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Effect of oxytocin treatment on the reproductive performance of sows after artificial insemination with liquid semen

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Abstract: This study was designed to evaluate the effect of oxytocin treatment at the time of insemination on fertility and prolificacy of sows during the summer season (July and September). The study included 107 Polish Large White × Polish Landrace sows divided into 3 groups: C, control (without oxytocin); I, experimental (5 IU oxytocin administrated intramuscularly per sow, 2 min before insemination); and II, experimental (5 IU of oxytocin added into a 100-mL seminal dose, at the time of insemination). Semen was collected from 11 boars: 2 Polish Large White, 5 Polish Landrace, and 4 Duroc × Pietrain. The highest farrowing rate was obtained in group II at 94.4%. Compared with groups C at 63.9% and I at 71.43%, the demonstrated differences were statistically significant ($P \leq 0.01$). The interaction between oxytocin and the breed of boar was also demonstrated. The highest significant differences were observed for Polish Landrace boars semen from group II compared with that of group C ($P \leq 0.05$), regardless of the insemination month. Application of oxytocin for artificial insemination did not affect the number and weight of piglets born. In conclusion, addition of oxytocin to seminal doses improved the farrowing rate after artificial insemination during the summer season.

Key words: Pig, reproduction performance, summer season, oxytocin

1. Introduction

Pigs belong to the group of polyestrous animals with spontaneous ovulation. Unfortunately, they are also characterized by seasonal variation that may interfere with the continuity of the production of piglets, especially in the summer and early autumn (1–4). Pig crossing programs are important to improve the profitability of reproduction performance (5,6). The decline in production at this period of the year is estimated to be between 10% and 25% (7). Changes in temperature and daylight length were indicators for the wild ancestors of the domestic pig. The wild boar (*Sus scrofa*) belongs to the group of periodically polyestrous animals with estrus occurring in late autumn and early winter. Fertilization is determined not only by the numbers of deposited spermatozoa but also by the time of insemination (8). Uterine contractions play a specific role in the transport of sperm, since they accelerate the arrival of spermatozoa at their destination (9). The problem of seasonal infertility in pigs is observed especially, but not only, in moderate climates (1). Research projects on the addition of hormones to semen during summer infertility come from the last decade (10–14). They mainly focus on using progestagens, gonadotropins, oxytocin, and prostaglandin and its derivatives. Parallel studies have also been conducted on boar synthetic seminal plasma, which has led to the stimulation of the genital tract of sows and gilts (15,16). It contains substances, such as glucose, potassium chloride, potassium phosphate, magnesium acetate, sodium acetate, and hypotaurine.

Oxytocin as a neurotransmitter is released from the hypothalamus via stimulation of the mechanical impulse on the lactic gland, pressing the fetus on the cervical end or the mechanoreceptors of the vagina during copulation. The main purpose of oxytocin is contraction of the smooth muscle during parturition and copulation. Progesterone and stress factors (also heat stress) block the release of oxytocin. Oxytocin is sometimes regarded as one of the factors influencing the standing reflex and the process of fertilization of sows (13). Strong sexual stimulation of sows results in an increased secretion of oxytocin, prolactin, and luteinizing hormone. In Europe, studies on the addition of oxytocin were initiated in the 1970s. The results were related to breeding material with limited production.

The aim of this study was to examine the effect of oxytocin as semen supplement or after intramuscular administration in sows at the time of insemination during the summer season on their reproductive performance.

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2. Materials and methods

The research material consisted of 107 Polish Large White × Polish Landrace (PLW × PL) sows, including 28 primiparous and 79 multiparous ones. The experiment was conducted twice during the summer season: in July (59 sows) and September (48 sows). Average air temperatures during the day were 26.3 °C (6–13 July) and 21.3 °C (8–14 September). Indications of heat were detected in the presence of a boar (visual and olfactory contact) twice a day, starting on the fourth day after weaning. Experimental groups were formed randomly from sows showing their first estrus at a regular interval of 4–8 days after weaning. Sows were divided into 3 groups:

1) C- Control group (36 sows): sows were inseminated without oxytocin treatment.
2) I- Experimental group (35 sows): 0.5 mL of oxytocin (5 IU, Oxytocinum 10 IU, Vet Agro) was administered to sows via intramuscular injection 2 min before insemination. Injection was performed using the platysma by sterile syringe.
3) II- Experimental group (36 sows): sows were inseminated with 100 mL of semen doses to which 0.5 mL of oxytocin (5 IU, Oxytocinum 10 IU, Vet Agro) was added just before insemination. These seminal doses were given after shaking.

Parity among sows in all groups was similar (from 1 to 8). The average parities were (mean ± SEM) 3.31 ± 1.95 for the control group (C), 3.40 ± 2.13 for group I, and 2.81 ± 1.94 for group II.

Sows were inseminated with sperm collected from 11 boars: 2 Polish Large White (PLW) boars (22 sows), 5 Polish Landrace (PL) boars (32 sows), and 4 Duroc × Pietrain (D × P) boars (53 sows). Ejaculates were assessed by volume and concentration of spermatozoa (SpermaCue, Minitube) (Table 1). The concentration of spermatozoa for insemination was 3.5×10^9 per 100-mL dose. Semen

Table 1. Characteristics of ejaculates used in the experiment.

Breed of boar	ID of boar	Date of collection of ejaculate	Volume of semen (mL)	Concentration of spermatozoa (millions/mL)	Number of seminal doses
July					
D × P	267	10.07	122	422	14
	268	11.07	262	398	28
	269	12.07	277	335	26
PL	128	7.07	200	422	24
	124	9.07	195	394	22
	127	11.07	313	352	30
PLW	66	9.07	344	217	22
	64	10.07	179	341	16
	66	12.07	463	178	22
September					
D × P	266	10.09	269	411	30
	269	12.09	298	361	30
PL	128	10.09	180	430	22
	123	12.09	319	326	26
	127	13.09	231	293	16
	129	14.09	197	337	20
PLW	66	10.09	326	259	24
	64	12.09	348	345	30
	66	14.09	452	203	26

was diluted in a seminal diluent BTS boar semen extender (Minitube). Sows were inseminated with fresh semen or semen stored at 15 °C for 48 h. Safe Blue Clear Glide catheters (Minitube) were used for standard insemination. Before insemination, seminal doses were warmed to a temperature of 35 °C. Insemination was repeated after 24 h.

Postweaning sows (28 days) were kept in individual pens and they stayed there for 1 month after insemination. Afterwards, the sows were kept in group housing (8–10 sows) with a covered short walk outside. A week before the end of gestation, sows were moved into farrowing pens. Until the 90th day of gestation sows received LP feed mixtures, and after 90 days and farrowing they received LK feed mixtures. Boars received special feed mixtures. Animals were fed according to Polish Swine Nutrition Requirements (17).

A pregnancy diagnostic test was conducted twice during the period from 28 to 35 days after insemination using ultrasound (USG DRAMINSKI, SonoFarm profi). Evaluation of litters was made directly after complete parturition. The weight of each piglet born live was measured using an electronic scale.

The results were presented as percentages or arithmetic means and standard errors. The fecundity index was calculated per 100 sows as follows: farrowing rate × 100 × number of piglets born live per litter. The collected results of the study were analyzed statistically using StatSoft STATISTICA version 9. Comparison between means was performed using Duncan's multiple range test. Fertility and return to estrus were analyzed using Pearson's chi-square test. Levels of significance were set as follows: significant $0.01 < P \leq 0.05$, and highly significant $P \leq 0.01$.

3. Results

Table 2 shows the results of the effectiveness of varied inseminations, resulting in 2 separate periods of insemination. In July, group II achieved the highest farrowing rate (95%). Differences compared with group

Table 2. Results of the reproductive performance of sows (mean ± SD).

Item	Group		
	Control	I	II
July			
No. of sows (heads)	20	19	20
Farrowing rate (%)	55.0^{B}	68.42^{b}	95.0^{Aa}
No. of piglets born live per litter (heads)	11.10 ± 2.28	9.54 ± 2.60	11.16 ± 1.68
Piglet weight (kg)	1.59 ± 0.24	1.58 ± 0.27	1.62 ± 0.19
Fecundity index (heads)	611	653	1060
September			
No. of sows (heads)	16	16	16
Farrowing rate (%)	75.0	75.0	93.75
No. of piglets born live per litter (heads)	11.42 ± 1.16	12.08 ± 1.62	10.66 ± 1.72
Piglet weight (kg)	1.55 ± 0.11	1.59 ± 0.16	1.63 ± 0.11
Fecundity index (heads)	857	906	999
Total			
No. of sows (heads)	36	35	36
Farrowing rate (%)	63.9^{B}	71.43^{B}	94.4^{A}
No. of piglets born live per litter (heads)	11.27 ± 1.72	10.76 ± 2.50	10.94 ± 1.69
Piglet weight (kg)	1.57 ± 0.18	1.59 ± 0.22	1.62 ± 0.16
Fecundity index (heads)	720	769	1033

$^{a, b}$: values in the same rows show significant differences between groups at $P \leq 0.05$.
$^{A, B}$: values in the same rows show significant differences between groups at $P \leq 0.01$.

C (55%) and I (68.42%) were statistically significant ($P \leq 0.01$ and $P \leq 0.05$). In September identical group farrowing rates (75%) were observed for groups C and I. This was nonsignificantly lower (by 18.75%) than that obtained in group II (93.75%). For the whole experiment a significantly higher ($P \leq 0.01$) farrowing rate was demonstrated in group II when compared to groups C and I. The number of piglets born live per litter ranged from 9.54 to 12.08, values observed for group I (July and September). The control group in September was characterized by the lowest average piglet weight (1.55 kg), while the highest was achieved by group II in September (1.63 kg).

The activity of oxytocin was also determined by parity (Table 3). Addition of oxytocin to seminal doses (group II) regardless of parity resulted in a high farrowing rate, reaching even 100% as compared to 60% in the control group. Significant differences in farrowing rate ($P \leq 0.05$) were demonstrated between group II and the others (C and I). An exception were the sows of second parity treated with oxytocin intramuscularly (83.3%). A nonsignificant increase in the weight of piglets in primiparous sows after second parity was observed in the experimental groups (1.69 and 1.7 kg) compared to group C (1.57 kg). The highest fecundity index per 100 sows was observed in group II (1075 and 1013, parity 2 and 3+, respectively), while the lowest was noticed in group C (640, parity 2). Injection of oxytocin for sows of 3+ parity resulted in achieving a very low fecundity index per 100 sows (728).

The influence of boar breed on the farrowing rate was also analyzed (Figure 1). The highest significant differences (by 50%) were observed for PL boar semen from group II compared to the control group ($P \leq 0.05$), regardless of the month. For the remaining 2 breeds, the differences were nonsignificant. A lower value (by 32.7%) was reported for sows from group C in July (63.7%) than from group II in July (100%) when inseminated by D × P boar semen. The lowest farrowing rate in the experimental groups was characteristic for sows inseminated by PLW boars. Maximal results were obtained in September (group II, 87%) and minimal in July (group I, 58.3%).

Sows were divided on the basis of weaning to estrus time (Figure 2). The best reaction to experimental factors (100%) was observed for sows from group II in July and September with estrus after 6–8 days postweaning. It was noticed that higher farrowing rates (about 5%) were reached for groups C and I with a short weaning to estrus time (4–5 days).

4. Discussion

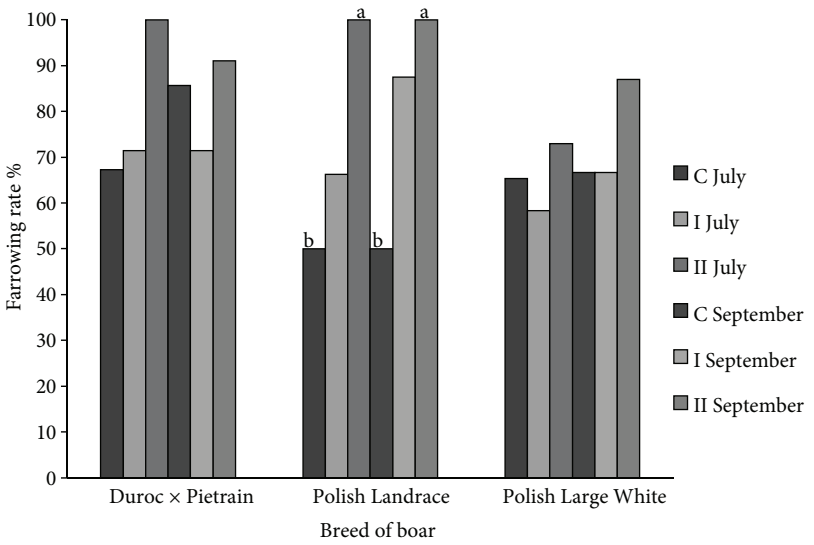
Sows used in the current experiment demonstrated various reactions to the experimental factor, which was oxytocin, as well as the method of its administration during the insemination. Farrowing rate values in the control group were the lowest in both periods. Oxytocin in the seminal dose probably acted in 2 ways. First, it could have had a positive impact on the movement speed of the spermatozoa, which was confirmed earlier in a study by Watson et al. (18). Thackare et al. (19) also explained that paracrine action manifests itself in the stimulation of contractility of the tubuli seminiferi, epididymis, and prostate in males. On the other hand, oxytocin administered with a seminal dose stimulated the smooth uterine muscles to action (20). Another study conducted by Langendijk et al. (13) demonstrated that intravenous or intramuscular administration of oxytocin during estrus affects the amplitude and frequencies of uterus muscle movements, especially in sows normally characterized by weaker activity of the uterus. This could explain the high farrowing rate in young females (2 parity) in our study.

Diluted insemination doses contain a lower amount of seminal plasma, and they consequently reduce the amount of estrogen. Estrogens increase synthesis of oxytocin and sensitize membrane receptors for this hormone in the central nervous system region responsible for sexual behavior. Positive correlations between the number of oxytocin receptors and the activity of the uterus, as well as

Table 3. Effect of parity on reproduction performance (mean ± SD).

Parity	2			3+		
Item	Control	I	II	Control	I	II
No. of sows (heads)	10	6	12	26	29	24
Farrowing rate (%)	60.0[b]	83.3	100[a]	65.4[b]	68.97[b]	91.7[a]
No. of piglets born live per litter(heads)	10.67 ± 2.42	11.6 ± 1.67	10.75 ± 2.22	11.5 ± 1.41	10.55 ± 2.67	11.05 ± 1.36
Piglet weight (kg)	1.57 ± 0.17	1.69 ± 0.18	1.70 ± 0.14	1.57 ± 0.19	1.56 ± 0.23	1.58 ± 0.16
Fecundity index (heads)	640	966	1075	752	728	1013

[a, b]: values in the same rows show significant differences between groups at $P \leq 0.05$.



a, b: values in the same month show significant differences between groups at $P \leq 0.05$.

Figure 1. Effect of boar breed on farrowing rate.

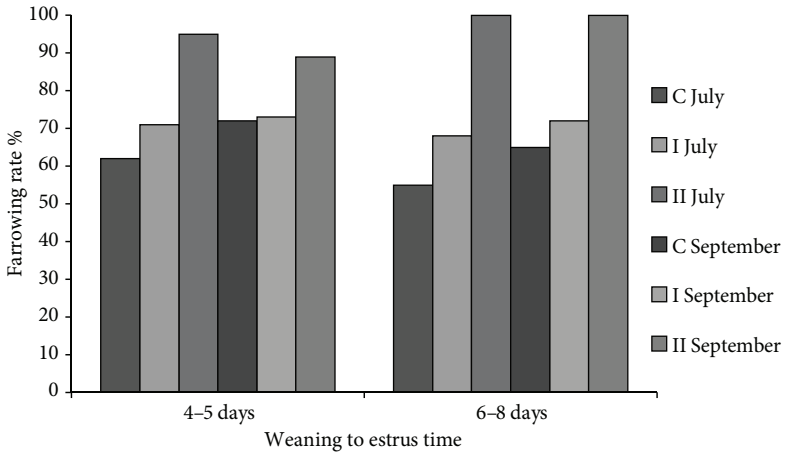


Figure 2. Farrowing rate depending on weaning to estrus time.

estrogen levels, were recorded by Okano and Okuda (21). Due to hormone addition, a higher level of myometrium activity was obtained, such as is not achieved normally in artificial insemination.

Stimulation of hypothalamus receptors in natural mating is followed by movements of the penis in the vagina and cervix. The copulation process lasts from 5 to 10 min (13). Oxytocin concentration in the blood of sows increases dramatically within 2 min of the onset of ejaculation by the boar (22). Increased sensitivity of the mucosa and endometrium results in easier and faster transport of spermatozoa to oviducts. The earlier arrival of spermatozoa and collection of the reservoir in the isthmus of the uterine tube affected the correct time of capacitating, successful fertilization of oocytes, and better embryo development (23). This probably resulted in a greater number of piglets born live in experimental group II compared to the control group (Table 3).

The results of our study can also be compared with those obtained by Pena et al. (10,12) during the summer season (sows were inseminated between July and September). The authors demonstrated significant differences ($P \leq 0.05$) in farrowing rates between the control group (54.39%) and sows inseminated with oxytocin in seminal doses (73.02%). A higher level of significant differences between groups ($P \leq 0.01$) was observed in this study. Using oxytocin for

intrauterine insemination is not obvious. Gibson et al. (14) noted the farrowing rate for a group with oxytocin addition at 70.3% and for the control at 69.4%.

The same farrowing rate was observed for groups C and I in September (Table 2). It is suggested that the end of the summer season resulted in a return to the normal function of the reproductive system of females. Heat stress was offset by optimal daily outdoor temperatures (21.3 °C). During high temperature stress, corticoids are over-released and inhibit estrus. Heat accumulation in pigs causes changes in metabolism, especially in individuals with high genetic potential (4). A question about the validity of using oxytocin in artificial insemination in other seasons was raised based on this thesis.

Differences in the average size of litters between experimental and control groups were not observed. This was also reported in another study conducted by Gibson et al. (14). However, Pena et al. (10,12) demonstrated an increased number of piglets born live ($P \leq 0.001$) during the summer season, from 8.53 in a control group to 10.77 in a group with oxytocin added to semen. It is suggested that the addition of some hormones to semen increased the number of fetuses (24). In contrast, Flowers (25) and Okrasa and Strzeżek (26) suggested that a higher number of fertilized cells results in less space for implantation and development of embryos. The present study showed that oxytocin has neither a positive nor a negative influence on litter size. In our experiment, piglet weight on the day of birth was measured. Results demonstrated only that the heaviest piglets (nonsignificant differences) were born in group II.

An interesting and new element not analyzed in earlier experiments was the verification of whether oxytocin action may depend on the breed of boar. It would suggest successful hormone effects on spermatozoa. The statistical analysis has demonstrated that there was a little interaction. Significant differences ($P \leq 0.05$) were observed only between groups C and II (Figure 1) and only for PL boars used in study. A growth tendency was noted for groups C, I, and II, regardless of the month. The addition of oxytocin to semen resulted in increasing farrowing rates. This type of research should be repeated using a greater number of animals.

The present study suggests that an addition of oxytocin (5 IU to 100 mL of seminal dose) just before artificial insemination gives positive results in terms of the reproduction performance of pigs during the summer season. Using oxytocin by intramuscular injection was not characterized by satisfactory effects. A correlation between oxytocin and the breed of boar was also demonstrated. The method showed in this paper could be used in breeding and production practice.

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