Introduction

Optimised insemination strategies on pig farms aim at reducing the number of inseminations, without reducing reproductive performance. At the moment, one insemination with good quality semen can result in good fertilisation results when insemination takes place in a 24 h period before ovulation. However, knowledge of this optimal period is not sufficient to limit the number of inseminations to only one in all sows, because the time of ovulation of sows can not be predicted within a 24 h range. Therefore, to optimise insemination strategies on farms, either the period during which one insemination leads to optimal fertilisation results must be increased and/or the prediction of ovulation time needs to be improved. Much work concerning the timing of insemination -relative to oestrus characteristics-and reproductive performance (litter size, farrowing rate) has been performed in the sixties and seventies. Since the early nineties, ultrasound has allowed assessment of the timing of ovulation in spontaneously ovulating sows. Since then, experiments have increased our knowledge on the timing of ovulation in sows relative to behavioural and physiological changes and on effects of insemination strategies on fertilisation. Besides the timing of insemination, also the circumstances around insemination are important for fertilisation chances. In this overview, also recent data on the role of boar presence on uterine motility are presented (Langendijk, 2001).

Optimal period between insemination and ovulation

The life span of eggs after ovulation and the life span of a sufficient number of sperm cells capable of fertilisation within the oviduct, limits the period relative to ovulation in which inseminations can lead to successful fertilisation (for review, see Hunter, 1994). Studies from the sixties already showed that sows inseminated relatively early or late in oestrus showed a significant reduction in fertilisation rate (Hancock and Hovell, 1962) and in litter size and farrowing rate (Willemse and Boender, 1967). From these experiments, it is difficult to draw conclusions about the fertile life span of sperm cells and oocytes, because the time of ovulation varies considerably relative to the onset of oestrus (for review, see Soede and Kemp, 1997). Therefore, in many experiments, the process of fertilisation was studied using gilts with induced ovulation (e.g. Dziuk, 1970; Hunter, 1967; Hunter, 1981; Hunter et al., 1987). Those experiments showed the importance of processes such as sperm transport, capacitation of sperm cells and the filling and emptying of the sperm reservoir for the chances of fertilisation.

In recent years, data have become available on the chances of fertilisation relative to spontaneous ovulation. It was found that in some sows, optimal fertilisation results can be achieved when insemination (with 3 billion sperm cells) takes place between as many as 40 h before ovulation and 16 h after ovulation (Soede et al., 1995a). However, to reach good fertilisation results in the majority of sows, it was found that insemination has to take place in the 12 ((Waberski et al., 1994a) or 24 h period before ovulation (Waberski et al., 1994b; Soede et al., 1995b; Steverink et al., 1997) This is illustrated in Figure 1. Figure 1 shows the fertilisation rates as assessed at Day 5 after ovulation in about 300 sows in which insemination took place one with a dose of 3 billion sperm cells. From those results, it is clear that fertilisation results are optimal when insemination takes place before ovulation. In the period of 0 to 24 hours before ovulation, the majority of sows have 100% fertilisation. Outside this interval, the percentage of sows with partial fertilisation and of sows in which none of the oocytes are fertilised increases considerably. Based on litter size and farrowing rate, the optimal interval between insemination and fertilisation was suggested to be even longer, between 28 h before ovulation and 4 h after ovulation (Nissen et al., 1997). The fact that an interval of more than approximately 24 h results in a reduction in fertilisation rate means that the fertile life span of sufficient numbers of sperm cells is limited to 24 h in the majority of sows. The fact that inseminations after ovulation result in a reduction in fertilisation rate means that the fertile life span of oocytes is about similar to the time it takes for sperm cells to capacitate and reach the site of fertilisation. Even in the optimal period, however, some sows have sub optimal or even no fertilisation (see Figure 1).

In recent years, experiments have been performed that studied the period in which inseminations lead to optimal fertilisation. Effects of the following factors were investigated:

- Semen ageing during liquid storage; the use of aged semen reduced the optimal period for insemination (Waberski et al., 1994b), although a semen age of up to 38 h at insemination did not affect results (Soede et al., 1995).
• Extender; negative effects of liquid storage on the optimal period for insemination depend on the extender used (Waberski et al., 1994b).
• Semen dosage; a 6-fold increase in number of sperm cells (from 1 to 6 billion) hardly influenced the optimal period for insemination (Steverink et al., 1997).
• Frozen semen; the use of frozen semen reduced the optimal period for insemination to the period of 0-4 h before ovulation (Waberski et al., 1994a).
• Semen backflow during and after insemination; backflow during insemination only affected fertilisation when a low semen dose (1 billion) was used and backflow exceeded 20 ml (of 80 ml) (Steverink et al., 1998). Semen backflow after insemination; no effect on fertilisation results (Steverink et al., 1998).

In conclusion, from the above, it seems that factors reducing the number and/or the quality of sperm cells that reach the oviduct, shorten the period in which insemination results in optimal fertilisation. It can be concluded that good quality semen of at most 2 days of age ensures good fertilisation rates when inseminated between 0 and 24 h before ovulation. Strangely enough, a doubling of the dose hardly had a positive influence.

From recent research, several indications exist that a further improvement of sperm transport and/or sperm survival can be achieved. A few examples are given of the possibilities:

• Increase in quality of semen?

Except for motility, few in vitro semen parameters have found to be related to fertilisation results in vivo (see Colenbrander, 2000). Recently, experiments were performed in which the ability of (bull and boar) sperm cells to bind to the zona pellucida or zona pellucida proteins was studied. Using boar semen, Harkema et al. (1998) found that the percentage of sperm cells that show enhanced binding to zona pellucida proteins in an IVF-medium after 3 hours of incubation (presumed to be the capacitated sperm cells) reaches a plateau. The level of this plateau varies considerably between boars (Harkema et al., 2002). Four boars of which 31%, 40%, 45% and 53% of the sperm cells showed an enhanced binding to the zona proteins after 3 hours incubation, had an in vivo fertilisation rate (insemination immediately after ovulation with 0.5 billion sperm cells) of on average 77%, 82%, 87% and 94% of the oocytes, with 40%, 62, 67 and 83 of the sows having 100% fertilisation (Harkema et al., 2002). Therefore, differences between boars in the percentage of sperm cells capable of in vitro capacitation were positively related to in vivo fertilisation results. It needs to be investigated whether this positive relation is also found when insemination takes place well before ovulation and not after ovulation. If a negative relation exists between the rate of in vitro binding to zona proteins and the fertile life span of sperm cells in vivo, the average fertilisation rate of the boars may be similar, which would not make this a useable tool for selection of boars. However, in that case, a selective mixing of semen of different boars might aid fertilisation results.

• Reduction of phagocytic ingestion of sperm cells?

Sperm cells that do not reach the oviduct within an hour or so after insemination are thought to be lost for the process of fertilisation due to phagocytic ingestion by leucocytes. Rozeboom et al. (1999) showed that the rate of influx of leucocytes into the uterine lumen is changed by the addition of seminal plasma to the inseminate. Further, data show that phagocytic ingestion of sperm cells by leucocytes is influenced by the composition of the inseminate (Woelders, 2001). Therefore, manipulation of leucocyte influx and phagocytic ingestion of sperm cells may lead to changes in the number of sperm cells that reach the site of fertilisation and consequently fertilisation rate.

• Insemination procedure: (deep) uterine insemination?

Especially when semen is costly, procedures to inseminate with low numbers of sperm cells is important (e.g. sexed semen, semen of boars with a specific genetic make-up). Deep-uterene insemination procedures have been developed in laboratories in Spain (Martinez et al., 2001) and Germany (Rath et al., 1999) and seem to result in pregnant sows with as few as 50 million sperm cells inseminated. On farm trials with inseminations taking place cranial of the cervix (but not deep uterine) suggest that this technique allows a reduction in the sperm dose to 1 billion (Watson, 2001). However, disadvantages of the current uterine insemination techniques are the limited use (older parity sows only) and the need for more skilled staff.

• Sow characteristics?

Some indications exist that the fertile life span of oocytes differs between breeds (Kemp and Soede, 1997), but little is known about the (sow) factors that may influence e.g. capacitation rate, uterine activity, sperm transport, or sperm survival in the reproductive tract. However, recently, information has become available on factors affecting uterine activity (see further).
Summarising, it seems there are several possibilities of further improvement of transport and survival of sperm cells within the female reproductive tract. These improvements may lead to either lower numbers of sperm cells in a semen dose and/or an improvement of fertilisation results under otherwise suboptimal insemination conditions (aged semen, inexperienced inseminators). The presence of the boar during insemination also seems to be of importance in this respect (see further).

Prediction of the time of ovulation

On average, ovulation takes place at 35 to 45 h after onset of oestrus (standing response in presence of a boar). However, the variability between sows is large, between e.g. 10 and 85 (Weitze et al., 1994) or 10 and 58 h (Soede et al., 1995a) although sometimes less variation is found (35 to 43 h in 20 sows Mburu et al., 1995). Also parameters such as vaginal temperature and vaginal mucus conductivity have proven to be bad predictors for ovulation time (Soede et al., 1997; Stokhof et al., 1996).

In a number of German, Dutch, Swedish and Danish investigations in the nineties, the average timing of ovulation (percentage of oestrus) varied between 64% and 72% (see review by Soede and Kemp, 1997); the duration of oestrus (that is the period in which sows show a standing response in presence of a boar) explained 50-60% of the variation in the timing of ovulation. At the moment, therefore, the duration of oestrus seems the best estimator for the time of ovulation during oestrus. Unfortunately, the duration of oestrus is highly variable and gives only a retrospective estimate of the time of ovulation. Therefore, research should be aimed at finding other prospective estimators for the time of ovulation.

In the course of estrus, responsiveness of the sow to stimuli applied to evoke estrus behaviour (standing response) increases and decreases again (Willemse and Boender, 1967). This means that early and late in estrus the sow will be responsive to intense stimuli (e.g. a DMA (Detection-Mating-Area) or intensive boar contact). When she is in the middle of the estrus period she is expected also to be responsive to lower levels of stimuli (e.g BPT (Back-Pressure-Test) in absence of boar). By applying different levels of stimuli during the course of estrus different receptive phases may be distinguished (e.g. receptive to BPT in absence of a boar, receptive to BPT when fence line contact with boars is used or receptive to BPT when brought in a DMA). Langendijk et al. (2000b) studied whether applying different levels of boar stimuli during detection of estrus might distinguish more phases of responsiveness and whether this information could be used to yield a more accurate predictor of ovulation. The results are not very encouraging. A large percentage of sows will not show a standing response at lower levels of stimuli at all during the course of estrus. Therefore, in such sows different responsive phases during estrus can not be distinguished. Moreover, even in sows showing more responsive phases during the course of estrus, these phases were poorly related to the ovulation moment.

Possibly, a combination of parameters (maybe both physical and behavioural) can give a better estimate of ovulation time than only one parameter. Such an attempt was recently made by Langendijk et al. (1999b), who combined the redness of the inner vulva to oestrous behaviour characteristics. In sows that showed vulva reddening at the onset of boar oestrus (60% of the sows), the change from red to pink occurred on average at 18 h before ovulation with a range from 36 h before to 2 h after ovulation. In their study, no hormone profiles were measured, but it seems plausible that the change in vulva colour from red to pink is related to the changes in the oestrogen profile. If these results prove to be repeatable, it would mean that sows with a red inner vulva at onset of oestrus do not need to be inseminated before the end of vulva redness, which would result in a more efficient use of semen.

The ultimate prediction of ovulation time would be to be able to monitor the rise in LH concentrations or the decline in oestrogen concentrations in a simple way, but for pigs this may still be impractical. For the immediate future, possibilities to ‘predict’ ovulation time are limited to the prediction of the duration of oestrus for sows.

Towards more efficient insemination strategies

The variation in oestrous behaviour and the related low predictability of ovulation time makes it very difficult to inseminate sows in the optimal period before ovulation using one insemination only. Therefore, most sows are inseminated repeatedly during oestrus. One recurrent question is whether such repeated inseminations should be performed at 12 h or 24 h intervals. Lamberson and Safranski (2000) made an economical comparison between different insemination schedules in combination with once or twice per day detection of estrus. In their model, the likelihood of conception was set at a maximum of 90% (when insemination took place at ovulation) and dropped to about 62% with insemination at 24 h before ovulation and also at 6 h after ovulation. Ovulation was programmed to occur at 40±12 h after onset of oestrus and the weaning to ovulation interval was set at 136±18 h. Using those parameters, economic returns were calculated to be highest with inseminations at 12 h intervals; at 12, 24 and 36 h after onset of oestrus with twice per day oestrus detection and at 0, 12, 24 and 36 h after onset...
of oestrus with once per day oestrus detection. These results are a logical result seeing the (relatively low) fertilisation rates in the model for inseminations in the period of more than 12 h before ovulation. Results from a survey on German pig farms showed that herds in which sows were inseminated every 12 h did not have a better reproductive performance than herds where sows were inseminated at 24 h intervals (VFV, 1999). Similarly, Castagna et al. (2001) and Thorup (2001) also conclude from their experiments that inseminations at 12 h and 24 h intervals can result in similar reproductive performance. These latter results more reflect results from fertilisation experiments as mentioned before (Waberski et al., 1994b; Soede et al., 1995; Nissen et al., 1996; Steverink et al., 1997) that clearly suggest that inseminations at 24 h intervals should be sufficient. However, it is clear that factors such as inexperienced inseminators (Flowers, 1994) or the use of older semen (Waberski et al., 1997) may cause the need for shorter intervals between inseminations.

Inseminating sows as often as possible may not just be a waste of semen, labor and money, but may also have negative effects. Rozeboom et al. (1997) concluded that a second insemination during late- or met-oestrus decreased farrowing rate and litter size and De Winter et al. (1992) showed that uterine inoculation with bacteria resulted in more uterine infections during late- or met-oestrus than during early- or mid-oestrus. This phenomenon may be related to the oestrogen/progesterone ratio, affecting both the blood circulation and therewith the influx of leucocytes and the contraction activity of the uterus. Therefore, very intensive insemination strategies can result in poor reproductive performance due to infections when many sows are inseminated during late oestrus.

**Use of knowledge of oestrus duration**

Because ovulation takes place at a relatively fixed two-thirds of oestrus, a prediction of the duration of oestrus is an indirect prediction of ovulation and therewith of the optimal time for insemination. Unfortunately, the duration of oestrus is very variable and seems to be influenced by many factors, such as housing conditions, stress conditions, season, parity, genetic background (see review by Soede and Kemp, 1997). Nevertheless, to some extent, prediction of the duration of oestrus is possible. First of all, the average duration of oestrus varies considerably between farms (from 31 to 65 h), but is highly consistent from month to month within a farm (Steverink et al., 1999a), which implies that the optimal timing of insemination during oestrus should vary between farms. Second, it has been well established that the duration of oestrus is related with the weaning-to-oestrus-interval (WOI) (e.g. Rojkittikhun et al., 1992; Weitze et al., 1994; Kemp and Soede, 1996); sows with a short (3-4 days) WOI on average have a long oestrus, associated with an advanced ovulation time (Weitze et al., 1994; Kemp and Soede, 1996). Steverink et al. (1999a) found that this relationship between WOI and duration of oestrus was significant in 43 (80%) of 54 farms. As a consequence, on most farms sows with a WOI of 6 days or more should be inseminated sooner after onset of oestrus to make sure that the first insemination is before ovulation. The effects of the relation between oestrus duration and optimal insemination time are illustrated in Table 1 for two farms that differ in average duration of oestrus (Steverink et al., 1999b). The data are generated with a simulation model for insemination strategies in pigs (PIGSIS; Steverink, 1999). The simulation confirms that the timing of the first insemination can easily be too late, especially on farms with a short duration of oestrus and sows with a WOI of 5 to 6 days. Too early first inseminations are not really a problem; sows can be inseminated again, but sows in which the first insemination takes place after ovulation should be avoided. Therefore, to get insight in the efficiency of the insemination strategy (and quality of oestrus detection) on farms, farmers should establish the duration of oestrus and their farms, and also taking into account the effect of Weaning-to-Oestrus Interval on the duration of oestrus. This also enables checking of the appropriateness of insemination timings of individual sows.
Table 1. Timing of first insemination relative to ovulation\(^1\) on a farm with an average oestrus duration of 36 h or 60 h, simulated with PIGSIS\(^2\). On both farms, sows are inseminated at 24 h after observed onset of oestrus and every 24 h increase in Weaning-to-Oestrus-Interval is associated with a decrease in oestrus duration of 6 h.

<table>
<thead>
<tr>
<th>Weaning-to-Oestrus Interval (d)</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sows (%)</td>
<td>17.5</td>
<td>32.8</td>
<td>23.3</td>
</tr>
<tr>
<td>Farm oestrus duration: 36 h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Too early (%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Correct (%)</td>
<td>55</td>
<td>37</td>
<td>21</td>
</tr>
<tr>
<td>Too late (%)</td>
<td>45</td>
<td>63</td>
<td>79</td>
</tr>
<tr>
<td>Farm oestrus duration: 60 h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Too early (%)</td>
<td>21</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Correct (%)</td>
<td>66</td>
<td>68</td>
<td>68</td>
</tr>
<tr>
<td>Too late (%)</td>
<td>14</td>
<td>20</td>
<td>25</td>
</tr>
</tbody>
</table>

\(^1\) Too early: >24 h before ovulation, Too late: after ovulation
\(^2\) PIGSIS: PIG Simulation model for Insemination Strategies (Steverink, 1999)

**Fixed-time AI**

To improve the prediction of the timing of ovulation and therewith the possible use of fixed-time AI, exogenous hormones (eCG, followed by either hCG or GnRH) could be used. However, the success of these strategies appears to be very dependent on the management system used (Brüssow et al., 1996). The use of these hormones may mask poor management, is costly and it is not unthinkable that such a use of ovulation-inducing hormones will be banned in a number of (EU-) countries in the near future.

**Role of boar presence during insemination, with emphasis on uterine contractions**

Besides the timing of insemination, also insemination conditions are important for the success of the insemination, for example suggested to be related to their effects on uterine contractions. Recent research has shed some (extra) light on the effects of boar presence around insemination on uterine contractions.

In the sow, during mating sperm is deposited intracervically, and has to be transported through both uterine horns to the oviduct, where fertilisation takes place. Porcine uterine horns can be 1 to 1.5 m in length, and the intrinsic motility of sperm cells can not be responsible for the short period of time in which sperm cells have been observed to reach the oviduct (Viring, 1980). Especially when timing of insemination is sub optimal (i.e. long before ovulation or after ovulation), fast transport of semen to the relatively ‘safe’ utero-tubal junction might be critical. Uterine myometrial contraction activity is believed to have a function in transport of sperm cells from the uterine body to the oviduct. Therefore it is believed that uterine contraction activity is important to get optimal fertilisation results. In Figure 2, uterine contraction activity of a typical sow at different phases of the reproductive cycle is shown.

As in most mammalian species, myometrial activity in the sow increases around estrus (Figure 3, Langendijk et al., 2001a). Although all sows in the study of Langendijk et al. (2002a) showed an increase in uterine contraction activity during estrus the variation between sows is substantial. Frequency of contractions ranged from 6 to 40 h\(^{-1}\), and the amplitude of contractions ranged from 16 to 57 mmHg. These differences between sows were consistent over the days around estrus, i.e. sows with a relatively high level of uterine activity during the days before estrus also showed a relative high level of uterine activity during estrus. It seems plausible that sows with relatively low uterine activity also have an increased chance of suboptimal fertilisation results due to suboptimal semen transport. From a review by Soede (1993) it can be concluded that specific boar stimuli at or around the moment of insemination can influence reproductive processes such as sperm transport and consequently affect fertilisation. Besides external stimulation (like olfactory and tactile stimuli), also internal stimulation (like sperm plasma or some of its components) is important. This paper will only discuss effects of external boar stimuli on fertilisation of sows. Effects of semen or seminal plasma components on fertilisation are reviewed by e.g. Claus (1990) and Waberski, (1997).
External boar stimuli are believed to exert their effects on uterine contraction activity through a stimulation of acute central release of oxytocin. Oxytocin is a smooth muscle stimulator. The sensitivity of the myometrium to oxytocin and to stimuli that induce its release is probably high during estrus (Sheldrick and Flint, 1985). Langendijk (2001) studied effects of different boar stimuli on oxytocin release during estrus in sows. In their study they compared either BPT alone, or BPT in combination with boar pheromone spray or BPT in presence of a boar.

Back Pressure Test with or without boar spray did not result in any changes in oxytocin release. However, boar presence resulted in an acute and clearly pronounced release of oxytocin (Langendijk, 2001). The fact that boar spray was not inducing oxytocin release was not expected since Mattioli et al. (1986) found a release of oxytocin after using boar spray. The absence of oxytocin release in response to only BPT was confirmed by Mathiasen (2001) although in their study, the boar was housed next to the sows. He further showed, that intense human stimulation (a BPT in combination with manipulation of the abdominal, inguinal, pelvic area and the area under the vulva), again using sows that were housed next to boars, could result in release of oxytocin. The levels of oxytocin release were however lower than with full boar exposure. It appears therefore that full boar contact induces oxytocin release in sows but the effects of lower levels of stimuli (or fewer stimuli) on oxytocin release are less clear. Langendijk (2001) also studied effects of different boar stimuli on uterine contraction activity during estrus. Tactile stimuli, boar pheromone and boar presence caused only a slight increase in frequency of contractions and a slight increase in mean amplitude of contractions. However, in those cases in which the spontaneous uterine activity was low (frequency of contractions <26 h⁻¹, ca 50% of the sows), boar presence clearly increased frequency of uterine contractions (+ 7 h⁻¹), in contrast to tactile and pheromone stimulation (P < .05). From this one can conclude that boar presence during insemination will stimulate uterine contractions in sows which have weak uterine contractions before stimulation.

Can artificial insemination in itself stimulate uterine contractions? Claus and Schams (1990) found no oxytocin release after insertion of an insemination catheter and Langendijk et al. (2002a) showed that uterine infusion with physiological saline did not increase uterine contractions. However, in a recent study at our laboratory, artificial insemination of 80 ml of a standard insemination dose increased uterine contraction frequency by 50%. Additional use of a mating clamp mimicking the pressure on the flanks of sows during mating proved unsuccessful in inducing extra uterine contraction activity. Also, leaving the catheter in the cervix for an additional 5 min while regularly moving the catheter did not result in extra contractile activity.

Summarising, the data suggest that boar presence during insemination positively influences uterine contraction activity especially when the contraction pattern of a sow is low. Using components of boar presence like BPT, mating clamps or BPT plus boar spray is not as effective as the whole boar. Therefore it is advisable to use a boar in front of the sow during insemination.

**Table 2** Effects of intra-uterine infusion of 40 ml saline with 1 mg prostaglandins at 10 minutes before insemination (40 ml; 0.5x10⁹ sperm cells), on backflow of semen during insemination and on fertilisation results (based on Langendijk et al., 2002b)

<table>
<thead>
<tr>
<th>Backflow</th>
<th>Control (n=16)</th>
<th>Cloprostenol (n=18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>11 (69%)</td>
<td>3 (17%)</td>
</tr>
<tr>
<td>Little</td>
<td>3 (19%)</td>
<td>9 (50%)</td>
</tr>
<tr>
<td>Much</td>
<td>2 (13%)</td>
<td>6 (33%)</td>
</tr>
</tbody>
</table>

| Median fertilisation rate (%) | 81a (0-100) | 21b (0-100) |
| Median accessory sperm cells (n) | 2.1a (1-21) | 0.8 b (0-19) |

1 The distribution of the animals over the categories of backflow differed between treatments (P<0.05) ab P<0.05

Not only oxytocin, but also prostaglandins can stimulate myometrial activity. Field trials in which oxytocin or prostaglandins are injected in sows during insemination or used in the insemination dose seem to indicate that these treatments may improve reproductive results in sub optimal conditions (Levis, 2000), for example when inseminations are performed by inexperienced inseminators (Flowers, 1995), when using old semen (Flowers, 1996) or during summer infertility (Pena et al. 1998a,b).

However, there are some indications that overstimulation of contraction activity may also occur, resulting in a lower reproductive performance (Langendijk et al., 2002b; see Table 2). In their study, sows were infused intra-uterine with either 40 ml of saline (control) or with 40 ml of saline containing 1mg cloprostenol (prostaglandins) at ten minutes before insemination (40 ml; 0.5x10⁹ sperm cells). Ovulation was timed with GnRH (50 µg at 85 h after weaning) and insemination
took place at 20 h before expected ovulation (at 40 h after GnRH-injection on average). In Table 2, effects on backflow of semen and on fertilisation results are shown. The prostaglandin treatment was earlier shown to increase uterine contractions (Langendijk et al., 2002a), but was now found to also increase backflow of semen during insemination and resulted in lower fertilisation results. Apparently, uterine contractions can be stimulated to such an extent that negative effects on sperm transport and consequently, fertilisation results can be expected. From the studies in which effects of treatments were assessed it appeared that, at the applied dosage, prostaglandin treatment increased uterine contractions in all the sows, irrespective of their spontaneous uterine activity (Langendijk et al., 2002a), whereas oxytocin (either by infusion (5 IU) or due to boar presence) seems to stimulate contractions especially in sows with low spontaneous activity. Therefore, stimulation of the myometrium seems beneficial as long as contractility does not exceed a certain level. In this respect, boar presence and treatment with lowe levels of oxytocin are probably a safe way to stimulate uterine contractions.

**Final remarks**

The choice for a more efficient insemination strategy (that is, a decrease in number of inseminations per oestrus) depends on e.g. labour costs of insemination, costs of an insemination dose or costs of boars on the one hand and on e.g. labour costs for oestrus (ovulation-) detection on the other hand. The balance between these costs can change and for example the application of frozen semen, of sexed semen, or of semen from boars with a specific genetic makeup may increase the demands for more efficient insemination strategies. Therefore, research should continue to be focused on extension of the period in which an insemination leads to optimal fertilisation results and the predictability of ovulation time and on efficient delivery of inseminated sperm cells to the site of fertilisation.

From the data present in this paper it is clear that use of boars during estrus detection and presence of boars during insemination is highly advisable. Generally one can say that using only components of boar stimuli (BPT or boar spray) gives limited effects as compared to full boar exposure. Probably there are differences between boars in effectiveness to stimulate the above mentioned processes. There is some evidence that there are boar effects on the duration of oestrus of sows (Soede and Kemp, 1997). It is known that boars should be at least 11 month old to be able to induce estrus in gilts (Kirkwood and Hughes, 1980). Probably from a behavioral point of view boars need to be active and enthusiastic in their interaction with sows. Turner et al. (1996) showed that the level of sexual motivation of boars does not influence the efficiency of detecting hormonally induced estrus using the BPT in ovariectomized gilts. However, sexual motivation of the boars was scored as number of copulations in a mating test and reaction time before first mating. One can question if this parameter is an accurate one to select boar for. Further research on parameters to select boars for good estrus detection is needed.

**Cited literature**

Castagna CD, et al. 2001. 6th International Conference on Pig Reproduction, Columbia MO, p. 100
Steverink DWB, 1999. PhD-thesis Wageningen University, Wageningen, The Netherlands
Thorup F, 2001. 6th International Conference on Pig Reproduction, Columbia MO, p. 102
Willemsen AH and Boender J, 1967. Tijdschrift Diergeneeskunde 92:18-34
Figure 1: Percentage of sows having a fertilisation rate of 0%, 1-20%, 21-40%, 41-60%, 61-80%, 81-99% and 100% after one insemination at variable intervals from ovulation. Insemination was done with a dose of 3 billion sperm cells. Compiled data from Soede et al., 1995ab and Steverink et al., 1997.
Figure 2: Uterine luminal pressure during 25 min recordings on different days around estrus for one sow. Arrows indicate contractions according to predefined criteria.
Figure 3: Spontaneous myometrial activity around estrus. Top: % sows with no myometrial activity; Bottom left: average frequency of contractions for sows with myometrial activity; Bottom right: average amplitude of contractions for sows with myometrial activity. Values are averages and s.e.m. Values below X-axis are days to onset of estrus (D0 is first day of estrus) and number of sows (Langendijk et al., 2002a).