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Intrauterine artificial insemination of swine with different sperm concentrations, parities, and methods for prediction of ovulation

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Abstract

This study compared the reproductive performance of sows that were submitted to cervical artificial insemination (CAI) using concentrations of 3.5 x 10^9 spermatozoa per dose or intrauterine artificial insemination (IUAI) with 2, 1, or 0.5 x 10^9 spermatozoa per dose. Within all treatments, females were inseminated either after conventional estrus detection or after ultrasound-guided ovulation diagnosis. Farrowing rate did not differ between CAI and IUAI, regardless of the concentration of spermatozoa used ($P > 0.05$). In comparison with CAI in parity-3+ females, the probability of failure to farrow was greater ($P < 0.05$) with IUAI in parity-1 females inseminated with 2 x 10^9 spermatozoa per dose, parity-2 females with any concentration, and parity-3+ females inseminated with 0.5 x 10^9 spermatozoa per dose ($P < 0.01$). Total litter size did not differ across AI methods ($P > 0.05$), but it was smaller ($P < 0.0005$) in parity-1 females than for higher parity females. Total litter size was lower with IUAI in parity-1 females with any concentration and in parity-2 females with 2.0 x 10^9 spermatozoa per dose ($P < 0.05$). The estimation of ovulation via conventional estrus detection or ultrasound, as well as the occurrence of semen backflow and bleeding during AI, did not influence farrowing rate or litter size ($P > 0.05$). Intrauterine AI had a lower probability of farrowing with the concentration of 0.5 x 10^9 spermatozoa per dose and in parity-2 females and also reduced litter size in parity-1 females.

Keywords: intra-uterine artificial insemination, farrowing rate, litter size, swine.

Introduction

Artificial insemination (AI) in swine is increasing worldwide as a function of the benefits related to genetic improvement. Estrus detection is the most important factor to be considered when implementing AI protocols at the farm level (Dial *et al.*, 1992; Kemp and Soede, 1996). Conventional estrus detection is based on determining the time of the first positive response of sows to back pressure, once or twice daily and in the presence of a boar (Weitze *et al*., 1994). The weaning-to-estrus interval (WEI) may be inversely related to estrus duration (Weitze *et al.*, 1994; Kemp and Soede, 1996), but this association can be moderate to weak (Lucia *et al*., 1999; Corrêa *et al.*, 2002). The duration of estrus is highly variable, between 48 and 60 h (Weitze *et al*., 1994; Soede *et al*., 1996; Nissen *et al.*, 1997; Lucia *et al.*, 1999). Ovulation usually occurs during the final third part of the estrus. Conventional estrus detection procedures can be potentially imprecise, depending on the skills of the farm staff. Ovulation diagnosis by real-time ultrasound can overcome the limitations of estrus detection when implementing AI protocols (Soede *et al.*, 1996; Nissen *et al.*, 1997), but it is not routinely used at many farms due to cost constraints.

Conventionally, AI is performed in swine by depositing semen in the cervix (intracervical artificial insemination; CAI); thus, spermatozoa must cross the uterus and reach the oviduct to undergo fertilization (Rath, 2002). During this transit, loss of spermatozoa can occur due to leukocyte influx into the uterine lumen, which may lead to post-breeding inflammatory responses especially when AI is performed during late estrus or metestrus (Rozeboom *et al*., 1997; 1999; Kaeoket *et al*, 2005). Additionally, loss of spermatozoa can occur due to semen backflow (Steverink *et al*., 1998). Thus, to compensate for the imprecision in ovulation diagnosis and potential loss of spermatozoa, two or three inseminations are commonly performed during estrus (Xue *et al.*, 1998a; b; Corrêa *et al*., 2002) using concentrations of spermatozoa (2.5-3 x 10^9) each time that are much higher than what would be necessary for fertilization (Rath, 2002).

Intrauterine artificial insemination (IUAI) is a technique that allows for nonsurgical deposition of semen into the uterine body (Watson and Behan, 2002). Because of a reduction in the number of mechanical and physiological barriers that could lead to loss of spermatozoa during their transit up to the oviduct, IUAI can be performed using concentrations as low as 2-1 x 10^9 (Watson and Behan, 2002; Benneman *et al*., 2004) and 0.5 x 10^9 spermatozoa per dose (Mezalira *et al*., 2005). This would allow farms to increase the sow:boar ratio and increase the impact of individual

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boars on both reproductive efficiency and genetic progress. In the studies mentioned above, reproductive performance with IUAI was similar to that obtained with CAI. However, it is still necessary to evaluate the efficiency of IUAI in commercial farm conditions, since some field trials reported suboptimal performance with IUAI (Rozeboom *et al*., 2004; Roberts and Bilkei, 2005). Additionally, other factors should be investigated, such as the comparison between conventional estrus detection and ultrasound-guided ovulation diagnosis and also the effect of parity. Most of the studies mentioned above only used pluriparous females. The objective of the present study was to examine the effects of AI method (IUAI or CAI) in field conditions, concentration of spermatozoa (2, 1, or 0.5 x 10^9 spermatozoa per dose) within the IUAI method, parity, and method for prediction of ovulation on farrowing rate and total litter size.

Materials and Methods

The study was conducted at a commercial farm housing 1700 females and located in the Midwest region of Brazil. Eight mature Duroc boars with known fertility and from the same genetics were used as semen donors. The boars were at an AI stud located 5 km from the farm. Semen collection was done via the hand gloved method by a trained technician. Semen samples were diluted 1:1 in BTS (Pursel and Johnson, 1975). All ejaculates were kept at 34-35 $^{\circ}$C to prevent cold shock. Semen samples were combined to form two semen pools. Each semen pool consisted of samples from four boars. Only samples having at least 80% of motility, spermatozoal vigor equal to 4 or higher, and at most 20% abnormalities before pooling were used. Spermatozoa concentration was determined by spectrophotometer. Each semen pool was fractioned into 4 samples, one for each AI method. The samples were stored at 17 $^{\circ}$C and used at most 48 h after collection.

This study included 338 crossbred F1 females from parities 1-8 and from the same genetics (Genetiporc®). For the statistical analysis, parity was categorized as 1, 2, and 3 or higher (P1, P2, and P3+, respectively). From the post-weaning period to the time of mating, females were fed a lactation diet (18% crude protein) twice daily, each time with *ad libitum* access. During the gestation period, the females were fed a diet with 14% crude protein twice daily; the amount fed to each female was adjusted to each female's body condition. Both feeding strategies followed the recommendations of the National Research Council (NRC; 1998). In each weekly weaning group, estrus detection commenced on the day of weaning and was conducted twice daily (7:30 and 16:00 h) by applying back pressure to females in the presence of four, sexually-mature boars. Estrus detection was not performed at 12-h intervals in order to adhere to the same management procedures routinely conducted at the farm.

Estrus duration was characterized as described by Weitze *et al*. (1994) as the difference between the beginning (time of the first positive response to back pressure minus 6 h) and the end of estrus (time of the first negative response to back pressure minus 6 h). The WEI (Weaning-to-Estrus Interval) was defined as the number of hours between weaning and the beginning of the estrus. Females showing signs of estrus after 10 days post weaning were not included in the study.

A sample of females from each weekly group was submitted to twice-daily ovulation diagnosis by real-time ultrasound performed by a trained technician. The exam was done by the transcutaneous technique using a convex 5.0 MHz probe (Anser Vet 485, Pie Medical®) positioned on the right side of standing females, nearly at the midpoint between the femur-tibia joint and the last rib and 10 cm above the udder. The moment of ovulation was characterized when no pre-ovulatory follicles were found in the ovaries or when the follicle number was lower than that observed in the previous exam, as long as this diagnosis was confirmed in the following exam to avoid false positive diagnosis (Soede *et al*., 1996).

Females were allocated to four different AI methods: CAI with 3.5 x 10^9 spermatozoa per ml and a volume of 100 ml or IUAI with 2, 1, or 0.5 x 10^9 spermatozoa per dose and a volume of 50 ml. Females submitted to conventional estrus detection were inseminated at 12, 24, and 36 h after estrus detection. Females submitted to ovulation diagnosis by ultrasound were inseminated immediately after the observation of pre-ovulatory follicles (> 7 mm) and received at most two additional inseminations at 12 h intervals as long as they showed signs of estrus. No female in any treatment received more than three inseminations. The occurrence of semen backflow or bleeding during the AI was recorded. Intracervical AI was conducted with Melrose-type pipettes, whereas IUAI was conducted with two types of commercially-available intrauterine catheters (Magaplus®, Magapor S.L., Zaragosa, Spain; and Fada®, Fada Plásticos, Canoas-RS, Brazil).

Farrowing rate was defined as the percent of inseminated females that farrowed (Wilson *et al*., 1986; Dial *et al*., 1992). Data regarding total litter size were extracted from the farm's information management system (PigWIN®, Farmwise Systems Inc., Little Canada, MN, USA). Logistic regression was used to test for the effects of parity, method of ovulation estimation, AI method, and occurrence of semen backflow and bleeding on farrowing rate. The probability of failure to farrow was estimated by odds ratio. As there was a significant interaction between parity and AI method, both individual factors were dropped from the final model. For comparisons among interaction terms, the reference level included P3+ females that received CAI, following the assumption that such a combination of factors would incur a low probability of failure to farrow. Chi-square tests were used to test whether the frequency of semen backflow and bleeding during AI differed among females receiving either CAI or IUAI.

Analysis of variance (ANOVA) was used to compare WEI, estrus duration, and weaning-to-ovulation and estrus-to-ovulation intervals across parities. The weaning-to-ovulation and estrus-to-ovulation intervals were also compared according to AI method, but only for females submitted to ovulation diagnosis by ultrasound. Analysis of variance was also used to evaluate the association of total litter size with the same independent variables mentioned above, along with potential interactions. Comparisons of means were conducted using the LSD method. All analyses were conducted with the Statistix® software (Statistix, 2003).

Results

A total of 338 females, having a mean parity of 3.5 ± 1.7 and mean lactation length of 20.3 ± 2 d, were inseminated. Among those females, 18% were P1, 15.4% were P2, and 66.6% were P3+. Ovulation was detected in all females submitted to ultrasound-guided diagnosis. The mean weaning-to-ovulation interval was 146.6 ± 20.8 h, whereas the mean estrus-to-ovulation interval was 51.2 ± 12.8 h. Neither interval differed (P > 0.05) in females allocated to different AI methods (Table 1). Mean WEI was 103.5 ± 30.4 h, and mean estrus duration was 57.1 ± 13.3 h. As shown in Table 2, P1 females presented a longer WEI than higher-parity sows (P < 0.0001). The weaning-to-ovulation interval was longer for P1 and P2 females than for P3+ females (P = 0.03). No effect of parity was observed for estrus duration or the estrus-to-ovulation interval (P > 0.05).

Artificial inseminations were conducted with 139 doses from one semen pool and 132 from the other pool. The effect of semen pool, initially tested in both logistic regression and ANOVA models, was subsequently excluded because it was not significant. The effect of IUAI device was also excluded due to lack of significance. Among all females, 28.4% received CAI and 71.6% received IUAI. Considering the number of inseminations during estrus, 1.8% of the females received a single insemination, 27.8% received two inseminations, and 70.4% received three inseminations. While 93.5% of the females submitted to conventional estrus detection received three inseminations, 81.7% of the females submitted to ultrasound-guided ovulation diagnosis were inseminated at most twice.

Table 1. Weaning-to-ovulation and estrus-to-ovulation intervals by artificial insemination (AI) method in females having ovulation detected by real-time ultrasound*.

AI (x 10^9)[a]	n	Weaning-to-ovulation interval (h)	Estrus-to-ovulation interval (h)
CAI (3.5)[b]	17	157.8 ± 4.9	50.4 ± 3.1
IUAI (2.0)[c]	19	148.5 ± 4.6	47.8 ± 3.0
IUAI (1.0)	18	148.0 ± 4.7	49.2 ± 3.0
IUAI (0.5)	18	150.9 ± 4.7	54.5 ± 3.0

*Means ± SEM did not differ across groups (P > 0.05).
[a]Concentration of spermatozoa per dose.
[c,d]CAI: intracervical artificial insemination; IUAI: intrauterine artificial insemination.

Table 2. Weaning-to-estrus interval (WEI), estrus duration, weaning-to-ovulation interval (WOVI), and estrus-to-ovulation interval (EOVI) by parity.

Parity	n	WEI (h)	Estrus (h)*	n	WOVI (h)	EOVI (h)*
P1	61	126.9 ± 3,6[a]	53.9 ± 1.7	13	156.3 ± 6.1[c]	47.7 ± 3.9
P2	52	99.7 ± 3.9[b]	56.7 ± 1.8	13	155.4 ± 5.6[c]	51.8 ± 3.8
P3+	221	96.4 ± 1.9[b]	57.9 ± 0.9	48	142.2 ± 2.9[d]	51.8 ± 1.9

[a,b] Means ± SEM within columns having different superscripts differ across parities (P < 0.001).
[c,d] Means ± SEM within columns having different superscripts differ across parities (P ≤ 0.03).
*Means ± SEM did not differ across parities (P > 0.05).

Mean farrowing rate was 83.5%. Farrowing rates by AI method and parity are shown in Table 3. The logistic regression analysis (Table 4) indicated that the probability of failure to farrow was not influenced by the occurrence of semen backflow, and bleeding during AI, or by the method of ovulation diagnosis (P > 0.05). Semen backflow was observed in 69 inseminations (20.7% of the total), with 23 occurring with CAI and 46 with IUAI (P = 0.31). Farrowing rates for females that did or did not present semen backflow during AI were 79.7% and 84.5%, respectively. Bleeding during AI was observed in only 22 females (6.6% of the total), including 4 that received CAI and 18 that received IUAI (P = 0.27). Only two of the females that bled during AI were P1. Farrowing rates for females bleeding or not during AI were 81.8% and 83.7%, respectively. Mean farrowing rate was 86.1% for females submitted to conventional estrus detection and 83.7% for females submitted to ovulation diagnosis by ultrasound.

In comparison with P3+ sows receiving CAI (Table 4), the probability of failure to farrow was 14 times greater in P2 females receiving IUAI with 2 x 10^9 spermatozoa per dose (P ≤ 0.03) and 23 times greater in P1 females receiving IUAI with 2 x 10^9 spermatozoa per dose

($P \leq 0.007$). Among females receiving IUAI with 1 x 10^9 spermatozoa per dose, only P2 females presented a greater probability of failure to farrow than the reference level ($P \leq 0.03$). For females receiving IUAI with 0.5 x 10^9 spermatozoa per dose, probability of failure to farrow was greater in P2 and P3+ than in P1 females ($P < 0.01$).

Mean total litter size was 11.1 ± 3.5. Total litter size of females submitted to conventional estrus detection (10.6 ± 0.5) did not differ ($P = 0.22$) from that of those submitted to ultrasound-guided ovulation diagnosis (11.2 ± 0.6). The occurrence or not of semen backflow did not influence ($P = 0.42$) total litter size (10.7 ± 0.3 and 11.1 ± 0.5, respectively). In females presenting bleeding during AI, total litter size was 11.2 ± 0.8, which did not differ ($P = 0.51$) from that observed for those without bleeding during AI (10.6 ± 0.3).

Total litter size for CAI did not differ ($P = 0.11$) from that observed for IUAI with any of the tested concentrations of spermatozoa (Table 5). However, total litter size was reduced ($P < 0.0001$) in P1 females in comparison with higher-parity females (Table 5). Additionally, there was a significant interaction between AI method and parity ($P \leq 0.001$) indicating that total litter size was reduced with IUAI in P1 females with any concentrations of spermatozoa and in P2 females with 2 x 10^9 spermatozoa per dose (Table 5).

Table 3. Farrowing rate by artificial insemination (AI) method and spermatozoa concentration and parity*.

Parity	AI method (spermatozoa concentration; x 10^9)				Total
	CAI (3.5)	IUAI (2.0)	IUAI (1.0)	IUAI (0.5)	
P1	92.0 (23)	71.4 (10)	75.0 (6)	84.6 (11)	83.3 (60)
P2	100.0 (11)	71.4 (10)	75.0 (12)	72.7 (8)	78.8 (52)
P3+	93.2 (55)	85.5 (47)	86.8 (46)	72.7 (40)	84.7 (222)
Total	93.7 (95)	80.7 (83)	83.1 (77)	74.7 (79)	83.5 (334)

*CAI: intracervical AI; IUAI: intrauterine AI.

Table 4. Logistic regression model for farrowing rate.

Predictor	Level	Odds ratio	95% CI	P
Semen backflow	No	-	-	-
	Yes	1.6	0.7-3.9	0.2544
Bleeding	No	-	-	-
	Yes	1.3	0.4-4.5	0.6344
Ovulation	Ultrasound	-	-	-
	Estrus detection	0.7	0.3-1.5	0.3742
AI method-parity *	3.5 CAI*P3+	-	-	-
	3.5 CAI*P2	0.001	0.0001-694.0	0.7982
	3.5 CAI*P1	2.1	0.1-36.3	0.5948
	2.0 IUAI*P3+	6.9	0.8-59.8	0.0780
	2.0 IUAI*P2	14.2	1.3-150.9	0.0279
	2.0 IUAI*P1	23.6	2.4-235.2	0.0071
	1.0 IUAI*P3+	7.15	0.83-61.7	0.0736
	1.0 IUAI*P2	13.8	1.3-144.2	0.0284
	1.0 IUAI*P1	8.45	0.5-163.1	0.1487
	0.5 IUAI*P3+	16.9	2.1-135.7	0.0079
	0.5 IUAI*P2	20.0	1.8-219.2	0.0142
	0.5 IUAI*P1	0.003	0.001-553.0	0.7781

*Model Deviance: 214.83; Model degrees of freedom: 319; Model P-value: 1.000.
AI: artificial insemination; CAI: intracervical AI; IUAI: intrauterine AI.

Table 5. Total litter size by artificial insemination (AI) method and parity.

Parity	Artificial insemination method (x 10^9)				Total
	CAI (3.5)	IUAI (2.0)	IUAI (1.0)	IUAI (0.5)	
P1	11.5 ± 0.8^{ab} (23)	8.7 ± 1.1^{c} (10)	8.8 ± 1.4^{c} (6)	7.6 ± 1.1^{c} (11)	9.1 ± 0.6^{A} (50)
P2	12.7 ± 1.1^{a} (11)	9.6 ± 1.1^{c} (10)	12.9 ± 1.1^{a} (12)	11.9 ± 1.2^{ab} (8)	11.8 ± 0.7^{B} (41)
P3+	11.2 ± 0.6^{bc} (55)	12.7 ± 0.6^{a} (47)	11.3 ± 0.6^{ab} (46)	11.6 ± 0.6^{ab} (40)	11.7 ± 0.4^{B} (188)
Total*	11.8 ± 0.6 (89)	10.3 ± 0.6 (67)	11.0 ± 0.7 (64)	10.4 ± 0.7 (59)	11.2 ± 3.5 (279)

CAI: intracervical AI; IUAI: intrauterine AI
^{a,b,c}Means ± SEM having different superscripts differ for parity-AI method combinations by at least $P < 0.05$.
^{A,B}Means ± SEM having different superscripts differ across parities by at least $P < 0.0005$.
*Means ± SEM do not differ across AI methods ($P < 0.05$).

Discussion

To our knowledge, this is the first study to report detrimental effects of IUAI on reproductive performance in P1 females under field conditions, since most studies did not include P1 females (Watson and Behan, 2002; Dallanora *et al.*, 2003; Bennemann *et al.*, 2004; Mezalira *et al.*, 2005; Roberts and Bilkei, 2005). Rozeboom *et al.* (2004) evaluated IUAI in P1 females, but no effect of parity was reported. In P1 females receiving IUAI, total litter size was reduced, regardless of the concentration of spermatozoa used, and the probability of failure to farrow was higher with 2 x 10^9 spermatozoa per dose. Watson and Behan (2002) implied that resistance in passing the catheter through the cervix and the presence of either a lesion in the cervix or bleeding during AI could lead to suboptimal performance. Such situations could occur more often in gilts and P1 females since they might not have undergone total physical development of the reproductive tract, which is partially supported by the statement that IUAI could not be performed consistently in gilts (Rozeboom *et al.*, 2004). The present study did not evaluate gilts, but only two P1 females showed bleeding during AI, and both farrowing rate and litter size did not differ in females that did or did not bleed during AI. The percent of inseminations presenting bleeding and the lack of significance of this effect on farrowing rate and litter size are consistent with the findings of Rozeboom *et al.* (2004).

Parity-1 females from the present experiment had a longer WEI than that observed for higher-parity females by nearly one day, as reported elsewhere (Xue *et al.*, 1992). The mean duration of estrus observed in this study is consistent with other studies (Weitze *et al.*, 1994; Kemp and Soede, 1996; Nissen *et al.*, 1997; Bracken *et al.*, 2003) although no differences were observed across parities, as reported by Lucia *et al.* (1999). Thus, among the females submitted to conventional estrus detection, which were all first inseminated 12 h after estrus detection, P1 females could have ovulated earlier after onset of estrus and thus likely needed to have been inseminated earlier (Kemp and Soede, 1996). The mean estrus-to-ovulation interval reported in Table 2 refers only to a smaller sample of females for whom ovulations were detected by ultrasound and the first AI was conducted immediately after ovulation diagnosis. It is possible that, in females receiving more than one AI, at least one of the subsequent inseminations may have been performed after the ovulation, which may have resulted in uterine inflammatory processes and loss of spermatozoa that could have led to a reduction in reproductive performance (Rozeboom *et al.*, 1997; 1999; Kaeoket *et al*, 2005). On the other hand, less than 20% of the females submitted to ultrasound-guided ovulation detection received three inseminations. Among those inseminated with 0.5 x 10^9 spermatozoa per dose, the lower number of inseminations per estrus combined with the lowest concentration of spermatozoa may have influenced their undesirable reproductive performance. However, the method used to estimate the time of ovulation did not influence farrowing rate and litter size, either directly or through interactions with other variables.

Parity-2 females receiving IUAI had an increased probability of failure to farrow, regardless of the concentration of spermatozoa used, and had a reduced litter size with 2 x 10^9 spermatozoa per dose. Those results may have been due to the fact that the sample size for this category was the lowest across parities, which might reflect the fact that the herd's parity distribution was skewed towards older parities during the period of data collection. Despite this, the mean parity for this herd (3.5) is consistent with industry standards (Dial *et al.*, 1992). Additionally, using the lowest concentration of spermatozoa for IUAI, probability of failure to farrow was higher for females having 2 or more parities although no negative effect of AI method was observed on their total litter size. These results could be a consequence of the reduced concentration of spermatozoa since the total litter size for P1 females with this concentration was also reduced. The 100% farrowing rate observed for P2 females that received CAI with 3.5 x 10^9 spermatozoa per dose should not be overemphasized, since such a rate probably occurred randomly for a small number of females, as suggested by the large confidence intervals observed for that category in the logistic regression analysis. Mezalira *et al.* (2005) mentioned that farrowing rates would be reduced using concentrations as low as 0.25 x 10^9 spermatozoa per dose, but, in that study, such an effect was not observed when using 0.5 x 10^9 spermatozoa per dose and no effect of parity was reported either.

In this study, only CAI resulted in farrowing rates within the target rates desirable for commercial farms (Wilson *et al.*, 1986; Dial *et al.*, 1992), Even though farrowing rates for IUAI with 2.0 and 1.0 x 10^9 spermatozoa per dose were very close to the acceptable target, the rates obtained with 0.5 x 10^9 spermatozoa per dose would make this technique unfeasible under routine farm conditions. No differences in farrowing rates between CAI and IUAI with concentrations as low as 1.0 x 10^9 spermatozoa per dose were reported by Watson and Behan (2002). Dallanora *et al.* (2003) described similar results, but using IUAI with only 1.5 x 10^9 spermatozoa per dose. In one field trial (Roberts and Bilkei, 2005), IUAI with 1.0 x 10^9 spermatozoa per dose resulted in farrowing rate similar to that obtained with CAI, but in other field study, farrowing rate with IUAI decreased with 0.5 x 10^9 spermatozoa per dose (Rozeboom *et al.*, 2004). In studies considering only comparisons among different concentrations of spermatozoa used in IUAI, farrowing

rates were similar up to 1 x 10^9 spermatozoa per dose (Bennemann *et al.*, 2004) or when comparing 1, 0.5, and 0.25 x 10^9 spermatozoa per dose (Mezalira *et al.*, 2005). The farrowing rate for the lowest concentration of spermatozoa used in this last study mentioned was four percent lower than that obtained with 0.5 x 10^9 spermatozoa per dose used in the present study. The large numerical difference observed across AI methods (at least 10%) suggests that results with CAI would be generally better than for IUAI. However, it is important to consider that the farrowing rate observed with CAI was close to 94%, which is higher than normal farm standards.

Differences in litter size across AI methods were not significant even though litter size for CAI was at least 0.8 pigs greater than for IUAI. Since all females were from the same genetics, such a difference may be considered important in the field. No differences in total litter size for those AI methods were also reported elsewhere (Watson and Behan, 2002; Dallanora *et al*., 2003), evaluating concentrations of 0.5 x 10^9 spermatozoa per dose. However, such a concentration was associated with reduction in litter size in two field trials (Rozeboom *et al.*, 2004; Roberts and Bilkei, 2005). Considering only IUAI, one study reported no difference in the number of embryos in the uterus of slaughtered females when concentrations between 2 and 1 x 10^9 spermatozoa per dose were used (Bennemann *et al.*, 2004). However, Mezalira *et al.* (2005) described that the number of embryos did not differ using concentrations of 1 and 0.5 x 10^9 spermatozoa per dose with IUAI, but observed a significant reduction with concentrations of 0.25 x 10^9 spermatozoa per dose.

The percent of semen backflow observed in this study is consistent with the levels reported in other studies that used IUAI (Dallanora *et al*., 2003; Mezalira *et al.*, 2005). This percent did not differ between CAI and IUAI and did not influence either farrowing rate or litter size, as stated by Dallanora *et al.* (2004). Thus, semen backflow is apparently a common event in AI in swine that does not depend on the site of semen deposition and is not related to a reduction in reproductive performance (Steverink *et al.*, 1998; Rath, 2002).

In conclusion, in comparison with CAI, IUAI was associated with higher probability of failure to farrow with concentrations of 0.5 x 10^9 spermatozoa per dose in females having had two or more parities. Additionally, IUAI was associated with reduced litter size in P1 females with any of the tested concentrations of spermatozoa. These findings suggests that the intra-uterine technique may be used for AI, but its use under routine field conditions still requires adjustments related to female parity, determination of the optimal concentration of spermatozoa per dose, preparation of the doses, and training of farm staff.

References

Bennemann PE, Milbradt E, Diehl GN, Weber D, Schmidt ACT, Bernardi ML, Wentz I, Bortolozzo, FP. 2004. Reproductive performance of sows submitted to intrauterine insemination at different pre-ovulatory intervals. *Anim Reprod*, 1:106-110.

Bracken CJ, Safranski TJ, Cantley TC, Lucy MC, Lamberson WR. 2003. Effect of time of ovulation and sperm concentration on fertilization rate in gilts. *Theriogenology*, 60:669-676.

Corrêa MN, Lucia T Jr, Afonso JAB, Deschamps JC. 2002. Reproductive performance of early-weaned female swine according to their estrus profile and artificial insemination frequency. *Theriogenology*, 58:103-112.

Dallanora D, Mezalira A, Katzer LH, Bernardi ML, Bortolozzo FP, Wentz I. 2003. Intrauterine insemination with reduced sperm number on a commercial pig farm. *In*: Proceedings of the 5th International Conference on Boar Semen Preservation, Doorwerth, The Netherlands. Doorwerth: The Conference. pp.50. (Program and abstract book Session IV).

Dallanora D, Mezalira A, Katzer LH, Bernardi ML, Bortolozzo FP, Wentz I. 2004. Volume and sperm number in the semen backflow after intrauterine and cervical insemination in sows. *In*: Abstracts of the 15th International Congress on Animal Reproduction, Porto Seguro, Brazil. Belo Horizonte, Brazil: CBRA. pp.387.

Dial GD, Marsh WE, Polson DD, Vaillancourt J-P. 1992. Reproductive failure: differential diagnosis. *In*: Leman AD, Straw BE, Mengeling WL, D'Allaire S, Taylor DJ. (Ed.). *Diseases of swine*. 7th ed. Ames, IA: Iowa State University Press. p.88-137.

Kemp B, Soede NM. 1996. Relationship of weaning-to-estrus interval to timing of ovulation and fertilization in sows. *J Anim Sci*, 74:944-949.

Kaeoket K, Tantasuparuk W, Kunavongkrit A. 2005. The effect of post-ovulatory insemination on the subsequent embryonic loss, oestrous cycle length and vaginal discharge in sows. *Reprod Dom Anim*, 40:492-494.

Lucia T Jr, Corrêa MN, Deschamps JC, Peruzzo IA, Matheus JEM, Aleixo JAG. 1999. Influence of equine chorionic gonadotropin on weaning-to-estrus interval and estrus duration in early-weaned, primiparous, female swine. *J Anim Sci*, 77:3163-3167.

Mezalira A, Dallanora D, Bernardi ML, Wentz I, Bortolozzo FP. 2005. Influence of sperm cell dose and post-insemination backflow on reproductive performance of intrauterine inseminated sows. *Reprod Dom Anim*, 40:1-5.

National Research Council. 1998. *Nutrient requirements of swine*. 10th ed. Washington, DC: National Academy Press.

Nissen AK, Soede NM, Hyttel P, Schmidt M, D'Hoore L. 1997. The influence of time of

insemination relative to time of ovulation on farrowing frequency and litter size in sows, as investigated by ultrasonography. *Theriogenology*, 47:1571-1582.

Pursel VG, Johnson LA. 1975. Freezing of boar spermatozoa: fertilizing capacity with concentrated semen and a new thawing procedure. *J Anim Sci*, 40:99-102.

Rath D. 2002. Low dose insemination in the sow: a review. *Reprod Dom Anim*, 37:201-205.

Roberts PK, Bilkei G. 2005. Field experiences on post-cervical artificial insemination in the sow. *Reprod Dom Anim*, 40:489-491.

Rozeboom KJ, Reicks DL, Wilson ME. 2004. The reproductive performance and factors affecting on-farm application of low-dose intrauterine deposit of semen in sows. *J Anim Sci*, 82:2164–2168.

Rozeboom KJ, Troedsson MHT, Molitor TW, Crabo BG. 1999. The effect of spermatozoa and seminal plasma on leukocyte migration into the uterus of gilts. *J Anim Sci*, 77:22201-2206.

Rozeboom KJ, Troedsson MHT, Shurson GC, Hawton JD, Crabo BG. 1997. Late estrus and metestrus insemination after estrual inseminations decreases farrowing rate and litter size in swine. *J Anim Sci*, 75:2323-2327.

Statistix®. 2003. Statistix® 8 analytical software. Tallahassee, FL: Analatical Software.

Soede NM, Wetzels CCH, Kemp B. 1996. Optimal interval between insemination and ovulation in sows, as judged by fertilization rate and accessory sperm count of day 5 embryos. *Reprod Dom Anim*, 31:295-296.

Steverink DWB, Soede NM, Bouwman EG, Kemp B. 1998. Semen backflow after insemination and its effect on fertilization results in sows. *Anim Reprod Sci*, 54:109-119.

Watson PF, Behan JR. 2002. Intrauterine insemination of sows with reduced sperm numbers: results of a commercially-based field trial. *Theriogenology*, 57:1683-1693.

Weitze KF, Wagner-Rietschel H, Waberski D, Richter L, Krieter J. 1994. The onset of heat after weaning, heat duration, and ovulation as major factors in AI timing in sows. *Reprod Dom Anim*, 29:433-443.

Wilson MR, Friendship RM, Mcmillan I, Hacker RR, Pieper R, Swaminathan S. 1986. A survey of productivity and its component interrelationship in Canadian swine herds. *J Anim Sci*, 62:576-582.

Xue JL, Dial GD, Marsh WE, Davies PR, Momont HW. 1992. Influence of lactation length on sow productivity. *Liv Prod Sci*, 34:253-265.

Xue JL, Dial GD, Trigg T, Davies PR, King VL. 1998a. Influence of mating frequency on sow reproductive performance. *J Anim Sci*, 76:2962-2966.

Xue JL, Lucia T, Koketsu Y, Dial GD, Marsh WE. 1998b. Influence of mating frequency and weaning-to-mating interval on sow reproductive performance**.** *Swine Health Prod*, 6:157-162.