TECHNIQUES TO FINE-TUNE REPRODUCTION

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ABSTRACT

When an analysis of herd records indicates relatively good fertility, there may still be room for further improvements. Herd output can be measured as weaned pig production. However, while the average number of pigs weaned per week may be good, weekly production may not be consistent (e.g. +/- 10%). Fine-tuning reproduction may allow increases in pig production, or just improve consistency of production. This may be achieved by consistently meeting breeding targets, or by improvements in farrowing rate or litter size. This paper will examine the potential to fine-tune the control of estrus and breeding management to aid the achievement of maximum reproductive output.

INTRODUCTION

Techniques to fine-tune the reproductive performance of the sow-herd may be farm-specific, i.e. may work on one farm but not another. To make a decision concerning the use of a particular technique, and to determine why the technique may or may not work, an understanding of the biology of reproduction is necessary.

Before considering the implementation of any technique to improve herd fertility, knowledge of the sow herd's current performance is needed. This requires detailed records since if you cannot measure it, you cannot manage it. With knowledge of current performance, you can decide where improvements may be made. To this end, a decision as to desired performance levels is needed, which can be made in consultation with your veterinarian/farm consultant and/or by making comparisons with industry benchmarks.

Following a brief outline of the reproductive biology of pigs, this paper will focus on techniques to fine-tune performance. Specifically, the control of estrus and breeding management will be examined.

REPRODUCTIVE BIOLOGY

An understanding of the estrous cycle is essential before intervention is considered. In simple terms, the 21-day porcine estrous cycle is composed approximately of a 16-day luteal phase and a 5-day follicular phase (I have included a 2-day estrous period in the luteal phase).

- After ovulation, the remains of the ovarian follicles are luteinized to become the progesterone secreting corpora lutea (hence "luteal" phase).

- During the luteal phase, the corpora luteal production of progesterone limits gonadotrophin (LH and FSH) secretion and thus restricts follicular development to the medium follicle stage and prevents the onset of estrus.
- At about 12 to14 days of the luteal phase in the non-pregnant female, uterine production of prostaglandin $F_{2\alpha}$ (PGF) causes regression of corpora lutea and so terminates progesterone production.
- The removal of the progesterone block allows resumption of appropriate secretory patterns of the pituitary gonadotropins, which, in turn, allows ovarian follicular development to be completed (the follicular phase). In weaned sows, the 4 to 5-day wean-to-estrus interval is equivalent to the follicular phase.
- Renewed follicular development produces estrogen, ultimately resulting in behavioral estrus.

Approximately coincident with the onset of estrus there is a surge release of LH which causes a cascade of events within the follicle including a switch from estrogen to progesterone production and culminating with a new ovulation approximately 40 hours after the start of the LH surge.

If the female is successfully bred, embryonic estrogens are produced between about day 11 and 19 of pregnancy. These estrogens constitute the first and second signals for maternal recognition of pregnancy. Other factors are also involved (e.g. LH and PGE), but the net effect is that the PGF is secreted into the uterine lumen rather than into the blood. If the litter is lost after the start of embryonic estrogen production, the result is an irregular return to estrus (25 to 37 days) or possibly pseudopregnancy. Around the time of farrowing, fetal cortisol production initiates the hormonal changes that result in estrogen production, prostaglandin secretion to induce luteolysis, and piglet delivery.

CONTROL OF ESTRUS

Estrus Stimulation

The factor most affecting the predictability of weaner pig output is hitting breeding targets (Dial *et al.*, 1996). Each breeding group is composed primarily of sows having a normal return to estrus after weaning and replacement gilts. The ability to meet breeding targets therefore requires a predictable supply of service ready gilts which is best realized by having them achieve an early puberty. Two methods to stimulate an earlier pubertal estrus are boar exposure and injection of exogenous gonadotrophins.

Boar exposure is the most common practice for inducing early puberty. However, it is important to understand the difference between estrus *stimulation* and estrus *detection*. Adequate stimulation requires direct physical contact while detection may only need fenceline contact (although direct physical contact is better). To maximise efficacy of boar stimulation, follow the rules of boar contact (Kirkwood and Thacker, 1992; Hughes, 1997). The major rules are:

- Gilts must be old enough (ie. at least 150 days of age).
- Boars must be old enough (ie. at least 10 months of age).
- Gilts should be in physical contact with the boar for at least 15 minutes per day.

Fine-tuning boar exposure may involve:

- Taking gilts to the boar and not vice versa.
- Housing gilts at least one meter away from potential stimulus boars. Gilts housed adjacent to boars will be stimulated to an earlier puberty but the estrus detection rate declines. In the event of poor estrus detection management, the use of a separate detection-mating area (DMA) should be considered.
- Performing boar contact twice daily to improve the response.
- Rotating stimulus boars to minimize the potential impact of boars of low stimulus value.
- Ensuring that gilts are not crowded. Allow at least 1.5 m^2 per gilt to prevent delayed puberty and/or reduced estrus detection rates.

When boars are used to stimulate the achievement of the pubertal estrus but gilts are not bred, a regular return to estrus in 18 to 24 days can be expected. However, if the farm protocol is to delay breeding until third or fourth estrus, boar exposure should be allowed every 2 or 3 days to promote regular estrous cycles. In a 100-day test period, the number of estrous periods in boar-exposed gilts was about 5 but, in the absence of boar exposure, gilts averaged only about 3 estrous periods.

If boar exposure appears not to be effective (e.g. a seasonal effect), then a hormonal intervention strategy may be considered. Gonadotrophin treatment (eg. PG600®) is effective for the induction of estrus and ovulation in prepubertal gilts. When hormones are administered, research and clinical experience have demonstrated that up to 30% of treated gilts may ovulate without showing behavioral estrus (Tilton *et al.*, 1992) and about 30% of those having a behavioral estrus may fail to cycle normally (Kirkwood, 1999). Since predictability beyond the induced estrus is not good, gilts should be bred at the induced estrus. A recent study illustrates one outcome of breeding gilts at a gonadotrophin-induced estrus (Table 1).

Table 1. **Performance of gilts bred at a PG600®-induced or natural first estrus (lsm ± se).**

	Control	PG600	P
Service ready gilts, %	37.5	78.0	0.0001
Service age, d	192.6±6.2	185.9±1.7	0.02
Farrowing rate, %	88.6	74.4	0.01
Litter size (total)	9.7±0.3	9.4±0.3	NS

Kirkwood, 1999.

In sows, wean-to-estrus intervals greater than 5 days are associated with reduced farrowing rates and litter sizes (Wilson and Dewey, 1993; Steverink *et al.*, 1999). The reason for this is unclear but may involve poor synchrony between time of ovulation and time of breeding because these sows will be early ovulators (see below). Therefore, when records indicate a likelihood of frequently delayed estrus (e.g. seasonal or associated with primiparous sows) gonadotrophins can be used to induce a more prompt return to estrus. This hormone treatment will cause more sows to be late ovulators and so also may impact breeding management (see below).

Estrus synchronisation

Depending on how gilts are flowed into the breeding herd, it is possible that there will be a glut of service-ready gilts during one breeding week but too few in other weeks. The challenge is then to control estrus so as to move gilts into another breeding week. If the gilts are prepubertal, injection of PG600 may be effective. If gilts are known to be cyclic, the options for control are limited to breed-and-abort and the feeding of the orally active progestagen, allyl trenbolone (Regumate®). Note that, unlike cattle, a single injection of prostaglandin will not induce luteolysis before day 12 to 14 of the estrous cycle so is of limited value.

For breed-and-abort, the successful establishment of pregnancy results in the endogenous production of progesterone and so blockade of estrus until pregnancy is terminated. Pregnancy can be terminated at any time prior to term and the gilt or sow should return to estrus 5 to 6 days later (but may be as long as 10 days). However, at some stage during pregnancy a requirement for uterine involution will likely become an issue such that, while a female may return to estrus, incomplete uterine involution may limit subsequent litter size. Also, terminating pregnancy after 25 to 30 days may raise ethical and esthetic issues. If undertaken, terminate pregnancy 25 to 30 days post breeding with a split dose of prostaglandin (e.g. half dose intravulvally in the morning and again 6 to 8 hours later). Females returning 5 to 6 days later had normal fertility (Pressing *et al.*, 1987).

The feeding of Regumate is an effective means of controlling estrus (Foxcroft *et al.*, 1998). While being fed, Regumate does not prevent normal luteolysis but will maintain the block on estrus onset after luteolysis occurs. In effect, the luteal phase is being artificially prolonged. Ideally, gilts should be individually fed so that they consume at least 15 mg/d. While there is likely no problem with overdosing (except economic), underdosing Regumate (<13 mg/d) will likely cause cystic follicles (Davis *et al.*, 1979; Kraeling *et al.*, 1981). If fed appropriately, expect 90 to 95% of gilts to exhibit estrus on days 4 to 8 after last feeding (Figure 1). Fine-tuning the feeding of Regumate is possible. Since Regumate needs to be fed only from luteolysis, if cycle dates are known you can minimize Regumate feeding by only providing it from day 12 to 14 of the estrous cycle until 5 days before gilts are scheduled to be bred.

Figure 1.   Timing of return to estrus after Regumate® withdrawal in gilts (data from University of Alberta).
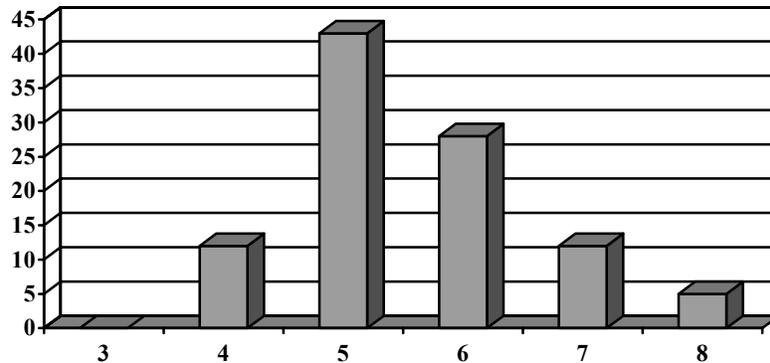
Regumate can also be fed to sows from weaning and the estrus response following withdrawal is the same as for gilts. Note that the first Regumate feeding must be on the day of weaning. The synchronised wean-to-estrus interval will be longer, but predictably so. Also, feeding Regumate for 7-days after weaning improved litter size of primiparous sows (Kirkwood *et al.*, 1986). Presumably, the feeding of Regumate captured the effect of skip-a-heat breeding but with fewer non-productive sow days. Further, where early weaning is practiced and is believed to be affecting sow fertility, delaying the post weaning estrus with Regumate permits sows to have a longer recovery period and will likely improve sow fertility (Table 2).

Table 2.   Effect of a 12-day lactation followed by 12-day Regumate feeding on primiparous sow performance.

	12-d, Regumate	12-d, control	24-d, control
Interval to estrus, d	6.2	7.3	5.6
Percent estrus by 7-d	97	64	87
No. corpora lutea	16.9	15.4	14.9
Embryo survival, %	77	68	68
No. embryos	13.0	10.5	10.1

Koutsotheodorus *et al.*, 1998

BREEDING MANAGEMENT

Semen backflow

The basic principles of artificial insemination are simple; place enough viable sperm in the right place at the right time, and keep it clean. Using current insemination technology, 3×10^9 sperm are deposited in the cervix. This large number is necessary because most of the sperm will either be lost due to back-flow of semen, as well as entrapment and death in the cervix

and uterus (Steverink *et al.*, 1998). When backflow was considered to be excessive during insemination, sow fertility was reduced. Therefore, fine-tuning AI technique aims to minimize semen backflow. The most obvious components of AI to assess are catheter placement and whether semen is being forced through the AI catheter. If backflow is excessive, insufficient sperm will remain in the sow, fertilization rate will be compromised, and an increased regular return rate will be observed.

Sperm transport

In reality, it is not the number of sperm deposited in the cervix or uterus that ultimately controls fertility, it is the number of sperm that enter the oviduct that is important. The proportion of inseminated sperm that actually get to the oviduct is variable, but 2% is a reasonable figure. The sperm in the oviduct enter an arrested state and constitute the sperm reservoir potentially available to fertilise ova. In order to reach the oviduct, the sperm must traverse about 1 meter of uterus and get through the junction of the uterus and oviduct (uterotubal junction or UTJ). This sperm transport is performed by uterine contractions. Most estrous sows will have some spontaneous uterine contractility, which is improved by boar stimuli. If uterine contractions are reduced (e.g. if the boar is not present), sperm transport will be poor, the sperm reservoir reduced, and fertility lowered. Uterine contractility cannot be monitored on-farm so fine-tuning sperm transport involves implementing techniques known to enhance uterine contractility. The key to good uterine contractility is stimulation of the sow during and after insemination. Aim for 10 min of boar contact after insemination. If the boar has to be moved, have a second boar come behind him to continue the stimulation. If boar power is limited, use a stink-stick. For this, a rag soaked in preputial fluid and a very little urine is tied to a stick and left to hang over the sow's head. If a breeding belt or other similar accessory is employed, do not remove it for about 10 min. Remember, once the semen dose has been taken up by the sow, a lot of the sperm are in the body of the uterus and still need to be transported towards the oviducts.

Hormones can also be used to stimulate sperm transport. The rationale is that the hormonal content of natural seminal plasma has a functional role and the absence of these hormones from extended semen may be involved in performance depression on some farms (e.g. start-ups). In support of this suggestion, previous work has shown that reproductive performance may be improved with the addition of estrogen or oxytocin to extended semen (Kirkwood and Thacker, 1991; Pena *et al.*, 1997), or injection of oxytocin or PGF at the time of insemination (Flowers, 1996; Pena *et al.*, 1998). The effect of these hormones is to increase uterine contraction and so improve sperm transport (Claus *et al.*, 1989). Although oxytocin is very inexpensive, and therefore cost-effective, its routine use should be recommended with care. Contractions may be excessive and so increase sperm backflow resulting in reduced fertility. When breedings are performed by well-trained personnel there is likely to be little benefit from the use of hormones. Therefore, the use of hormonal adjuncts at breeding is likely covering up inadequate breeding management. While this may be acceptable during the transition period of adoption of artificial insemination, long-term performance is best achieved by appropriate training of personnel.

After deposition into the female, sperm have to undergo the process of capacitation before

they can fertilise an egg. Once started, this process takes about 6 hours to complete. Capacitation is a "one-way street" at the end of which the sperm must either fertilise an egg or die. However, fresh sperm are non-capacitated and so can attach to the epithelium near the UTJ, and enter the arrested state that slows (but does not stop) their attrition. Signals arriving near the time of ovulation cause the release of sperm from their arrested state and allow them to redistribute along the oviduct towards the site of fertilisation (isthmus-ampulla junction) and to complete capacitation. The number of functional sperm available for fertilisation (which will impact sow fertility) will be dependent on the number originally entering the sperm reservoir (which is influenced by sperm transport) and the interval between sperm entry to the reservoir and their redistribution at the time ovulation (which is influenced by timing of insemination relative to ovulation).

Timing of insemination

Sow fertility following AI (i.e. fertilisation rate, farrowing rate, litter size) depends on the time of insemination relative to ovulation (Kemp and Soede, 1996). If insemination occurs at or soon after the time of ovulation, by the time capacitation has occurred the eggs may be too old. Late inseminations are also associated with an increased risk of urogenital disease and reduced sow performance (Rozeboom *et al.*, 1997; Tarocco and Kirkwood, 2001). If inseminated too far in advance of ovulation, too many sperm capacitate and die before ovulation occurs. The result is the same as inseminating too few sperm to begin with. To maximise fertility, deposition of fresh-extended semen into the sow should occur during the 24-hours before ovulation (Table 3).

Table 3.   Effect of insemination to ovulation interval on sow fertility.

	Farrowing rate, %	Litter size
Before ovulation		
24-36 h	68	11.8
0-24 h	92	13.2
After ovulation		
0-12 h	76	12.3

Nissen *et al.*, 1997

Assuming good quality semen, inseminations need only be performed every 24 hours. However, if the sperm are not fully viable (e.g. >48-days since collection), more frequent inseminations may be beneficial because sperm viability may be reduced (Figure 2). Presumably, the effect of aged semen is that the number of viable sperm in the sperm reservoir is too low. Therefore, performing am/pm breedings will "top up" the sperm reservoir.

Figure 2.   Effect of semen age and time of ovulation on fertilization rate (Waberski et. al. 1994).
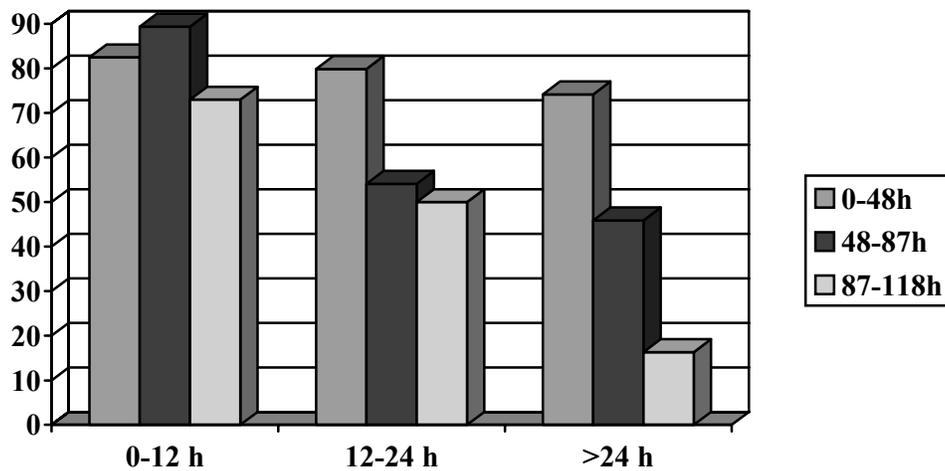

The time from detection of estrus to ovulation is variable (Figure 3). In this data set 7-19% of sows ovulated by 24 hours after detection of estrus (early ovulators). Unless still showing a good standing estrus, females ovulating by 24 hours after estrus detection should not be bred on day 2. Although the exact figure is going to depend on the assessment of each farms estrus detection management and expertise, it is reasonable to suggest that about 10% of females will be early ovulators. Single mating of these animals is not a problem since it almost guarantees that they will be bred during the 24-hour window before ovulation. However, if too many females receive a single breeding (e.g. more than 15%), detection of estrus onset is probably inadequate. Further, if too few females receive a single breeding (e.g. less than 5%) it is probable that some early ovulators are being bred in late estrus (or possibly diestrus). Using the same data sets, 20-25% of females will ovulate more than 48 hours after the detection of estrus onset (late ovulators). Breeding of these females on day 3 of estrus is not a problem. Indeed, limited field data showed a 6% increase in overall farrowing rate when these sows are bred (G. Ludvigsen, personal communication). So, if the breeding records show few if any third-day breeding, it is possible that some females are being bred too early. Alternatively, greater than 25% third-day breeding indicates that some females are being bred too late.

Timing of ovulation

It is accepted that sows having a short wean-to-estrus interval will tend to exhibit a longer duration of estrus and, conversely, sows having a long wean-to-estrus interval will tend to have a short duration of estrus. Further, ovulation is believed to occur at about 70% through estrus, independent of the duration of estrus. The effect of this is that sows having a short wean-to-estrus interval (e.g. 4 days) will tend to be late ovulators while sows having a long (e.g. >5 days) wean-to-estrus interval will tend to be early ovulators (Table 4).

Figure 3.   Interval from estrus onset to ovulation in sows.
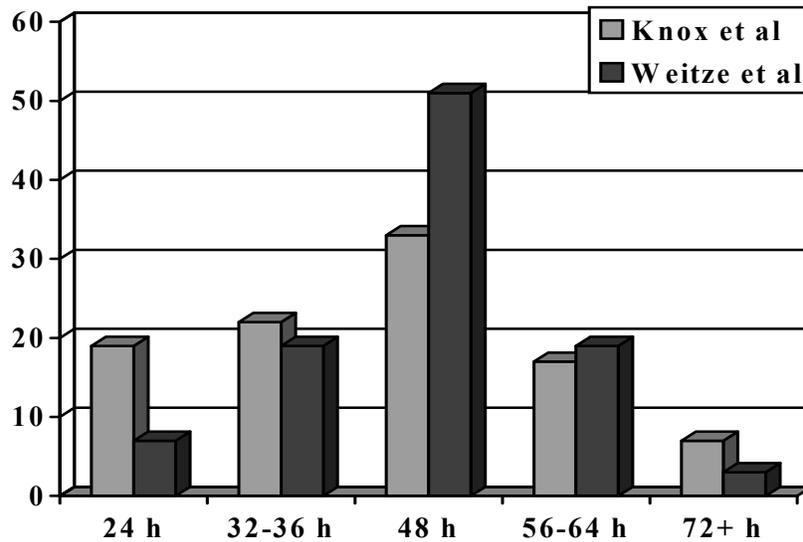
Table 4.   Effect of wean-to-estrus interval (WEI) on estrus-to-ovulation interval.

	4-d WEI	5-d WEI	6-d WEI
0-24 h	5%	16%	45%
24-32 h	19%	36%	17%
32-40 h	34%	25%	18%
>40 h	42%	23%	9%

Kemp and Soede, 1996.

In commercial practice, it is often observed that the fertility of sows inseminated following a wean-to-estrus interval of 6 or more days is less than for sows inseminated following shorter wean-to-estrus intervals (Vesseur *et al.*, 1994; Steverink *et al.*, 1999). The etiology of this effect is unknown but, given that these sows will likely be early ovulators, it may involve the timing of insemination relative to ovulation in these sows. Indeed, with once-daily estrus detection, some sows may already have ovulated when estrus is first detected. A component of the interval between insemination and fertilisation is the approximately 6 hours required for capacitation of the sperm. The effect of this is that when a short interval between sperm deposition and fertilisation capability is required, such as following insemination at about the same time as ovulation, the time required for capacitation may be a factor in the resultant poor fertility. To reduce the effect of early ovulation, sows not detected in estrus by 5 days after weaning should be heat-checked at least twice daily to more accurately detect onset of estrus. A further method for reducing the impact of long wean-to-estrus intervals is to shorten the interval by the injection of gonadotrophins (e.g. PG600). If this is done, appreciate that using hormones will create late ovulating sows (Knox *et al.*, 2001) and many of these sows will require a day-3 breeding.

Housing pregnant sows

There is a growing impetus to group house sows, for both welfare perceptions and economics. However, with large groups of sows, individual housing for estrus detection and breeding is still the method of choice. When this is done, at some point the females will need to be mixed. The safest time to mix bred sows, in terms of maintenance of pregnancy, remains to be determined. However, based on zero evidence, the concensus is that if sows are to be mixed, it should be done between 1 and 3 days after the final insemination (i.e. before the conceptus arrives in the uterus) or from 28 days after the final insemination (i.e. after placentation is complete). When sow groups are formed, the inclusion of a mature boar in the group may reduce aggression between sows.

An alternative is to create groups at weaning. This minimises the effect of aggression on pregnancy maintenance but estrus detection and breeding become more difficult. It is possible that, if electronic feeders are employed, the transponders could be used to monitor sow traffic to boars housed adjacent to the sow pen. Proestrous and estrous sows will spend much more time in the vicinity of the boars. Once identified, sows can be moved to a detection-mating area for insemination and then returned to the group.

Induction of farrowing

The ability to predict times of farrowing allows for ease of supervision of farrowing, which in turn can potentially save 0.5 pigs per litter. Before employing farrowing induction, calculate the average gestation length for the individual herd from at least the previous 100 gestations. Do not induce more than 2-days before due date. To induce the sow, inject prostaglandin in the morning and again in the afternoon. Use the full-recommended dose if injecting intramuscularly, or half dose if injecting into the vulva. If there is a history of savaging, consider treating all gilts with an intramuscular injection of corticosteroid when signs of impending delivery become evident.

CONCLUSIONS

Fine-tuning control of estrus in gilts should involve a critical assessment of boar exposure technique. If performed appropriately and further control of estrus is required (e.g., better synchrony), hormones can be employed to either stimulate onset of estrus or to suppress estrus until required for breeding. In sows, estrus suppression can be employed to allow sows a longer recovery period after weaning which likely will result in improved fertility.

Fine-tuning of breeding management involves critically assessing insemination techniques to minimise semen backflow. Also, insemination in the 24-hours before ovulation is important. Therefore, inseminations should be performed at 24-hour intervals but only if the females are exhibiting strong signs of estrus. Twice daily inseminations should be considered when semen age exceeds 48-hours. To reduce the potential for late insemination of early ovulators, sows not showing estrus by day 5 should be heat-checked twice daily and inseminated immediately.

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