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An automated oestrus detection system for sows in group housing

Ir. C. Lokhorst
Ing. H.W.J. Houwers

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Postbus 43 – 6700 AA Wageningen
Telefoon 08370-76300
Telefax 08370-25670

Preface

At the DLO experimental farm for pig husbandry and breeding research the Bantham, which is managed by the DLO-institute for animal breeding and husbandry (IVO-DLO), a team of researchers from IMAG-DLO is developing a high tech housing and management system for group housed sows. The pregnant, lactating and empty sows are kept in one group, in which they remain during their reproductive life. Automated oestrus detection is one of the aspects being investigated in this management and housing system.
Oestrus detection consumes much of the pig breeders time available. In this report a management tool is described which helps the pig breeder to find the sows which are in oestrus. With a boar and some intelligent data collection and data manipulation the pig breeder daily gets a list of sows that have to be checked.

The help with the statistical handling of the data by Mr B. Keen of the DLO-Agricultural Mathematics Group is highly appreciated.

Ir. A.A. Jongebreur,

director.

Contents

Samenvatting

Door toepassing van automatisering wordt het mogelijk om zeugen weer in groepen te huisvesten. Omdat de controle op bronst veel tijd vraagt van de varkenshouder is gewerkt aan de ontwikkeling van een automatisch bronstcontrolesysteem.
Allereerst is een beschrijving gegeven van de kenmerken van bronst waarop gelet kan worden. Hieruit zijn enkele voorwaarden geformuleerd die betrekking hebben op de registratie van de aanwezigheid van een zeug bij een beer, waarbij gebruik gemaakt wordt van de electronische herkenning d.m.v. een responder. Bij de formulering wordt gelet op de bouwkundige aspecten, waar moet een berehok geplaatst worden, en op modelmatige aspecten.
Uit een analyse van activiteitsgegevens, die bepaald zijn op basis van waarnemingen van een voercomputer (CRF) en die gericht zijn op de aanwezigheid bij een beerhok, volgt dat er een duidelijk verschil is tussen het wel of niet bronstig zijn.
Op basis van de CRF waarnemingen zijn twee signaleringsmodellen ontwikkeld die uit de activiteitsgegevens halen of een zeug gecontroleerd moet worden. Model 1 houdt in dat een signaleringsdrempel is bepaald aan de hand van groepsgegevens. Indien de activiteit die gericht is op de beer, boven een bepaalde grens komt wordt een melding aan de varkenshouder gegeven. Model 2 volgt, met behulp van een tijdreeksanalyse, voor een individueel dier de activiteit. Indien de voorspelling boven een bepaalde waarde komt of als de afwijking van de gerealiseerde waarde teveel afwijkt van de voorspelde waarde komt er een melding.
Model 3 is ontwikkeld op basis van gegevens die verzameld zijn met behulp van een personal computer. Elk uur van de dag wordt bepaald hoeveel tijd een zeug de voorgaande 24 uur voor het berehok heeft gestaan. Zodra deze waarde een grenswaarde overschrijdt, wordt een mededeling gegeven dat de zeug gecontroleerd moet worden.
De testresultaten van de drie modellen zijn bevredigend. Model 1 en 2 detecteren 88% van de dieren die bronstig zijn. Dit kan nog verbeterd worden als meerdere keren per dag gekeken wordt (model 3). Model 3 detecteerd 90% van de bronstige zeugen 12 uur voor het midden van de bronstperiode.
In 16 % van het aantal waargenomen uren dat een zeug boven de signaleringsdrempel van model 3 was, waren meerdere zeugen tegelijkertijd bronstig.
De belangrijkste conclusie is dat het mogelijk is om automatische bronstdetectie toe te passen.

Abstract

The report describes the development of an automated oestrus detection system which can be used in group housing systems for sows. With the existing technology for electronic identification it is possible to register the presence of sows near a boar pen. The construction of the boar pen, its location in the stable and the use of models are discussed.
An analysis of data on sows' presence near the boar pen (Computer Registered Frequency), shows a clear difference in CRF between oestrous and non-oestrous sows.
Three models are developed for on-farm use to detect oestrus. The results of the tests of the three models are satisfying. The models detect more than 88% of the sows in oestrus. This can be improved when the intensity of the reporting is increased to two times a day (model 3). The findings indicate that model 3 will identify about 90% of the sows in oestrus 12 hours before mid-oestrus. The most important conclusion is the on-farm automated detection of sows in oestrus is feasible.

1 Introduction

In recent years much agricultural research in the Netherlands has focused on developing group housing systems for sows. The new housing systems being developed are intended to produce good alternatives to the individual, tethered or stall housing systems. The new systems must be technically and economically viable and take account of the farmer's welfare as well as the welfare of the animals.

Pig breeders spend much time and labour identifying sows in oestrus. A sow in oestrus can be mated or artificially inseminated. Failure to identify a sow in oestrus means losing about three weeks before the sow comes back in oestrus. A non-productive sow is uneconomic for the farmer, therefore it is in his interests to detect sows in oestrus in time.

Sows are most likely to come in oestrus in 4 to 12 days after weaning. Some sows (known as repeat breeders) come in oestrus again three or six weeks after mating. A sow that comes in oestrus outside the three-week cycle is called an irregular breeder (PV,SIVA,1986). The sows are at different stages of the production cycle, so every day checks must be done to detect sows in oestrus.

Research is being done on ways of improving the viability of group housing systems; one such way is to automate the detection of sows in oestrus. This report describes research refining the preliminary work done by Houben and Houwers (Houben,1988) to find out if the automatic registration of a sow near a boar pen can be used to automate the detection of sows in oestrus. The aim of the research described in this report was to develop an automated system for identifying sows in oestrus that can be used in a group housing system and that warns the farmer or pig breeder in time that a certain animal is in oestrus. This report shows the development and the test results for such a system.

In chapter 2 the symptoms of sows in oestrus and present methods of oestrus detection are explained. Then the requirements an automated system for oestrus detection must meet are described in chapter 3. Various alternative methods that affect the choice of a model and the construction and siting of the boar pen are presented. Chapter 4 describes the chosen variant in the housing situation and how the different models for detecting sows in oestrus were developed. Chapter 5 describes the results obtained when the accuracy of the models was tested. Conclusions are presented in chapter 6.

2 Oestrus symptoms and methods of oestrus detection

One of the major aims of a pig farmer is to maximize his production of piglets. To do this he ensures that his sows are mated at the right time. Various complications may arise and prevent sows from attaining their potential productivity.

The farmer buys or rears a gilt. When the animal becomes sexually mature (this varies among five to eight months, depending on the breed) and is in good condition it will come in oestrus for the first time. It will come in oestrus at regular intervals until it conceives. When a sow is empty a cyclic pattern will arise in which it will display symptoms of being in oestrus. The cycle lasts about three weeks. A repeat breeder will come in oestrus again three or six weeks after being mated, or any time in between in case of an irregular breeder (PV,SIVA, 1986).

Only sows in oestrus can be successfully served. Oestrous sows have certain characteristics that distinguish them from other sows. Van Putten (1965) mentioned the following *external* characteristics:

- a change in the vulva
- a standing reaction when pressed at the back by a boar or stockman
- loss of appetite
- restlessness

Also certain *internal* characteristics change when a sow is in oestrus:

- hormone levels (Mattheij, v.d. Lende, 1984)
  [GnRH, FSH, LH, sex hormones]
- rectal temperature (Schilling, Rostel, 1964)
- fall in the pH of the vaginal discharge
- electrical conductivity of vaginal mucus (Hooper et al., 1982)

Porzig (1969), Willemse and Boender (1966) described the oestrous cycle in terms of certain symptoms of behaviour. The following stages were distinguished (see fig. 2.1 too):

di-oestrus:

- period between post-oestrus and pro-oestrus
- no sexual activity exhibited
- no interest shown in the boar

pro-oestrus:

- sow restless, more active
- activity focused on boar
- sow mounts other sows
- no standing reaction
- sow grunts rhythmically
- vulva becomes red and swollen
- sow seeks contact with boar
- sow loses appetite

oestrus:

- sow calms down
- standing reaction when pressed on the back
- sow seeks contact with boar

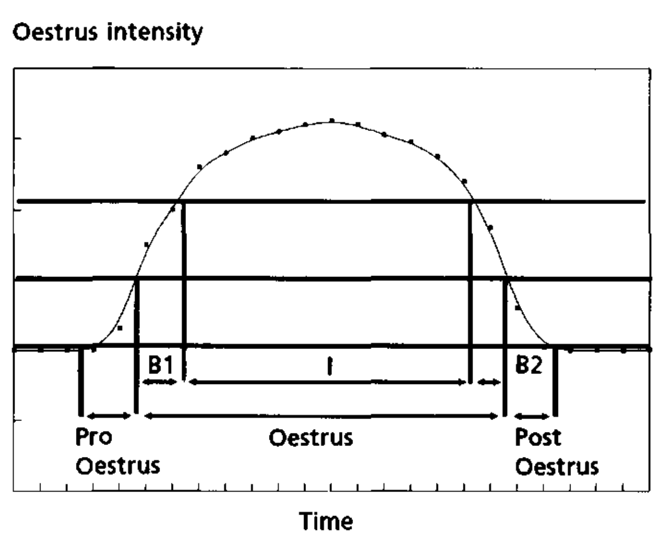
post-oestrus:

- activity decreases
- no standing reaction

The degree to which a sow reacts to a boar, called the *standing reaction* (Willemse and Boender,1966), is a very important behaviourial characteristic. The oestrous period can be divided into a first boar period (B1), an inseminator period (I) and a second boar period (B2) (see figure 2.1). Only during the inseminator period the pig breeder can induce the standing reaction. The Back Pressure Test (BPT) has been specially developed to test this. The boar is a stronger stimulus than the pig breeder and can induce a reaction in the sow in an earlier stage of the sexually receptive period (Schenk,1967). The boar can stimulate the sow via the following senses:

1. optical : the sight of the boar
2. acoustic : the sound of the boar
3. olfactory: the smell of the boar
4. tactile : the touch of the boar

In current housing systems, where the sows are kept individually, usually a teaser boar is used to find out which sows are in oestrus. The sows are stalled in a row and the pig breeder leads the boar along the row once or twice a day or the sows are lead to the boar pen. Sows in oestrus are aroused by the presence of the boar and the boar shows interest in sows that are in



(after Willemse and Boender,1966)

Figure 2.1 Intensity of the oestrus

oestrus. The pig breeder can determine the intensity of the sow's receptiveness by observing vulva changes, the sow's behaviour and the Back Pressure Test.

All the boar's stimuli are used in this method, and the pig breeder gets to know the signs of oestrus in his animals. However, using a teaser boar in this way is labour intensive, because the pig breeder himself has to be present and there is a realistic chance that the boar will become aggressive. In group housing systems it is undesirable to use a teaser boar in the group. This becomes to dangerous for the pig breeder.

3 Requirements of an automated system for dectecting oestrus

3.1 Introduction

To be able to develop an automated method for detecting oestrus one must first define the requirements for such a method. Chapter 2 described how oestrus proceeds and the symptoms that can appear in a sow in oestrus. At present it is still too difficult to continuously monitor and interpret internal parameters such as temperature and hormone levels. To link up with the method used in practice, it is sensible to find out if the strongest stimulus can be used – that is, the presence of the boar. It can be assumed that the greatest response will be achieved when all the boar's stimuli (optical, acoustic, olfactory, tactile) are being used.

The solution that makes use of most of the boar's stimuli is to construct a pen for the boar near the group of sows. This limits the tactile stimulus of the boar. The boar is used to lure the sows. In contrast with the teaser boar method, in which the boar is led past the sows, it is the sow which has to go to the boar. This method makes use of the increasing restlessness of the sow which seeks contact with the boar. Other characteristics, such as the BPT-index, the changes in the vulva and the loss of appetite, determined by the pig breeder, can be used as the final convincing establishment of oestrus.

A sow in oestrus can be expected to be more active and to seek for the boar. As a result of this behaviour she can be expected at the boar pen. So the automated method of detecting oestrus could register this activity induced by the presence of the boar.

The best moment for a sow to be served is during the inseminator period (fig. 2.1). The duration of this period varies among individuals. It is important to detect the oestrus at the earliest possible stage, the (pre-)oestrous phase.

The observations must be translated into an advice for the pig breeder. Given the pig breeder's daily routine, it is best to provide an overview of animals that are possibly in oestrus at least once a day, preferably in the morning. The pig breeder decides if the sow in question should be served.

In group housing systems sows in oestrus are part of the herd. It must be clearly demonstrated that the behaviour of a sow in oestrus differs from that of a non-oestrous sow. Furthermore, several sows may be in oestrus at the same time; hence the method must indicate which animals are in oestrus.

3.2 Constructional provisions

The location for the boar pen in the pigshed must be determined. A pigshed has various areas with a certain function (Koning et al., 1987). The sows must make an effort to get to the boar and therefore the pen must not be adjacent to a busy area (e.g. an electronic sow feeder). On the other hand, the sows in oestrus must not disturb the other animals in the group, and therefore the boar pen may not be approached from a resting area.

The boar pen must have solid walls. In one wall there must be a grille so the sow and boar can touch, smell, hear and see each other. An identification unit should be fixed at the grille, to identify the sows visiting the boar. This unit must operate round the clock and react to the transponders worn by the sows to enable them to obtain feed at the feeding station.

The boar pen must be sited in relation to the other functional areas of the pigshed. The different functional areas and their relation and setting to one another are pictured in figure 3.1.

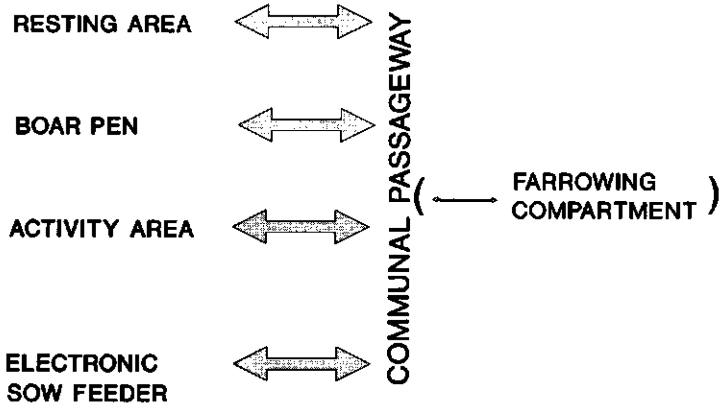


Figure 3.1 Relations between function areas in group housing systems.

From figure 3.1 it is clear that the boar pen should be approached from the communal passageway. The boar pen can be situated next to the resting area or the activity area. If the boar pen is situated in a far corner, that is a dead end, the sows must deliberately seek for it and accidental visits are unlikely. However the sows should have room enough to avoid each other. The fewer false registrations (i.e. the fewer chance visits from sows not in oestrus), the more accurate the identification of sows in oestrus.

3.3 Data collection

The processing of the recorded data must be considered. When developing the automated method for detecting sows in oestrus we opted to record the activity of sows that focuses on the boar. Therefore the use of pedometers is rejected, because these record activity throughout the pigshed. A pedometer is attached to one of the sow's trotters and records her movements continuously.

The identification unit near the boar pen, which reacts to the sows' transponders, records the activity of individual sows daily. The activity can be recorded in two ways: by the electronic sow feeder and by a personal computer (PC). These two methods will be elaborated in paragraph 4.2.

All the data will be read automatically into the IMAG-DLO management system MIS-Piggy (Lokhorst,1990), so they could be combined with other data of the sow.

3.4 Model possibilities

The data produced must be readily understandable by the pig breeder. All he wants to know is which sows are in oestrus. This means that the data from all the animals must be screened. It should become known if sows that are not in oestrus approach the boar, because if they do, then this spurious data must be filtered out. It also should become known if an oestrous sow behaves differently from when it is not in oestrous, and if all sows react in the same way and to the same degree. If this indeed is the case, the data from all sows can be used to make a detection model. But if there are differences between individuals, then the detection model must take account of this.

Various mathematical techniques are appropriate for processing the data. For example, statistical techniques can be used to compare animals, or different observation periods for one animal. A second possibility is to create an explanatory model (e.g. a regression line) if the occurrence of oestrus is correlated with certain parameters (e.g. feed intake and hormone levels). The presence of oestrus then can be inferred from a combination of certain parameters. A third possible strategy is to attempt to predict the onset of oestrus, e.g. by time series analyses. The latter method can be used if it is not certain what causes the sow to come in oestrus. The prediction is based on measured data which tell something about the outcome of the process, in this case the process of coming in oestrus. The sow's presence near the boar pen is monitored over a period of time (days). This enables the sow's behaviour on the following day to be predicted. The fourth technique is to use heuristics. This involves developing a simple rule of thumb, e.g. one that recognizes a certain pattern in the data and then issues a warning.

Two different errors can arise when indicating which sows should be checked. First, a sow may be wrongly indicated to be in oestrus. If this happens often, the pig breeder's confidence in the detection system will be reduced. The second error could be failure to detect that a sow is in oestrus. This error must be minimized. If the animals all display the same behaviour and this behaviour clearly differs, depending on whether they are in oestrus or not, then these errors are unlikely to arise. But if the sows do not react the same way, then the variation will be greater and the errors will increase. Reducing the number of oestrous sows that escape detection will result in an increase in the number of non-oestrous sows that are reported to be in oestrus.

4 An automatic method of detecting sows in oestrus

4.1 Constructional provisions in the pigshed

Transponders are used to identify individual sows in group housing systems. Each transponder has a unique number that is recognized by transceivers in certain places (e.g. in an electronic sow feeder). The transponder number can be read only if its nearby a transceiver.

In pig breeding, transponders are currently used only to identify animals at electronic sow feeders. Transponders also can be used in automated systems for detecting oestrous sows in group housing systems. A boar pen is constructed adjacent to the communal passage way (figure 4.1). One of the walls of the pen contains a metal grille to enable the sow and boar to establish contact. A bar on the floor prevents the sows from lying down in front of the boar pen and a bar on each side of the grille prevents more than one sow standing in front of the grille. A transceiver is installed near this grille and in between the two bars so only one sow will be identified at a time.

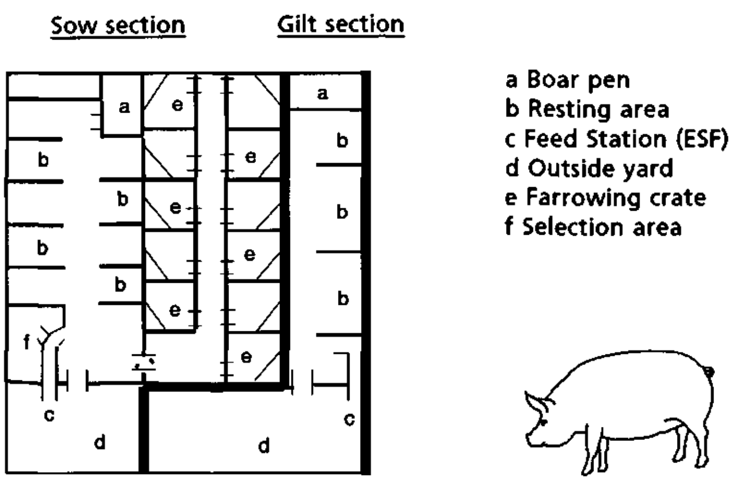


Figure 4.1 Locations of boar pens in an integrated sow housing system (after Buré and Houwers, 1989)

The transceiver is linked to a Nedap/Poiesz electronic sow feeder that records the number of portions for each individual sow. The sows are fed twice a day, at 7.00 and 15.00 and thus at these times the data from the preceding feeding period are retrieved from the electronic sow feeder and stored in the farm computer (a PC). The IMAG-DLO sow herd management program MIS-Piggy was installed on the farm computer.

4.2 Data collection

4.2.1 Registration by the electronic sow feeder

This method is based on the principle of the electronic sow feeder. The identification station at the grille in the boar pen is the same as that used at the electronic sow feeder. At the feeding station the computer will dispense a portion of feed once in a certain period (set by the pig breeder) if the sow is still entitled to rations. The same procedure can be used at the identification point at the grille, but then using imaginary rations.
Each time a sow is identified at this point, an imaginary portion of feed is subtracted from her total allocation. The disparity between the sow's original imaginary ration and the imaginary 'rest feed' indicates how much time she has spent near the boar pen, during a certain period.
We used an imaginary feed allowance of 20 kg per day, an interval of 30 seconds between imaginary 'feeds' and an imaginary portion of 100 g. The electronic sow feeder will see if there is a sow each time after the interval time. The time for recognition is between 3 and 5 seconds. If by the end of the day the computer has registered that 5.0 kg of feed has been dispensed to a certain sow, this means the sow had been near the boar pen for about (50*34) 1700 seconds that day.
This method does not indicate how many times the sow visited the boar pen. It merely indicates the time the sow spent there. The advantage of this method is that it can be applied directly using the electronic sow feeder and enables sows to be monitored round the clock. From now on the data collected by the electronic sow feeder are called Computer Registered Frequency (CRF)

For example the feed and imaginary feed of sow 12 at the end of a feeding cycle is given in table 4.1.

Table 4.1 Example of feed data from a sow to calculate the CRF.

Sow	Planned feed	Rest feed	Planned im. feed	Rest im. feed
12	2.4	0.0	20.0	15.0

Sow 12 has eaten all her food and the CRF value was 50, which means that she was recognised 50 times in 24 hours and thus spent about 1700 seconds near the boar pen.

4.2.2 Registration by a Personal Computer

For this method a special computer program was written to establish which sow is at a certain identification point at what time. This program is used to record visits to feeding stations, boar pens and the entrances to the farrowing compartment (figure 4.1).
The resulting data can be analyzed, to yield the number of visits made and how these visits were distributed over the day. A disadvantage of this method is that it requires the PC to be used continuously. An example of the crude data as registered by the PC is given in table 4.2.

Table 4.2 Example of crude data registered by the PC.

date	time begin	sow	planned feed	rest feed	time (s)
01/06/91	05:17:01	D8E263	20.0	17.8	65
01/06/91	06:10:40	D8E263	20.0	16.8	312
01/06/91	06:30:53	D0O119	20.0	19.5	51

In this research the models, warning of the automatic detection of oestrus, will be part of MIS-Piggy, because the latter has all the data on the sows. All the data in the electronic sow feeder belonging to a certain transponder are stored in MIS-Piggy under the name of the sow carrying that transponder. If a transponder breaks down, the sow can be given another number. The old data remain correct because they have been stored under the sow's name.

Every day MIS-Piggy determines which animals can be identified at which locations in the pigshed. Only those animals which have access to the boar pen need to be identified when they approach that pen. MIS-Piggy sorts out which animals should be identified. The electronic sow feeder is automatically programmed with these data. The electronic sow feeder controls the feeding process and the identification process at the various transceivers. The electronic sow feeder is updated daily and therefore does not become clogged with these data.

4.3 Analysis of measurements of oestrus-related activity

4.3.1 Introduction

The first question to be answered is if oestrus sows will visit the boar pen more often than non-oestrus sows. To answer this question and the question if computer registration can be used as a parameter an experiment has been done by Houben and Houwers. This experiment is described in paragraph 4.3.2. In paragraph 4.3.3 two question will be answered. The first is if a sow behaves differently when it is in oestrus from when it is not in oestrus. The second question is if all the sows react in the same way if they come in oestrus.

The experiments to answer the questions in paragraph 4.3.2 and 4.3.3 use the CRF data.

4.3.2 Reliability of automatic measurements

At first it should be known if the measurements of CRF indicate the occurrence of oestrus in sows. An experiment was done by Houben and Houwers (Houben,1988) to compare three methods of ascertaining if sows are in oestrus:

1. computer registration
2. video registration
3. visual observation

These three methods were applied simultaneously to 28 Duroc/NL sows during a certain period (group 1 Appendix I). The aim was to find out if computer registration could be used for the automated detection of sows in oestrus. The computer recorded the number of 'portions' dispensed to a sow (CRF). One portion was equivalent to spending about 34 seconds at the boar pen. The video recorded which animals visited the boar pen, and enabled the time they visited the boar pen to be determined. The third method was determining the standing reaction (BPT index). For this method the researchers checked the sows twice a day for external signs of oestrus.

For each method figure 4.2 shows how many times sows in oestrus were identified at the boar pen on the day they were served and on the three days before and after they were served.

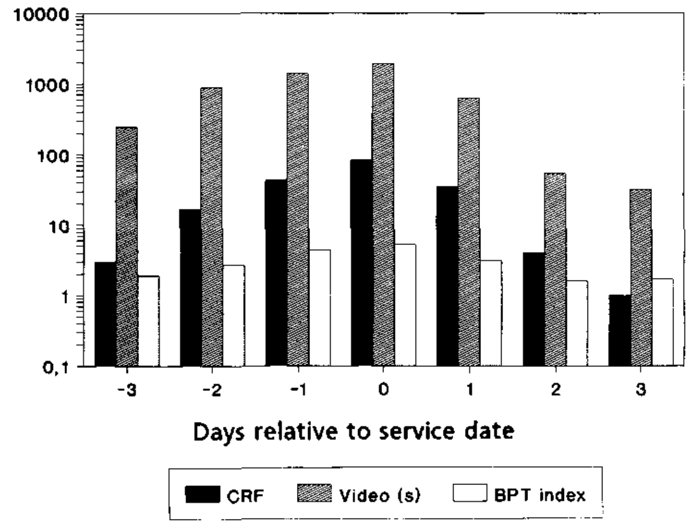


Figure 4.2 Results of three methods of determining oestrus in sows (after Houben, 1988)

Figure 4.2 shows that in all three methods the measurements started to increase a day before the sows were served, peaked on the day of service and then declined. In practice, pig farmers use the standing reaction method. As the computer registration showed the same trend as the Back Pressure Test it was provisionally concluded that the computer method was worth further investigation.

4.3.3 Differences between oestrous and non-oestrous sows

It was found that the occurrence of oestrus coincided with the peak in activity measured by the computer. The next step is to predict and automatically detect oestrus and to translate the data on CRF into an advice for the pig breeder. Figure 4.2 shows that the sow's activity changes round about the day on which she is inseminated. It should be known if the CRF of non-oestrous sows also changed at that time. Two months' (61 days) of CRF data on 36 Duroc/NL sows in the integrated group housing system were collected (group 2 Appendix I), to find out whether there are differences between oestrous and non-oestrous sows. Fifteen of these 36 sows were served during this observation period: two were artificially inseminated; three were served in the gilt section and ten were served in the sow section.
The results were classified for the section in which the animals were housed, to find out if the location influenced the sows' activity.

Table 4.3 shows the frequency distribution during the monitoring period. The CRF has been divided into 11 classes: 0, 1__5, 6__10, 11__15, 16__20, 21__25, 31__35, 36__40, 41__45, 46__50

Table 4.3 Frequency distribution of number of days per sow on which the measured CRF falls in a class of activity. (n = total no. of days of the monitoring period)

n	Animal nr	class											
		0	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	>50
		Not served or inseminated											
61	4	48	12		1								
61	7	59	2										
61	8	45	12	1	2	1							
61	32	56	5										
61	33	29	31	1									
61	34	51	10										
61	36	36	13	7	3	1	1						
61	37	31	23	5	1				1				
61	38	50	7	3				1					
57	41	24	17	10	4	2							
61	42	42	19										
61	53	58	3										
61	56	39	17	2	1	1	1						
61	57	46	13	1		1							
61	60	26	22	9	4								
57	61	39	15	2	1								
57	63	35	21	1									
50	64	26	16	5	2	1							
61	65	49	11		1								
61	69	43	12	5	1								
61	70	43	16	2									
		Artificial insemination											
50	9	28	13	3	1				1	2	1	1	
50	66	26	14	4	3								3
		Served in the gilt section											
50	1	22	12	9	1	1	1	4					
61	47	32	24	3							1	1	
61	59	30	15	8	2	2				1		1	2
		Served in the sow section											
61	5	35	19	2					1				4
61	27	14	15	10	11	5	2			1			3
61	30	38	14	5		1			1	1			1
61	40	30	14	10	1	2		1		2			1
61	44	37	18	2			1				1		2
61	45	38	17	2	1							1	2
61	58	15	33	4		3		1	1	2			2
61	62	13	36	7	2	1			1			1	
61	67	32	22	1	2		1			1			2
61	68	34	19	5	3								

and 50+ registrations (i.e. the number of times an imaginary portion of feed was 'dispensed'). The number of days a certain sow's CRF falls in a certain class is indicated. The sows were subdivided into animals not served in the monitoring period, served in the sow section, served in the gilts' section, and artificially inseminated. The boars were also used to serve the sows.

The pig breeders detection of oestrus was done independently of the recording of the CRF. Two hypotheses were tested:

Null hypothesis:
There is no systematic difference between the CRF of oestrous and non-oestrous sows and the way or place of serving

Alternative hypothesis:
Oestrous sows are found near the boar more often than non-oestrous sows and the way or place of serving does matter

The sows were randomly allocated to the unserved or served group. The served sows were split according to how they were served. A sow's behaviour could be dependent on other sows, but is independent with respect to the group to which she has been allocated. The only precondition is that the detection of oestrus is strictly independent on the registration of the CRF. This seems to be a reasonable assumption.

The linear logistic method with unknown class boundaries was used. This method is comparable with the more familiar table of analysis of variance. According to this method, differences between sows are shifts in the logistic distribution when the boundaries of classes remain constant. Four methods were applied consecutively:

1. All sows were assumed to be identical.
2. Two groups: served and unserved. The animals within a group were assumed to be identical.
3. Four groups: unserved; served in gilt section; served in sow section and artificially inseminated.
4. The sows were treated as individuals.

Of course, observations on the same animal are not independent over time and therefore the numbers per class are also not independent. This means that much greater differences between the sows can be expected than would be the case with multinominal classification, even if the method with the same classification of animals in one group held strictly. The variance was assumed to differ from the variance according to the multinominal distribution by a factor θ

Table 4.4 Deviations of four methods to test differences between oestrus and non-oestrus sows.

method	deviation
1	700.0
2	577.2
3	576.2
4	327.3

(called the dispersion factor). The deviation indicates the method's appropriateness; it is based on the log likelihood on the basis of the multinominal distribution with independent observations per animal in time. Table 4.4 gives the deviations of the four methods mentioned above.

If the method, including the independence of time, holds, then the difference between two hierarchical methods (in which one method constrains the other) is chi square divided, with the number of degrees of freedom being the difference between the number of parameters to be estimated in the two methods. Note that the four methods are hierarchical, with method 1 constraining method 2, method 2 constraining method 3, and method 3 constraining method 4. Because independence does not hold, the difference is θ times greater. θ is estimated from the difference in deviation between methods 3 and 4, based on 32 degrees of freedom. This difference in deviation can be considered to be the variance (between animals). Differences between groups are tested against this variance. The analysis of deviation (comparable with the more familiar table of analysis of variance) is given in table 4.5.

Table 4.5 Analysis of deviation of four methods to test difference between oestrus and non-oestrus sows

cause of variance	deviation	DF	mean dev	DevRatio
	(difference between methods)			
served or unserved	122.7	1	122.73	15.8
way of serving	1.0	2	0.51	0.1
rest	248.9	32	7.78	

The DevRatio can be considered as the F value in the analysis of variance. There is a clear difference between served and unserved, but there is no difference according to the way the sow is served. The dispersion factor (θ) is estimated to be 7.78.
No specific differences among the individual sows can be demonstrated, because the observations were not made independent of each other. The sows were not segregated. However, individual differences are likely.

4.4 Detecting oestrus on the basis of group data (model 1)

When developing models for detecting oestrus it is most important to look at the animals in oestrus and to be able to assume that they react relatively uniformly and that the activity during oestrus differs from the activity at other times.

A model for warning sows are in oestrus must process data on the activity that is focused on the boar. It must warn the pig breeder if he needs to check a certain sow. It has been proved that oestrous sows react differently to non-oestrous sows in activity focused on the boar. It is assumed that all sows in oestrus react in a similar way and thus exhibit increased interest in the boar. This assumption allows a certain warning threshold to be calculated by working out how active oestrous sows are on the day they are served and on the preceding day. The warning model is relatively simple. When the CRF of a sow exceeds the calculated limit (the warning threshold) the model advises the pig breeder to check that sow. The automated method of detecting sows in oestrus must warn the pig breeder in time. In the real instance of a sow in oestrus it must be capable of recognizing the (pro-)oestrous phase. Hence the day before the measured CRF peaks and the probable day on which the sow is expected to be served must be incorporated in the calculation of the threshold.

CRF data of 97 served sows on the day and the day before serving where used to estimate the threshold value (group 3 Appendix I). Note that the actual check upon whether sows were in oestrus was independent of the observations made by the pig breeder. This could mean a sow was not necessarily served at the moment she was at her oestrous peak or at her peak of CRF registration. This is why the maximum activity of these two days was determined.
Table 4.6 shows some of the percentiles of the CRF distribution. A percentile of 5 indicates in 5% of the 97 oestrus periods the maximum CRF was less than 25.9.

Table 4.6 Percentiles of the CRF from 97 oestrus periods, determined from the maximum CRF on the day on which they were served and the day before.

Percentile	CRF
5	25.9
10	31.2
15	35.7
20	43.2

The above table enables a tolerance limit to be chosen. The model is formulated so that it alerts the pig breeder to check a sow if the CRF on one day is 26 or more. This means that a tolerance limit of 5% is chosen. Once this number exceeds 50, then the pig breeder can be advised to have the sow served. The value of 50 has no basis, but one can say that there will be a graduation in the height of the CRF value. The decision on whether to have the sow served always remains the pig breeder's responsibility. Actually, the advice consists of indicating at which phase in the oestrous cycle the sow could be in. The level of the CRF could be an indication if the sow is in the di-oestrous, pro-oestrus, oestrus or post-oestrous phase.

When this method is used in practice an initial period will be spent collecting data. Only after sufficient successful matings the warning thresholds for a particular section can be calculated. Until then an advised default warning threshold can be used. The level of CRF measured may still depend on the layout of the section. Thus new thresholds have to be calculated every time the layout is changed. This problem can be solved by expanding the model with an automatic calculation of the threshold limits. The data on each successful service must be input into the model. The warning thresholds will be calculated when sufficient data have been input. Each new service yields new information so the thresholds can be recalculated.

The model with the default thresholds therefore looks like this:

CRF more than 26	**check the sow**	**(c)**
CRF more than 50	**sow probably in oestrus**	**(b)**

Remember, the CRF is measured as the number of 'portions' the electronic sow feeder allocates to a sow on one day.

4.5 Prediction-based warning model (model 2)

The second warning model is based on data on individual animals monitored over time. The course of the animal's CRF when it is not in oestrus is compared with its CRF during oestrus.

The method is as follows. The observations made during several days before a given observation are compared with that observation and used to predict the CRF on the following day. On that day the measured CRF is compared with the predicted CRF. The pig breeder can be warned how much the actual value deviates from the predicted value. If the deviation is too large, a message must appear telling the pig breeder to check the sow. The difference in level of CRF in oestrus and at other times is sufficient to be able to give good warning.

A prediction must be made every day for each sow. Which method of prediction should be used? The following basic elements can be incorporated into a prediction model: stationary pattern, trend, seasonal effect, cyclic pattern and a chance component (Makridakis, 1983). The model's predictions for oestrus detection have a very short time horizon (several days to several weeks) and therefore the model does not have to take account of seasonal effects or a cyclic component. A method using progressive means is suitable for the data available. All the observations (say, 10) from the past have the same weight, so the observations from the non-oestrous period are seen as chance deviations. Progressive means have the disadvantage much data have to be stored for each sow. The use of an exponential smoothing prediction technique is a good alternative. Instead of each observation being of equal weight, the most recent observation has the most weight and this weight depends on the smoothing parameter chosen by the user. It must be assumed a sow continues to exhibit the same level of CRF during the period she is not in oestrus, so no trend is present. The prediction can be made using the following model:

$$F(t+1) = \alpha X(t) + (1-\alpha) F(t)$$

in which X(t) represents the CRF of the measured day, F(t) the CRF predicted on bases of the past, and F(t+1) the CRF predicted for the next day. When making the first prediction the first observation has to be chosen; it is usually set to be equal to the first observation or to the mean of the first ten observations. The deviation of the measured value from the predicted value can be calculated using the formula:

$$\text{Percentage deviation} = [X(t) / F(t)] * 100$$

As soon as the percentage deviation exceeds a certain threshold, a message is displayed warning the pig breeder to check the sow to see if she is in oestrus.

The method works as follows. The data are collected per sow. The measured value is compared with the predicted value and, if necessary, a warning is generated for the pig breeder. After the comparison a new prediction is made on the basis of the preceding prediction and the present observation. In this instance, only the predicted value needs to be stored per sow.

When specifying the warning model the value of the smoothing parameter (α) and of the first prediction must be decided on. The value of α determines how many of the preceding days still influence the prediction. If α is assigned a high value (e.g. α = 0.3), the most recent observations have a very strong influence. But if α is small, many observations have an influence and the predicted value will react very sluggishly to chance deviations. Choosing the most appropriate value for α is a tricky business. The problem is that during the non-oestrous period the observation can also have a value of zero. If this occurs often, the predicted value also approaches zero. Then every value above zero has a large percentage deviation. Be careful to ensure the predicted values are not too small. This means α must be relatively small, so the predicted activity does not react so quickly to a change. This is equivalent to a progressive mean over a long period. It is assumed that the difference between oestrus and non-oestrus is sufficiently large for a deviation to be spotted.

The first prediction chosen can have a major influence on the accuracy of the prediction. Often, the first observation is chosen to be the same as the first prediction. But this cannot be done when predicting activity during oestrus, because there is a large chance that the first activity measured will be small or zero and hence the subsequent predictions could show enormous deviations. The result would be many spurious warnings of sows in oestrus. To prevent this, the first prediction must not be too low. The choice of the first prediction also depends on whether predictions are begun anew before each production cycle (parity.) A new production cycle begins when a sow is weaned, a sow has aborted or when a gilt is sexually mature. As a rule, most sows or gilts are in oestrus within twelve days from the start of the production cycle. If the predictions are started at the beginning of the production cycle the first prediction should not be too high, because otherwise the percentage deviation will not be perceived.

Data from the non-oestrous period are used when determining α and the starting value of the prediction. We decided to choose a relatively low α (0.01) and to ascribe a first prediction of 5 to the beginning of the production cycle. The prediction for gilts which are not weaned begins at the moment they are obtained or recognized as being sexually mature. As soon as the measured activity is seven times higher than the predicted activity (this is equivalent to a 700% deviation), sows in oestrus are signalled as needing to be checked. If the deviation exceeds 1000% the sow can be signalled as being in oestrus. These thresholds are comparable to the thresholds of model 1. For the determination of the threshold the data from group 2 (Appendix I) are used.

Then the model is:

$F(0) = 5.0$ at the start of a production cycle

- weaning
- abortion
- gilt's arrival in a pigshed with automated detection of oestrus
- when a gilt reared in the pigshed becomes sexually mature

$F(t+1) = 0.01\ X(t) + (1-0.01)\ F(t)$

Percentage deviation $= [X(t)/F(t)] * 100$

If percentage deviation exceeds 700% check the sow (c)

If percentage deviation exceeds 1000% sow is probably in oestrus (b)

4.6 Prediction on the basis of cumulative time per 24 hour (model 3)

Writing about the initial trial on the automatization of oestrus detection, Houben (1988) reported that oestrous sows exhibit different levels of activity near the boar pen at different periods of the day. If the daily total of visits or time spent is calculated only once a day at a fixed time, oestrous sows with a low peak of activity near the boar pen at that time might escape detection. The trial reported here was intended to develop a model that eliminates this problem by using an hourly report of the sow's presence at the boar pen during the preceding 24 hours. These data enable the period before mid-oestrus to be detected. The mid-oestrus is estimated by the Back Pressure Test. Thus, when this model is used in practice, the total time each sow spends near the boar pen each hour of a 24-hour period has to be stored in the computer.

The personal computer continuously registered the presence of sows near the boar pen. From these data the computer hourly calculated and stored each sow's total presence at the boar pen during the preceding hour. From now on the cumulative time over 24 hours will be referred as the 'computer registered time', abbreviated 'CRT'. Model 3 works the same as model 1. The differences between the two are the used data and the moments of the day the attentions could be made. The hour that the CRT reaches a value of 900 seconds (in our study this was equivalent to a CRF of 26: according to model 1) is the warning threshold. This will be called 'the moment of alert', abbreviated 'Ta'.

The model with the default threshold therefore looks like this:

CRT more than 900 check the sow (c)

Figure 4.3 shows an example of a calculation, using hypothetical data (see Appendix III). In this example it is assumed there were no registrations before hour 1 and after hour 22.

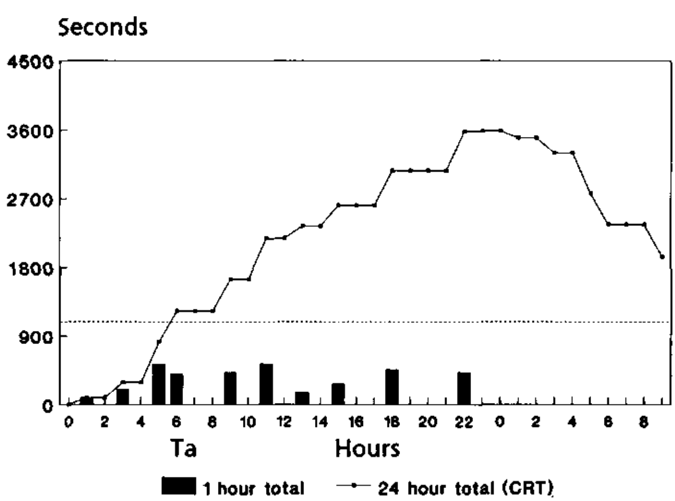


Figure 4.3 An illustration of the way the continuing total of the time a sow has been registered at the boar pen (CRT) during the preceding 24 hours is calculated. The moment of first alert is indicated by Ta.

Figure 4.3 shows in this example the cumulative total exceeds the threshold value of 900 seconds in hour 6 (Ta), whereas the CRT peaks in hour 22.

Figure 4.4 depicts the course of the cumulative total over 24 hours of a random sow. It appears that the time this sow was registered at the boar pen in a 24-hour period took 1½ days to peak and then remained at a high level for 2 more days, before dropping rapidly to a basic level. In this case the warning threshold was exceeded for about 4 days, the moment of alert (Ta) was almost 48 hours before the estimated middle of oestrus (Te), and the peak of the cumulative total (Tp) occurred about half a day before the middle of the oestrus.

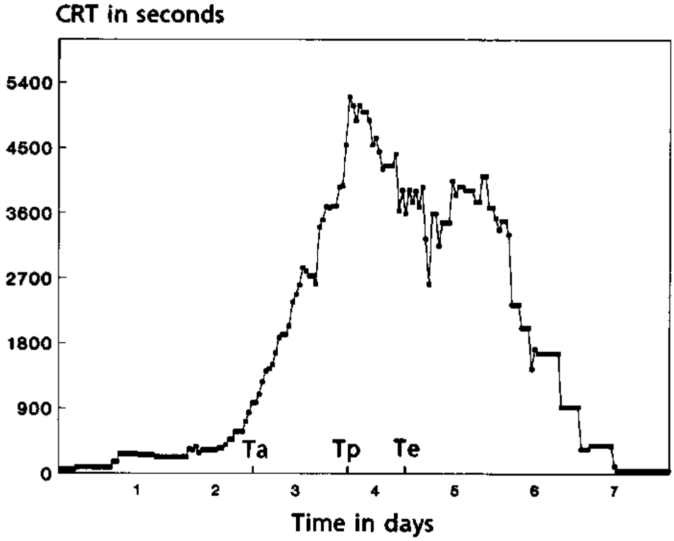


Figure 4.4 The cumulative total of time a random sow spend near the boar pen during the preceding 24 hours (CRT), showing the CRT peaked (Tp), the moment of alert (Ta) and the middle of the oestrus (Te).

5 Testing the detection models

5.1 Models based on CRF data

Data relating to checking for oestrus were collected 112 days from 31 sows to test the models one and two (group 4 Appendix I). These data were from a different period than the one used when establishing the threshold values for the models (group 2 and 3 Appendix I). Seventeen of the 31 sows were served in the observation period, the others were not. The pig breeder carried out the checks for oestrus and decided whether the animals should be served or not. The observed data were collected in the sow section and there were only multiparous sows present.

Appendix II gives a summary of the observations made during this test phase. They were, per sow: the number of days she passed the threshold to be checked (c), the number of days she passed the threshold for oestrus (b), the number of days she was wrongly signalled as being oestrous and the number of times her oestrus was not detected by the model.

Table 5.1 shows the data from a random sow to illustrate the effectiveness of the two detection models.

Model 1: Detection on the basis of group data:

CRF more than 26 check the sow (c)
CRF more than 50 sow probably in oestrus (b)

Table 5.1 Data from a random sow to illustrate the effectiveness of model 1 and model 2.

CRF X(t)	prediction F(t)	dev. %	Model 1	Model 2	
0	5.00	0			date of weaning
1	4.95	20			
0	4.91	0			
2	4.86	41			
2	4.83	41			
2	4.80	42			
5	4.77	105			
8	4.77	168			
77	4.80	1604	b	b	
147	5.52	2663	b	b	
122	6.93	1760	b	b	date served
117	8.08	1448	b	b	
34	9.17	371	c		
0	9.42	0			

Model 2: Detection on the basis of prediction:

perc. deviation more than 700% check the sow (c)
perc. deviation more than 1000% sow probably in oestrus (b)

F(0) = 5.0
F(t+1) = 0.01 X(t) + (1-0.01) F(t)
Percentage deviation = [X(t) / F(t)] * 100

For the sow in table 5.1 the difference between the two models is that model 1 gives one more warning, after the sow has been served. Both models give a satisfactory result.

The results as presented in detail in Appendix II are summarized in table 5.2. The latter table shows the number of oestrus periods and the number of days in a certain category. 'Signalled' means a message a sow must be checked (c) or that she is in oestrus (b). The number of times a false alert was given (resulting in the pig breeder doing an unnecessary check) is also given. The number of oestrus periods that were missed by the model but detected by the pig breeder is also given. Both numbers, especially the latter one must be kept as low as possible.

Table 5.2 Summary of the test results for model 1 and model 2.

		Served		Not served	
		Oestrus	Sow-days	Oestrus	Sow-days
		17	1904	14	1568
Model 1					
	signalled	16	72	5	11
	false alert	4	10	5	9
	missed	2	2		
Model 2					
	signalled	15	38	4	4
	false alert	0	0	4	6
	missed	2	3		

From table 5.2 it can be seen that two sows were not detected by both models. This means that 12% of the sows did not react to the boar. The models did give timely warnings to check the sows in oestrus. The difference between the two methods is the amount of false alerts, 19 versus 6, which are higher with model 1. The percentage of false alerts are 0.5 with model 1 and 0.2 with model 2. Both models can be used, as the results they give do not vary greatly. Only animals that approach the boar pen can be detected by the automatic oestrus detection system and therefore these methods are able to automatically detect only 88% of the sows in oestrus depending on the willingness of the sows to come to the boar pen.

5.2 Model based on CRT data

In this trial, which ran from January 15 to June 1 1990 (group 5 Appendix I), the first insemination-rewarded oestrous period of all the sows and gilts in the sow section and the gilt section was analyzed. During this period all the sows present had at least one opportunity of becoming oestrous.

All sows which management data indicated they were likely to become oestrous were given the Back Pressure Test (BPT) twice daily at 7.30 and 15.30 h (for a description of this test, see Willemse and Boender, 1966). The aim of the BPT was to estimate the middle of the oestrous period, which generally is an appropriate time to inseminate a sow. The sows were first tested on the outside yard, away from the boar, and then at the gate of the boar pen, near the boar. The BPT executed away from the boar gives an indication of the inseminator period, while the BPT executed near the boar indicates when the boar period can be expected. The sows were not admitted to the boar pen. The BPT is positive when a sow does not walk away when a tester tries to sit on her back. The mid-oestrus (Te) was estimated by calculating the mid-point between the first and last observation of a positive response to the BPT.

Willemse and Boender (1966) report that the ratio in time between the first boar period, the inseminator period and the second boar period is 1:4:1. This implies the inseminator period falls in the middle of the boar period. Either the inseminator period or the boar period can be used to calculate the middle of the oestrus period.

To minimize the chance of affecting the sows' normal movement to the boar pen, any treatment that might influence their behaviour was avoided as much as possible, as was frequent contact with the boar. A sow's response to the Back Pressure Test can be affected if it is afraid of other sows or of the stockman (Hemsworth et al., 1981 and 1989).

In the trial a total of 18 sows and 6 gilts in the sow section and 7 gilts in the gilt section could be tested. It is coincidental that this is the same number of animals studied in the trial described in paragraph 5.1.

Table 5.3 gives an overview of the degree to which the animals in the different sections responded positively to the tests. Of the 31 oestrous sows, 28 reached the warning threshold of 900 seconds. In total, these 28 oestrous periods accounted for 1684 reports of a CRT of 900 or

Table 5.3 Number of positive responses to the BPT, and CRT of 31 served animals, specified by section and parity.

	Sow section		Gilt section	Total
	Par. >1	Par. 1	Par. 1	
Back Pressure Test (BPT)	15	2	5	22
CRT >900 s	18	4	6	28
BPT+CRT >900 s	15	1	4	20
Total number of animals	18	6	7	31

above. This means, on average, these 28 animals were detected as being in oestrus for 60 hours. The length of the oestrus period varied from 21 to 98 hours.

More sows reached the warning threshold than the number of sows that reacted positively to the BPT. Twenty of the 28 animals that reached the warning threshold of 900 seconds responded positively to the BPT.

Three animals were not detected. This is 10% which is almost the same as the 12% with the test for model 1 and model 2. The 3 animals that did not reach the warning threshold of 900 seconds were all gilts (parity 1). Their maximum CRT's were 878, 650 and 139 seconds, respectively. The gilt with the CRT of 650 seconds did not show a standing reflex in the BPT either. The gilt with CRT 139 was lame. Seven of the nine animals that did not show a sufficient standing reflex were less than one year old at the start of the experiment. Three other gilts in the sow section that had shown no signs of oestrus, and so were not included in the trial, proved to be cyclic at the post-mortem examination when they were 11 months old.

All cases, the moment sows exceeded the warning threshold for the first time, were well before Te (the middle of the oestrus estimated from the BPT). Sometimes, the CRT peaked after the estimated mid-oestrus. The higher the peak, the earlier the alert is likely to be. This is illustrated in figure 5.1. In this figure the moment of alert (Ta) and the moment the peak was reached (Tp) are displayed as a function of the level of the peak of the CRT and the time before the middle of oestrus. These moments are expressed in 'hours before the estimated middle of the oestrous period'.

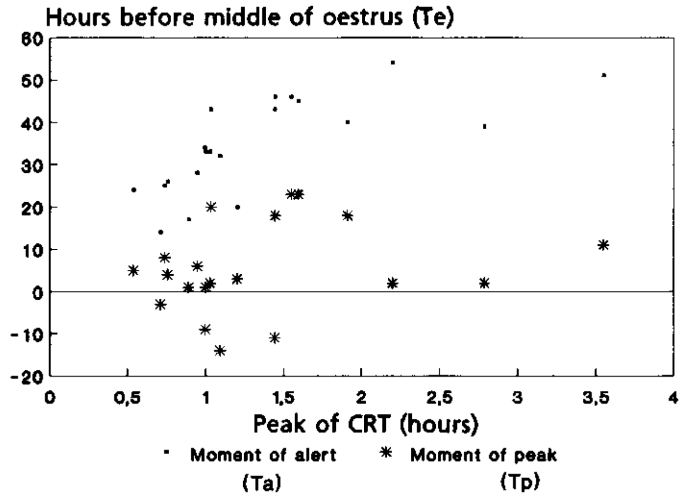


Figure 5.1 The moments of alert (Ta) and peak (Tp) in relation to the middle of oestrus (Te) and the peak of the CRT.

In all cases, the warning threshold was reached well before the middle of the oestrus, whereas the moment the CRT peaked was registered closer to the middle of the oestrus. This leads to the conclusion that the time oestrous sows spend near the boar pen has a rather uniform course. However, there is a considerable difference between sows in the level of this course; this was also noted by Houben (1988) and Houwers (1988).

For the 20 sows for which Ta and Tp could be determined, the time between the estimated middle of the oestrus and the moment they reached the warning threshold of 900 seconds varied from 14 to 54 hours (Appendix IV and V). Seventeen sows (85%) had reached the warning threshold 24 hours before the middle of the oestrus (figure 5.2). The period between the estimated mid-oestrus and the moment of alert could not be ascertained for the 8 animals that reached the warning threshold but reacted negatively to the BPT.

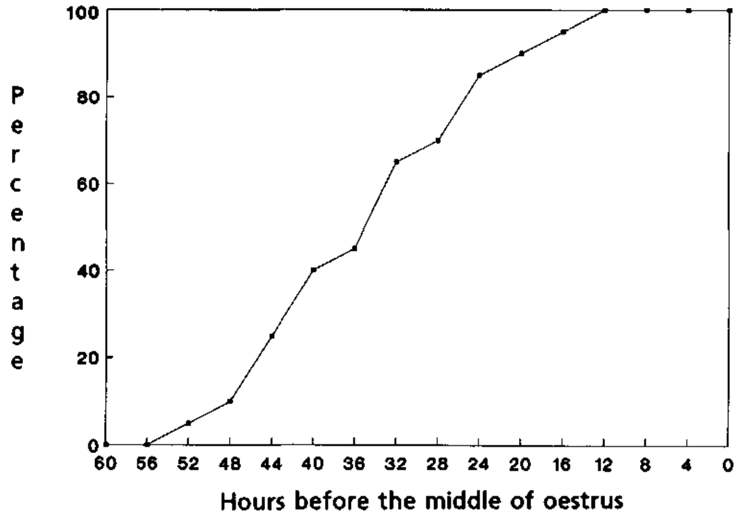


Figure 5.2 Cumulative percentage of alerted sows relating to the time interval before the estimated middle of the oestrus from the 20 sows that responded positive to the BPT and the CRT-threshold.

Despite the staggered weaning, the oestrous periods of different sows appeared to overlap. From the 1684 times that sows reached the warning threshold, in 398 cases 2 sows did so simultaneously, in 21 cases 3 sows did so simultaneously and in 84 cases 4 sows did so simultaneously (table 5.4). This means that in over 16 % of the number of hours that the warning threshold was exceeded, more than one sow was involved.

The figures shown in the table 5.4 refer only to the first oestrus of each sow that was rewarded with a service. Later oestrous periods of the same sows and possible false alerts were not included in the analysis; therefore it can be assumed that in reality more sows would have exceeded the warning threshold simultaneously than the table indicates.

Table 5.4 Frequencies and percentiles of occurrences and hours with alerts for different numbers of sows in oestrus that exceeded the warning threshold of 900 seconds simultaneously.

Number of sows	Occurrence of alerts		Hours with alerts detected	
	Frequency	Percentile	Frequency	Percentile
1	1181	70.1	1181	83.9
2	398	23.6	199	14.1
3	21	1.2	7	0.5
4	84	5.0	21	1.5
>1	503	29.9	227	16.1
Total	1684	100.0	1408	100.0

6 Discussion and conclusions

As a result of developing an automated method for oestrus detection it can be concluded there is a clear difference between an oestrous and a non-oestrous sow, in terms of activity focused on the boar (CRF or CRT). This finding was used when developing the detection models.

The methods of model 1 and model 2 differ in that model 1 works with a warning threshold based on group data and model 2 with predictions for individual animals. The data in model 1 are based on the CRF, which differs from model 3 where the data are based on CRT. Model 3 is an elaboration of model 1 to enable hourly alerts.

The models developed react sufficiently quick, implying that they spot the transition in behaviour from the di-oestrous to the (pro-)oestrous phase. The pig breeder then always has enough time to check the sow and to decide whether or not she should be served.

Testing the models 1 and 2 using the default threshold values enabled 88% of the sows in oestrus to be detected. The number of false alerts for model 1 and model 2 were respectively 0.5 % and 0.2 %. In practice, the optimal set-up must be found by examining the number of false alerts of sows in oestrus and the number of oestrous sows that escape automated detection and changing the standard set-up as necessary.

With model 3 the percentage of sows that reached the default warning threshold was 90%, which agrees with the models 1 and 2. If the sows that were negative to the BPT show the same activity near the boar pen as the BPT-positive animals, it can be assumed that in the trial situation described and at a warning threshold of 900 seconds, about 77% of the sows can be detected 24 hours before the middle of the oestrus. This is the minimum success rate of the models described. Model 3 will be able to detect 90% of the oestrus sows 12 hours before mid-oestrus. At a lower warning threshold the percentile of sows detected will probably increase. Lowering the warning threshold will result in most sows being detected earlier, and the additional sows detected will be detected relatively close to the middle of the oestrus. This means that the total period in which sows can be detected will increase, which might complicate herd management.

As mentioned with model 3, in over 16 % of the number of hours sows exceeded the warning threshold, more than one sow was involved. This indicates the method of automatic oestrus detection enables several sows to be detected in oestrus simultaneously.

Automatic oestrus detection will prove its value when the empty sows are kept together for a longer period, for example until after the three- or six-weekly post-insemination check or together with sows in other states of the reproduction cycle, with the pregnant sows or with all the sows as in the integrated group housing system. In these cases automated oestrus detection will be useful and also will be a way of detecting repeat breeders in time.

The fact that the animals in the trial were housed in a group near the boar and had contact with different people may have affected the results of the Back Pressure Test. This may have reduced the number of animals that reacted positively to the BPT.

The results of the BPT suggest that not all oestrous animals showed a standing reflex when the tester sat on their backs. This agrees with the findings of earlier researchers (e.g. Willemse and Boender, 1966; Schenk, 1967; Hemsworth et al., 1984, 1987 and 1988). According to Signoret (1961) 97 % of the animals are BPT-positive when they can see, hear and smell a boar. This means the results of the BPT executed near the gate of the boar pen should not differ much from the results found by these researchers. The fact that all BPT- negative animals could be served, which indicates there had been a boar period, suggests other factors (e.g. the fact that the sows were housed near the boar – see Hemsworth et al., 1984, 1986 and 1987) influenced the response to the BPT as well.

Gilts should not be transferred to the sow section before they are pregnant, because there are strong indications that although they are probably cyclic, virgin gilts will not show signs of oestrus when put in with older sows.

The gilts and young sows exhibited a particularly poor response to the BPT. No oestrus was observed in three gilts in the sow section, even though they were cyclic. The reason for this might be these young animals were under high stress, because of fear induced by agonistic interactions with other sows. Therefore there are grounds for not transferring gilts to the sow section until 3 weeks after insemination. This is supported by fertility results from an experiment in which sows were introduced in a group at different moments after insemination (Te Brake, Houwers, 1990).

The course of the CRT and the variation of the moment the CRT peaked means the moment of peaking is not very useful for giving warning of oestrous sows: the peak can only be identified retrospectively and sows would have to be inseminated directly after the alert, if this is not too late.

In case of model 1, only the two thresholds need to be stored. A database could be created for the thresholds; in it the CRF data before, after and during the day of service could be stored.

The prediction method (model 2) requires a predicted value to be stored for each sow, in addition to the threshold values. The smoothing parameter ($\alpha = 0.01$) and the initial value at the beginning of a production cycle F(0) also can be recorded as variables per section; in that case, the whole model becomes variable and can be adapted to fit the section situation exactly. Every day the predicted value for each sow must be modified, using the previous prediction and the actual measured value. Thus no new data need to be stored for the automated checking for oestrus.

Model 3 should store the same as model 1 and extra the time spent per hour per sow.

In the day-to-day running of the farm the pig breeder must ensure the detection program is ready before he inspects the sows in the section. This means the program must be run automatically in the morning. In the integrated group housing system the first feed begins at 7 o'clock in the morning. Immediately after this the CRF data in the preceding feed period are known. If the detection program is run immediately after the start of feeding, the most recent data are used and any warnings are given before the pig breeder enters the section. Figure 6.1 shows what an advice looks like. Each day these messages will be printed for the farmer.

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Appendix I

Groups of sows used to develop and to test the models

Group	Number of sows	Paragraph	Used for
1	28	4.2.2	Test video, BPT, CRF
2	36	4.3.3	Difference between oestrus and non-oestrus
			Determine thresholds model 2
3	97	4.4	Determine thresholds model 1 and 3
4	31	5.1	Testing model 1 and model 2
5	31	5.2	Testing model 3
			Determining simultaneously oestrus periods

Appendix II

Results of detection models 1 and 2, based on the CRF, during the testing phase

In the test 31 sows were followed for 112 days (group 4 Appendix I). The amount of days the CRF falls in a certain category is given per sow. The alerts given by each model are subdivided into a check phase and an oestrous phase.

A. Detection on the basis of group data (model 1):

CRF more than 26	**check sow**	**(c)**
CRF more than 50	**sow probably in oestrus**	**(b)**

B. Detection on the basis of prediction (model 2):

perc. deviation more than 700%	**check sow**	**(c)**
perc. deviation more than 1000%	**sow probably in oestrus**	**(b)**

The model is:

$$F(0) = 5.0$$
$$F(t+1) = 0.01\ X(t) + (1-0.01)\ F(t)$$
$$\text{Perc. deviation} = [X(t) / F(t)] * 100$$

1. No. of observations with alert 'check'
2. No. of observations with alert of 'in oestrus'
3. No. of false alarms
4. No. of oestrus periods that escaped detection

Not served			Served		
Sow	Model 1 1 2 3 4	Model 2 1 2 3 4	Sow	Model 1 1 2 3 4	Model 2 1 2 3 4
1	0 0 0 0	0 0 0 0	4	2 3 2 0	0 2 0 0
5	0 0 0 0	0 0 0 0	8	0 0 0 1	0 0 0 1
27	1 0 1 0	1 0 1 0	33	5 3 0 0	3 1 0 0
32	0 0 0 0	0 0 0 0	34	1 2 0 0	0 2 0 0
40	1 0 1 0	0 0 0 0	36	0 4 0 0	1 3 0 0
47	0 0 0 0	0 0 0 0	37	0 1 0 0	0 1 0 0
58	0 0 0 0	0 0 0 0	38	3 2 1 0	1 2 0 0
59	4 2 5 0	2 1 3 0	41	7 4 6 0	0 3 0 0
62	0 0 0 0	0 0 0 0	42	4 1 1 0	2 1 0 0
64	0 0 0 0	0 0 0 0	45	2 0 0 0	1 0 0 0
65	0 0 0 0	0 0 0 0	53	2 0 0 0	2 0 0 0
66	0 0 0 0	0 0 0 0	56	1 0 0 0	1 0 0 0
67	2 0 1 0	0 2 1 0	60	3 1 0 0	1 1 0 0
69	1 0 1 0	1 0 1 0	61	0 2 0 0	0 2 0 0
	\ /	\ /	63	1 5 0 0	1 4 0 0
	5 signalled	4 signalled	68	2 0 0 1	0 0 0 2
	5 false alert	4 false alert	70	2 1 0 0	1 2 0 0
				\ /	\ /
				16 signalled	15 signalled
				4 false alert	0 false alert
				2 missed	2 missed

Appendix III

Example of the calculation of the cumulative 24-hour total of the time (s), a sow has been present at the boar pen.

Hour	1-hour total		24-hour total	
0	0		0	
1	89		89	
2	0		89	
3	197		286	
4	0		286	
5	534		820	
6	406		1226	Hour of alert.
7	0		1226	
8	0		1226	
9	419		1645	
10	0		1645	
11	536		2181	
12	0		2181	
13	159		2340	
14	0		2340	
15	268		2608	
16	0		2608	
17	0		2608	
18	459		3067	
19	0		3067	
20	0		3067	
21	0		3067	
22	521		3588	
23	0		3588	
0	0		3588	
1	0	(− 89)	3499	
2	0		3499	
3	0	(−197)	3302	
4	0		3302	
5	0	(−534)	2768	
6	0	(−406)	2362	
7	0		2362	
8	0		2362	
9	0	(−419)	1943	
etc.	0		etc.	

Appendix IV

Observation data on time of service, first CRT alert, peak of CRT, end of CRT alert, end Back Pressure Test.

Data are based on group 5 from Appendix I.

Name	Tattoo number of the sow or gilt
Par.	Parity; parity 1 means that an animal is inseminated to conceive the first litter.
s	Section; 'o' means gilt section, 'c' means the sow section
CRT-alert (Ta)	The hour when the total time a particular sow has been registered at the boar pen during the preceding 24-hour period exceeded 900 seconds.
Peak CRT (Tp)	The highest value of the CRT reached by a particular sow

Name	Par	s	Tm Service date	Ta CRT alert date	hr	Tp Peak CRT date	hr	level	Tl End CRT date	hr	Te Middle BPT date	hr
d9u747	1	o	19900513	19900512	12	19900513	7	1933	19900513	22	19900513	12
d9u749	1	o	19900517	19900517	7	19900518	15	3602	19900519	11	19900518	16
d9m016	1	o	19900126	19900125	14	19900127	9	3593	19900128	12	19900126	24
d9o239	1	c	19900325	19900326	6	19900327	1	2728	19900327	10	19900327	8
d9m014	1	o	19900326	19900325	8	19900326	5	3339	19900327	8	19900326	12
d8a014	5	c	19900507	19900505	8	19900506	7	6883	19900508	12	19900506	24
d8u157	3	c	19900424	19900423	10	19900425	14	7925	19900427	7	19900425	16
d8o034	3	c	19900122	19900121	16	19900122	8	4322	19900123	7	19900122	12
d7m374	5	c	19900322	19900321	23	19900322	15	3211	19900323	8	19900322	16
d7o333	6	c	19900409	19900408	13	19900410	5	12773	19900412	14	19900410	16
d6s009	7	c	19900306	19900306	10	19900307	3	2559	19900307	18	19900306	24
d8k268	4	c	19900419	19900419	7	19900420	14	3703	19900422	14	19900420	16
d6v289	7	c	19900307	19900305	8	19900306	11	3761	19900308	5	19900306	16
d8e128	4	c	19900227	19900226	11	19900227	9	5742	19900301	13	19900228	8
d9e124	2	c	19900212	19900211	23	19900212	16	2659	19900214	6	19900212	24
d6o315	7	c	19900327	19900326	13	19900328	19	5200	19900329	18	19900328	8
d9e120	2	c	19900324	19900323	10	19900324	8	5584	19900325	7	19900325	8
d8u156	3	c	19900325	19900324	2	19900325	7	5203	19900328	4	19900325	24
d8a017	4	c	19900421	19900420	13	19900421	12	3725	19900423	4	19900422	8
d6v303	6	c	19900217	19900216	17	19900218	6	10042	19900220	7	19900218	8
Sows with alert but without standing reflex												
d9m377	1	o	19900216	19900215	9	19900215	15	1644	19900216	8		
d9x098	1	o	19900515	19900513	17	19900514	8	1223	19900514	15		
d9m372	1	c	19900327	19900326	10	19900326	15	1154	19900327	9		
d9m013	1	c	19900309	19900307	16	19900308	23	2811	19900310	9		
d9e122	2	c	19900227	19900226	11	19900227	6	6399	19900228	0		
d9e061	1	c	19900127	19900125	10	19900126	2	2305	19900127	5		
d8k299	3	c	19900128	19900126	17	19900128	8	7529	19900130	5		
d7x159	4	c	19900118	19900117	15	19900118	8	6144	19900121	6		
Sows with no alert but with a standing reflex												
d9u752	1	o	19900503								19900502	16
d9o387	1	c	19900430								19900429	16
Sow with no alert and no standing reflex												
d9i667	1	c										

Appendix V

Time intervals between first CRT alert, peak of CRT, end of CRT alert, estimated middle of oestrus and hour of insemination.

Data are based on group 5 from Appendix I.

Name	Tattoo number of the sow or gilt
Par.	Parity; parity 1 means that an animal is inseminated to conceive the first litter.
s	Section; 'o' means gilt section, 'c' means the sow section
Ta	The hour when the total time has been registered at the boar pen during the preceding 24-hour period exceeded 900 seconds.
Tp	The hour that the highest value of the CRT was reached
Tl	The hour the last value of the CRT was above 900 seconds
Te	The middle of the oestrus was estimated by the BPT test

Name	par	s	Ta__Tp	Tp__Tl	Ta__Tl	Ta__Te	Tp__Te
d9u747	1	o	19	15	34	24	5
d9u749	1	o	32	20	52	33	1
d9m016	1	o	43	27	70	34	−9
d9o239	1	c	19	9	28	26	7
d9m014	1	o	21	27	48	28	7
d8a014	5	c	23	53	76	40	17
d8u157	3	c	52	41	85	54	2
d8o034	3	c	16	23	39	20	4
d7m374	5	c	16	17	33	17	1
d7o333	6	c	40	57	97	51	11
d6s009	7	c	17	15	32	14	−3
d8k268	4	c	31	48	79	33	2
d6v289	7	c	27	42	69	32	5
d8e128	4	c	22	52	74	45	23
d9e124	2	c	17	38	55	25	8
d6o315	7	c	54	23	77	43	−11
d9e120	2	c	22	23	45	46	24
d8u156	3	c	29	69	98	46	17
d8a017	4	c	23	40	63	43	20
d6v303	6	c	37	49	86	39	2
Sows with alert but without standing reflex							
d9m377	1	o	6	15	21		
d9x098	1	o	15	7	22		
d9m372	1	c	5	18	23		
d9m013	1	c	31	34	65		
d9e122	2	c	18	18	36		
d9e061	1	c	16	27	42		
d8k299	3	c	39	44	83		
d7x159	4	c	17	70	87		
Sows with no alert but with a standing reflex							
d9u752	1	o					
d9o387	1	c					
Sows with no standing reflex and no alert							
d9i667	1	c					

Appendix VI

Glossary and abbreviations.

Name	Tattoo number of the sow or gilt
Par.	Parity; parity 1 means that an animal has been inseminated to conceive the first litter.
CRF	The amount of imaginary feed portions dispensed by the electronic sow feeder. This gives the total time over 24 hours.
CRT	The total time a particular sow has been registered at the boar pen during the preceding period of 24 hours
CRT-alert (Ta)	The hour when the total time a particular sow has been registered at the boar pen during the preceding period of 24 hours exceeded 900 seconds.
Peak CRT (Tp)	The highest value of the CRT reached by a particular sow
Te	The hour of the middle of the oestrus, estimated by calculating the moment between the first registration of the standing reflex and the last registration of the standing reflex by the Back Pressure Test.
Ts	The hour that the CRT exceeds or achieves a value of 900 and oestrus can also be detected
BPT-B	Back Pressure Test performed with boar stimuli (near the boar pen)
BPT-I	Back Pressure Test performed without direct boar stimuli (on the outside yard)

Cumulative total: The total time, recalculated hourly, a sow has been registered at the boar pen in the previous 24 hours.