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Responses to delayed estrus after weaning in sows using oral progestagen treatment[1]

J. Patterson,*[2] A. Wellen,* M. Hahn,* A. Pasternak,* J. Lowe,† S. DeHaas,† D. Kraus,† N. Williams,‡ and G. Foxcroft*

*Swine Reproduction-Development Program, Dept. AFNS, University of Alberta, Edmonton, Alberta, T6G 2P5, Canada; †The Maschhoffs Inc., 7475 State Road 127, Carlyle, IL 62231; and ‡PIC North America, 100 Bluegrass Commons Boulevard, Suite 2200, Hendersonville, TN 37075

ABSTRACT: Oral progestagen treatment extends the weaning-to-estrus interval (WEI) in weaned sows. Particularly in lower parity sows, this allows recovery from lactational catabolism and improves sow productivity. However, the optimal duration of progestagen treatment in contemporary dam-line sows is unclear. Therefore, sows (n = 749) weaned over consecutive 3-wk periods in June and July and classified as parity 2 and 3 (P2–3); 4, 5, and 6 (P4–6); or parity 7 or higher (P7+) were organized into 2 breeding groups using 1 of 3 strategies: 1) oral progestagen for 2 d before and 12 d after weaning (M14; n = 249); 2) oral progestagen for 2 d before and 5 d after weaning (M7; n = 250); or 3) no progestagen treatment (M0; n = 250). Progestagen (altrenogest) was administered directly into the sow's mouth at a dosage of 6.8 mL (15 mg of altrenogest) daily. Sows were bred using artificial insemination at first detection of estrus after weaning (M0) or altrenogest withdrawal, and every 24 h thereafter, until they no longer exhibited the standing reflex. The WEI for M0 sows was 5.1 ± 0.1 d. Estrus was recorded sooner ($P < 0.001$) after withdrawing treatment in M14 than in M7 sows (6.9 ± 0.1 vs. 7.4 ± 0.1 d, respectively). More ($P < 0.001$) M14 sows (88.6 ± 2.5%) were bred within 10 d of altrenogest withdrawal than M7 (72.8 ± 2.8%) sows, or within 10 d of weaning in M0 sows (78.8 ± 2.6%). Reproductive tracts were recovered after slaughter at d 30 or 50 of gestation. For P2–3 sows, ovulation rate (least squares mean ± 95% confidence interval) in M7 (23.1 ± 1.0) was greater ($P < 0.001$) than in M14 (20.7 ± 1.0) or M0 (19.7 ± 1.0) sows; no differences were detected in P4–6 and P7+ sows. At d 30, M7 and M14 sows had more ($P < 0.01$) embryos (16.4 ± 0.6 and 15.8 ± 0.4, respectively) than M0 (13.9 ± 0.5) sows. At d 50 of gestation, number of fetuses in M14 sows (13.6 ± 0.4) was greater ($P < 0.001$) than in M0 (11.8 ± 0.4) and M7 (12.2 ± 0.3) sows. Use of oral progestagen to delay the return to postweaning estrus for greater than 18 d appears to have potential for improving weaned sow productivity. Given the incidence of high ovulation rates and associated evidence of intrauterine crowding of embryos around d 30 of gestation, the changing dynamics of prenatal loss resulting from longer periods of progestagen treatment may represent an additional production advantage.

Key words: estrus, lactation, postweaning fertility, progestagen, sow

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INTRODUCTION

A "second parity dip" due to lactational catabolism is common in primiparous sows and is associated with extended weaning-to-estrus intervals (**WEI**; Zak et al., 1997a) and reduced embryonic survival in the subsequent parity (Clowes et al., 1994). Breeding at second compared with first estrus after weaning ("skip-a-heat") counteracts these effects (Clowes et al., 1994), albeit at the cost of 22 nonproductive days. Alternatively, treatment with progestagens in weaned sows also extends the WEI interval and allows additional time for recovery from lactational catabolism (Santos et al., 2004; Fernández et al., 2005). As reviewed by Kemp et al. (2006), progestagen treatment also has been shown to improve the percentage of sows in estrus within 7 d after weaning and to increase ovulation rate, embryonic survival, and subsequent litter size.

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[2]Corresponding author: jlp2@ualberta.ca

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The efficacy of progestagens in synchronizing estrus in sexually mature gilts (Stevenson and Davis, 1982; Martinat-Botté et al., 1985; Ashworth et al., 1992; Horsley et al., 2005), weaned sows (Martinat-Botté et al., 1995; Koutsotheodoros et al., 1998; Tilton and Weigl, 2000), and in commercial production (Fernández et al., 2005) has been well documented. However, duration of progestagen treatment after weaning that produces optimal sow productivity is still unclear. The changing physiology of the weaned sow (Kemp et al., 2006) suggests that longer periods of progestagen treatment may produce fertility outcomes more analogous to the response to "skip-a-heat" breeding. Therefore, the primary objective of this study was to determine effects of different durations of progestagen treatment in weaned commercial sows with lactation lengths typical of the North American swine industry. A secondary objective was to define the relationships between ovulation rate, and embryonic/fetal survival and development, in this contemporary sow population, as an extension of the earlier studies of Vonnahme et al. (2002) and Town et al. (2004, 2005).

MATERIALS AND METHODS

Animals and Treatments

Treatment protocols were administered on-farm, under the supervision of the herd veterinarian (J. Lowe) and with technical support from staff with certification for the use of swine in research obtained under the auspices of the Canadian Council for Animal Care at the University of Alberta (J. Patterson, M. Hahn, and G. Foxcroft). The recovery of reproductive tracts at a cooperating commercial abattoir was carried out under the routine surveillance provided by USDA personnel.

Multiparous crossbred (Genepacker 34, JSR Healthbred Inc.) sows (n = 749) from a 5,000 sow commercial farrow-to-wean facility located near Hinton, Oklahoma (Maschhoffs Inc., Carlyle, IL) were initially allocated to 1 of 3 treatments on the expectation of an 80% conception rate (based on previous production data) and the aim of having 150 sows/treatment group pregnant when slaughtered at d 30 or 50 of gestation. Animals were made available for this study as part of a genetic repopulation exercise. The herd was considered porcine reproductive and respiratory syndrome positive, but porcine reproductive and respiratory syndrome stable, at the time of the study.

Sows weaned over 2 consecutive 3-wk periods in June and July were allocated by weaning week to 1 of 3 breeding strategies (Figure 1a): weaning wk 1 and 4, oral treatment with the synthetic progestagen, altrenogest (MATRIX, Intervet, USA, De Soto, KS), administered directly into the sow's mouth at a dosage of 6.8 mL (15 mg of altrenogest) daily, for 2 d before and 12 d after weaning (M14; n = 249); weaning wk 2 and 5, oral progestagen treatment for 2 d before and 5 d after weaning (M7; n = 250); or weaning wk 3 and 6, no progestagen treatment (M0; n = 250). This strategy allowed shipment of all sows for slaughter in a single week at d 30 (weaning wk 4, 5, and 6) or d 50 (weaning wk 1, 2, and 3) of gestation. The day after last treatment (M7 and M14) or weaning (M0) was considered d 1. Three days after weaning for M0 sows, or 4 d after progestagen withdrawal for M7 and M14, sows were checked daily for estrus using fenceline contact with a mature boar. Sows in estrus within 10 d after progestagen withdrawal (M7 and M14) or weaning (M0) were bred by artificial insemination using semen (3 billion sperm/AI dose) from PIC, Line 337 boars. Sows were inseminated at first detection of standing estrus after weaning or progestagen withdrawal, and every 24 h thereafter, until they no longer exhibited the standing reflex. Sows not in estrus within 10 d were considered culls, and no further data was collected from these animals. At approximately d 30 of gestation, real-time ultrasonography was used to confirm that sows were pregnant.

Slaughter and Dissection Procedures

All presumed pregnant sows (n = 502) were transported to a cooperating commercial abattoir (Odom's Tennessee Pride, Little Rock, AR) as 6 separate loads over a 4-d period. Each load contained sows from only 1 treatment (2 loads/treatment) but included sows at both d 30 and 50 of gestation on the basis that d 30 vs. 50 reproductive tracts can be visually identified after collection. Sows within each load were color coded immediately before shipping to identify parity group and were entered for processing by color batch (parity group): Batches within a load were separated on-line by empty shackles. Sow color coding and individual ID tags were recorded at the preskinning stage of processing and used to verify the expected sows within treatment and parity group. Because the shackle sequence within a batch could not be guaranteed at the point where reproductive tracts were recovered after evisceration, although tracts within an on-line batch could be reliably linked to a specific treatment, parity group, and stage of gestation, each tract within the batch could not reliably be linked to an individual sow ID.

Reproductive tracts were dissected on the day of slaughter, and ovulation rate and number of viable conceptuses were recorded for all animals. Because extremes of intrauterine development are usually associated with the ovarian and cervical ends of the uterine horn (Town et al., 2004), 2 live conceptuses were dissected from each miduterine horn (4 conceptuses total) on d 30 and 50, and average embryonic or fetal weights and average wet placental weights were recorded as a conservative measure of overall effects on embryonic and fetal development. Conceptuses were visually appraised as live or degenerating. Embryos were classified as degenerate when the embryo or placental membranes, or both, showed gross signs of degeneration (e.g., loss of vascularity, tissue decay, or both), as

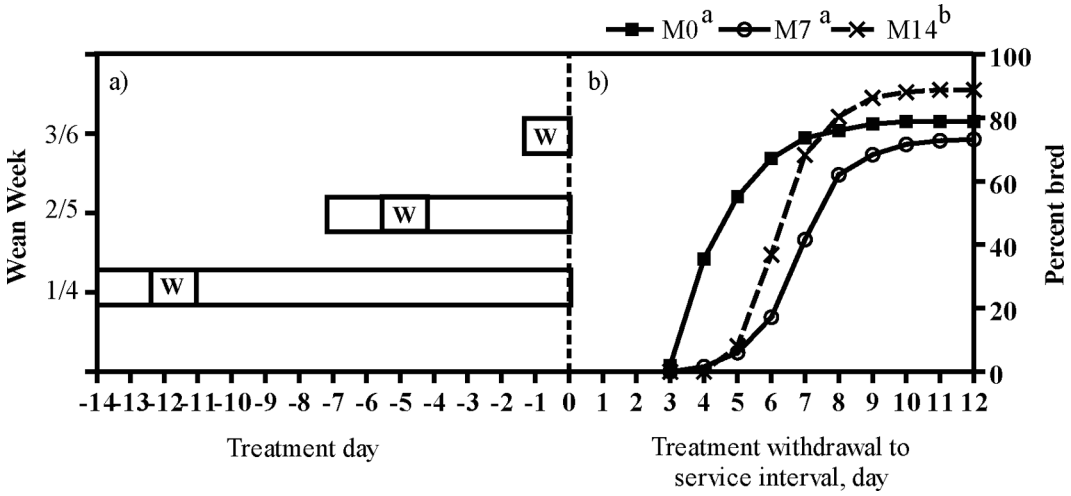

Figure 1. a) Description of the experimental design; sows weaned over two 3-wk periods were allocated by wean week to M14 (wean wk 1 and 4), M7 (wean wk 2 and 5), or M0 (wean wk 3 and 6) treatments. The rectangle represents duration of altrenogest treatment for M14 and M7 sows. W indicates the day of weaning. b) Overall distribution of sows exhibiting standing heat by day. [a–c]Different letters indicate differences ($P < 0.05$) in the proportion of sows bred within 10 d of weaning (M0) or treatment withdrawal (M7 and M14).

described previously by Geisert et al. (2007). Placentae from all 4 conceptuses were placed in a colander to remove excess fluid before recording wet placental weights. For the subset of sows with ovulation rates >25, embryonic and placental weights were recorded for all conceptuses.

Statistical Analysis

Logistical requirements during the week of slaughter determined the experimental design of this study. Staffing resources and constraints in scheduling shipment of sows and access to tracts in the abattoir dictated that all sows be slaughtered in a single week. Therefore, once the slaughter week was identified, two 10-d breeding periods (with each treatment represented in each breeding period) were identified that resulted in sows being at approximately d 30 or 50 of gestation in the designated slaughter week. Breed period, linked to the planned week of slaughter, thus became the key determinant of allocation to treatment. Sows available in the 3 weaning weeks previous to each of the 2 breeding periods were then identified and allocated sequentially by week to the M14, M7, and M0 treatments, respectively (see Figure 1). Furthermore, to facilitate comparisons with previous research (Clowes et al., 1994; Town et al., 2005), sows were grouped by parity (P2–3, P4–6, and P7+) as part of the shipping strategy, with similar numbers of sows falling into these parity groupings.

The MIXED procedure (SAS Inst. Inc., Cary, NC) was used to analyze 1) effects of treatment, parity group, treatment × parity groups interactions, and breed week on treatment withdrawal to service interval (**TWSI**), weaning to service interval (**WSI**) and ovulation rate, and 2) the effects of treatment, parity group, gestation day, and their interactions on number of live embryos/fetuses, embryonic/fetal survival rate, and placental and embryonic/fetal weights. Breed week was considered a random effect. Data were examined for normality and homogeneity of variance, and when these conditions were not met, the data were transformed as necessary. For data that required transformation (ovulation rate), the resulting least squares means were back-transformed for data presentation and an error term for the original units was estimated using a 95% confidence interval around the transformed mean. For data that did not meet the requirements for normality and homogeneity of variance (parity and previous lactation length), means and SD are presented. Sow was considered the experimental unit for analysis; treatment, parity group, and gestation day were considered fixed effects. Fetal weights and placental weights were subsampled and averaged within each reproductive tract (sow) before analysis. When appropriate, preplanned contrasts were used for specific comparisons between treatments within day of gestation and parity.

The percentage of sows recorded as exhibiting first estrus within 10 d after weaning by treatment, pregnancy check positive (**PCP**: number of sows determined to be pregnant at approximately d 30 of gestation using real-time ultrasound as a percentage of the total number of sows bred), estimated pregnancy rate (**EPR**: pregnant tracts dissected at slaughter (d 30 and 50) as a percentage of the total number of sows bred), estimated efficiency rate (**EER**: percent of pregnant tracts dissected at slaughter (d 30 and 50) as a percentage of the total number of sows weaned), and the percentage of sows with >25 ovulations were analyzed using the CATMOD procedure of SAS. Synchrony of the TWSI was defined as the variance in the interval to breeding

Table 1. Production summary for M0, M7, and M14 treatment sows[1]

Item	Treatment			
	M0	M7	M14	*P*-value[8]
No. assigned	250	250	249	—
Parity	4.8 ± 2.6	4.0 ± 2.4	5.3 ± 3.2	—
Lactation length, d	18.5 ± 3.5	17.4 ± 2.7	18.5 ± 3.1	—
No. bred[2]	197	183	221	—
Bred, %	78.8[ab]	72.8[a]	88.8[b]	<0.001
TWSI,[3] d	5.1 ± 0.2[a]	7.3 ± 0.2[b]	6.8 ± 0.2[c]	<0.001
Variance, TWSI	1.9[a]	1.9[a]	1.4[b]	<0.05
WSI,[4] d	5.1 ± 0.2[a]	12.2 ± 0.2[b]	18.8 ± 0.2[c]	<0.001
No. services	2.3 ± 0.04[a]	2.1 ± 0.04[b]	2.3 ± 0.04[a]	<0.05
PCP,[5] %	83.2	82.0	86.4	0.46
EPR,[6] %	77.7	77.5	82.6	0.34
EER,[7] %	61.2[a]	56.4[a]	72.7[b]	<0.001

[a–c]Means within rows with different superscripts differ ($P < 0.05$).

[1]Treatments involved oral progestagen for 2 d before and 12 d after weaning (M14), oral progestagen for 2 d before and 5 d after weaning (M7) or no progestagen treatment (M0).

[2]Sows bred include sows inseminated within a 10-d period from weaning (M0) or withdrawal of progestagen treatment (M7, M14).

[3]TWSI = Treatment withdrawal to service interval (M7 and M14 sows) (d from weaning to service in M0 sows).

[4]WSI = Weaning to first service interval.

[5]PCP = Pregnancy check positive. Number of sows determined to be pregnant at approximately d 30 of gestation using real time ultrasound as a percentage of the total number of sows bred.

[6]EPR = Estimated pregnancy rate. Pregnant tracts dissected at slaughter (d 30 and 50) as a percentage of the total number of sows bred.

[7]EER = Estimated efficiency rate. Percent of pregnant tracts dissected at slaughter (d 30 and 50) as a percentage of the total number of sows weaned.

[8]Significance of main treatment effect.

after treatment withdrawal (M7 and M14) or weaning (M0). Differences in the treatment variance, associated with TWSI, were tested by calculating individual treatment variance and dividing the greater variance by the lesser variance of each of the 3 treatment comparisons and performing a simple *F*-test (Snedecor and Cochran, 1989; Busch et al., 2007). Relevant correlations within gestation day, irrespective of treatment or parity, between ovulation rate, number of viable embryos/fetuses, embryonic/fetal survival rate, embryo/fetal weight, and placental weight were analyzed using PROC CORR of SAS.

RESULTS

Production Data

All sows were retrospectively grouped by parity (P2–3, P4–6, P7+) based on the expected parity of the current litter. Overall means and SD for parity and lactation length within these parity groups are presented in Table 1.

Significant main effects of treatment and parity, but no interaction, were detected for average WEI, TWSI, percentage of sows bred within 10 d, and the associated variance in TWSI (Table 1, Figure 1b). Weaning-to-estrus interval for M0 sows (5.1 ± 0.2 d) was shorter ($P < 0.001$) than the TWSI in M14 and M7 sows (6.8 ± 0.2 vs 7.3 ± 0.2 d, respectively). Weaning-to-first service interval was different ($P < 0.001$) among treatment groups, and duration of estrus appeared shortest in M7 compared with M14 and M0 sows, as evidenced by the difference ($P < 0.05$) in the total number of services (inseminations) between treatment groups (Table 1). Duration of estrus appeared longer ($P < 0.01$) in P7+ sows (2.4 ± 0.5 inseminations) than P2–3 and P4–6 sows (2.2 ± 0.04 vs. 2.2 ± 0.05 inseminations, respectively). As a proportion of sows originally bred, the estimated conception rate (PCP) and EPR (Table 1) were not affected by treatment. However, M14 sows had greater overall weaned sow productivity (EER) than either M7 or M0 sows (Table 2).

Slaughter Data

Sows were shipped in a single group at approximately d 30 (mean = 27.2, range = 22 to 30 d) and d 50 (mean = 49.1, range = 43 to 53) of gestation.

Ovulation Rate. Stage of gestation did not affect ovulation rate ($P = 0.68$; data not shown) and therefore, was not included in the analysis. An overall treatment × parity interaction was detected ($P < 0.05$; Table 2). Within the P2–3 group, M7 sows had a greater mean ovulation rate and a larger proportion of sows with >25 ovulations than M0 or M14 sows. Parity affected both mean ovulation rate and the proportion of sows with >25 ovulations in M0 and M14 sows ($P < 0.05$). For M0 sows, P2–3 sows had a lower mean ovulation rate and a lower proportion of sows with >25 ovulations than parity groups P4–6 and P7+ ($P < 0.05$; Table 2). For

Table 2. Combined (d 30 and 50 of gestation) ovulation rate and percentage of sows with >25 ovulations for different parity sows (P2–3, P4–6, and P7+) by treatment[1,2]

	Treatment		
Item	M0	M7	M14
Ovulation rate[3]			
P2–3	19.7 ± 1.0$^{a, x}$ (71)	23.1 ± 1.0^{b} (77)	20.7 ± 1.0$^{c, x}$ (85)
P4–6	23.1 ± 1.1^{y} (41)	23.3 ± 1.1 (39)	22.1 ± 1.0^{xy} (44)
P7+	23.7 ± 1.0^{y} (39)	24.6 ± 1.1 (25)	23.8 ± 1.0^{y} (52)
Percentage with ≥25 ovulations			
P2–3	9.9$^{a, x}$ (7)	32.5^{b} (25)	5.9$^{a, x}$ (5)
P4–6	39.0^{y} (16)	38.5 (15)	25.0^{y} (11)
P7+	41.0^{y} (16)	52.0 (13)	44.2^{z} (23)

[a–c]Different superscripts within a row indicate significant differences between treatment groups within parity ($P < 0.05$).

[x–z]Different superscripts within a column indicate significant differences between parity groups within treatment ($P < 0.05$). Numbers within parentheses are the number of sows represented.

[1]Treatments involved oral progestagen for 2 d before and 12 d after weaning (M14), oral progestagen for 2 d before and 5 d after weaning (M7), or no progestagen treatment (M0).

[2]Treatment × parity interaction ($P < 0.05$).

[3]Statistical analyses were preformed on log-transformed data. Least squares means and the 95% confidence interval around the mean were calculated and then back-transformed for presentation of data.

M14 sows, mean ovulation rate was lowest in P2–3 and highest in P7+, with P4–6 being intermediate, whereas the proportion of sows with >25 ovulations was lower in P2–3 sows than P4–6 or P7+ sows. In contrast, in M7 sows, no parity effects on mean ovulation rate or the proportion of sows with >25 ovulations were detected ($P > 0.05$).

Live Embryos/Fetuses. The main effects of treatment, gestation and parity were significant, and no interactions were detected. The number of fetuses at d 50 decreased with increasing parity grouping, whereas only P2–3 and P7+ sows differed in the number of embryos at d 30 ($P < 0.05$; Figure 2a). Treatments M7 and M14 had greater numbers of viable embryos than M0 sows at d 30 of gestation ($P < 0.05$; Figure 2b), and M14 sows had more surviving fetuses than M0 or M7 sows at d 50 of gestation ($P < 0.05$).

Irrespective of treatment or parity, there was a positive correlation (r = 0.25, $P < 0.001$) between ovulation rate and number of live embryos at d 30 of gestation. At d 50, this relationship did not exist ($P > 0.05$).

Embryonic/Fetal Survival Rates. The main effects of treatment, gestation, and parity on embryonic/fetal survival rates were significant ($P < 0.05$), and no interactions were detected. Parity effects (Figure 3a) showed the same trends as seen for the numbers of embryos and fetuses. For treatments (Figure 3b), M14 sows had greater embryonic survival than M0 sows at d 30 of gestation, with survival in M7 sows being intermediate, whereas at d 50 of gestation, M14 sows had greater fetal survival than M0 and M7 sows.

Irrespective of treatment or parity, ovulation rate was negatively correlated with embryo survival at d 30 of gestation (r = −0.29, $P < 0.001$) and with fetal survival at d 50 of gestation (r = −0.53, $P < 0.001$).

Embryonic/Fetal Weights and Placental Weights. For embryonic and fetal weights, the main effects of treatment, gestation stage, parity, and their interactions were significant. At d 30 of gestation, there were no effects ($P > 0.05$) of treatment on embryo or placenta weight (Figure 4a and c). At d 50 of gestation, treatment differences were detected in fetal weight and the pattern was dependent on parity (Figure 4b). Treatment had no effect on placental weight at d 50 of gestation in any parity group (Figure 4d). In contrast to the observed variance at d 30 of gestation, variance in fetal and placental weight at d 50 was low.

Irrespective of treatment or parity, average placental weight was positively correlated with average embryo weight at d 30 of gestation (r = 0.65, $P < 0.001$) and with average fetal weight at d 50 of gestation (r = 0.48, $P < 0.001$). The number of live embryos at d 30 of gestation showed no relationship with embryonic weight (r = 0.06, $P = 0.35$) but was negatively correlated with placental weight (r = −0.13, $P > 0.05$). At d 50 of gestation the number of live fetuses was negatively correlated with fetal weight (r = −0.24, $P < 0.001$) and placental weight (r = −0.30, $P < 0.001$).

DISCUSSION

In an experimental setting, past research has shown that a catabolic state at weaning in sows, often as a consequence of inadequate nutrition, low feed intake, or nursing of large litters during lactation (Kim and Easter, 2001; Quesnel et al., 2007), is associated with poor fertility (Kemp and Soede, 2004), extended weaning-to-estrus intervals (Zak et al., 1997a), and reduced numbers of live embryos (Vinsky et al., 2006) after weaning. However, in more recent experiments, the

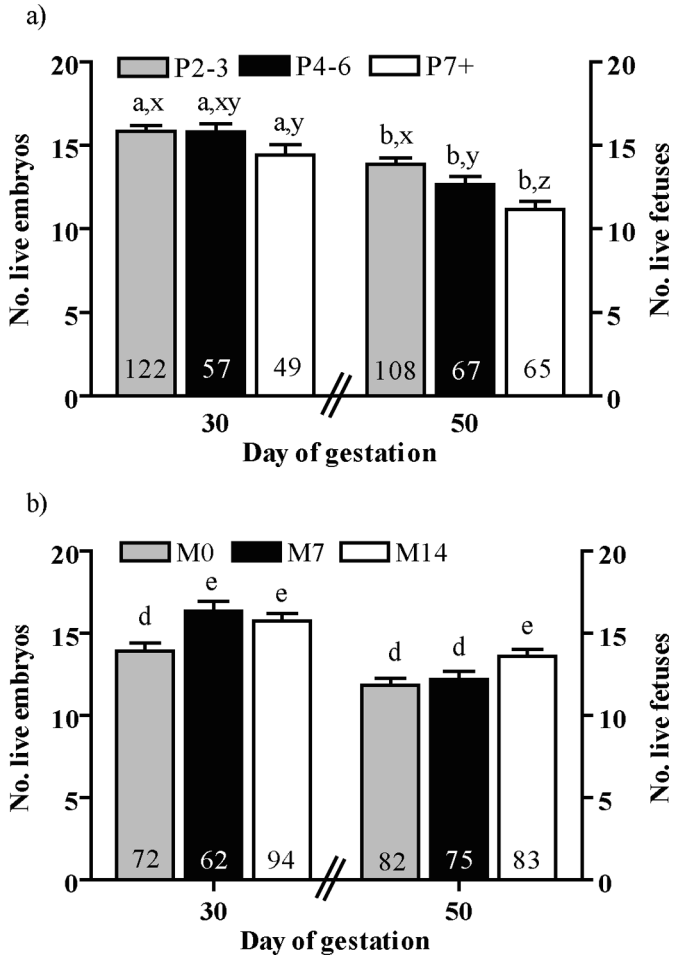

Figure 2. a) Effect of parity (P2–3, P4–6, and P7+) on total number of live embryos and fetuses (least squares means ± SE) at d 30 and 50 of gestation. [a,b]Different letters indicate differences between day of gestation within parity group ($P < 0.05$). [x–z]Different letters indicate differences between parity group within day of gestation ($P < 0.05$). Numbers within bars are the number of sows represented. b) Effect of progestagen treatment (M7 and M14) after weaning on total number of live embryos and fetuses (least squares means ± SE) at d 30 and 50 of gestation. [d,e]Different letters indicate differences between treatment groups within day of gestation ($P < 0.05$). Numbers within bars are the number of sows represented.

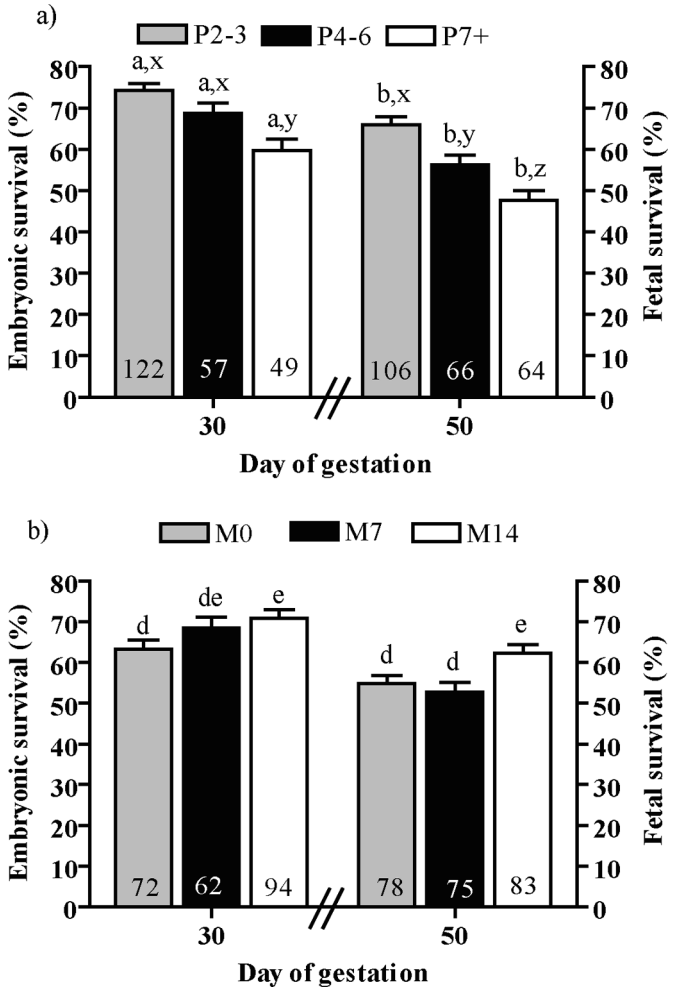

Figure 3. a) Effect of parity (P2–3, P4–6, and P7+) on embryonic and fetal survival rate (least squares means ± SE) at d 30 and 50 of gestation. [a,b]Different letters indicate differences between day of gestation within parity group ($P < 0.05$). [x–z]Different letters indicate differences between parity group within day of gestation ($P < 0.05$). Numbers within bars are the number of sows represented. b) Effect of progestagen treatment (M7 and M14) after weaning on embryonic and fetal survival rate (least squares means ± SE) at d 30 and 50 of gestation. [d,e]Different letters indicate differences between treatment groups within day of gestation ($P < 0.05$). Numbers within bars are the number of sows represented.

relative lack of an effect of lactational catabolism on many measures of postweaning fertility in contemporary commercial primiparous sows was evident (Foxcroft et al., 2006a; Patterson et al., 2007), indicating that the performance of contemporary first parity sows has changed.

In contrast, in commercial operations, second parity litter size is often negatively impacted by the demands of the first lactation (the "second parity dip"), and the strategy of delaying breeding of weaned first parity sows until their second postweaning estrus ("skip-a-heat" breeding) has been shown to increase subsequent litter size born (Clowes et al., 1994; Wellen et al., 2007). Alternative methods to increase second parity productivity, without incurring the cost of the 21 additional nonproductive days associated with "skip-a-heat" breeding, merit further investigation.

Altrenogest treatment effectively delays estrus after weaning in sows (Wood et al., 1992; Martinat-Botté et al., 1995; Tilton and Weigl, 2000; Santos et al., 2004; Fernández et al., 2005) by exerting negative feedback on GnRH release and thus LH and FSH secretion (Stevenson et al., 1985). Altrenogest treatment from the day of weaning is normally effective in blocking the increase in LH secretion that is triggered by removal of

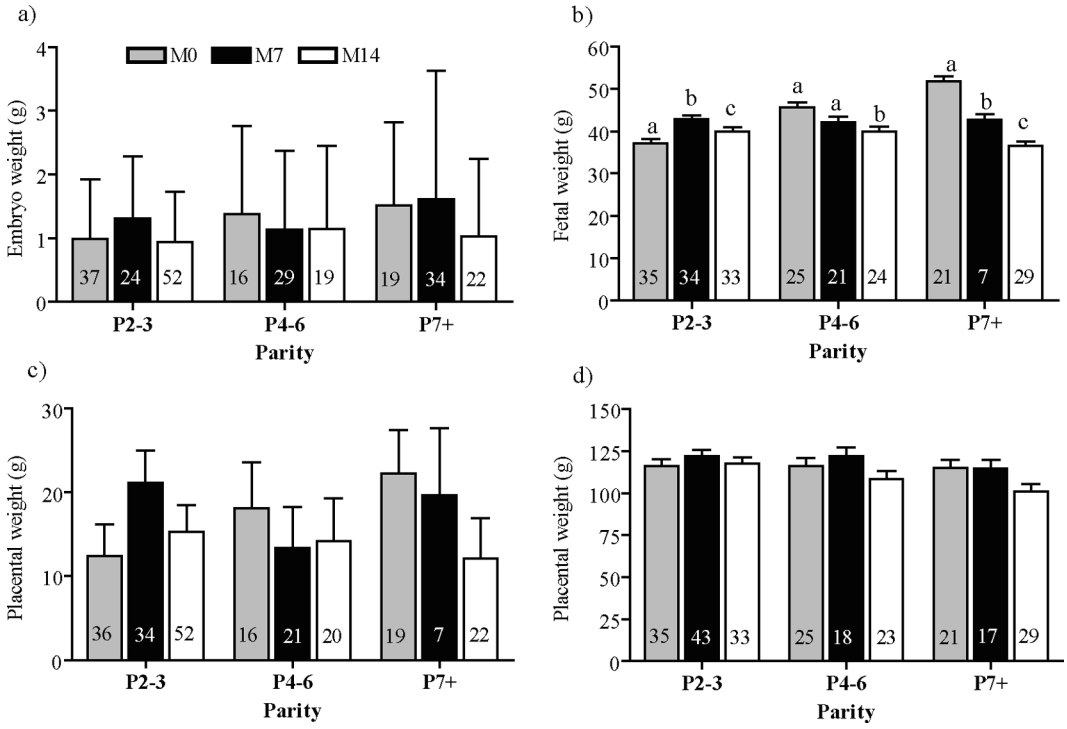

Figure 4. Effect of progestagen treatment (M7 and M14) after weaning on a) embryonic and c) placental weight at d 30, and b) fetal and d) placental weight at d 50 of gestation (least squares means ± SE). [a–c]Different letters indicate differences between treatment groups within parity group ($P < 0.05$). Numbers within bars are the number of sows represented.

the litter. However, in situations where inadequate inhibition of gonadotropin secretion may already be present at the time of weaning (use of interrupted suckling or split-weaning, and in specific genotypes and higher parity sows), lactational estrus may occur (Kemp and Soede, 2004). Therefore, in the present study involving multiparous sows, altrenogest treatment commenced 2 d before the day of weaning to ensure full efficacy.

Although altrenogest treatment after weaning has been shown to be beneficial in synchronization of estrus in sows, the duration of altrenogest feeding after weaning needed to produce optimal sow productivity is still unclear. Feeding altrenogest daily for between 3 and 7 d results in effective synchronization of estrus in weaned sows (Johnston et al., 1992; Martinat-Botté et al., 1995; Tilton and Weigl, 2000). Koutsotheodoros et al. (1998) and Kauffold et al. (2007) suggested, however, that longer treatment durations may produce better estrous synchronization. Results of the present study support this suggestion because altrenogest treatment for 12 d after weaning was more effective in synchronizing estrus than treatment for 5 d, as determined by the percentage of sows in heat within 10 d of altrenogest withdrawal and the decreased variance in WEI.

The recommended daily dose of altrenogest fed to gilts varies between 15 and 20 mg, depending on the country of registration. Although Fernández et al. (2005) reported that 20 mg of altrenogest daily for 5 d starting the day after weaning effectively synchronized estrus within a 7-d period, Kauffold et al. (2007) reported that feeding altrenogest at 16 rather than 20 mg/d may result in a greater percentage of females with polycystic ovaries, suggesting that underdosing in sows may be related to physical body size. In the present study, no adverse effects of using the lower 15 mg dose of altrenogest were apparent because 88.8% of M14 sows were in heat within 10 d after altrenogest withdrawal and these sows had the highest pregnancy rates at both d 30 and 50 of gestation.

The present study was conducted in July and August during the expected peak of seasonal infertility in the North American swine industry. The longer 12-d period of altrenogest treatment after weaning produced a greater percentage of M14 sows bred within 10 d after altrenogest withdrawal compared with M7 sows, or within 10 d of weaning in control (M0) females. The cost of nonproductive days accumulated with the delayed return to estrus, and the product-associated costs of treatment in the M14 sows was, therefore, partly offset by the 10% increase in the proportion of weaned sows successfully re-bred and the 11% increase in the number of weaned M14 sows found pregnant during this period of summer infertility.

Treatment with altrenogest has been reported to increase ovulation rate in gilts (Martinat-Botté et al., 1995; Soede et al., 2007) and sows (Koutsotheodoros et al., 1998). In the present study, the effect on ovulation rate was both dose and parity dependent. Altrenogest treatment had little effect on ovulation rate in higher parity (4–6 and 7+) sows, whereas in the parity 2–3

group, M7 sows had a greater ovulation rate than M14 or M0 sows, and a greater percentage of M7 sows had >25 ovulations. It is unclear why similar greater ovulation rates were not seen in M14 sows. Lack of an increase in ovulation rate and the marked reduction in the proportion of M14 sows with >25 ovulations appeared to favor the dynamics of prenatal survival. An increased number of viable fetuses at d 50 in M14 sows compared with M0 or M7 suggests that the quality of preovulatory ovarian follicles and the enclosed oocytes may be improved by imposing a longer weaning-to-ovulation interval.

Good fertilization rates (>90%) can be achieved when a single insemination is performed during the 24-h period before ovulation (Soede et al., 1995). In the present study, sows were bred at first detection of estrus and every 24 h thereafter until they were no longer exhibiting a strong standing heat, thereby ensuring that at least one insemination fell within the 24-h period before ovulation. Furthermore, because sows in each of the 3 treatments were bred over the same 10-d breeding periods and semen also was reported to be no greater than 3 d old at insemination, it can be assumed that semen quality and variability in fertilization rates did not confound the results of the present study. Although M7 had a greater ovulation rate than M14 sows in the P2–3 category, the number of viable embryos were greater in M7 and M14 sows than in the untreated M0 group at d 30 of gestation. These data are consistent with results of Koutsotheodoros et al. (1998) who reported an increase in number of viable embryos at 25 to 28 d of pregnancy in early-weaned, altrenogest-treated compared with control sows. However, by d 50 of gestation in the current study, M14 sows had the greatest number of live fetuses and better fetal survival than M7 sows. The mechanism by which the longer period of altrenogest treatment acts to regulate ovulation rate is uncertain at this time.

Although no treatment differences were detected in embryonic or placental weight at d 30, or in placental weight at d 50 of gestation, the actual day of slaughter around d 30 ranged from 22 to 30 d of gestation and may have caused the considerable variability observed in these characteristics. Town et al. (2005) reported a positive relationship between placental weight, and embryo weight at d 30 and fetal weight at d 50 of gestation, and suggested a functional relationship between these characteristics. Results from the present study confirm these results, despite the variability in the data on placental, embryonic, and fetal weight. Consistent with the results of Town et al. (2005) and Vonnahme et al. (2002), placental weight was negatively correlated with both the number of live embryos at d 30 and fetuses at d 50 of gestation, and there was a negative relationship between number of viable fetuses and fetal weight by d 50 of gestation.

As reviewed by Foxcroft et al. (2006b), high ovulation rates (>25) in higher parity commercial dam-line sows can result in intrauterine crowding in early gestation and thus affect placental and fetal development. High ovulation rates combined with even modest embryonic survival rates was associated with increased uterine crowding at d 30 of gestation in the earlier study of Vonnahme et al. (2002) and was considered to drive a peak of postimplantation loss between d 30 and 50 of gestation. In the present study the overall positive relationship between the number of live embryos at d 30 of gestation and ovulation rate indicates an increased risk of encountering a similar detrimental effect of uterine crowding. This appeared to be confirmed by the lack of a relationship between ovulation rate and the number of live fetuses present at d 50 of gestation. Furthermore, in the study of Town et al. (2004), a difference of 9 vs. 15 embryos in utero at d 30 of gestation was associated with differences in placental development at d 30 and residual negative effects on placental and fetal development, including the number of secondary muscle fibers at d 50 of pregnancy. This is important because M7 sows had greater ovulation rates than M0 or M14 sows, and in M7 sows the increased numbers of embryos at d 30 were not sustained to d 50 of gestation. In contrast, the lower ovulation rates and the better balance between ovulation rate and the number of fetuses at d 50, in M14 sows, suggests that the risks associated with excessive intrauterine crowding are reduced in this treatment group.

Altrenogest was effective in synchronizing the return to estrus in weaned sows and the duration of altrenogest treatment affected subsequent sow productivity. Sows treated with altrenogest for 12 d after weaning produced the greatest percentage of sows bred within 10 d of altrenogest withdrawal and pregnant at d 50 of gestation, and an increase in the number of fetuses at d 50 of gestation, comparable with that seen in previous "skip-a-heat" studies. Use of oral progestagens to delay the return to postweaning estrus for greater than 18 d may also optimize the dynamics of embryonic and fetal survival in higher parity sows.

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