no effect on subsequent ovulation rates in sows.[12,13]

Uterine data

Decreased uterine length due to lactation length less than 21 days has been reported previously.[13] This study found a trend for decreased uterine length for early-weaned sows. Increased numbers of animals per treatment group would be needed to validate this finding. It was beyond the scope of this study to determine whether the decreased uterine length was due to the decreased lactation length, decreased number of embryos at maternal recognition time, or other factors.[11,15] Further studies prior to breeding, or earlier in gestation, will be needed to help differentiate lactation length effect on uterine length.

Because ovulation rate and mating type did not differ between treatments in our study, we would expect that fertilization rates would be the same across treatments. However, possibly due to a shorter mean uterine length in EW sows, fewer embryos survived. Other possible explanations could involve differences in uterine environment or variation in embryo maturation and maternal recognition of pregnancy. More embryos were lost in the EW group, which allowed for more embryo space in the EW group. Further research is needed to test these hypotheses.

Prenatal fetal loss due to uterine crowding is most important to the developing fetus between days 50-70 of gestation (Figure 1).[11,15] With the increased uterine space in the EW group, it is possible decreased fetal loss would occur in the EW group, thus allowing liveborn numbers between treatment groups to become more similar. Further research is needed to test this hypothesis.

Embryo data

We speculate that embryo weights were greater in CW sows due to a more favorable uterine environment. Further research is needed to test this hypothesis.

Male embryos weigh more than their female contemporaries.[32] Because crown-rump length and embryonic weight is highly correlated,[32,33] we only collected embryo weight data in this study. Further research is needed to determine embryo gender and whether individual liveborn pig weights would be greater in CW than EW sows.

Embryo survival was lower in this experiment compared with other studies.[12,13,24,25] This could be due to several factors--higher ovulation rate, the shorter lactation lengths, longer gestation lengths over which embryos were assessed, and sow housing (pen gestation) differences in our study. Further research is needed to determine what sow management techniques are needed to achieve increased embryo survival in sows with similar lactation lengths.

Our findings in this study agree with previous studies[10,12,13] that describe fewer live pigs per litter in sows weaned at 10 days versus those weaned at 20 days of lactation. Our study needs to be repeated in other herds, allowing some animals in both treatment groups to farrow, to accurately determine whether there would be significant differences in liveborn numbers between the two treatment groups.

Our findings agree with other studies, which indicate that early weaning has a greater effect on subsequent embryo survival than it does on ovulation rate. Thus, reduced embryo survival is responsible for the decreased numbers of live embryos in early gestation among early-weaned sows.[12,13] The embryonic survival differences in this study apparently occurred very early in gestation and the embryo remnants were likely resorbed by slaughter. This would agree with literature that indicates the largest number of embryos are lost between day 9-18 of pregnancy (Figure 1).[15]

Implications

- A lactation length of 8-12 days versus 18-21 days had a significant effect on weaning-to-first-service interval, farrowing rate, embryo survival, live embryo numbers, and average individual live embryo weight in this herd.
- Further studies are needed to gain more understanding of swine embryo survival and the effect of management practices thereupon.
- Pig age at weaning needs to be evaluated economically on a herd-by-herd basis.[34] Skip-mating sows or partially weaning litters offsite may be options to consider when weaning sows at 8-12 days to achieve best breeding-herd efficiencies in SEW systems.

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We welcome your contributions of:

- Original research,
- Case reports,
- Practice tips,
- Perspectives from the field,
- Literature reviews,
- Commentary, and
- Letters to the editor