MONITORING INDIVIDUAL SOWS IN GROUP-HOUSING: POSSIBILITIES FOR AUTOMATION

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MONITORING INDIVIDUAL SOWS IN GROUP-HOUSING: POSSIBILITIES FOR AUTOMATION

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Proefschrift

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In this thesis the possibilities for automated monitoring of aspects of health and reproduction in sows were studied. The emphasis was on group-housed sows. Automation of oestrus detection was studied by means of recording visits of sows to a boar. It was concluded that automated oestrus detection with the use of parameters on sow visits to a boar is technically feasible, also in a situation were serveral sows are in oestrus simultaneously. Physical activity of sows was shown to increase around oestrus, but more research is needed before oestrus detection on basis of physical activity is ready for practical use. Around farrowing, changes in body temperature measured close under the skin, just behind the ear base, showed were similar to those previously reported for rectal and deep-body temperatures. Also, the feeding order at an individual electronic feed station was studied. Sows have been reported in quite a stable order. In this study, the feeding order was not stable enough to use deviations from that order to monitor health or reproduction in sows. It is concluded that automation of individual sow monitoring in group-housing systems could be an important aid to the stockperson.

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Stellingen

1) Bij een juist gebruik vormt automatisering van de bronstdetectie bij zeugen in groepshuisvesting voor de zeugenhouder een wezenlijke ondersteuning van het management.

Dit proefschrift

2) De resultaten van bronstdetectiesystemen bij zeugen in groepshuisvesting kunnen verbeterd worden door rekening te houden met circadiane patronen in het gedrag van de dieren.

Dit proefschrift

3) Zeugen vertonen rond de bronst een verhoogde lichamelijke activiteit (*Dit proefschrift; Altmann, M. 1941. J.Comp.Psychol.*). Dit verschijnsel kan als uitgangspunt dienen voor een systeem voor automatische bronstdetectie.

4) Lichaamstemperaturen van zeugen in een verwarmde kraamstal, gemeten dicht onder de huid vlak achter de oorbasis, laten rond het werpen een verloop zien dat vergelijkbaar is met dat van respectievelijk rectaal en diep in het lichaam gemeten temperaturen.

Dit proefschrift

5) Bij invoering van groepshuisvesting voor zeugen dient bij de genetische selectie rekening te worden gehouden met de eisen die een dergelijk systeem aan de dieren stelt.

6) Een goede bronstdetectie bij zeugen is goed voor het milieu.

7) De eisen die aan de sensitiviteit en specificiteit van een bronstdetectiesysteem voor zeugen dienen te worden gesteld zijn aanzienlijk hoger dan die welke gelden voor bronstdetectie bij koeien.

8) Een belangrijk aspect van de kwalitatieve meerwaarde van produkten afkomstig van dieren uit alternatieve huisvestingssystemen is het imago van het betreffende huisvestingssysteem in de ogen van de consument.

9) De verdeling van beschikbare werkgelegenheid over zoveel mogelijk arbeidsplaatsen zou gebaat zijn bij verplichte uitbetaling van overuren op ieder functieniveau.

10) Het gebruik om duiven op de uitslag van een postduivenvlucht te rangschikken aan de hand van een tot op 2 of 3 decimalen berekende gemiddelde snelheid (in meters/minuut of millimeters/seconde) is niet gerechtvaardigd gezien de nauwkeurigheid waarmee de afstand tussen de lossingsplaats en de thuishokken wordt bepaald.

11) De functienamen Assistent-In-Opleiding en Onderzoeker-In-Opleiding suggereren ten onrechte dat een opleiding tot (onderzoeks)assistent respectievelijk onderzoeker wordt bedoeld. Het verdient daarom aanbeveling om de functienaam Assistent-In-Opleiding af te schaffen.

12) Een "fout van de computer" is maar zelden een fout van de computer.

Proefschrift van H.P.M. Bressers
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VOORWOORD

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Eric

CONTENTS

GENERAL INTRODUCTION

Considerable effort has been made in recent years to develop group-housing systems for sows. These systems are considered to provide a better basis for the well-being of sows than individual-housing systems (De Koning, 1985). Incorporation of proposed European Communities regulations (Commission European Communities, 1989) into national legislation will likely further promote the introduction of group-housing systems in practice. Currently, most sows are kept in individual-housing systems. These systems are popular, in part because they allow the stockperson to monitor the sows with more ease than in group-housing systems. Sows can not hide themselves between group-mates, so it is easier to identify specific sows.

The size of sow herds in the Netherlands has increased dramatically over the last 15 years. The average number of sows per sow herd has increased from 27 in 1975 to 112 in 1990. During the same period, the percentage of sow herds with more than 100 sows has increased from 3.9 % to 44.3 % (LEI-DLO / CBS, 1991).

The combination of an increasing number of sows per farm and the introduction of group-housing can bring about a number of problems for the stockperson. Potential problem areas include the management of social behaviour and monitoring health and reproduction of the animals (Süss, 1988; Van Putten, 1989). Some of these problem areas, such as the management of social behaviour, apply specifically to group-housing. In other cases, problems with the individual monitoring of sows might also occur in individual-housing systems. One example would be if an automated feeding system is used. Stockpersons can get a great deal of information about sows by observing sows while they feed. This information is lost when the stockperson is not present.

For stockpersons used to dealing with sows housed individually, the management in a group-housing situation might require additional training to prevent problems with social behaviour. Pigs are social animals, not solitary beasts, and they require different management in a group-housing situation. Incorporation of social behaviour principles into management could be used to improve the sows well-being. For example, sows can be introduced into a large group individually or in stable subgroups. In the latter case, individual sows can find protection from sows that are already present in the large group by associating with familiar subgroup-mates (Van Putten, 1993).

Health and reproductive status can be improved by increasing the amount of time a stockperson spends monitoring these aspects. The economical profit margins in modern sow breeding are already very small (Baltussen et al., 1988). These low profit margins make prevention of health and reproduction problems even more important. Adequate monitoring of reproduction and health requires accurate information. Data collection and data processing must be done in a short period of time, since reproductive or health problems will generally require a quick response by the stockperson. Spending additional time on these tasks, let alone employing extra personnel, is often not economically affordable. On the other hand, the computer price/performance ratio has decreased drastically. Computers could facilitate the transformation of raw data into information that is meaningful for the stockperson. They can also be used to automate the collection and processing of data on individual sows. Implantable devices can be used for automated identification of animals. Advances in sensor technology facilitate the automated collection of data on physiological and behavioural parameters.

In summary, likely future animal health and welfare policies will promote group-housing for sows. Increasing herd sizes in addition to the application of group-housing could make it more difficult for the stockperson to monitor health and reproduction of individual sows. Small economical profit margins make an adequate individual monitoring of sows more important, but it also reduces the possibility to employ extra personnel for this task. Recent advantages in computer and sensor technologies could open the way for the use of these technologies in sow management.

Huirne (1990a) described a management information system, called CHESS, which is primarily intended to support the analysis of the economic situation of individual sow herds. CHESS was extended with a stochastic dynamic programming model to determine the economically optimal replacement policy in pig breeding herds. This illustrates the use of computers and software for farm-level decision support of the stockperson. Geers et al. (1992) monitored groups of pigs, using automatic analysis of the pigs' vocalisations. The study was aimed at determining those components of the pigs' vocalisations associated with stress when pigs are being handled. This is an example of automated data collection and processing of group-level parameters. The present research deals with collection and processing of individual sow data. Monitoring of individual animals can be used to provide decision support for different aspects of reproductive and health management.

SIVA (the Dutch branch organisation for automation in the pig industry) presented a detailed description of the "health control" component of an information model for the pig industry (Anonymous, 1989). That study states that: "...suspicion of health problems on basis of any parameter should never lead to direct action, but must always be followed by examinations.". A similar approach applies to reproductive parameters. Automated monitoring of sows may help the stockperson to focus attention on the animals which need it most, not replace the stockperson.

Oestrus detection is an important aspect of sow reproductive management. Automation of oestrus detection based on several parameters has been studied in different species. Among these parameters are physical activity (e.g. pigs: Altmann, 1941; cattle: Kiddy, 1977; Redden et al., 1993; goats: Doherty et al., 1987; Egyptian buffalos: Williams et al., 1986), milk and body temperature (pigs: Junge-Wentrup and Holtz, 1985; Hendrix et al., 1978; cattle: Maatje and Rossing, 1976; Nieuwenhuizen et al., 1979; Fordheim et al., 1988; Redden et al., 1993) and electrical conductivity of the vaginal mucosa (pigs: Zink and Diehl, 1985; Ko et al., 1989; cattle: Smith et al., 1989). The location of sows in a group-housing system has also been used to assist oestrus detection (Houwers, 1988; Lokhorst and Houwers, 1991).

Checking up on farrowing sows and perinatal piglets by the stockperson is important. Detection of parturation has been studied with the use of devices which are expelled from the vagina during parturition (pigs: Bate et al., 1991; cattle: Niggemeyer and Holtz, 1988). Milk and body temperature (pigs: Elmore et al., 1979; Littledike et al., 1979; cattle: Gil, 1988) or respiration rate measurements have also been used (e.g. pigs: Kelley and Curtis, 1978; Hendrix et al., 1978). Prolonged tail elevation during parturation in cattle has also been investigated (Bueno et al., 1981).

Body temperature has been used for health monitoring (e.g. pigs: Furniss, 1987). Conductivity of milk has been studied as a parameter to monitor dairy cows for mastitis (Maatje et al., 1992). Several presentations on the use of milk temperature, milk conductivity and physical activity to monitor health disorders and oestrus in dairy cattle were delivered at an international symposium (Ipema et al., 1992).

Research has been carried out in the Netherlands on the development of an electronic identification device to be implanted in piglets before weaning (Lambooy and Merks, 1989). The device is intended to remain functional for the lifetime of the animal, and even until the carcass is cut in the slaughterhouse. A national programme to introduce these injectable electronic identification devices as a life number for each animal has been studied. Such a programme could be used to trace animals throughout the production chain. Contagious diseases might be controlled more easily through tracing infected animals from the slaughterhouse back to the farms where those animals have been. Electronic identification may also prove to be an aid to the management of individual sows. It can be used to automate feed stations and for recording the presence of the animal at specific locations in the housing accommodation.

A programme for the national introduction of an obligatory electronic identification device could find additional justification and support if the required devices could measure body temperature or other parameters. One potential problem with implantable devices might be the removal of these devices. If a national programme for injectable identification devices is adopted, slaughterhouses will have to solve this problem. The large number of devices required for such a programme will help to keep the costs down to an acceptable level. Another potential problem would be the loss or technical malfunctioning of these devices. For essential systems, a backup system should be available for those sows without a properly functioning injectable device.

Animal and farm management decisions have to be made on a strategic, tactical and operational level. In general, information for monitoring individual animals will be used for short term decisions at the operational level. In order to be an aid to the stockperson, raw data on individual sows must be collected, processed and presented to the stockperson within a short time (e.g. Huirne, 1990b). Automated recording and processing of data could facilitate the short term availability of information to the stockperson.

SCOPE OF THIS RESEARCH

The general objective of this research is to evaluate the potential to automate monitoring of individual sows in group-housing.

- Special attention has been given to the automation of oestrus detection. Parameters used were visits of sows to a boar and physical activity of sows around oestrus. Oestrus detection was considered a model for the possibilities of automated monitoring of individual animal behaviour. Oestrus detection was chosen since the number of sows that come into oestrus within a relative short experimental period of a few weeks can be preplanned, a known endpoint is reached and oestrus is an economically important behaviour in sows.
- Some attention has been paid to parameters which could be used to monitor other aspects of reproduction and health. In particular, ear base temperature during the periparturient period and the feeding order of gestating sows at an individual electronic feed station were studied.

The studied parameters were chosen on the basis of scientific literature and personal communications among the scientists involved in design and conduction of the research project. The methods to automatically collect raw data on these parameters as well as the formulae and thresholds needed to convert these raw data into information for the stockperson were considered in this research. Technical feasibilities for automatically recording these parameters was also taken into account. Some of the parameters studied will only be useful in a group-housing system. These parameters included visits of peri-oestrous sows to a boar, feeding order of sows at a feed station and physical activity. Body temperature is an example of a parameter which might also be useful for monitoring both individually and group-housed sows.

The parameters used in this study are discussed in detail in chapters 1 through 5 and the general discussion. In the next paragraphs, an overview is given of each parameter on basis of literature.

(1) Visits of peri-oestrous sows to a boar

Peri-oestrous sows are often observed to go to a boar and stay close to him (Burger, 1952). He wrote: "It was a matter of common practice to locate such females [females in pro-oestrus] simply by the fact that they either persisted in standing at the grating separating them from the boar's pen, or otherwise by the fact that they almost invariably leave their pens at the slightest disturbance, while their pen-mates continue to sleep.". He further stated that females in oestrus have an even more intense interest for the boar. Signoret (1967, cited by Signoret, 1970) described T-maze experiments which demonstrated that pro-oestrous and oestrous females are strongly attracted towards the male. Houwers (1988) and Lokhorst and Houwers (1991) described an automated oestrus detection system in which the duration of visits of sows to a boar were recorded. These studies were designed so that no more than one sow was usually in oestrus at one time. No distinction was made between visits made at different times of the 24-hour period. In the present study, the potential for an automated oestrus detection system based on visits of sows to a boar was evaluated for a service house, where several sows may be in oestrus at the same time. The duration and frequency of visits were studied. Furthermore, the influence of omitting visits made during specific parts of the day on the efficiency of the oestrus detection system was studied.

(2) Physical activity around oestrus.

Kiddy (1977), Doherty et al. (1987) and Williams et al. (1986) reported that physical activity increased in association with oestrus in cattle, goats and Egyptian buffalos, respectively. Altmann (1941) reported increased physical activity at oestrus in a small number of sows and Burger (1952) pointed to the restlessness of (pro-)oestrous sows in an early description of oestrous behaviour. In the present study, a prototype device was used to study physical activity in group-housed sows. After further research, a refined version of the prototype may be used as an aid in automated oestrus detection.

(3) Ear base temperature around farrowing

Incorporating sensors into an electronic identification device may enhance its usefulness to the stockperson. A temperature sensor is an example. The devices will likely be injected just under the skin, to avoid damage to valuable parts of the carcass. Variations in rectal and deep body temperature around farrowing are well documented(e.g. Elmore et al., 1979; Hendrix et al., 1978; Kelley and Curtis, 1978; Littledike et al., 1979). Farrowing was chosen to study whether physiological temperature changes can be reliably measured with a device implanted just under the skin. Monitoring temperature could also be used to detect some health disorders, like mastitis. A relatively high incidence of mastitis has been reported for group-housed sows (Van Putten, 1993). Ebner (1993) reported that group-housed sows had significantly more clinical udder changes than individually housed sows but no increase in other clinical signs of mastitis were found. Further research is needed to confirm these observations and to make reliable indicators for mastitis easily available.

(4) Feeding order ranking at an individual electronic feed station during gestation

Hunter et al. (1988 and 1989) reported that group-housed sows which can only feed one at a time at an electronic feed station, visit this station in a fairly stable order. Deviations from this order may be used to detect sows with some kind of problem (e.g. lameness) which would cause them to be less able or less motivated to compete for entrance to the feed station.

OUTLINE OF THIS THESIS

Chapters 1, 2 and 3 deal with automation of oestrus detection in post-weaning group-housed sows. In chapter 1, visits of sows to a detection area in front of a boar-pen are studied. Formulae are derived for the identification of sows which are likely to be in oestrus. In chapter 2, these formulae are evaluated, using a data set obtained from other sows. Visits of sows to a ticket-window in the front partition of the boar-pen, either within the detection area or freely accessible by the sows, are also issues to study in chapter 2. This is done to get an indication of the relative advantages or disadvantages of a ticket-window instead of a detection area for recording visits of sows to a boar. In chapter 3, a prototype activity sensor is used to determine if physical activity is an adequate parameter for oestrus detection in sows.

Changes in ear base temperature around farrowing are described in chapter 4, for seven individually housed sows. This is done to assess whether temperatures measured close under the skin are useful for monitoring (patho)physiological processes, e.g. farrowing.

When a sow does not eat her feed ration, seems reluctant to eat or has problems getting up, these are obvious indications of a problem to a stockperson who is observing the sow. This information would to a large extent be lost if the animals are fed automatically, without the stockperson being present. This problem can only partly be dealt with by listing sows with uneaten or not fully eaten food rations, as is usually done by process computers of automated individual feeding systems. In chapter 5, the order in which gestating group-housed sows make their first daily rewarded visit to an electronic individual feed station is determined. Stability of feeding order is evaluated to determine whether deviations from this order can be used to identify sows which may need special attention from the stockperson.

Finally, a general discussion is presented on the possibilities and limitations of automated reproduction and health monitoring in sows.

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CHAPTER 1

OESTRUS DETECTION IN GROUP-HOUSED SOWS BY ANALYSIS OF DATA ON VISITS TO THE BOAR

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ABSTRACT

This study deals with (automated) oestrus detection in a group-housing system where several sows may come into oestrus at the same time. Time-lapse video recordings were made from 5 groups of 10 recently weaned sows. Data on both the frequency and duration of visits by these sows to a Detection Area in front of a boar-pen were collected. Checklists can be drawn up to enable the stockman to determine which sows should be examined for oestrus. We show that a formula combining the parameters frequency and duration can be used to detect sows coming into oestrus in time for them to be served. The total number of false-positive listings for the 50 sows used in this study was 21 for the first 10 days they stayed in the Service House. Using duration of visits as the only parameter was not sufficient to detect a minimum of 95% of the sows in time for them to be served. Using only frequency, it was possible to detect at least 95% of the sows in time for them to be served, but with a total number of 100 false-positive listings for this study. The system was improved by excluding data collected during periods of generally increased activity during the morning and the afternoon.

The same system can also be used to detect at least 95% of the sows correctly at the first time they show the standing response. The total number of false-positive listings found for this study was 132.

With an automated system based on the guidelines described in this paper it should be possible to detect sows that come into oestrus in time for them to be served and even as early as the time of the first standing response.

INTRODUCTION

Currently much research is being carried out to improve group-housing systems for sows (Bokma, 1988; Houwers, 1988; Kirchner 1989; Petersen, 1989; van Putten, 1989; Süss, 1988). In article 3 of the proposed EEC-regulations concerning minimum standards for the protection of pigs kept in intensive farming systems (Commission European Communities, 1989), it is stated that: "After weaning, sows shall not be confined by tethers for a period of at least 4 weeks; during that period they shall only be confined in individual crates or stalls if they are released for daily exercise.". Incorporation of this proposal into national regulations will support the further introduction of group-housing systems for dry sows.

Apart from the advantages, e.g. sows having contact with group mates, such systems also have some disadvantages compared with individual-housing systems. For example, the stockman may have more difficulty in detecting oestrus than when sows are kept individually. Furthermore, it is more difficult to observe individual sows kept in groups with electronic feeding stations than in systems where the sows are kept individually (Süss, 1988, van Putten, 1989) and this results in loss of information. Kirchner (1989) stated that stockmen used to an individual-housing system found it more difficult to check up on the sows in group-housing systems with electronic feeding stations, while stockmen used to keeping sows in small groups without electronic feeding stations thought that checking became easier in larger groups with electronic feeding stations.

Labour costs are of great importance in commercial pig farming, and detecting oestrus in group-housed sows requires much of the stockman's attention and time. Computers are already used for better management of sow herds and research in this field will be increased (Petersen, 1989). In most cases computers are only used to evaluate data collected by the stockman and/or the veterinarian. However, computers could also be used to compile data automatically, for example, in detecting oestrus. One of the options is to automatically register visits by sows to a boar housed adjacent to the sow-pen. Sows may contact the boar through an opening in the wall of the boar-pen as discussed by Bokma (1988) and Houwers (1988). These authors focused on the detection of oestrus in systems where usually no more than one sow at a time exhibited oestrus. In that situation, the area where sows can contact the boar can be quite small. However, detecting oestrus in a group of recently weaned sows requires a different approach, because several sows can be in oestrus simultaneously.

Using the data from this study, we investigated the possibilities of compiling checklists which the stockman could use to determine which sows should be tested for oestrus.

The objectives of this study were to determine whether information about the sows' visits to a boar could be used to: (1) predict the time that sows will start showing the mating stance when mounted by a boar, and (2) detect sows that come into oestrus in time for them to be served.

ANIMALS, MATERIAL AND METHODS

Animals

A group of ten hybrid sows of various parities (1-8) was transported to our experimental farm approximately every 3 weeks, immediately after weaning of the piglets. All the sows came from one commercial farm, where they were kept individually, tethered by the chest. Only sows without clinical abnormalities were accepted. A total of 50 sows were used in this experiment; no sows died, became seriously ill or were injured during the experiment.

Housing

After a 24-h preparation period elsewhere for settling hierarchical problems, each group of ten sows was moved to a spacious pen (8.4 x 10 m), (the Service House, Figure 1), where they stayed for at least 10 days.

The sows could visit a sexually active, mature boar, housed in a boar-pen located in a corner of the Service House. This boar-pen was separated by wooden partitions and bars from the remainder of the Service House. The sows could not only hear and smell the boar but could also see and touch him through the bars. In front of the boar-pen was a separate Detection Area. The floor of the Service House was partly covered with straw, whereas the Detection Area was bare tarmac. Food could be obtained from an electronic feeding station (NEDAP-POIESZ, Hengelo (Gld.), the Netherlands). The sows received 3.5 kg day^{-1} of a complete commercial sow diet up to and including the day of first service or until the eleventh day after weaning, after which they received 2.3 kg day^{-1}. Water was available ad libitum from nipple drinkers and in the feeding station. The sows could not obtain food or water in the Detection Area. Lights were on from 06:30 to 21:00 h and there was dim lighting during the night.

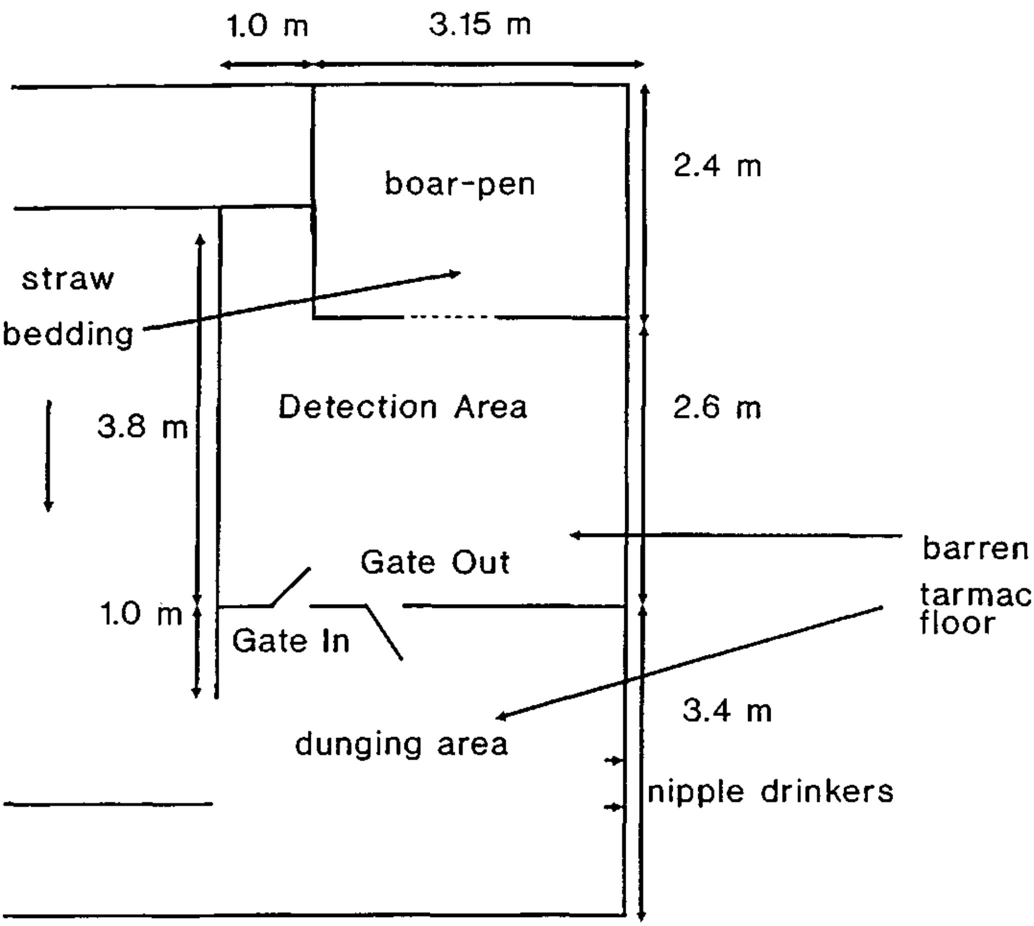

Figure 1. Plan of the part of the Service House used for the detection of the sows' visits to a boar in this study.

Routine checking for oestrous symptoms

Each sow was checked for oestrous symptoms from the second day after the sows were moved to the Service House. A standardised method of oestrus detection, based on a method described by Willemse and Boender (1966), was used. The sows were tested routinely twice daily during checkup periods between 07.00 and 08.00 h and between 16.00 and 17.00 h. Each sow was tested with a teaser boar to check if she showed the standing response when mounted. As soon as this happened, sows were tested with the back pressure test by the stockman, in absence of a boar. When the response to this test decreased, the sows were again tested with a teaser boar until they stopped showing the standing response.

Collection and analysis of data

Registration of visits to the Detection Area

Sows could enter the Detection Area by passing through a narrow gate with a one-way swing door (Gate In) and leave it by a similar gate (Gate Out) (Figure 1). Time-lapse video recordings (1 frame s^{-1}) were made from 16:00 h on Day 1 (the day the sows entered the Service House) until Day 10. Tapes of five groups (ten sows each) were analysed to record the date and time of the start and end of each visit by a sow to the Detection Area. Sows were identified by spray-painted numbers on their backs and flanks.

Between 06:30 and 08:00 h and between 16:00 and 17:00 h, the stockman worked in the Service House and carried out oestrus detection. During part of these periods, the sows were removed from the Detection Area and prevented from entering it. Therefore, sows in the Detection Area at 06:30 or 16:00 h were considered to have left this area at 06:29:59 and 15:59:59 h, respectively. Sows inside the Detection Area at 08:00 or 17:00 h were considered to have entered the area at 08.00 and 17.00 h, respectively. Between 10:45 and 11:15 h, sows were served by artificial insemination (A.I). Data from sows who did not enter or leave the Detection Area during this period were not changed. Visits within this period were not included in the data. If a visit ended during this period, it was considered to have ended at 10:45 h. If a visit started during this period, it was considered to have started at 11:15 h.

Data sets

The available data were assigned to three sets, in order to evaluate the feasibility of using selected data from specified parts of every 24-hour period. Table 1 shows which parts of each 24-h period were used to form the three data sets. Data set 1 includes all available data. The periods from 06:00 to 06:30 h and from 13:30 to 17:30 h were not included in data sets 2 and 3 because during these periods all the sows, including the ones that were not in oestrus, were rather active. The sows that were not in oestrus were resting during the remainder of the time whereas, in general, those in oestrus remained more active. The period from 08:00 to 13:30 h was not included in data set 3 because the sows were then more likely to have been disturbed by people on the farm than during the night.

Table 1 : Parts of the 24-h period used in the three data sets evaluated in this study

	Data set		
Time period	1	2	3
00:00 h - 06:00 h	x	x	x
06:00 h - 06:30 h	x		
06:30 h - 08:00 h[1]			
08:00 h - 13:30 h[1]	x	x	
13:30 h - 16:00 h	x		
16:00 h - 17:00 h[1]			
17:00 h - 17:30 h	x		
17:30 h - 24:00 h	x	x	x

[1] see text

Formulae

The creation of checklists at 07:00 and 16:00 h was simulated. These times coincided with the start of each checkup period. A sow was selected if the formula X*duration + Y*frequency exceeded a threshold T. For X and Y, the following combinations were examined:

X = 0, Y = 1 (which gives the formula with only frequency);

X = 1, Y = 0 (which gives the formula with only duration);

X = 1, Y ranging from 50 to 10 000 with steps of 50.

These formulae were evaluated for each of the three data sets. The duration was defined as the number of seconds a sow was in the Detection Area during the selected parts of those 24 h for which the checklist was simulated. The frequency was defined as the number of times a sow passed through either Gate In or Gate Out during the same parts.

Values for T for detecting the first standing response

The outcome of the formula was calculated for all the sows that came into oestrus in the 24-h period before the first check when the sows showed the standing response. The 5 and 1% points for these values were calculated. These limits can be used as T5-fsr (5 % point, first standing response) and T1-fsr (1 % point, first standing response) respectively for the threshold T. If the outcome of a formula is higher than the 5% point, 95% of all receptive sows are identified.

These limits were determined for all combinations of the formulae and data sets. This was only useful if the thresholds were higher than 0, otherwise all the sows would have appeared on every checklist. Therefore, no results will be presented for any $T \leq 0$.

Q-values for detecting the first standing response

The number of false-positive listings, i.e. the total number of times sows that were not (yet) in oestrus were selected by the checklist for attention, during the first 10 days the sows were in the Service House (the Q-value), helps to determine the accuracy of the detection system.

Peak values for detecting oestrus in time for service

If a sow is selected by the computerized checklist, she should be tested for oestrus by the stockman. If she shows the standing response when mounted by the boar, A.I. could be performed during the next checkup period, allowing time for semen to be ordered. During this next checkup period, the sow should still show the standing response, otherwise A.I. is not possible. This means that each sow that comes into oestrus should appear on at least one checklist during the whole period she shows the standing response, but not later than one checkup period before the last period in which she showed the standing response. If it is supposed that a sow shows the standing response for five checkup periods, the formula will be tested at the start of each period and its value should exceed T during at least one of the first four of these periods. Using a given data set and formula, each sow has (at least once) a maximum value for that formula, during the period in which she should be placed on a checklist. This maximum value will be referred to as the peak value for that sow.

Values for T and Q for detecting oestrus in time for service

For all combinations of formulae and data sets, the 1 and 5% points were calculated for the peak values. These limits were used in the analysis as values for the threshold T, and will be referred to as T5-ts (ts, time to be served) and T1-ts. Again, no results will be presented for $T \leq 0$. It should be noted that for all combinations of formulae and data sets, T5-ts, T5-fsr, T1-ts and T1-fsr will have different values. Q-values as described before, were also calculated for T5-ts and T1-ts.

RESULTS

Of the 50 sows involved in this study, 42 came into oestrus during the experiment. Table 2 presents the results of this study. If the 1 or 5% points of T ≤ 0, the combination of data set and formula does not help reduce the work of the stockman in checking the sows. All sows would be on every checklist. Therefore, only results where T > 0 are presented.

Table 2. Results of the detection of oestrus in sows by a simulated automated system.

fsr/ts[1]	data set[2]	X[3]	Y[3]	T-value[4]	% point[5]	Q-value[6]
fsr	1	1	2000	11045	5	145
fsr	2	1	2600	5894	5	132
ts	1	0	1	8	5	100
ts	1	1	2100	55152	5	29
ts	2	0	1	2	5	172
ts	2	1	2600	46819	5	21
ts	3	0	1	2	5	105
ts	3	1	1500	22357	5	26
ts	1	0	1	3	1	160
ts	1	1	1500	29994	1	56
ts	2	1	1650	23994	1	42
ts	3	1	1600	14605	1	42

[1] Indicates detection of the first standing response (fsr) or of sows in time for them to be served (ts), respectively.

[2] Number of the data set used (see text).

[3] X and Y respectively, in the formula X*duration + Y*frequency.
The value for Y gives that for which the lowest Q-value was found.

[4] Used as T in case the outcome of the formula ≥ T. See text for calculation.

[5] Indicates which %-point was used for T.

[6] Number of times that outcome of the formula ≥ T for sows not (yet) in oestrus.

Results for detecting oestrus in time for service

The lowest number of false-positive listings was obtained with a formula including both the frequency and duration, using data set 2. When the 5% point for T was used, a total number of 21 false-positive listings per 50 sows in the first 10 days was found with the formula

duration + 2600 * frequency $\geq$ 46819.

When the 1% point for T was used, the total number of false-positive listings rose to 42 with the formula, duration + 1650 * frequency $\geq$ 23994.

Using only duration as a parameter was not sufficient to detect at least 95% of all the sows that came into oestrus in time for them to be served. Using only frequency, this detection level can be achieved, but the total number of false-positive listings is high (at least 100 for data set 2).

DISCUSSION

With the use of a *formula* of the type

(X*duration) + (Y*frequency) $\geq$ threshold T,

developed from the data collected in this study on visits by sows to a Detection Area in front of a boar-pen, it is possible to detect sows that come into oestrus. This can also be done by simply checking up on all sows twice daily. The advantage of any automated system is the reduction in the number of times that sows not (yet) in oestrus have to be checked for oestrus (the Q-value). When we tried to detect sows in time for them to be served, we found a Q-value as low as 21 for 50 sows, if 5% false-negative listings are accepted. When we aimed to detect the sows on the first morning or afternoon they showed the standing response, we found a Q-value of 132 ($\leq$ 5% false-negative listings).

The percentages of 1 and 5 false-negative listings reported in this study should be considered as approximations, as the collected data did not follow exactly the normal distribution, and possible interactions between animals were neglected.

In this study, we aimed at a formula with a single threshold for all sows. No attempt has been made to calculate an individual threshold for each sow, using the frequency and duration of visits by the sows before they came into oestrus. The system was new to the sows used in our study. Most sows came into oestrus only a few days after they were transferred to the Service House. Therefore, there was no time to find an individual threshold for each sow. During the first day in the Service House, some sows were seen in the Detection Area quite often, but this did not seem to correlate with the frequency and duration recorded during oestrus.

For ease of calculations, the frequency was defined not as the number of visits, but as the number of times that a sow passed through either Gate In or Gate Out. This has only a limited effect on the Q-values. For every visit a sow has to pass through both Gate In and Gate Out. If a sow passes through one gate in a period that is not included in the data set, and the other gate in a period that is included, only the latter will contribute to the frequency. The Y-values in this study are about half of those found when frequency is defined as the number of visits.

It is likely that the value for Y which gives the best results, will have to be adapted if sows of another crossbreed or pure breed are used, or if the entrance and/or exit to the Detection Area is changed. Furthermore, the parts of each 24-h period that would give the best results may depend upon conditions such as the lighting and the feeding regimes. An automated system based on this study should use formulae and parts of each 24-h period adapted to the conditions in the service house were it is used. Although this may reduce the initial usefulness of the procedure, we still believe it to be a promising aid for the stockman.

In this study, the use of only frequency or only duration did not give as good a result as the combination of these parameters, although frequency seemed to be the more important. Other studies (Bokma, 1988; Houwers, 1988) used only the duration of visits to the boar as a parameter. Their systems used a small window in the wall of the boar-pen, whereas we used a larger Detection

Area. With a system in which the sows can only contact the boar through a small window in the wall of the boar-pen, it is even more likely that "frequency" will be more important than "duration". In the present study, sows could enter the Detection Area and lie there for a whole night. If a window is used, the sow must stand and look through that opening in order to be detected, which is a much more active process.

It is unlikely that a system that uses such a window as a detection area would function in a service house, where several sows are in oestrus at the same time. During the periods that several sows were in oestrus, it was often very crowded in our Detection Area. If sows can only be detected when they look through a window in the wall of the boar-pen, they have to compete for space near the boar. Detecting sows at the entrance and exit of a detection area that is large enough for all sows to enter at the same time avoids this problem.

Other research indicates that pigs kept under a light-dark regime show an increase in activity during the light phase and are less active during the dark phase. Furthermore, their diurnal pattern of behaviour is readily influenced by human activities or other factors (Ingram et al., 1980; Fraser, 1985). This corresponds with our own findings, although activity seemed to decrease a few hours before the end of the light phase. This diurnal behaviour pattern justifies the choice of the parts of each 24-h period used in data sets 2 and 3.

We found that the quality of the detection system improved if only parts of each 24-h period were used. Data from the parts when all sows are more or less active should be omitted. These parts can depend on the conditions in the service house, like the lighting and the feeding regimes.

The first objective of this study was to see if it was possible to use information about the sows' visits to a boar to predict the time when they will first show the standing response. In this study and with the restrictions discussed, less than 1% false-negative listings could not be reached. Less than 5% false-negative listings were reached, but only with a high number of false-positive detections, a total of 132 for 50 sows.

The second objective of this study was to investigate whether sows could be detected in time for them to be served. Under the conditions of this study, less than 1% false-negative sows was achieved, with a total number of 42 false-positive listings for 50 sows. If 5% false-negative listings were accepted, the total number of false-positive listings was 21 per 50 sows.

We would like to stress that automated systems in animal husbandry should be used as an aid for the stockman and not as a means of replacing him. It is and remains important for stockmen to see the animals in the flesh. The results presented here indicate that recording visits to a boar is a promising way to detect oestrus in a group of recently weaned sows.

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CHAPTER 2

AUTOMATED OESTRUS DETECTION IN GROUP-HOUSED SOWS BY MONITORING VISITS TO THE BOAR

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ABSTRACT

Detecting oestrus automatically based on visits to a boar was studied in recently weaned, group-housed sows. Data were collected on both the frequency and duration of visits of sows to (1) a detection area in front of a boar-pen, (2) a ticket-window in the front partition of the boar-pen within the detection area or (3) a freely accessible ticket-window. Formulae combining duration and frequency of visits, derived from other sows in a previous study, were tested on the data collected in this study. The results were well in agreement with the results found in the previous study. New formulae were derived to minimize the number of checkups that have to be made on sows not (yet) in oestrus. A reduction of more than 90 % in the number of checkups was achieved, accepting 5 % of the sows not being detected during oestrus (5 % false negative). The results of detection methods based on visits to each of the ticket-windows could not be compared statistically with those obtained using the detection area, but they did not differ very much.

INTRODUCTION

Incorporation of the proposed European Community-regulations concerning minimum standards for the protection of pigs kept in intensive farming systems (Commission European Communities, 1989) into national legislation will support the further introduction of group-housing systems for dry sows. A possible disadvantage of group-housing of sows is that the stockperson may experience more difficulty in monitoring sows' reproductive and health status than when they are kept individually (Süss, 1988; Van Putten, 1989). One of the areas of interest in monitoring sows' reproductive status is the detection of oestrus. An automated oestrus detection system (Bressers et al., 1991; Houwers, 1988; Lokhorst and Houwers, 1991) can help the stockperson to focus his attention on specific animals. The system described by Bressers et al. (1991) was based on formulae combining both duration and frequency of visits of sows to a detection area in front of a boar-pen. Accepting 5 % of the sows not being detected during oestrus (5 % false-negative sows), this system could potentially reduce the number of checkups on sows not (yet) in oestrus to 7.3 % of the maximum number of checkups when no detection system is used. These results were obtained by using the same data set on the basis of which the formulae were developed. Because this may lead to a too optimistic impression of the scope of the detection system, the formulae derived in Bressers et al. (1991) should be validated on new data as well.

In other studies (e.g. Lokhorst and Houwers, 1991), a "ticket-window" was installed in one side of the boar-pen to record visits of sows to a boar. A ticket-window requires less space in front of the boar-pen than a detection area. However, the sows might hinder each other at the ticket-window when more animals are in oestrus simultaneously, especially if the the space in front of the boar-pen is limited. With more space in front of the ticket-window, the contrast between pre-oestrous and oestrous periods within sows might be reduced because sows might visit such a freely accessible ticket-window more often during the explorative behaviour before oestrus.

The objectives of the present study were:

1) to validate the formulae derived in Bressers et al. (1991) for oestrus detection based on visits of sows to a detection area in front of a boar-pen, and
2) to get an indication of the differences between the results of this detection system and those obtained by using a ticket-window in the front partition of the boar-pen situated either within a detection area or freely accessible by the sows.

ANIMALS, MATERIALS AND METHODS

Animals

Fourteen groups of ten hybrid sows of various parities (1-10) were transported over 30 km to our experimental farm, immediately after weaning the piglets. Although sows came from the same commercial farm as those used by Bressers et al. (1991), they were different individuals. On that commercial farm the sows were kept individually, tethered by the chest. Only sows without clinical abnormalities were accepted.

Housing and Management

The sows were housed in a service house identical to the one used by Bressers et al. (1991). Sows could visit a sexually active, mature boar, which was housed in a corner of the service house (Figure 1). The partitions of the boar-pen were 1.70 m high and did not reach to the ceiling. The floor of both the boar-pen and the lying area for the sows was covered with straw and the floors of the dunging area and the detection area (DA) were bare tarmac. Water could be obtained ad libitum from nipple drinkers and food was available from a electronic feed station (NEDAP-POIESZ, Hengelo (Gld.), the Netherlands). All sows were carrying transponders on a neck collar for identification in the feed station. The sows each received 3.5 kg day^{-1} of a complete commercial sow diet up to and including the day of first service or until the eleventh day after weaning, whichever came first, and 2.3 kg day^{-1} thereafter. Lights were on from 06:30 to 21:00 h and there was dim lighting during the night.

Experimental Design

Sows of groups 1 through 6 and 8, 10, 12 and 14 could enter the detection area in front of the boar-pen through a passage-way. For groups 7,9,11 and 13, this passage way was removed, so no detection area could be distinguished in that situation. In both situations, the sows could see the boar through a 50 cm wide barred ticket-window which invaded the boar-pen for 40 cm. The detection area will be referred to as the DA, the ticket-window inside the detection area as TW_{+DA} and the freely accessible ticket-window TW_{-DA}.

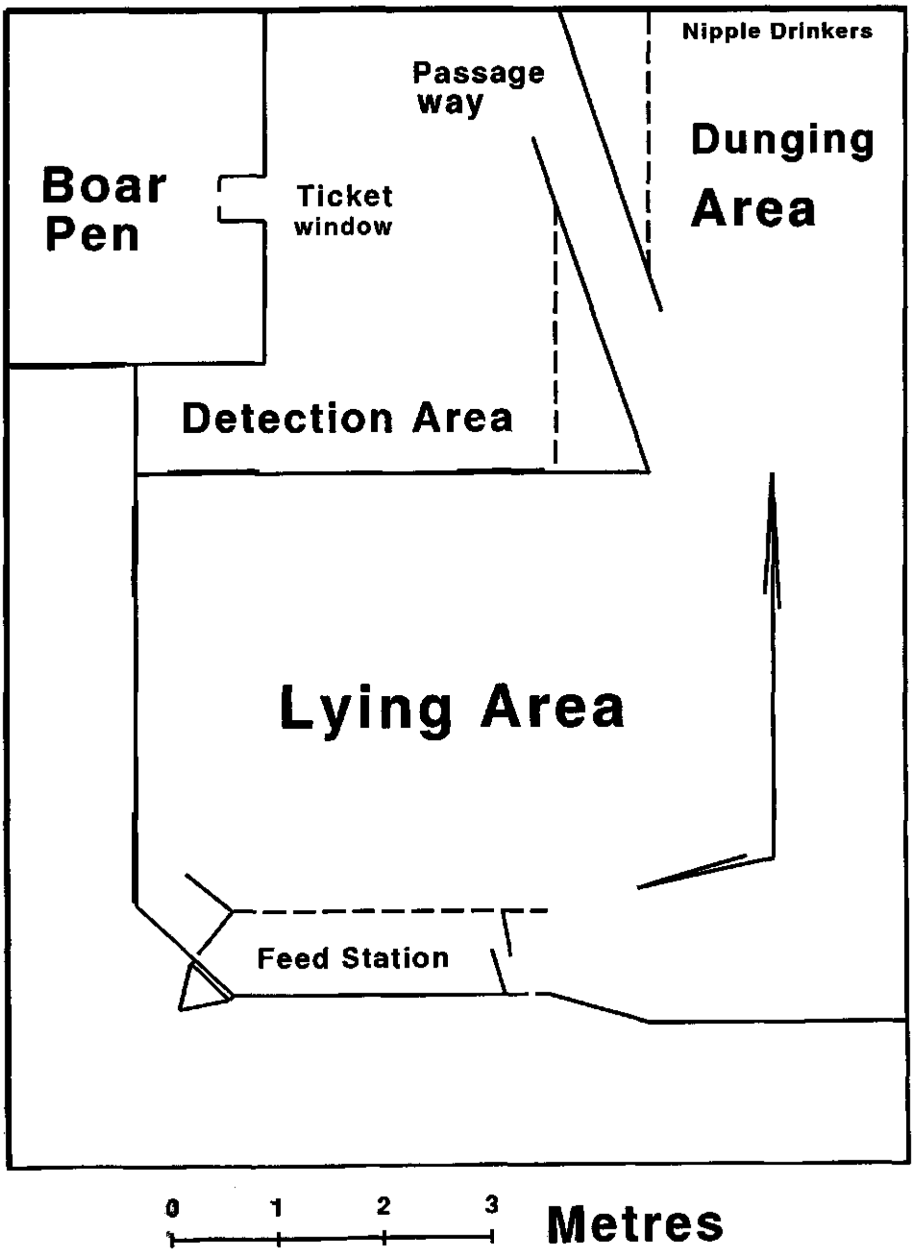

Figure 1: Layout of the Service House.

Routine checking for oestrous symptoms

Each sow was checked visually for oestrous symptoms twice daily during checkup periods between 7:00 and 8:00 h and between 16:00 and 17:00 h from the third day after weaning onwards. This was done according to a standardised method based on that described by Willemse and Boender (1966). In the bedded lying area, each sow was tested with the teaser boar from the boar-pen to check if she showed the standing response when mounted. When she had shown this response, during following checkup periods the sow was tested with the back pressure test by the stockperson in absence of the boar. When the response to this test decreased, the sow was tested again with the boar until she stopped showing the standing response. Oestrus was defined as the period from the first up to and including the last checkup period a sow showed the standing response to the boar. The first checkup period a sow showed the standing response to the boar will be referred to as checkup period 0 for that sow. Other checkup periods will be numbered ...,-2, -1 and 1, 2,... relative to checkup period 0.

Collection and analysis of data

Recording of visits to the detection area

Two walk-through antennas were placed in the passage-way between dunging area and DA and scanned every 0.7 second by a personal computer. These antennas picked up a signal from the transponder on the collar of a sow walking through the passage way. Time of day and identification number of the sow were recorded for each antenna. Two consecutive identifications of the same sow by one antenna were merged into one if there were less than 7 seconds between these identifications. This time-limit was based upon the duration of the shortest real visits to the DA, as determined from time-lapse video recordings. Software was developed to determine the times of entrance and exit of the DA from the data. If a sow was first detected by antenna 1 and then by antenna 2, she was assumed to have entered the DA. If she was first detected by antenna 2 and then by antenna 1, she was assumed to have left. Time-lapse video recordings were used to check and correct any unclarity in the list of visits to the detection area produced by the program (2 consecutive "in"'s or "out"'s for the same sow). Unclarities occurred in less than 1% of all cases.

Recording of ticket-window visits

An antenna, similar to the one used in the feed station, was placed in the TW. The antenna was scanned every 0.7 second by a personal computer. Nearly all intervals of less than 20 seconds between recordings by the antenna occurred when a sow moved her head back and forth from the antenna. Because this did not mean that the visit to the ticket-window was interrupted, consecutive recordings of the same sow less than 20 seconds apart were merged into one visit. This time limit was derived from time-lapse video recordings. For intervals of more than 30 seconds, nearly all interruptions were caused by sows actually moving away from the antenna. A mixture of both kind of interruptions was seen for intervals between 20 and 30 seconds.

Data subsets

Three different data subsets of the sows' data for each 24 hour period were created. These subsets corresponded to different combinations of time periods when the stockperson was not working in the service house. They are described in table 2. The time combinations used for the three data subsets were the same as in Bressers et al. (1991). In data subset 1, only those hours the stockperson was regularly working in the service house were omitted. In data subset 2, also parts of general activity periods of the sows during the morning, afternoon and early evening were omitted. In data subset 3, only data from the evening and night were used, when sows are less likely to be disturbed than during day-time.

Boar Visitation Indexes (BVI)

For each data subset, Boar Visitation Indexes (BVI) were calculated for each sow for the 24 hour period preceding each checkup period in the period of 3-17 days after weaning the piglets. No BVI-values were calculated for sows after the end of their oestrous period.

BVI was defined as (X x duration) + (Y x frequency). Duration was defined as a count of the number of seconds that a sow was in the detection area or visited a ticket-window in the time intervals of the 24 hours considered for the data subset involved. Frequency was defined as the total number of times a sow either entered or left the detection area or the number of times that a visit to a ticket-window started or ended during those same parts. Constant X is either taken equal to 1 (duration included) or 0 (duration omitted). If a BVI-value exceeded a threshold, a sow can be listed for attention.

Using thresholds and Y-values from previous research

The data on visits of sows to a detection area in front of the boar-pen collected in this study were used to test the results obtained in Bressers et al. (1991). Bressers et al. (1991) reported for the three data subsets the following formulae as the ones with the lowest number of false-positive listings while the number of false-negative sows was fixed at 5 %.

data subset	formula
1	duration + (2100 * frequency) > 55152
2	duration + (2600 * frequency) > 46819
3	duration + (1500 * frequency) > 22357

These formulae were used on the data subsets collected in the present study for visits to the DA to determine the number of false-negative sows and the number of false-positive listings. This was repeated, multiplying the thresholds by 0.9, to built in a "safety margin", and by 1.1 to see how sensitive the system is for changes of this magnitude.

Indication of differences between DA, TW_{+DA} and TW_{-DA}

Calculation of BVI-values

In the present study, the following 3 types of combinations were examined for X and Y for the calculation of BVI-values:

X = 1, Y = 0 (duration only);

X = 1, Y = N*S (N = stepnumber, N = 1 - 199; S = stepsize, S = 50 for visits to the DA, S = 5 for visits to TW_{+DA} or TW_{-DA})

X = 0, Y = 1 (frequency only);

A high maximum value for N was chosen to ensure that the optimal combination of duration and frequency was found. The values for S were chosen after some trial-and-error attempts, to obtain series of values which were likely to contain a close approximation to the optimal combination.

Peak BVI-values

The BVI-value for the last checkup period during oestrus was excluded from the analysis, since it would be too late to inseminate a sow if she was not listed before that time. If a sow shows the standing response to the boar, she can be artificially inseminated during the next checkup period, allowing time for semen to be ordered. For each sow, the highest of the remaining BVI-values during oestrus was designated as the peak BVI_{ts}-value (ts = in time to be served) for each data subset and combination of X and Y.

It is quite well possible that detection of a sow late during oestrus leads to poor reproduction results (Willemse and Boender, 1967). Therefore, the BVI-value of the checkup period 0 (peak BVI_{bo1}, bo = beginning of oestrus) was taken into consideration and also peak BVI-values for checkup periods 0 and 1 (peak BVI_{bo2}) were determined. These calculations were done for each sow and for each combination of data subset and constants X and Y.

Estimation of threshold values

In this study, new formula parameters were derived to get an impression of the differences in results between the use of DA, TW_{+DA} and TW_{-DA} to record visits of sows to a boar. The peak BVI-values were used to estimate a threshold by which approximately 5 % of the sows would not be listed during oestrus. Such a threshold is referred to as Th.

To avoid distributional assumptions for the peak BVI_{ts}-values, a non-parametric estimate for Th_{ts} was derived. The peak BVI_{ts}-values were numbered in ascending order. When n is the number of peak BVI_{ts}-values, Th_{ts} was estimated to be the peak BVI_{ts}-value numbered the closest to (n*0.05). For the visits to the DA and TW_{+DA}, n was 74. Therefore, Th_{ts} = peak BVI_{ts}-value with rank number 4 ((4/74) * 100 % = 5.4 %). For the visits to TW_{-DA}, n was 35. Therefore, Th_{ts} = peak BVI_{ts}-value with rank number 2 ((2/35) * 100 % = 5.7 %).

To determine Th_{bo1} and Th_{bo2}, the same procedure as described for Th_{ts} was followed, using the peak BVI_{bo1}-values or peak BVI_{bo2}-values, respectively.

No Th-values for a given combination of data subset and checkup period were calculated if 4 or more sows failed to visit the DA or TW_{+DA} or if 2 or more sows failed to visit TW_{-DA} during the selected parts of the 24 hour period prior to that checkup period.

RESULTS

General remarks

The data collected for group 3 could not be used due to malfunction of equipment. Therefore, the calculations for DA and TW_{+DA} were based on data collected from 9 groups. Two of the 90 sows in these groups were treated for lameness and were removed from their group during part of the study period. Their data were not used.

Average duration of visits

In Figure 2, the average duration of visits to the DA, TW_{+DA} and TW_{-DA}, respectively, is shown. For this Figure, data from data subset 2 were used. On average, the duration of visits to TW_{+DA} and TW_{-DA} was equal up to and including checkup period 1. At the next checkup period, the average duration of visits to TW_{+DA} decreased and that of visits to TW_{-DA} increased.

Results obtained by formulae derived in previous research

Table 1 shows the results obtained using the formulae derived in Bressers et al. (1991), after multiplication of the thresholds by 0.9, 1 and 1.1, respectively. Using the original threshold value, data subset 2 gave 3 false-negative sows out of 74 which came into oestrus in this study (± 4 %). The number of false-positive listings was 64, which was 6.9 % of the maximum possible number attainable.

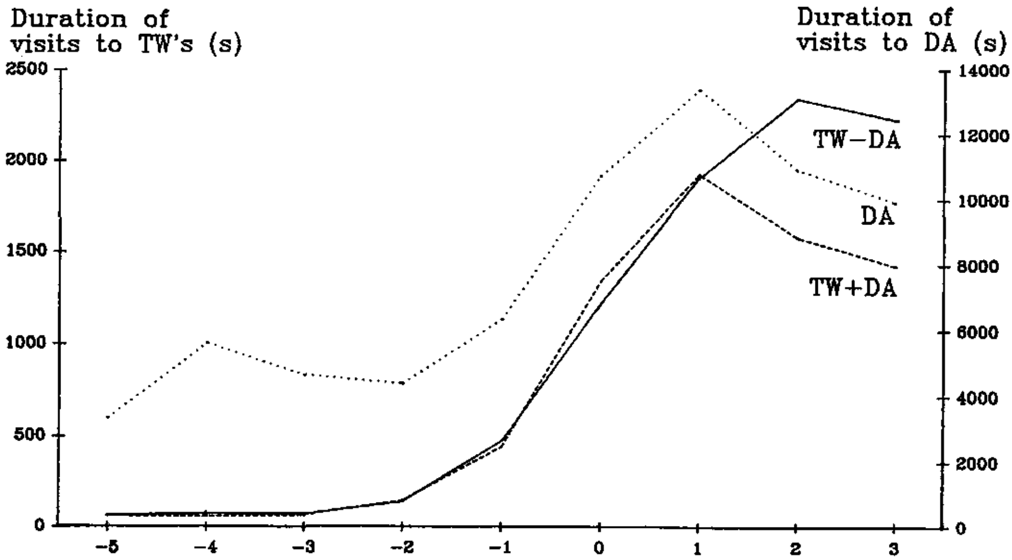

Figure 2. Average durations of visits to the ticket-windows TW_{+DA} and TW_{-DA} and to the detection area DA. Sows were checked for oestrous symptoms twice daily during checkup periods between 7:00 - 8:00 h and between 16:00 - 17:00 h. Checkup period 0 is the first checkup period at which a sow showed the standing response to the boar, other checkup periods are numbered relative to checkup period 0.

Table 1. Results obtained using formulae from Bressers et al. (1991).

Shown are numbers (#) of false-positive listings and false-negative sows. Results are also expressed as percentages (%) of corresponding maximum numbers. The maximum number of false-positive listings is obtained when all sows are listed twice daily from day 3-17 after weaning, until they showed the standing response to the boar. This number was 933. From the 88 sows used in this part of the study, 74 came into oestrus within 18 days after weaning. Consequently, the maximum number of false-negative sows is 74.

		Threshold value multiplied with					
Data subset		0.9		1.0		1.1	
		#	%	#	%	#	%
1	false-negative sows	4	5.4	7	9.5	12	16.2
	false-positive listings	68	7.3	52	5.6	43	4.6
2	false-negative sows	3	4.1	3	4.1	5	6.8
	false-positive listings	87	9.3	64	6.9	55	5.9
3	false-negative sows	5	6.8	7	9.5	7	9.5
	false-positive listings	95	10.2	79	8.5	70	7.5

Results regarding Th_{ts}, Th_{bo2} and Th_{bo1}

Table 2 shows the percentage of reduction in false-positive listings achieved for the thresholds Th_{ts}, Th_{bo2} and Th_{bo1} for different data subsets and different combinations of X and Y. Not all reduction percentages were estimated, since in a number of occasions more than 5 % of the sows did not visit the DA of TW in the period under investigation. The maximum number of false-positive listings (listings on a checklist of sows which were not yet in oestrus) is obtained when Th <= 0, since then all sows will be placed on every checklist. In that case, the number of false-positive listings would be 933 for DA and TW_{+DA} and 430 for TW_{-DA}. If for a given data subset and combination of X and Y there were 43 false-positive listings found for visits to TW_{-DA}, this would mean a reduction percentage of 90 %. Y_{opt} refers to the value of Y at which the largest reduction in false-positive listings was achieved.

Table 2: Results of a partially automated oestrus detection system for sows.
Creation of attention lists twice a day was simulated from 3-17 days after weaning the piglets. The maximum number of false-positive listings for DA and TW_{+DA} was 933 and for TW_{-DA} was 430. Results are expressed as the percentage by which these maximum numbers are reduced. The detection system was based on visits of sows to a detection area DA or to ticket-windows TW_{+DA} or TW_{-DA}, using formulae of the form (X x duration) + (Y x frequency) > Th.
sows (# sows in oestrus) for DA and TW_{+DA} was 88(74) and for TW_{-DA} 40(35).
For explanation of DA, TW_{+DA}, TW_{-DA}, Th_{ts}, Th_{bo2}, Th_{bo1} and data subsets, see text.

		data subset 1			data subset 2			data subset 3		
		00:00 - 06:00 h 08:00 - 10:40 h 11:20 - 15:00 h 17:00 - 24:00 h			00:00 - 06:00 h 08:00 - 10:40 h 11:20 - 13:30 h 17:30 - 24:00 h			00:00 - 06:00 h 17:30 - 24:00 h		
formula parameters	period around oestrus	DA	TW_{+DA}	TW_{-DA}	DA	TW_{+DA}	TW_{-DA}	DA	TW_{+DA}	TW_{-DA}
X = 1	Th_{ts}	86.3	78.0	96.3	87.2	84.9	96.0	87.4	-	96.7
Y = 0	Th_{bo2}	85.2	78.0	94.9	86.3	78.3	94.2	83.7	-	93.3
	Th_{bo1}	80.9	53.2	71.9	78.8	-	78.6	42.3	-	70.2
X = 1	Th_{ts}	94.2	83.1	97.9	94.9	90.2	98.1	91.6	-	98.6
$Y = Y_{opt}$	Th_{bo2}	87.7	83.1	96.3	86.3	82.0	94.7	83.8	-	91.9
	Th_{bo1}	78.8	53.4	87.2	78.8	-	86.3	46.4	-	77.2
X = 0	Th_{ts}	78.9	75.5	96.7	77.8	84.6	96.0	77.0	-	91.9
Y = 1	Th_{bo2}	78.9	75.5	94.2	77.8	79.1	89.8	61.1	-	89.8
	Th_{bo1}	59.4	58.7	86.0	52.4	-	87.0	-	-	79.5

Underlined percentages indicate that more than 4 (DA and TW_{+DA}) or 2 (TW_{-DA}) of the sows were false-negative.
X, Y: used in the formula (X x Duration)+(Y x Frequency) (see text).
Y_{opt}: (lowest) value of Y with the highest reduction in false-positive listings.

Based on visits of sows to the DA, TW_{+DA} and TW_{-DA}, respectively, the formulae using Th_{ts} which yielded the highest reduction percentage in false-positive listings are given in table 3.

Table 3. Formulae giving the best results expressed in terms of reduction percentages in false-positive listings. Formulae were based on based on visits of sows to DA, TW_{+DA} or TW_{-DA}, respectively, using Th_{ts}. For explanation of terms, see text.

DA TW_{+DA} TW_{-DA}	data subset	formula		reduction (%)
DA	1	duration + (2250 * frequency) >	51785	94.2
DA	2	duration + (2550 * frequency) >	47472	94.9
DA	3	duration + (700 * frequency) >	10894	91.6
TW_{+DA}	1	duration + (20 * frequency) >	463	83.1
TW_{+DA}	2	duration + (210 * frequency) >	2743	90.2
TW_{-DA}	1	duration + (100 * frequency) >	5344	97.9
TW_{-DA}	2	duration + (75 * frequency) >	3667	98.1
TW_{-DA}	3	duration + (15 * frequency) >	1064	98.6

DISCUSSION

A problem with the approach chosen by Bressers et al. (1991) is the fact that formulae were optimized on basis of a data set and then tested on the same data set. This might give a too optimistic picture of the possibilities of the detection system. Therefore, these formulae were validated in this study. Bressers et al. (1991) derived a formula, using data subset 2, to detect 95 % of all sows that came into oestrus in time to be served. This formula was applied to the data collected in the present study. In this way, at least 95 % of all sows that came into oestrus were detected during oestrus, while the number of checkups on sows not (yet) in oestrus could be reduced by more than 90 %. For data subsets 1 and 3, the results were less good. However, building in a 'safety limit' by reducing the threshold by 10 % improved these results.

In Bressers et al. (1991), sows had to pass gates with a one-way swing door in order to enter and leave the DA. This system was hard to automate and the gates were therefore replaced by a passage-way. In that study, the sows to be listed were determined after finishing the experiment. In practice, attention lists should of course be available at the start of each checkup period. With the layout of the DA used in the present study, recording visits of sows to the DA could be automated. This makes it possible to derive attention lists when needed. Even though the layout of the entrance to the detection area was changed, the formulae derived by Bressers et al. (1991) were still applicable in this study.

Most of the few unclarities in the list of visits to the DA occurred if identification of a sow by one of the antennas was disturbed because of the proximity of the transponder of another sow. Also, the order in which a sow was identified by the antennas could get mixed up if she moved back and forward in the middle of the passage way, since there was technically a small blind spot between the antennas in which a sow could not be identified. Adjusting the antennas in such a way that the blind spot is avoided was difficult because of technical problems related to interference of the high frequency fields of the antennas. This technical problem might be solved by redesigning the equipment or the shape of the passage-way.

Houwers (1988) and Lokhorst and Houwers (1991) described an oestrus detection system based on visits of sows to the ticket-window in the wall of a boar-pen. They used data on duration of visits to a ticket-window from all parts of each 24 hour period, whereas Bressers et al. (1991) indicated that using only data from selected parts of each 24 hour period might improve the results. In the present study, the results for TW_{+DA} improved, if data subset 2 was used instead of data subset 1. In data subset 2, data collected during the afternoon were omitted. For DA and TW_{-DA}, there was little or no improvement. Combining duration and frequency in one formula improved the results of the study reported by Bressers et al. (1991) and in most cases also in the present study.

The reduction percentages reached with the use of a freely accessible ticket-window (TW_{-DA}) are higher than those found using DA or TW_{+DA}. However, these results should be interpreted with caution, because of estimation error in the 5 % points used as threshold. The results indicate that an automated oestrus detection system using a ticket-window with limited space (TW_{+DA})in front of it works very well, but the system might be improved with more space in front of the ticket-window (TW_{-DA}).

The method used to estimate the thresholds Th was non-parametric. In most cases, the distribution of peak values could be transformed to a Normal Distribution using the Box-Cox family of power transformations (Montgomery and Peck, 1982). A modified Shapiro-Wilk test for normality (Shapiro and Francia, 1972) could be used to test for Normality. However, such a test determines whether there is an acceptable overall resemblance to the Normal distribution, while in this study we are mainly concerned with the lower tail of the distribution. Therefore, a non-parametric method was chosen.

Figure 2 shows that average duration of visits to the ticket-windows $TW_{+DA}$and TW_{-DA} was very similar for checkup periods -5 through 1. Thereafter, the average duration of visits to the ticket-window decreased for TW_{+DA} and increased for TW_{-DA}. The threshold levels used in the formulae in this study are not dependent on the mean, but on the 5 % point of the distribution of the peak-values. Therefore, the fact that the average duration of visits to $TW_{+DA}$and to TW_{-DA} is almost equal up to and including checkup period 1, does not imply that the results of detection systems based on visits to $TW_{+DA}$and TW_{-DA} should be equal too.

In conclusion:

1) The formulae for automated oestrus detection based on visits to a detection area in front of a boar-pen which were found by Bressers et al. (1991) were

validated with a new dataset. Accepting 5 % false-negative sows, the number of checkups on sows not in oestrus can be reduced by ± 95 %.

2) No marked differences were found in results between oestrus detection methods based on visits to DA, TW_{+DA} or TW_{-DA}, although there is an indication that TW_{-DA} yields better results than DA and TW_{+DA}.

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CHAPTER 3

OESTRUS-ASSOCIATED PHYSICAL ACTIVITY IN GROUP-HOUSED SOWS

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ABSTRACT

Physical activity has been shown to be a useful parameter for oestrus detection in several species of animals. In this study, a prototype telemetric activity sensor was used to measure oestrus-associated activity changes in group-housed sows. Two types of parameters were derived from this telemetrically recorded activity signal and their values were determined twice daily. The contrast between the values for the parameters for physical activity during pre-oestrous and oestrous periods respectively was determined. The physical activity parameter based on a simulated mercury switch with a relatively high sensitivity gave the best results. Specific parts of each 24 h period were analyzed to see whether the contrast in parameter values between pre-oestrous and oestrous periods could be improved. The results were better when only data recorded during the night, when non-oestrous sows usually rest or sleep, were used. In the best case, considering all sows, 90 % of the pre-oestrous values were lower than the highest oestrous value for the same sow. These measurements look to be quite promising for the detection of oestrus.

INTRODUCTION

One of the problems that stockpersons encounter with group-housing systems for sows is the amount of labour required to monitor individual sows (Süss, 1988; Van Putten, 1989). Oestrus detection requires monitoring of the individual sow. The amount of labour spent on checking sows could be reduced if an automatic system could be developed which would focus the attention of the stockperson on a limited number of sows. Such an automated system could facilitate the introduction of group-housing systems in practice.

Physical activity has been shown to be a useful parameter for oestrus detection in several species. Oestrus-associated increases in physical activity have been reported for dairy cows (Eradus et al., 1992; Holdsworth and Markville, 1982; Kiddy, 1977; Lewis and Newman, 1984; Peter and Bosu, 1986; Pulvermacher and Maatje, 1992; Schofield and Phillips, 1987), for Egyptian buffalos (Williams et al., 1986) and for dairy goats (Doherty et al., 1987). Morris and Udry (1970) reported variations in physical activity during the menstrual cycle in women. Altmann (1941) used activity sensors in a small number of sows and showed that their activity increased 2.5 - 3 times at oestrus.

Currently available activity sensors process data on acceleration in a fixed way, e.g. with a mercury switch, and summarize the data over certain time periods. These devices either present information directly to the stockperson or data that can be read into a computer at fixed locations, e.g. in a milking parlour. In order to be able to study original and successive data on activity-associated acceleration of group-housed, freely moving animals, this data should be continuously measured and transferred to a computer to be sampled and stored. In this way, several parameters for physical activity can be derived from the recorded acceleration data and data can be summarized over any desired time period.

In this study, a prototype of a first-generation radiotelemetric activity sensor has been used to study the activity patterns of group-housed sows prior to and during oestrus. With the objective of improving the measured contrast in physical activity before and during oestrus, two types of parameters on physical activity were derived and specific parts of the 24 h period were studied. The final objective was to evaluate the possibilities and limitations of a telemetric activity sensor prototype in measuring oestrus-associated activity changes.

ANIMALS, MATERIALS AND METHODS

Animals

Every three weeks, a group of 10 hybrid sows of various parities (1-10) was transported to our experimental farm, immediately after weaning the piglets. All the sows came from one commercial farm, where they were kept individually, tethered by the chest. All the sows, except for 3 sows of one group, were new to the housing system. Only sows without clinical abnormalities were accepted. Eight groups were involved in the experiment.

Housing and Feeding

All groups were housed and managed in a service house (8.4 m x 10 m) as described by Bressers et al. (1991). Sows from groups 2, 4, 6 and 8 could only go back and forth between the dunging area and the detection area through a passage-way, as shown in figure 1. The passage-way was not present for groups 1, 3, 5 and 7. Bressers et al. (1991) used two one-way swing doors between the dunging area and the detection area instead of a passage-way.

A mature, sexually active boar was housed in a boar-pen in the corner of the service house. The sows were individually fed from an electronic feed station. In the feed station (NEDAP-POIESZ, Hengelo (Gld.), the Netherlands) some water was mixed with the food. A new ration could be obtained daily from 15:00 h onwards. Water was available ad libitum from nipple drinkers. Lights were on from 06:30 to 21:00 h. During the night, dim light was maintained.

Routine checking for oestrous symptoms

From the third day after weaning, sows were checked for oestrous symptoms twice daily during check-ups between 7:00 and 8:00 h and between 16:00 and 17:00 h. This was done by experienced stockpersons who did not have any knowledge of the results of the activity measurements. The method used was based on Willemse and Boender (1966) as described by Bressers et al. (1991). In this study, the period the sows showed the standing response to the boar will be referred to as the oestrous period.

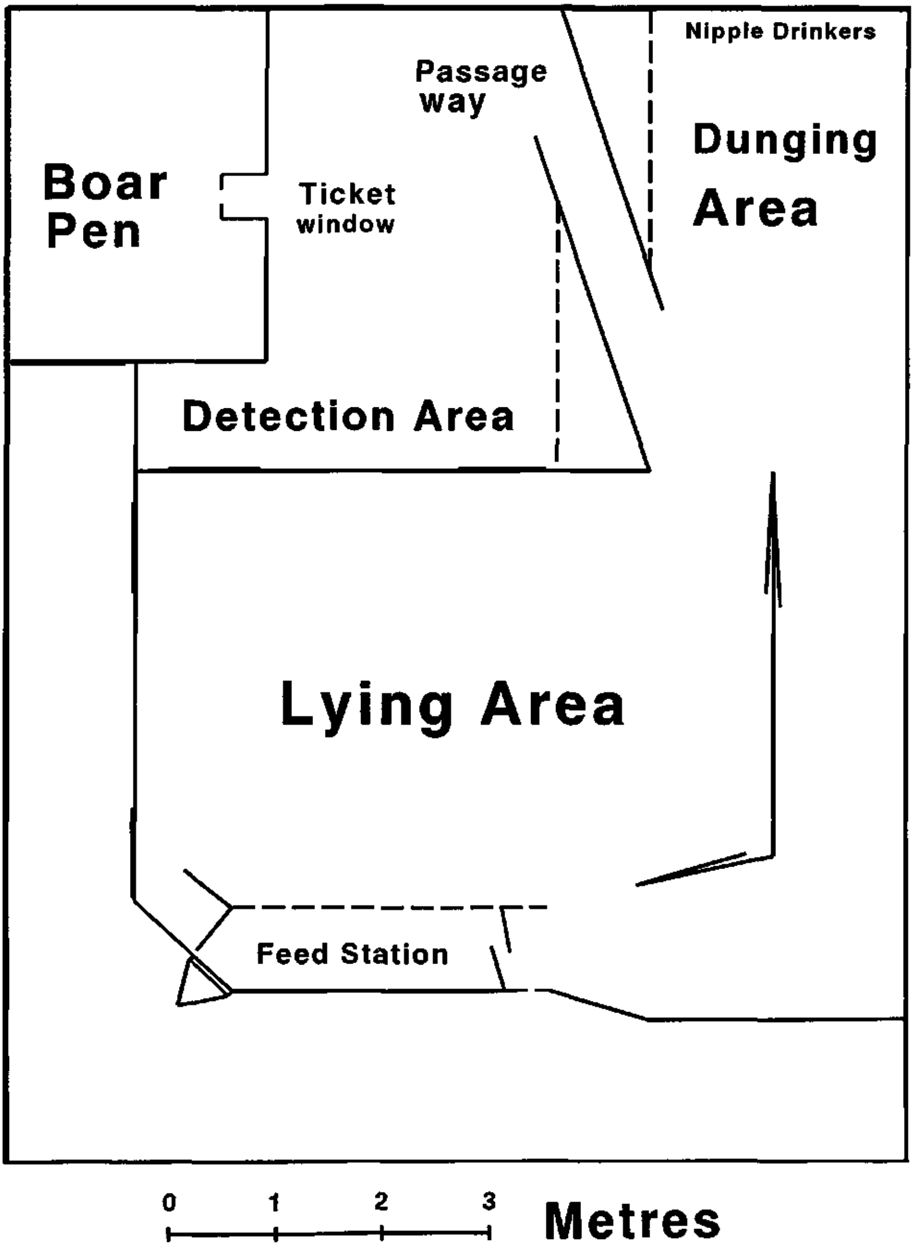

Figure 1. Layout of the service house. The situation is given for the even-numbered groups. In the odd-numbered groups used in the present study, the passage-way between the dunging area and the detection area was removed.

Data collection

Each sow carried a transmitter with an acceleration sensor attached to a neck collar, designed and manufactured by TFDL-DLO and IMAG-DLO (Cats et al., 1993). This device includes a piezoelectric accelerometer, sensor electronics, a transmitter and batteries. The whole device weighed approximately 140 grams. The acceleration was continuously measured and transmitted as an analog signal to a receiver connected to an analog-digital interface board (Metrabyte Das16) in an Olivetti M300 personal computer. There the signal, referred to as the sow's activity, was converted into a value between 0-254 every 20 ms (50 Hz). In this way 10 sows could be monitored simultaneously. A zero-acceleration corresponded to a value of 128. Values in the range from 123 through 133 were set to 128 for noise reduction. A value of 255 was used to indicate a transmission failure. For each sow, each value will be referred to as D_k (Datum k).

Data were collected for each sow starting on the day after weaning at 17:00 h until she stopped showing the standing response to the boar. Sows which had not shown oestrous symptoms by day 11 after weaning were not included in the analysis.*Calculations on the contrast between pre-oestrous and oestrous periods*

General approach

Based on the main parameter "physical activity", two types of sub-parameters were derived: one based on the mean amplitude of the activity signal, the other on the number of times certain threshold values were passed by the signal. These sub-parameters will be described in detail, but first the general approach used for both these sub-parameters is explained. In the following, they will be referred to as "parameters" instead of as "sub-parameters".

For each sow, the value of each parameter was calculated over the 24 h period before each oestrous check-up, starting with the morning check-up on day 3 after weaning until the end of the oestrous period.

For each parameter, the number of pre-oestrous values higher than or equal to the highest value during the oestrous period was determined per sow. These values were summed over all sows. Next, the resulting sum was expressed as a percentage of the total number of pre-oestrous values over all sows. This procedure was used as a way of describing the contrast between pre-oestrous and oestrous periods. A low percentage means that, on average, there were few pre-oestrous values that were higher than or equal to the highest value during oestrus of the same sow. This indicates a high contrast between pre-oestrous and oestrous values, with relatively high oestrous values.

The last check-up during oestrus, i.e. the last check-up during which the sow showed the standing response to the boar, was omitted from the analysis. In view of practical applications in the future, it was considered that reproduction results might be negatively influenced if the stockperson is only alerted to a particular sow at the last check-up during oestrus (Willemse and Boender, 1967). Furthermore, by that time it may be too late to order semen for artificial insemination.

After a period with $D_k = 255$, indicating a transmission failure, an artificial reduction of the baseline signal was sometimes observed, which lasted for up to 4.5 seconds. Therefore, data collected during 5 seconds after such a period were set to 255 and not used in the analysis. Periods with D_k unequal to 128 adjacent to such a (prolonged) period with $D_k = 255$ were not used for analysis either. If less than 75 % of the data collected during any 24 h period during a sow's oestrus was valid, then no data at all for that sow were used in the analysis. For the remaining sows, pre-oestrus values based on less than 75 % valid data were excluded from analysis.

Data subsets

For each sow, 4 data subsets were made up of data collected during selected parts of the 24 h period before each check-up. Table 2 shows which parts of each 24 h period were included in which data subset. The data subsets were formed to test whether the contrast in physical activity between periods with and without oestrous symptoms was larger when only certain parts of the 24 h period were used. The subsets were chosen to exclude times during which the stockman was working in the service house (all data subsets) and times during which the sows were generally active (data subsets 2 through 4).

Derived parameters

The two types of parameters derived from the data are the main amplitude $\bar{A}$ and the number of times a certain threshold was exceeded N(th):
1) $\bar{A}$. The mean amplitude of the signal-curve is a measure of the mean activity of an individual sow for the period over which the signal was analyzed. To study this, the mean amplitude was defined as $\bar{A} = (\Sigma \mid D_k - 128 \mid)/n$ in which n is the number of D_k involved in the analysis.

2) N(th). This was defined as the number of times that $\mid D_k - 128 \mid$ < th and the next value $\mid D_{k+1} - 128 \mid \geq$ th, in which th is a threshold value. This simulates a mercury switch with a sensitivity that would cause it to switch on at an acceleration corresponding to $\mid D_k - 128 \mid$ = th. For this parameter the following values for th were considered: 10, 15, 20, 25, 30, 35, 40, 45 and 50. All values for this parameter were adjusted for the fraction of data that was invalid. For example, if any value was based on data in which 10 % of all D_k were equal to 255 (invalid data), this value was then divided by 0.9.

All the calculations described were made for each data subset separately, using only data from the parts of the 24 h period included in the data subset under consideration.

RESULTS

Relation between telemetrically recorded activity data and sow movements

A couple of typical examples are given in figure 2 to illustrate the relation between the telemetrically recorded activity data, values for $\bar{A}$ and N(10) and movements of a sow. The sow chosen did not have any clinical health problems during the study period and she had a low percentage of D_k = 255. Signal patterns are presented for the two-hour period "A", and for a ten-minute period "B" during which the sow first laid down, then stood up, walked to the feed station and subsequently started feeding. Signal patterns of two one-minute parts ("C" and "E") from this ten-minute period are also given. Finally, from each of these one-minute periods, signal patterns are given for a ten-second part ("D" and "F"). In "D", the sow stood up very suddenly when the stockman entered the service house, in "F" she was eating in the feed station.

For each ten-minute part of a two-hour period, the $\bar{A}$ and the N(10) value were calculated. These values are given in table 1, together with a short description of the sow's behaviour, taken from time-lapse video recordings, during each of these ten-minute parts.

There is an association between the general activity of the sow and the values for $\bar{A}$ and N(10). Not only walking, running and fighting contribute to the values for $\bar{A}$ and N(10), but also behavioural elements like eating and even head movements of a sow when lying down.

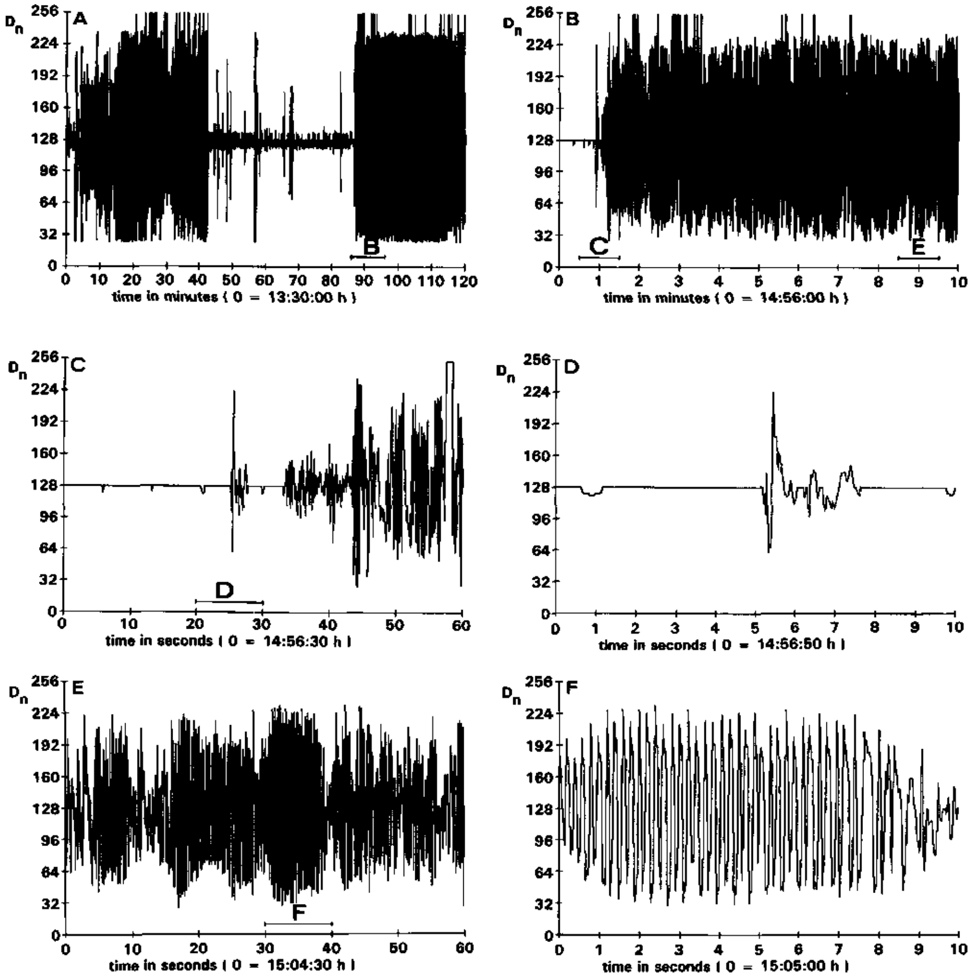

Figure 2. Transmitted activity signal of a group-housed sow.

"A" shows the compressed signal of a sow not (yet) in oestrus during a two-hour period (4 days after weaning the piglets; 13:30 - 15:30 h). The position of "B" in "A", "C" and "E" in "B", "D" in "C" and "F" in "E" are indicated by horizontal bars above the time axis. Data used for "D" and "F" were not compressed. Data for "A", "B", "C" and "E" were compressed by plotting only the highest and lowest values of a number of values. See text for further explanation.

Table 1. Relation between values for the parameters $\bar{A}$ and N(10) for a sow's physical activity and her behaviour for ten-minute parts of a two-hour period (4 days after weaning the piglets; 13:30 - 15:30 h). See also Figure 1.

Part	value $\bar{A}$	value N(10)	short description of behaviour
13:30 - 13:40 h	6.0	1210	lying down, many head movements
13:40 - 13:50 h	23.7	2097	first lying down, later walking and fighting
13:50 - 14:00 h	26.9	2500	fighting, running
14:00 - 14:10 h	24.4	2525	walking, running
14:10 - 14:20 h	9.5	514	lies down (14:12 h)
14:20 - 14:30 h	1.4	123	lying down, sitting for one minute
14:30 - 14:40 h	0.5	35	lying down, 14:38 shifts position
14:40 - 14:50 h	0.2	1	lying down
14:50 - 15:00 h	10.6	684	14:57 jumps on feet, walks to feed station
15:00 - 15:10 h	43.0	2237	eating in feed station
15:10 - 15:20 h	47.1	1958	eating in feed station
15:20 - 15:30 h	35.1	2116	eating until 15:28, walking, lying down

Contrast between pre-oestrous and oestrus periods

The results for the parameters $\bar{A}$ and N(th) (th = 10 through 50) are presented in table 2. For each parameter, the results are expressed as the percentage of pre-oestrous values higher than or equal to the highest value during the oestrous period. The total number of pre-oestrus values for the 4 data subsets was 481, 489, 481 and 481, respectively. The number for data subset 2 is higher because fewer pre-oestrus values were omitted from the analysis because of invalid data than for the other data subsets.

From table 2, it is apparent that the best results are achieved for parameter N(th) at low thresholds (more sensitive mercury switch; N(10) and N(15)). Further, the contrast between pre-oestrous and oestrous periods is greater when only those parts of the 24 h period are taken into account during which the sows usually rest or sleep (data subset 4).

Table 2: Contrast between pre-oestrous and oestrous values of parameters for physical activity. The contrast for each parameter is expressed as the percentage of pre-oestrous values higher than or equal to the highest value during the oestrous period of the same sow. Percentages were calculated for the parameters $\bar{A}$ and N(th) (th = 10 through 50), separately for data subsets 1 through 4, for all sows that came into oestrus during the study period.

		data subsets and the parts of the 24 h period they covered			
		1	2	3	4
parameters		00:00 - 06:00 h 08:00 - 10:40 h 11:20 - 15:00 h 17:00 - 24:00 h	00:00 - 06:00 h 08:00 - 10:40 h 11:20 - 13:30 h 17:30 - 24:00 h	00:00 - 06:00 h 17:30 - 24:00 h	00:00 - 04:00 h 22:00 - 24:00 h
$\bar{A}$		29	25	22	14
N(th)	N(10)	21	20	18	11
	N(15)	25	22	17	11
	N(20)	26	23	20	12
	N(25)	27	23	22	14
	N(30)	28	24	23	14
	N(35)	28	25	24	15
	N(40)	29	27	26	16
	N(45)	30	28	27	18
	N(50)	31	28	27	18

DISCUSSION AND CONCLUSIONS

For a number of species, oestrus has been shown to be associated with increases in physical activity. This study was part of a research project aimed at improved monitoring of health and reproduction of individual animals in pig husbandry. It was focussed on the development of a device for monitoring physical activity to aid oestrus detection. This study was a first step towards such a device.

The transmitted activity signal, as it was used in this study, does not represent all of what can be called physical activity. First of all, the accelerometer in the device was sensitive mainly in one direction. To get a complete representation of the physical activity of a sow, activity should be measured in three dimensions whereas our recordings were mainly of accelerations in the most sensitive direction of the device. This would also have applied if a single mercury switch was used, because such a mercury switch is also sensitive in only one direction. Secondly, the attachment of the device to a neck collar contributed to differences between sows, which made it more difficult to determine an overall threshold for all sows in an automated oestrus detection system. The fact that the device was hanging loosely from the neck of the sow when she moved was not considered to be an objection when the detection system could be based solely on the contrast between periods with and without much physical activity.

The contrast between pre-oestrous and oestrous periods was determined on the basis of changes in the value of two types of parameters. These parameters gave an impression of the general level of physical activity over selected parts of 24 h periods. Although this approach has a number of limitations, a definite contrast between pre-oestrous and oestrous periods was found.

In an automated oestrus detection system, each time a value for a parameter is higher than a pre-set threshold, the sow can be listed for attention. These sows would then be checked visually for oestrous symptoms. A procedure now has to be developed to determine such a threshold so that both the number of false-positive listings as well as the number of false-negative sows are minimised. Using the highest value derived during the desired period as a threshold for the detection of oestrus is of course not feasible in practice, since the activity level during this period is not known prior to the measurements. For an automated system, a threshold would have to be determined based on the sow's activity level before oestrus. Because of the short interval between the sows' arrival at our experimental farm and the onset of oestrus in most of them, it was difficult to derive such a threshold from measurements made before oestrus.

It is quite possible that certain behavioural elements are characterised by specific patterns of the recorded activity signal. In this way, activity associated with behavioural elements that are of less interest for identifying oestrous sows may be given a lower weighting than activity associated with other selected types of behaviour. A high correlation between the signal and specific types of behavioural elements is needed for this. This correlation might be improved by attaching the device to the sow in a different way. Further research is planned by IMAG-DLO and TFDL-DLO, which will involve implanted devices.

In this study, about 85-90 % of all the pre-oestrous values for the parameters were lower than the highest value during oestrus. This means that the number of check-ups could potentially be reduced to 10-15 % of the number when no system is used. Although this percentage is still higher than that reached with other detection systems (Bressers et al. 1991), it is encouraging at this stage. However, it indicates that more research is necessary for further development of the system before it can be applied in practice. Within data subsets, the results do not differ widely between most parameters.

For each parameter, a larger contrast between pre-oestrous and oestrous periods was found for data subset 4 (22:00 - 04:00 h) than for the other data subsets. This indicates that in sows the contrast between oestrous and pre-oestrous periods is more pronounced when only those parts of the 24 h period are taken into account in which the animals usually rest or sleep. Due to dependencies in the data used, no formal test of statistical significance in these differences was carried out.

In conclusion, it was found that oestrus in group-housed sows is associated with increased activity. This is in agreement with the results reported by Altmann (1941) for five sows. The best contrast between pre-oestrous and oestrous periods was achieved with parameters based on a sensitive simulated mercury switch. The contrast between pre-oestrous and oestrous physical activity is more pronounced during the periods when the sows normally rest or sleep than during other parts of the 24 h period. Further work will be done to develop both the prototype as well as methods to analyse the data to improve the contrast between pre-oestrous and oestrous periods. This may lead eventually to practical application of such a device in sow husbandry.

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CHAPTER 4

MONITORING INDIVIDUAL SOWS: RADIOTELEMETRICALLY RECORDED EAR BASE TEMPERATURE CHANGES AROUND FARROWING

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ABSTRACT

*An implantable radiotelemetric temperature measuring device has been developed in order to assess the applicability of ear base temperature measurements in sow management. The radiotelemetric device was implanted in 7 sows (Dutch Landrace and Great Yorkshire * Dutch Landrace) just behind the base of the ear, 2 to 7 cm beneath the skin surface. Temperatures were recorded every 6 minutes from 2 days prior to farrowing until the piglets were weaned. Statistically significant changes (P < 0.05) in ear base temperature around farrowing followed a pattern similar to those reported in the literature for rectal and deep body measurements. The sows' temperature started to rise between 6-12 hours before farrowing. Until weaning it remained higher than before farrowing. A radiotelemetric temperature measurement unit, included in an electronic identification device implanted close under the skin and just behind the ear, may contribute to improved monitoring of some (patho)physiological processes in individual sows.*

INTRODUCTION

Information about individual sows is important for management of their health and reproduction. Automation of both the collection of relevant data and the analysis of these data can help to focus the stockperson's attention on those animals which need it the most. When individual-housing systems are replaced by group-housing systems, this will be of even more importance, since one of the problems of group-housing is the stockperson's difficulty in observing individual animals. Body temperature is frequently used by stockpersons and veterinarians to monitor e.g. the health status of animals.

In the Netherlands, research has been carried out on the development of an electronic identification device to be injected in piglets before weaning (Lambooy and Merks, 1989). A possible site for such an identification device is the base of the ear. Including a facility to measure temperature in such a device may enhance its usefulness to the stockperson.

Changes in ear base temperature around farrowing can be used as a model that may be representative for other (patho)physiological processes. The objective of this study was to determine whether a radiotelemetric device implanted under the skin close to the base of the ear could be used to detect changes in ear base temperature normally associated with farrowing in individually housed sows.

ANIMALS, MATERIAL AND METHODS

Animals

Seven sows (Dutch Landrace and Great Yorkshire * Dutch Landrace) of parity 2 or 3 were assigned to this study. Temperature transmitting devices were implanted by a surgical procedure, 6-7 weeks prior to the expected date of farrowing (see Temperature transmitters). All sows farrowed within a one week period at the end of January. The piglets were weaned at 5 weeks of age.

Housing

The sows were kept individually in crates from 3 days before until 1 week after surgery. Thereafter, they were kept in stalls, tethered by the chest, until 1 week before the first sow was expected to farrow. From this time until five weeks after the birth of the last litter, the sows stayed in individual crates in the Farrowing House.

The ambient temperature in the Farrowing House was maintained between 24 and 27 °C from two days before the first litter was born until 3 weeks after the birth of the last litter. Before and after this period, the temperature was maintained between 21 and 24 °C.

A 24 h photoperiod was maintained for a period of three weeks, starting 1 day before the birth of the first litter, in order to provide sufficient lighting for video recording. Outside this period the animals were kept in semi-darkness. During the periods of semi-darkness artificial lighting was supplied during feeding time and for short periods when it was needed by the stockperson.

Feeding regime

In the Farrowing House, all the sows were fed a commercial sow diet with an energy value of 9.05 MJ kg^{-1} NE_f. On the day of farrowing the sows received 2.0 kg of food. After farrowing, the amount of food was raised every second day by 0.5 kg until the maximum daily amount of 2.0 kg + 0.4 kg per piglet was reached. The resulting feeding level was maintained until weaning. The sows were fed between 6:15 and 6:30 h and between 15:00 and 16:00 h. Water was available ad libitum.

Radiotelemetric temperature transmitters

Prototype radiotelemetric temperature transmitters were developed and manufactured by TFDL-DLO (Jansen et al., 1987). Each temperature transmitter was embedded in paraffin and encased in a glass tube (6.1 cm x 1.9 cm) with a stainless steel lid. The entire device was covered with two layers of medical grade silicon rubber. A small strip (1 cm x 3 cm) of double felt dacron fabric was attached to the silicon rubber in the middle of the device in order to prevent it from migrating. The multiple-transmitter/multiple-channel system used in this study is capable of handling up to 20 transmitters with one fully-automated receiving system. The sows' temperature was recorded every 6 minutes from each transmitter with an absolute accuracy of 0.1 °C and a resolution of 0.01 °C. All transmitters were calibrated in a warm water bath before use and were checked in the same way after the experiment. No shift in the accuracy of the transmitted temperatures was observed.

In each sow, a temperature transmitter was inserted through an incision 10 cm behind the base of the right ear, after separating muscle and skin tissue (including fat tissue) by blunt surgery. Before surgery, each sow was tranquilized with Stresnil®[1] (1 ml/20 kg body weight i.m.) and additionally anaesthetized with Hypnodyl®[1], injected into an ear vein. The dosage of Hypnodyl®[1]

[1]Janssen Pharmaceutica, Tilburg, The Netherlands

was controlled by means of the cornea reflex. The incision was finally sutured. The transmitters were removed 8 to 9 weeks after the piglets were weaned.

Data collection

Temperature data were collected in the Farrowing House from 2 days before the expected date of farrowing until the time the piglets were weaned. Due to incidental computer malfunctioning and transmission problems, data were lost during short periods for some sows. Temperature values between 34.0 and 41.5 °C that substantially deviated (> 1.0 °C / 6 minutes interval) from adjacent values were omitted from the data before analysis. Temperatures below 32.0 °C or above 42.0 °C were rare. These were also omitted. In total 0.23% of the recorded values were omitted. No values between 32.0 and 34.3 °C or between 41.5 and 42.0 °C were recorded. The date and time of birth of the first and last piglets of each sow were derived from time-lapse video recordings (1 frame/s) made during farrowing.

Data analyses

In the following the duration of farrowing has been defined as the time between the birth of the first and last piglets of a litter.

To illustrate the changes in ear base temperature during farrowing, mean temperatures were calculated for two sows for each 30-minute period during the period from 2 days before until 2 days after the day of farrowing.

To estimate if ear base temperature remained high until weaning or for a shorter period after farrowing, the mean transmitted ear base temperature for each sow was calculated for each day the sows stayed in the Farrowing House.

To determine if ear base temperatures changed around farrowing, the mean temperature and standard deviation were calculated for each sow for the nine periods given in table 1. The Wilcoxon Matched Pairs Signed Rank Test (Conover, 1980) was applied to test two-sided for differences between these periods. For each of the periods, the average of the mean temperatures of the sows and the average of the standard deviations of the sows were calculated. Furthermore, the mean temperature for each sow for each of the periods given in table 1 was decreased by the mean temperature of a period of equal length, taken at the same time of day, but 24-48 hours before farrowing. This was done to take into account diurnal temperature changes. The Wilcoxon Matched Pairs Signed Rank Test (Conover, 1980) was applied to test two-sided for differences between the periods.

To determine how often 24-hour temperature changes occurred of the magnitude found for the period 0-6 hours before farrowing, we looked for similar changes lactation. For days 9-21 after the birth of the last litter, the differences and standard deviations between mean ear base temperatures for each 6-hour period and the corresponding period on the previous day were calculated. Only 6-hour periods with at least 15 transmitted temperature values were used.

To estimate the magnitude of 24 h changes in ear base temperature measurements, the first transmitted temperature value for all sows, in each 30-minute period for days 9-21 after birth of the last litter, was compared with the temperature value collected approximately 24 hours earlier. For the 30-minute periods between 00:00 and 24:00 h, the range of standard deviations of the differences was determined. Furthermore, the standard deviation is given for all temperature differences combined.

RESULTS

All incisions healed well within 10 days after surgery. At removal, the transmitters were covered by skin (including subcutaneous fat) and 2 to 7 mm (30-50 mm in 2 sows) of muscle tissue (*M trapezius* and *M brachiocephalicus*). In general, the transmitters were situated 2 to 7 cm beneath the surface.

Figure 1 shows 30-minute period means of the ear base temperature for two sows during the period from 2 days before until 2 days after farrowing.

These sows were chosen because they had few transmission errors in the two 24-hour periods before the 24-hour period in which they farrowed. Between farrowing and weaning, the mean daily transmitted ear base temperature of all sows was always higher than before farrowing.

For nine periparturient periods, table 1 shows the average of the mean temperatures with the average of the standard deviations. For the same periods, table 1 also gives the average changes in temperature relative to a period of equal length taken at the same time of day, but 24-48 hours before farrowing. The average temperatures given in table 1 were based on all 7 sows (6 sows for period 1) and the temperature changes were based on 6 sows (5 for period 1). The restriction to 6 and 5 sows occurred because of lack of data on ear base temperatures before farrowing for 1 and 2 sows, respectively. All six sows for which periparturient temperature changes over 24 hours were determined showed an increase of 0.40 °C or more for the 0-6 hour period before farrowing. Four of them showed an increase of 0.70 °C or more. Of the 233 changes over 24 hours of 6-hour temperature means that were determined during lactation, 5.6 % showed an increase of 0.40 °C or more and 0.9 % of 0.70 °C or more. For 9-21 days after the birth of the last litter, the standard deviations of the differences in mean temperature between the periods 0:00 - 6:00 h, 6:00 - 12:00 h, 12:00 - 18:00 h and 18:00 - 24:00 h and the 6-hour periods 24 hours earlier were 0.26 °C, 0.19 °C, 0.21 °C and 0.30 °C, respectively.

In total, 2512 changes over 24 hours were determined for the first temperature value of 30-minute periods during lactation (9-21 days after the birth of the last litter). 1.6 % of these changes were < -1.0 °C or > 1.0 °C. The overall standard deviation of the differences was 0.42 °C with a range from 0.21 to 0.71 °C. Low standard deviations (0.21 - 0.34 °C), were found between 7:00 and 10:00 h (except 8:00 - 8:30 h) and high standard deviations (0.53 - 0.71 °C) were found between 18:30 and 20:30 h.

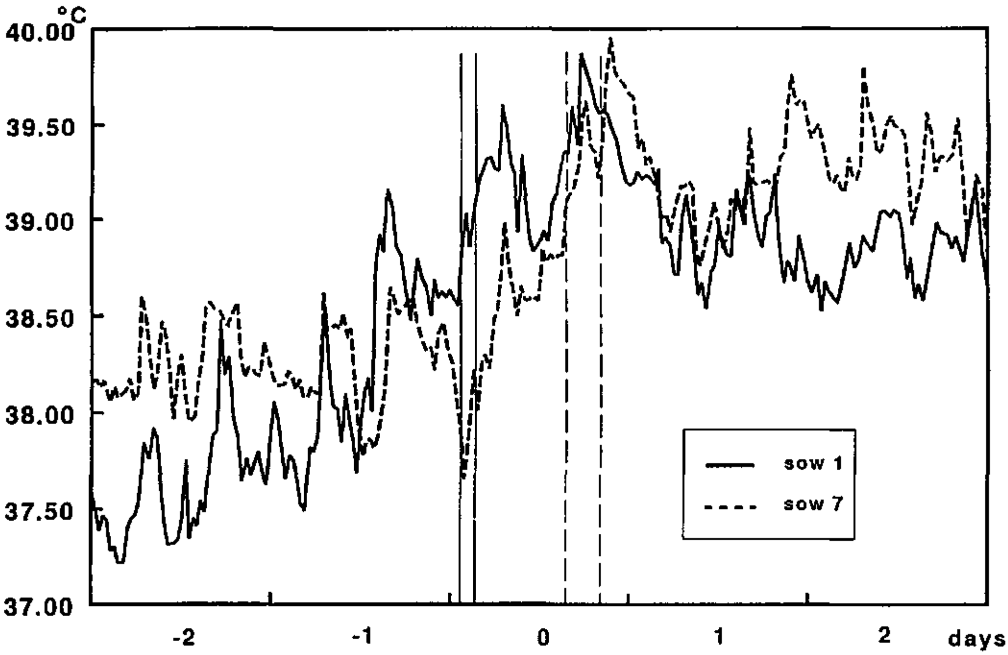

Figure 1: Changes in ear base temperature in sows 1 and 7 during the periparturient period (day 0 is day of farrowing). Vertical lines indicate time of birth of the first and last piglets. Each division of the X-axis indicates a 24-hour period.

Table 1. Periparturient ear base temperatures in sows.

Average of 6-hour period mean ear base temperatures (A) with average standard deviation (B) and average temperature changes relative to a 6-hour period taken 24-48 hours before farrowing (C) for nine periparturient periods. Different superscripts indicate significant differences between periods ($P < 0.05$). Duration of parturation (interval birth of first to birth of last piglet) was 3.45 ± 2.01 hour (range 1.25 - 7.20 h).

		A	B	C
Period	n =	7	7	6
1* : 24 h - 18 h prior to birth first piglet		37.6^{a}	0.3	0.2^{ab}
2 : 18 h - 12 h prior to birth first piglet		37.6^{a}	0.3	0.2^{a}
3 : 12 h - 6 h prior to birth first piglet		38.0^{ab}	0.2	0.6^{bc}
4 : 6 h - 0 h prior to birth first piglet		38.3^{bc}	0.3	0.7^{c}
5 : parturation		39.0^{de}	0.2	1.2^{d}
6 : 0 h - 6 h after birth last piglet		39.1^{d}	0.2	1.6^{d}
7 : 6 h - 12 h after birth last piglet		38.7^{e}	0.2	1.2^{d}
8 : 12 h - 18 h after birth last piglet		38.6^{cd}	0.2	1.2^{d}
9 : 18 h - 24 h after birth last piglet		38.7^{d}	0.2	0.9^{cd}

* n = 6 (A,B), n = 5 (C)

DISCUSSION

Temperatures measured at different sites of the body follow different patterns in time (Geers et al., 1992; Jørgensen et al., 1986). Measuring body temperature is not a goal in itself. It is a way to indirectly monitor those (patho)physiological processes affecting temperature. This study was not therefore aimed at predicting rectal or deep body temperatures from ear base temperatures, but at studying the possibility of using ear base temperatures to monitor a physiological process such as farrowing.

Ear base temperature in sows, measured during the periparturient period, started to rise 6-12 hours before parturition. Mean temperature values measured 0-6 hours before parturition were significantly higher than values more than 12 hours before parturition. Temperatures reached their highest values during and shortly after parturition and then remained higher than before parturition. This corresponds well with results reported in the literature for temperatures around farrowing measured by other means. Hendrix et al. (1978) found that the rectal temperature of sows started to increase 4 hours before the birth of the first piglet and remained high for at least 24 hours after the birth of the last piglet. Elmore et al. (1979) reported a rise in deep body temperature from 13 ± 4 hours prior to the birth of the first piglet. They also found that body temperature remained high during lactation and returned to mean pre-farrowing values within 24 hours after weaning. According to Littledike et al. (1979), deep body temperature starts to rise about 12 hours before the birth of the first piglet. It peaks 1 to 2 hours after the birth of the last piglet and decreases during the first day post-partum. Thereafter, until 12 days after farrowing, a slight increase was observed. Kelley and Curtis (1978) found an increase in rectal temperature as parturition approached in gilts and sows held at 20.5 °C and in heat-stressed gilts held at 29.5 °C, but not in heat-stressed sows. After parturition, rectal temperatures decreased, but in gilts and sows kept at 20.5 °C, they stayed higher than before parturition.

There are indications for diurnal temperature changes, for example linked to the time of feeding. If the sows' time of farrowing is not randomly distributed over the 24-hour period, the onset of temperature changes before farrowing could be estimated wrongly. Therefore, in the present study temperature changes over 24 hours were also evaluated. The results of this analysis also indicate a temperature increase at 6-12 hours before farrowing. After farrowing, ear base temperature remained high until weaning. Whether the onset of farrowing can be predicted by measuring ear base temperature will have to be evaluated after more research.

During the hours after feeding in the morning, 24-hour temperatures changes had relatively low standard deviations. Temperature changes due to (patho)physiological processes may therefore be more apparent during this period of the day.

For the detection of health problems, the stockperson should be warned if substantial temperature changes occur. In the present group of clinically healthy sows involved in this study, only 1.6 % of all 24-hour changes for individual temperature values calculated during the lactation period were larger than 1.0 °C. 0.9 % of the 24 hour changes for 6-hour means during lactation were larger than 0.70 °C. Therefore, this study indicates that a stockperson could be alerted to temperature changes of these magnitudes with only a limited number of false-positive occurrences.

Hahn et al. (1990) observed that sub-dermal temperatures measured in the neck and flank region of a steer were influenced much more by dynamic environmental conditions than rectal and tympanic temperatures. Under less dynamic conditions, a good correlation between the temperatures measured at these four sites was found. This implies that subcutaneous temperature measurements may have shortcomings in dynamic environments. However, in modern farrowing accommodations for sows, climatic conditions are well controlled and the presence of a fat layer in sows may also limit this problem. Further research is necessary in this subject.

In conclusion, temperatures measured near the ear base with a prototype radiotelemetric temperature measuring device change during the periparturient period, as has been shown for rectal and deep body temperatures. Further research and development may lead to the introduction of an injectable temperature measuring device which could also enclose an identification number. This could contribute to an improved monitoring of health and reproduction in pigs in practice.

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CHAPTER 5

FEEDING ORDER OF SOWS AT AN INDIVIDUAL ELECTRONIC FEED STATION IN A DYNAMIC GROUP-HOUSING SYSTEM

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ABSTRACT

Patterns, in the use of a feed station, by sows, in a dynamic group-housing situation, were studied because deviations from such patterns might indicate disease, oestrus, or reproductive or other problems.

Groups of ten sows of various parities were transported to our experimental farm on the day their piglets were weaned. They had no prior experience with group-housing. After 1 day elsewhere for settling dominance relationships, the sows were group-housed in a service house. After 10, 17 or 31 days in the service house, the groups were introduced as subgroups into a gestation house and stayed there until a few weeks before the expected date of farrowing. In both the service house and the gestation house the animals were fed by an individual electronic feed station.

The feeding order was defined as the order in which the sows obtained the first food from the feed station each day after the start of the feed cycle. The consistency of feeding order within and between subgroups, and the difference in rank number for feeding within and between subgroups on 2 consecutive days were studied during the period the sows stayed in the gestation house. Furthermore, the relation between the number of sows with uneaten food in the gestation house and the time the sows spent in the service house was studied.

Although the feeding order was not random within subgroups, it did not remain stable over a period of several weeks. In general, sows from the subgroup most recently introduced into the gestation house fed later than sows introduced earlier. The difference in rank number for feeding within Subgroups of ten sows on 2 consecutive days was three or more in 19.1 % of the studied cases. Overall (28-30 sows), it was six or more in 17.3 % of the studied cases. Allowing longer periods for learning to operate the feed station reduced the time the sows needed to become accustomed to the feed station in a new environment. No sufficiently stable patterns could be identified to make it feasible to monitor the sows using deviations from such patterns.

INTRODUCTION

One of the problems related to group-housing systems for sows is the difficulty that stockpersons have with monitoring feed intake, health and reproduction of individual animals (Süss, 1988; Van Putten, 1989). For this reason, sows are kept closely confined in individual-housing systems in many countries. These systems give rise to concern about the welfare of sows. De

Koning (1985) concluded that the well-being is generally better in group-housing than in individual- and cubicle-housing systems.

In 1989, the Commission of the European Communities proposed regulations concerning minimum standards for the protection of pigs kept in intensive farming systems (Commission of the European Communities, 1989). Incorporation of Article 3 of this proposal into national regulations will support the further introduction of group-housing systems for dry sows.

Since 1983, individual electronic feeding systems have been available for sows. Such equipment, in which sows are fed in succession, permits automatic individual rationing in group-housing systems. If the feeding system is not automated, a stockperson can gain information about individual sows by observing them as they feed. Such information is obviously lost with a system in which sows are fed without the stockperson being present. In a number of computerised feeding systems, those sows that have not eaten their full ration within 24 h are recorded on a list for attention. However, information about the sows' use of a feed station, such as the feeding order, is not given. In this study, the feeding order is defined as the order in which sows obtain the first food from the feed station each day after the start of the feed cycle. Hunter et al. (1988, 1989) reported that sows visit the feed station in a fairly stable order. Sows eating their full ration, but at an unusual position in the feeding order, might require special attention (Van De Burgwal and Van Putten, 1990).

In a dynamic group-housing system, sows are not only introduced into and removed from the group in subgroups, but such subgroups also act as social units (Van Putten and Van De Burgwal, 1990). Within subgroups, the feeding order is expected to be more stable than that within the whole group so the feeding order of sows and of the subgroups of sows was studied. Furthermore, the effect of different lengths of learning periods on feed-station usage was examined. The objective was to detect patterns in the use of a feed station because deviations from such patterns might be related to the occurrence of disease, reproductive or other problems or oestrus.

ANIMALS, MATERIAL AND METHODS

Animals

Groups of ten hybrid sows of various parities (1-12) were transported to the experimental farm (one group about every 3 weeks), immediately after weaning their piglets. All groups came from the same commercial farm where they had been kept closely confined. Only sows without clinical abnormalities were accepted. No sow was acquainted with a feed station or with group-housing systems before arrival at our experimental farm.

After arrival, the sows were placed in an introductory house for 28 hours for settling a dominance hierarchy. After that, they were transferred to a service house. Nine consecutive groups were studied. Since these groups were ultimately introduced into a gestation house, where two to four of these groups were kept simultaneously, they will be referred to as subgroups. After 10 days (Subgroups II, V, XIII), 17 days (Subgroups III, VI, IX) or 31 days (Subgroups I, IV, VII) in the service house, respectively, the subgroups were transferred to the gestation house. When sows of Subgroup I arrived in the gestation house, they joined three previously established subgroups which were already present. From 1 to 3 weeks before farrowing, the subgroups were returned to the commercial farm. Figure 1 shows the relative dates of transfer to and from our experimental farm, and relocation from the service house to the gestation house for each subgroup involved in the study.

Housing

In the service house (8.4 x 10 m), the sows were trained to use an electronic feed station. In a corner of the service house there was a boar-pen, used in experiments for the automatic detection of oestrus (Bressers et al., 1991).

The gestation house (Figure 2) had lying areas (1 m^2/sow) with a floor of well insulated tarmac. The dunging areas had slatted concrete floors (slats 8 cm, slots 18 mm). The lying areas comprised four sections, three of them were subdivided into two parts by a wooden partition.

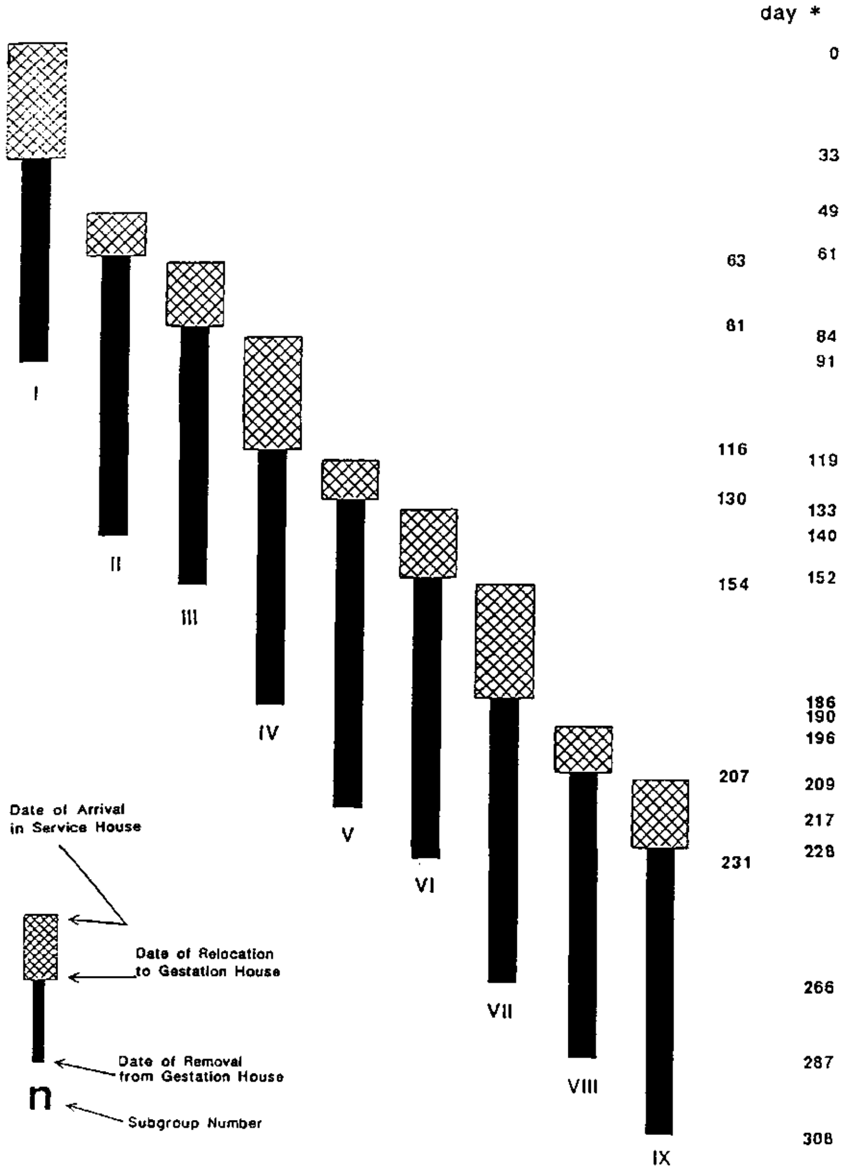

Figure 1. Days* of arrival, relocation and removal of the subgroups used in the experiment (*relative to the date of arrival of Subgroup I). Three previously established subgroups stayed in the gestation house from before Day 33 until 49, 63 and 84, respectively.

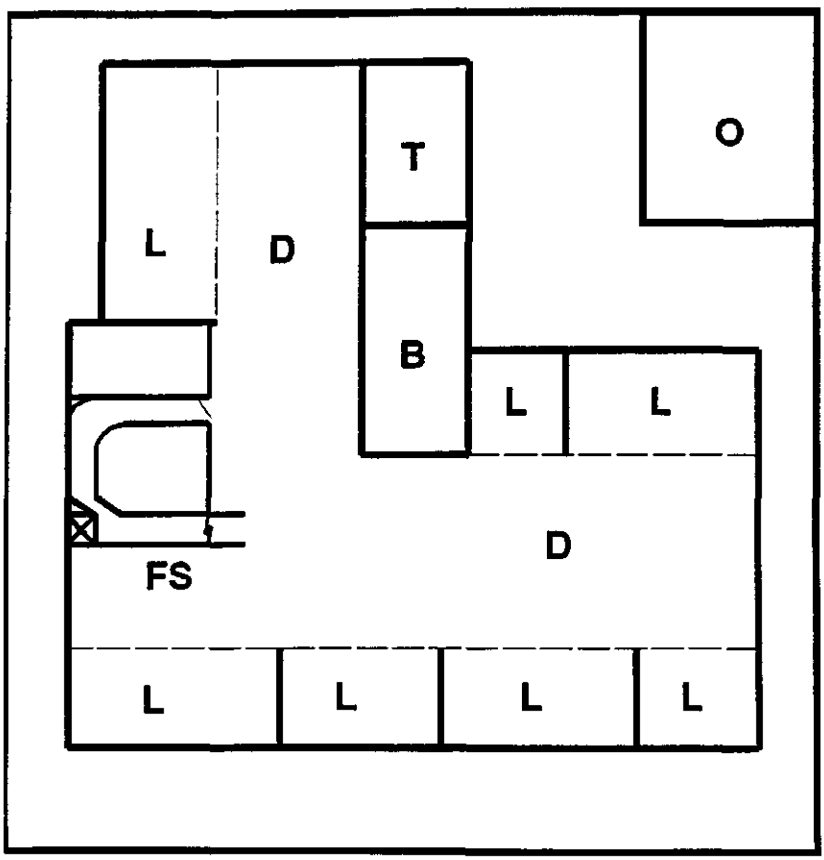

Figure 2. Layout of the gestation house.

B = boar-pen (straw bedding)
D = dunging area (slatted concrete floor)
FS = feed station
L = lying area (solid insulated tarmac)
O = office
T = treatment-pen (sick-bay) (straw bedding)

By closing off a section with an adjacent part of a dunging area, it could be reserved for a subgroup coming from the service house. After relocation from the service house to the gestation house (Day 0), a subgroup stayed behind a fence for 24 hours, before being released at 15.00 h on Day 1. During this 24-h period, the sows of the subgroup could not enter the feed station and were floor-fed. After removing a subgroup from the gestation house, the empty section was closed and allocated to the next subgroup to be introduced into the gestation house. Thus, each subgroup had its own reserved section in the gestation house.

Feed Stations and Feeding Regime

The feed stations in both the service house and the gestation house were rear-entrance/front-exit stations (Nedap-Poiesz, Hengelo [Gld.], the Netherlands). A complete commercial sow diet was supplied in pelleted form in a trough in which some water had been added. All sows carried a transponder on a neck collar to operate a feed station. The feed station in the service house was modified for its function as a training station. During the first 2 days that the sows were in the service house, one door of the entrance gate was permanently open. During the first 5 days both the entrance and the exit gates were equipped with lighter springs than normal in order to facilitate opening the gates. The entrance gate was adapted in such a way that it could be opened 15 cm without triggering the locking device. One side of the feed station was equipped with bars instead of the normal wooden board, so that the sows could see their pen-mates eating.

Each day, the feed-cycle was started at 6:30 h, but the entrance gate of the feed station in the service house was kept closed from 6:00 until 15:00 h.

After a subgroup was relocated to the gestation house and released there, the sows were encouraged to use the feed station in the new environment by being tempted to enter the station to eat a few portions of 100 g. For the next 2 days, sows who failed to eat were helped in a similar way at around 15:00 h.

In the service house, the sows received 3.5 kg day^{-1} of pelleted feed until service or until 11 days after weaning. After that, they were fed 2.3 kg day^{-1}. In the gestation house, they were fed 2.3 kg day_{-1} until Week 10 after service. From Week 10 until Week 15 after service they received 2.8 kg day^{-1} and from Week 15 they had 3.2 kg of pelleted feed daily.

In the gestation house, the animals were also fed 0.6 kg chopped corn silage per sow per day in the lying areas at 06:00 h and at 16:00 h. This was done in order to reduce competition for the feed station (Van Putten and Van De Burgwal, 1990). Water was available ad libitum through nipple drinkers in both the service house and the gestation house.

Monitoring of feed station use by the sows

The process computer (Popular VC3-140, Nedap-Poiesz, Hengelo, [Gld.], the Netherlands) controlling the feed stations was monitored by a personal computer (Olivetti M240, Ivrea, Italy). Each time a sow entered or left a station, the personal computer recorded the date and time, and the available feed ration for that sow. Data on sows with uneaten food were also available on lists provided by the process computer at the start of the next feed-cycle (06:30 h).

Parameters and Analysis

General

In a number of cases data were omitted from the available material. This was done for those days that sows were trained to use the feed station, sows had lost the transponder (11) and sows were treated for lameness (six). In these cases, not only the data of these particular sows were omitted, but also those of her subgroup mates, to avoid having missing values in the data to be analysed.

If the data for a sow could not be used for a longer period of time, all the data for that sow were omitted and the data for her subgroup mates were used for analysis. This was the case for one sow that only entered the feed station when a stockman was present and for six culled sows (two repeat breeders and four diseased).

Consistency of feeding order within subgroups

A permutation test (for details see next paragraph) was constructed to see whether the following null-hypothesis should be rejected or not:

H_0: the feeding order of sows remains the same within subgroups, apart from random variation.

H_0 is assumed to include, as a special case, the possibility that feeding order is completely random, i.e. feeding order is absent.

For each sow within a subgroup Spearman's rank correlation r_s (Gibbons, 1971) was calculated between the rank numbers for feeding order and days. Squared rank correlations were summed within a subgroup and multiplied by the number of animals (n) in the subgroup - 1: $t = (n-1)\Sigma r_s^2$. The factor $(n-1)$ is motivated by the asymptotic distribution of r_s for large n (Gibbons, 1971). Finally, results were summed over subgroups which stayed in the service house for 10, 17 and 31 days, respectively: $T_{10} = \Sigma t$ (Subgroups II, V and VIII), $T_{17} = \Sigma t$ (Subgroups III, VI and IX) and $T_{31} = \Sigma t$ (Subgroups I, IV and VII).

Permutation test for fixed feeding order

To see whether the null-hypothesis of fixed feeding order should be rejected or not, the distribution of the test statistics T_i (i = 10, 17, 31) under H_0 is needed. When the value of T_i found in the experiment is too high, i.e. ranks among the highest 5 % of the distribution under H_0, the null-hypothesis H_0 will be rejected.

To avoid complex distributional assumptions a permutation test was used. Basically, it is assumed that H_0 implies that the distribution of feeding order position for each sow remains the same over the days involved. Permutation of days for the data observed will generate new data configurations which are all equal under H_0. H_0 will be rejected when the actual value of T_i (i = 10, 17, 31) ranks with the highest 5 % of outcomes $T_{perm,i}$, calculated for the permutations involved. Since the total number of permutations is extremely large, the test procedure is put into effect by taking a random sample of size 3000 from all possible permutations.

The assumption with respect to the distribution of the feeding order position within sows under H_0 may be relaxed by assuming that differences between days are symmetrically distributed around 0. Note that with asymmetrically distributed differences the test procedure will be sensitive to systematic changes in the true median rather than mean position of a sow in the feeding order.

Consistency of feeding order between subgroups

To study the extent to which subgroups fed consecutively, the feeding order position of Subgroups SG and (SG-1) was compared for Days 11-20 after introduction of Subgroup SG into the gestation house. For each subgroup the feeding order position was determined by calculating the mean rank number for feeding, over all present sows, on each day during the given period. Feeding order positions were also calculated for Subgroups IV, V and VI for Days 15 - 29 after introduction of Subgroup VI and for Subgroups VII, VIII and IX for Days 17-33 after introduction of Subgroup IX. If data for less than 6 days were available for a given subgroup in any period, these data were not used in the analysis. Differences between feeding order positions of subgroups within days were analysed with the Wilcoxon Signed Rank Test.

Feeding order positions of sows on Days D and (D+1)

Beginning on Days 11 and 41 after the introduction of each subgroup, data sets were formed for each sow of that subgroup on both her position in the feeding order over all sows present as well as within her subgroup. The difference between the position in the feeding orders on Day D and Day (D+1) was determined for each sow. Data were compiled until 10 successive day combinations had been established, but not beyond Days 25 and 57, respectively, even if fewer than ten combinations could be formed owing to missing data. During all study periods, 26-30 sows stayed in the gestation house. For Subgroup II the periods of Days 41-57 and for Subgroup III the period of Days 11-25 days were excluded from the analysis, since only 20 sows were present at that time.

Number of sows with uneaten food before and after relocation from the service house to the gestation house

The number of sows that did not eat their allowed ration of concentrates was determined during the last three 24-h periods in the service house and the first ten 24-h periods after relocation of these subgroups to the gestation house. Each 24-h period started at 06:30 h, the time of the start of the feed cycle in the gestation house. The number of sows that did not eat their full ration was summed for the subgroups that had been in the service house for 10, 17 and 31 days, respectively.

RESULTS

Consistency of feeding order within subgroups

The null-hypothesis H_0 of a fixed feeding order, which was tested for subgroups staying 10, 17 and 31 days in the service house respectively, by utilizing a permutation test, was rejected in all three cases. This indicates that the feeding order of sows within their subgroups was not stable during the whole period the subgroups stayed in the gestation house. It also shows that the feeding order was not random, which is a particular form of stability.

Consistency of feeding order between subgroups

In most cases, the subgroup that had been in the gestation house the longest time fed earlier in the day than subgroups that had been added more recently. However, there were some exceptions.

The feeding order position of Subgroup IV and Subgroup V did not differ significantly in the period of 11-20 days after relocation of Subgroup V to the gestation house. About 30 days later (37-51 days after relocation of Subgroup V), the feeding order positions of Subgroup V were significantly lower than those for Subgroup IV ($P < 0.05$). Thus, Subgroup V had passed Subgroup IV in feeding order position, which means that the sows of Subgroup V fed earlier in the day. A similar observation was made for Subgroup IX, which passed not only Subgroup VIII but also Subgroup VII. In the time span of 11-20 days after its relocation, Subgroup IX passed Subgroup VIII ($P < 0.01$) and was in the process of passing Subgroup VII ($P = 0.07$). In the period of 17-33 days after relocation, sows of Subgroup IX fed earlier than those of both Subgroup VII and Subgroup VIII ($P < 0.05$).

Feeding order positions of sows on Days D and (D+1)

The frequency distribution of the feeding order position on Day D minus the feeding order position on Day (D + 1) was more or less symmetrical around zero. Within subgroups, the difference in rank number for feeding order between Day D and Day (D+1) was three or more for 19.1 % of the studied cases. Over subgroups, the feeding order position on Day D deviated six or more from that on Day (D+1) in 17.3 % of the studied cases. Note that not all studied cases were independent.

Table 1. Number of sows with uneaten food in the last 3 days before and the first 10 days after relocation from the service house to the gestation house.

Days in Service House	Before				After									
	-3	-2	-1	0*	1	2	3	4	5	6	7	8	9	10
10	4	3	0	-	13	6	6	4	1	1	0	0	1	0
17	1	1	0	-	13	6	2	1	0	0	0	0	0	0
31	5**	0	2	-	8	2	0	0	0	0	0	0	0	0

* Sows were not admitted to the feed station on Day 0.

** Four belonging to one subgroup.

Days are 24-h periods starting at 06:30 h (starting time of feed cycle in the gestation house).

Number of sows with uneaten food before and after relocation from the service house to the gestation house

Table 1 shows the number of sows that did not eat their full ration. The number of sows on Day 0 (Day of relocation) has been set at 0 because they were not given the opportunity to eat in the feed station on that day. The number of sows with uneaten food in the first ten days after relocation to the gestation house depended on the time the sows had spent in the service house.

DISCUSSION

In the present study the feeding order within subgroups did not remain stable over the total period the sows stayed in the gestation house. On the other hand, the feeding order was not random over this period. Hunter et al. (1988) found a fairly stable feeding order ranking over periods of 3 and 4 consecutive days, two weeks apart and even over these 7 days combined.

However, it was not clear whether these sows maintained the stable feeding order over longer periods of time. Hunter et al. (1989) found a positive correlation between the feeding orders of 25 resident sows taken 30 days apart in a dynamic group of 40 (Spearman's $r_s = 0.771$, $P < 0.001$). All 40 sows had been trained to use the feed station for about 1 week before the observations started.

The present study also shows that, although new subgroups tend to start feeding later than the subgroups already present, there are exceptions to this rule. In this study, feed became available at 15:00 h in the service house, but at 06:30 h in the gestation house. Therefore, subgroups newly introduced into the gestation house had been accustomed to feeding later in the day. In general, the principle of training subgroups newly introduced into the gestation house to feed after the resident subgroups was useful (see also: Van Putten and Van De Burgwal, 1990). After an introductory period, the sows gradually learned to eat at an earlier time than 15.00 h. Some time after introduction, some subgroups fed sooner in the day than subgroups which were introduced earlier.

A relevant point is that the subgroups were introduced into different areas of the gestation house (Figure 2). A subgroup which was introduced in an area close to the feed station was perhaps in a better position to compete for the use of the feed station than a subgroup which was introduced in a more distant area of the gestation house.

In order to detect deviations from the usual feeding order, one should be able to predict the position of a sow in that feeding order. From the present study, it is clear that feeding order is not stable over a longer period of time, so it is not sufficient to determine the feeding order on only one occasion at the start of any period of longer duration. Even when the feeding orders of Day D vs. Day (D+1) were compared, large deviations were noted.

The present study deals with sows without any prior experience of group-housing or an electronic feed station. The length of time the sows stayed in the service house where they learned to operate the feed station influenced the way the sows used the feed station in a new situation. During the first 10 days after relocation from the service house to the gestation house, the number of sows with uneaten food was highest for those sows which had stayed in the service house for the shortest period. Thereafter, until the end of the experiment, no effect of the length of the stay in the service house on the use of the feed station, was observed. Although the sows did know how to operate the feed station before they were relocated to the gestation house, experience obtained by a stay of sufficient length in the service house reduced the number of sows with uneaten food in a new situation.

The number of visits to a feed station and the total occupation time of a feed station are affected by diet-form (pelleted vs. non-pelleted, water vs. no water supplied) (Edwards et al., 1988a) and station design (rear-exit vs. front-exit) (Edwards et al., 1988b). These factors may influence competition for the feed station and, hence, the stability of the feeding order. In the present study, competition for the feed station was reduced by feeding the sows chopped corn silage in the lying areas twice a day (Van Putten and Van De Burgwal, 1990). In this study, no attention has been paid to social hierarchy. Hunter et al. (1988) showed that social hierarchy was positively correlated with feeding order in sows visiting a feed station. Csermely (1989) reported differences in feeding behaviour between floor-fed sows of different social rank.

Under the conditions of the present study, feeding order was not sufficiently stable to allow the stockman to detect health or other problems because of deviations from the usual order. For the stockman, the daily list of sows with uneaten food remains the only source of information provided automatically for detecting problems with sows or equipment.

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GENERAL DISCUSSION

1. INTRODUCTION

This study has been focused on automated monitoring of individual sows. The motivations that lead to the start of this research project, its objective and its scope were presented in the general introduction.

Chapters 1, 2 and 3 described studies concerning automated oestrus detection in group-housed sows. The studies described in chapters 1 and 2 were based on the recording of visits of peri-oestrous sows to a boar, whereas chapter 3 focused on continuous measurement of physical activity.

In chapter 4, a study using temperature sensors implanted close under the skin and just behind the ear base was described. Measuring temperature may be useful in monitoring (patho)physiological changes.

The study described in chapter 5 was aimed at detecting sows which needed special attention. Deviations from their normal position in the feeding order at an individual feed station were examined. Such deviations might be caused by several reasons (e.g. oestrus, health problems) which would require a stockperson attention.

The objectives, material and methods, and results of the studies were described and discussed in the respective chapter. This general discussion is divided in seven sections. Section 1 is this introduction. Section 2 will focus on such as the role of automation and the use of sensors in data collection and data processing in sow management. Section 3 deals with the motivations to study a group-housing situation and the possibilities for automated monitoring of sows offered by group-housing. Section 4 deals with general aspects of automated oestrus detection. The prospects and limitations of the results of the present research project are discussed in section 5. The main conclusions are summarized in section 6 and suggestions for further research are presented in section 7.

2. DATA COLLECTION AND DATA PROCESSING IN SOW MANAGEMENT

Information in sow management

Sow management decisions are made at the farm level, at group level and at sow level. On the farm level, it could be the decision to switch from individual housing to group-housing. On the group level, it could be the settings for the climate control in the barn where the group is housed. These kind of decisions do not require data on individual sows. Individual animal decisions, like placing a sow in a group could depend on such data. Reliable information is essential at all levels of decision making. Information can be defined as data which are meaningful to the recipient. It is obtained by processing raw data, which is collected for that purpose.

Monitoring individual sows, based on parameters relevant to aspects of health and reproduction, should notify the stockperson to situations which may potentially be detrimental to a sow's well-being or important for financial reasons. Sub-optimal monitoring of sows in the areas of health, reproduction and productivity could, for example, lead to inadequate recognition of health problems, sub-optimal timing of insemination or sub-optimal sow replacement decisions, respectively. Improvements in these areas could optimize the performance of the individual animals and, in that way increase the sustainability of the sow herd.

Automated or non-automated monitoring

Data can be collected in an automated or in a manual way. Similarly, the processing of data into information on which decisions can be based, can be done in an automated or in a non-automated way. Automated collection is not feasible for all kinds of data. Sometimes the required data are subjective, such as the degree to which a sow is easy to handle by the stockperson. In other cases, the technical means to measure a parameter automatically are not (yet) available, such as the on-line *in vivo* measuring of blood luteinizing hormone concentrations.

Automated collection of data on many other parameters could be an aid to the stockperson. The stockperson might be equipped with a (hand-held) terminal to allow him to enter data for processing. For example the number of piglets born or the number of piglets crushed by the dam might be entered. In these examples, it is still the stockperson who is doing the actual collecting of the data. For other parameters, the collection of data itself could be automated. This thesis focuses on the automated collection and processing of data for parameters related to reproduction and health. For example, data on visits of sows to a boar in a group-housing situation can be recorded and processed automatically (see chapter 2). Other examples are the automated recording of physical activity (chapter 3) and ear base temperature (chapter 4).

Besides collecting the data, the processing of data into information is necessary. If the amount of uneaten food per sow is listed on a computer printout, the processing of the raw data into information is in fact done by the stockperson when the resulting list is studied. The computer can support the stockperson in the interpretation and decision process by listing only those sows which did not eat all their food or less than a specific percentage of their ration. If visits of sows to a boar are considered, the amount of data collected is very large and should not be presented to the stockperson without prior processing. Automated processing of these collected data into information was demonstrated to be feasible (chapter 2).

Collecting and processing data

The way in which data relating to individual sows can be collected automatically will depend on the parameters involved and the opportunities and/or limitations provided by the specific housing system. For some parameters, determination of the location of the animal may be sufficient. The sows would then only require an electronic identification device capable of sending an identification number to an antenna. Recording data on sow visits to a boar in group-housing (see chapter 2) is an example of such a parameter. Data on uneaten food will generally be available, if an individual electronic feed station is used (see chapter 5). In this case too, only an animal identification device is required. Determining the location of an animal is of course only meaningful in housing systems where that location is not fixed. Generally, those will be group-housing systems.

Other parameters have to be measured in or on the animal itself. For such parameters, an identification device is not sufficient. For the recording of physical activity (chapter 3), the device in or on each animal must be capable of measuring a parameter indicative for physical activity. In this study, a device was attached externally to a neck collar. For this particular parameter however, more information might be gained if there would be a closer correlation between the movements of the sow and the movements of the device than was described in chapter 3. Research is planned (at IMAG-DLO[2]) to incorporate the measurement of parameters on physical activity in an implantable device. The movements of such a device will likely be better correlated with the movements of the sow than is the case with a device hanging loosely from a collar. Sensors for the measurement of other parameters might be added to this implantable device. Although physical activity is more likely to be relevant in monitoring freely moving animals, it might also be relevant to monitor animals which are kept more closely confined.

Body temperature was already described in chapter 4, but not only temperature could be measured by an implantable device. For example, if data on physiological parameters, such as hormone concentrations, are to be collected *in vivo*, the measuring device should be implanted. For dairy cattle *in vitro* measurements could be an alternative, if relevant parameters can be measured in the milk. For sows, this is not an alternative. Measurements in urine, faeces or saliva could also be an alternative for some parameters, but

[2]P.O.Box 43, 6700 AA Wageningen, The Netherlands

collecting these materials from individual animals is difficult in a group-housing situation and the collection of these materials is hard to automate.

In the Netherlands, the possibilities have been studied for a (national) scheme for the use of injectable electronic identification devices or life numbers. Every individual animal was to be injected with an electronic identification device (transponder) at an early age. The aim of such schemes is mainly the control of infectious diseases. Incorporating sensors for meaningful parameters into such transponders, for example for measuring body temperature, could enhance the usefulness of these devices to the stockperson. Peracute and acute processes which cause sharp changes in body temperature, for example mastitis (Furniss, 1987) are the most likely to be noted.

Implanted sensors and externally attached sensors have their advantages and disadvantages. Sometimes it will only be possible to include a measuring unit into an implatable or injectable device with great difficulty. Power supplies that last for a sow's lifetime could be a problem. In other occasions, it might be impossible to manufacture sensors at an acceptable price, even if large numbers are produced. It is certainly not necessary to enclose every useful measuring device into an implantable or injectable unit. If a parameter can also be measured with an external sensor it can be used at different times for different animals. Externally attached sensors, for example on a neck collar (see chapter 3), are easily replaced. Even if all pigs are equipped with an injected electronic identification device, stockpersons may still want to be able to identify the animals from a distance, especially in a group-housing situation. Therefore, some form of external device might be attached to the animals anyway. On the other hand, a collar requires regular checking and readjustment. Also, sows might lose their collar. Internal devices, once implanted or injected, should require less attention of the stockperson and are more suitable for recording physiological parameters which would be harder to record with an external device (see chapter 4).

One problem with injectable life numbers or sensors is the fact that the devices have to be removed in the slaughterline within seconds and without damage or contamination to valuable parts of the carcass (Merks and Lambooy, 1990). However, if a national scheme is adapted, slaughterhouses will have to solve this problem. If only a limited number of sows recieve an implant, removal would be more complicated to organize. Besides the ear base, the auricle of the ear was studied as a possible injection site (Lambooy, 1992). This would make the removal of the device more easy. However, only devices of very limited sizes can be used. Further, it is likely that the measurement of body temperature at this spot will give less reliable results because of local body temperature regulation mechanisms in the ear auricle.

The sensors used in the studies described in this thesis were based on electronics, using no components with biological origin. Currently, much research is being done in the field of biosensors. According to Hall (1990), the unique feature of a biosensor is that it includes parts of biological origin in close proximity or integrated with the signal transducer. Biosensors could open the way for measurement of parameters which are difficult to measure otherwise. However, a number of serious problems have to be overcome before this can be realised, especially for *in vivo*-measurements in research or private herds. One problem is degredation of the biological material in the biosensor. Also, encapsulation of the device could prevent it to be able to adequately measure substances in body fluids, such as luteinizing hormone in blood.

Generally, before information can be presented to the stockperson, the data must be processed. Data is to be transferred to a computer for processing or it would be processed within the device used for data collection. Also, a combination is possible. Input data can be processed into summarized data within the measuring device and the summarized data can then be transferred to a computer. There are several options for transferring data from a measuring device to a computer. If the location of an animal is to be determined, each animal should be equipped with an identification device, but the actual recording of data can be done by a stationary antenna. This antenna would then be connected to a computer with a wire-connection. If the measuring device is in or on a freely moving animal, a radiotelemetric transfer mechanism is an obvious choice. If the device uses an internal power source for the transmitter, it is called an active device. It could also use external energy provided as an energy field by an antenna. The captured energy can then be used by the device to transmit data to that antenna. In that case, it is called a passive device or transponder. The internal power source of an active device can wear out and require replacement, but the device can transmit data continuously over a longer distance. Continuous radiotelemetric transmission of data for each individual animal in a group would require a different radio-frequency for each animal. Legislation in most countries, including the Netherlands, limit the number of available radio frequencies, so the possibilities for this application are limited. A transponder can only send information over a short distance. This means that for freely moving animals in group-housing systems data on continuously measured parameters like physical activity, must be stored or processed within the device. Because a transponder can send data over only a short distance, transponders should be read at a location that is frequently visited by all animals. One option could be a feed station, which is visited by every sow one or more times a day. Another option are the drinkers. Most sows visit drinkers several times a day. If sows visit the drinkers more frequently than the feed station, the drinkers might be a better option than the feed station. Further research is required on the frequency of visits of group-housed sows to drinkers and the distribution of these visits over the 24 h period, to know how often data could be expected to become available when transponders are read at such a location.

Data could also be processed within the measuring device and communicated by that device directly to the stockperson. An external device equipped with a light emitting diode (LED) has been reported for monitoring physical activity (Pulvermacher and Maatje, 1992). When the LED flashes, the stockperson is warned of the increase in activity. If the device is used to measure more than one parameter, more than one LED could be used to give a code for each parameter. A system like this is used by Boumatic[3] in their activity sensors, used to detect oestrus in cows.

Alerting the stockperson

No matter what aspect of health or reproduction is monitored, the stockperson has to be informed as soon as possible if action is needed. There are several options to alert a stockperson to those sows which should be given special attention. Using LEDs on the device is one option. Placing sows on a list is another option. On such a list, a variety of information can be given, such as left-over feed rations, planned vaccinations and oncoming dates of relocation, e.g. from the gestation house to the farrowing house. Yet another option is to automatically spray sows with marking paint somewhere like in a feed station. A feed station can also be used to automatically separate sows that have to be checked. These options are open for those aspects of reproduction and health which do not require the immediate attention of the stockperson. Sows which have problems during farrowing or suddenly become ill, will require a warning mechanism for short-term notification of the stockperson. The stockperson could then be called on the phone by the computer.

For all aspects of automated monitoring of individual animals, it is important to give the stockperson the information needed in an adequate time frame and without obfuscating it with less important information. Finding the right compromise between presenting too little and too much information is one of the challenges producers of automated information systems have to face.

[3]Dairy Equipment Company, Madison, Wisconsin, USA

3. GROUP-HOUSING

In this thesis, the emphasis was on automated monitoring of group-housed sows. In the Netherlands, most sows are housed individually. However, questions have arisen about the well-being of sows in individual-housing systems.

An early and famous study on the well-being of farm animals is known as the Brambell-report (Brambell et al., 1965). In this report it is stated that "An animal should at least have sufficient freedom of movement to be able without difficulty, to turn round, groom itself, get up, lie down and stretch its limbs". These five freedoms of movement are available to sows in group-housing systems, but not to sows housed individually in crates or stalls. Wiepkema (1985) defined well-being of animals as the situation in which the internal and external environment of the animal is in agreement with the animals standards or in which the animal can deal with deviations between reality and standards with the behavioural programmes it has available. In other words, the animal tries to control it's internal and external environment as well as possible. In individual-housing systems, sows can not express behavioural programmes in order to have social contact with other sows than their direct neighbours. Neither can they turn around to observe events happening behind them or explore more than their immediate surroundings. This thwarting of behaviour leads to loss of control. Overmier et al. (1980) report that control is psychologically and biologically important to animals and absence of control is demonstrably stressful. The European Conference Group on the Protection of Farm Animals recommended that group-housing systems for dry (non-lactating) sows should replace stall systems (with or without tethers) (Carter and Carter, 1991). Group-housing gives the sows more opportunity to socially interact with other sows than they have in individual-housing systems. Although the opportunity for social interactions is generally an advantage for socially living animals, like pigs, agonistic interactions could have a negative effect on the well-being of the sows, if they lead to serious injuries in animals. Giving young pigs experience in settling hierarchical differences by frequent regrouping reduces fighting when sows are regrouped at a later age (Van Putten, 1993).

Furthermore, sows can be introduced into a large excisting group as members of small subgroups (see chapter 5), rather than as individuals. If adult sows are grouped, the layout of the pig-shed is important to reduce the chance that the animals get injured (Van Putten, 1993). These examples show that management of the social behaviour of the sows is required. For the studies described in chapters 1 through 3 of this thesis, each time 10 sows without any experience in a group-housing situation during their adult life were grouped. The sows were given enough room to be able to settle a dominance hierarchy. In this way, serious injuries were avoided, even though the sows were grouped on the day their piglets were weaned, which meant that their udders were very large and tense. However, when the space provided to the sows for agonistic interactions was reduced, injuries to the udders did occur.

Group-housing of sows provides the sows with the five freedoms of movement (Brambell et al., 1965) and if the social behaviour of the sows is managed properly, agonistic interactions will have no detrimental effect to the sows' health. The freedom of movement gives the animals better opportunities to control their environment. This contributes to a higher level of well-being for group-housed sows.

However, in group-housing systems stockpersons may have more difficulty in checking the animals for health problems or oestrus than in individual-housing systems, which are more surveyable for the stockperson. In individual-housing systems, it can easily be checked whether the sows have eaten their food and the way in which they feed, aborting sows can be identified more easily, etc. Therefore, especially in dealing with group-housed sows, automated collection of data on a number of relevant parameters on health and oestrus could be an aid to the stockperson. Furthermore, in group-housing systems, parameters for automated monitoring of individual sows can be used, which are not applicable in individual-housing systems, such as visits of sows to a boar (chapters 1-2), or which are probably less applicable in individual-housing systems, such as physical activity (chapter 3). In this thesis, the detection of oestrus is one area for which the possibilities for automation were studied (chapter 1-3). In the next section, the automation of oestrus detection will be discussed in greater depth.

4. AUTOMATED OESTRUS DETECTION

General

What are requirements for an automated oestrus detection system? First of all, a system should have a high sensitivity as well as a high specificity. That means, both the proportion of sows which are false-negative or false-positive must be low (Martin et al., 1987).

Secondly, the information from the system must be readily available to the stockperson in a user-friendly manner. One way to achieve this is to have timely lists available. Indicated sows should then be checked for oestrous symptoms. In this way, the stockperson's attention can be focused on sows which need it most.

Thirdly, the costs of the system must be acceptable. This does not necessarily mean that the economical benefits of the system should outweigh its costs. A sow-keeper might be willing to spend money according to his or her own priorities, e.g. to have more free time or just to change the type of work that has to be done. A extensive cost/benefit analysis was not within the scope of this research project, but is required.

Consequences of accepting 5 % false-negative sows in oestrus detection

Automated oestrus detection has been studied in several species, using several parameters. Much effort has been made to develop devices and procedures for automated oestrus detection, especially in dairy cattle. In chapters 1 and 2 of this thesis, the percentage of false-negative sows was fixed at 5 %. By accepting a 5 % limit on false-negative sows for oestrus, the number of times sows which are not (yet) in oestrus have to be checked by the stockperson can be reduced by more than 90 %, compared to the situation where no automated system is used. It will depend on the particular situation of a sow herd, whether 5 % false-negative sows is acceptable. If stockmanship is high and checks for oestrous symptoms are made with great care, 5% false-negative sows can be too much. Automated oestrus detection systems can also play a role in herds where there is less time for thorough checks for oestrous symptoms or stockmanship is not (yet) as high. An automated system will only be there to assist and not to replace the stockperson.

When an oestrual sow is not detected by the stockperson, it may reduce her reproductive performance. Missing one oestrous period increases the weaning-to-insemination interval of the sow in question with about 21 days, if she is not treated with hormones to induce oestrus. Huirne et al. (1990) determined the costs involved to be about fl 93,--, if an economically optimal sow replacement policy is used. If in practice the sow replacement policy is not optimal, the costs will be somewhat lower. However, there are some indications that these costs could be (partly) compensated by a larger litter size by increasing the length of the weaning-to-insemination interval. Leman (1990) studied data on 12577 sows (with in total 18738 matings or inseminations) from 66 US pig-farms. He reported a difference in litter size (total number of piglets born) of about 2 between sows which were inseminated 7-14 days after weaning (litter size about 10) and sows which were inseminated more than 20 days after weaning (litter size about 12). Vesseur et al. (1993) reported a significantly higher litter size (total number of piglets born) for sows inseminated more than 18 days after weaning compared to sows inseminated 4-18 days after weaning. Sows inseminated more than 18 days after weaning had an average litter size of 13.5, whereas a minimum litter size of 11.1 was obtained when sows were inseminated on day 8 after weaning. In contrast to the study of Leman (1990), in the study of Vesseur et al. (1993) no sows were included which had been treated with hormones to induce oestrus. Of course, among the sows which were inseminated late, there could have been animals with a previous silent oestrus and animals which had not been ovulating earlier in the weaning-to-insemination interval. Therefore, it is not quite clear whether sows, which were inseminated soon after weaning, would have had larger litters if they were inseminated during their next oestrous period. However, the data presented by Leman (1990) and Vesseur et al. (1993) indicate that this might very well be the case. If the litter size after insemination during the second post-weaning oestrus is larger than when sows are inseminated during their first post-weaning oestrus, then this would (partly) compensate the costs of an increase of about 21 days in the weaning-to-insemination interval.

Effects on reproductive performance of detecting sows late during oestrus

In chapter 2 of this thesis, formulae were derived which were aimed at detecting sows "in time to be served". This meant that sows were to be detected before the end of the oestrous period. However, detecting sows late during oestrus might cause poor reproductive results. Willemse and Boender (1966) divided the oestrous period of gilts into 3 main parts. First, the gilt only shows the standing response to the boar (period B1). Secondly, the gilt also shows the standing response if the stockperson applies the back pressure test. This was called period I (Inseminator). The I-period was divided into 4 parts of equal length (period I1 through I4). Thirdly, the gilt shows the standing response when mounted by the boar, but no longer when the back pressure test is applied (period B2). Willemse and Boender (1967) reported on the effect of inseminating gilts once during any of the periods B1, I1 through I4 and B2. They defined a fertility index (FI) as the percentage of all discharged ova, based on the number of corpora lutea, which had resulted in living or resorbing embryos at 21 to 28 days after insemination. For this, both pregnant and non-pregnant gilts were taken into consideration. Willemse and Boender (1967) reported that for the B1, I1 through I4 and B2 period, FI was 45.2, 60.7, 69.3, 72.7, 39.0 and 17.6, respectively. This demonstrates that inseminating gilts late during oestrus might reduce their reproductive efficiency. It is likely that this also applies for sows. On the other hand, inseminating a gilt (or sow) too early in the oestrous period might also have undesirable results. This problem was additionally studied using the groups of sows housed in the situation with a detection area in front of the boar-pen as they were used in the study described in chapter 2. Out of 80 sows, 74 sows came into oestrus during the study period. It was determined in which part of the oestrous period (B1, I1 through I4, B2) these sows would have been inseminated if the stockperson would have relied upon a detection system using a formula based either on visits to the detection area or on visits to the ticket-window inside the detection area. These formulae were derived in chapter 2. The times of insemination were compared to the part of the oestrous period during which they were actually first inseminated, which was solely done on basis of visual observations by the stockperson. The results are presented in Table 1.

Sows which did not demonstrate an I-period were considered to be in the B1-period during the entire oestrous period. The expected average FI for a group can be expressed as $\Sigma(FI_i * N_i)$, in which FI_i is the FI for sows inseminated during period i (i = 1 for B1, i = 2 for I1, etc.) and N_i is the number of sows inseminated in period i. From Table 1 it can be derived that, for oestrus detection based on visual observations, the expected average FI was 60.3[4]. If oestrus detection would be based on visits to a detection area in front of the boar-pen (DA), as described in chapter 2, the expected average FI was 57.3[5]. If oestrus detection would be based on visits to a ticket-window in the front partition of the boar-pen, within the DA, (TW_{+DA}),the expected average FI was 55.7[6]. In these figures, four (5 %) false-negative sows for the automated systems are included. This percentage of false-negative sows is inherent to the way the thresholds for the automated systems were calculated. It means that for detection systems based on visits to the DA and the TW_{+DA}, respectively, the expected average FI was 95.0 % and 92.4 % of the expected average FI for oestrus detection based on visual observations. These figures were achieved under experimental conditions where oestrus detection was very thorough. If in practice oestrus detection is sub-optimal, the expected FI would be lower, so the FI achieved by an automated sytem would be relatively better. If the four sows which were not detected by the automated systems were excluded, the expected average FIs are 60.3, 60.6 (100.5 % of 60.3) and 58.8 (97.5 % of 60.3), for oestrus detection systems based on visual observation, visits to DA and visits to TW_{+DA}, respectively. It can be concluded that, besides the 5 % false-negative sows inherent to the chosen approach, there is no reason to believe that the

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[4]((14 * 45.2) + (39 * 60.7) + (20 * 69.3) + 72.7) / 74 = 60.3

[5]((12 * 45.2) + (29 * 60.7) + (24 * 69.3) + (3 * 72.7) + 39.0 + 17.6 + (4 * 0)) / 74 = 57.3

[6]((13 * 45.2) + (29 * 60.9) + (21 * 69.3) + (2 * 72.7) + 39.0 + 17.6 + (4 * 0)) / 74 = 55.7

reproductive results would be negatively affected if automated oestrus detection is aimed at detecting sows "in time to be served".

Table 1. Differences in timing of first insemination between inseminations based on visual observations by the stockperson and based on an automated oestrus detection system, using either visits to a detection area (DA) in front of the boar-pen (above) or visits to a ticket-window in the front partition of the boar-pen within the detection area (TW_{+DA}, below).

		Automated oestrus detection system based on visits to detection area DA							
		B1	I1	I2	I3	I4	B2	false-neg.	Total
	B1	12	1					1	14
Visual	I1		29	3	3	1	1	2	39
Observations	I2			19				1	20
	I3				1				1
	Total	12	30	22	4	1	1	4	74

		Automated oestrus detection system based on visits to ticket-window TW_{+DA}							
		B1	I1	I2	I3	I4	B2	false-neg.	Total
	B1	13						1	14
Visual	I1		29	2	2	3	1	2	39
Observations	I2			18		1		1	20
	I3				1				1
	Total	13	29	20	3	4	1	4	74

5. PROSPECTS AND LIMITATIONS OF THE RESULTS OF THE PRESENT RESEARCH PROJECT

In this thesis, the potential of sow visits to a boar to automate oestrus detection was studied. Although others have studied this parameter too (Lokhorst and Houwers, 1991), they have done so in situations where usually no more than one sow came into oestrus at the same time. In the Netherlands, it is common practice to have an individual-housing system where many sows are weaned from their piglets at the same time and then are relocated from one pig-shed (the farrowing house) to another (the service house). In the present study, sows were also weaned in groups, but were kept in a group-housing situation. The present study was conducted using a service house, where up to 10 sows could be in oestrus simultaneously. If several sows are in oestrus at the same time, they could compete for a place near the boar and in this way influence the duration and frequency of visits of sows to the boar. The results of this study demonstrate that automated oestrus detection is technically feasible, even when several sows are in oestrus simultaneously. The present study has indicated that a detection system based on visits to a ticket-window in the front partition of a boar-pen might work quite well, if ample space is provided in front of the ticket-window (chapter 2). Further research is necessary to determine the amount of space in front of the boar-pen that is required. Recording visits to a detection area is an alternative approach. However, with the present equipment, recording visits of sows to a detection area is more difficult and more expensive than recording visits to a ticket-window.

For parameters on sow visits to a boar, a general threshold has been derived (chapter 1 and 2). The contrast between sow visit values before and during oestrus is in general larger than for physical activity. Because the contrast for parameters on visits to the boar is quite large, it was easier to derive a general threshold value for all sows than for physical activity. When sows are relocated from a farrowing house to a service house, it is likely that their activity pattern will change. Additionally, most sows will come into oestrus soon after relocation. Therefore, there will be a limited amount of time to determine individual base-line values for any parameter on physical activity. This is a problem that still has to be solved, before a practical application can be developed. Automated oestrus detection based on monitoring physical activity shows promise (chapter 3), but requires further development.

Periparturient ear base temperature patterns were shown in this thesis to be similar to those patterns known for rectal and deep body temperatures. This opens the way for practical applications of the automated monitoring of body temperature with an injectable device. Measurements in chapter 4 were done in a farrowing house with a high and fairly stable ambient temperature. The effect of more dynamic ambient temperatures upon body temperatures measured close under the skin is unknown and requires further research. When temperatures measured close under the skin have values lower than those considered normal for rectal or deep body temperatures, this would not be a cause for alarm. Increases in body temperature due to certain pathophysiological or physiological processes can likely be detected with a device placed close under the skin.

Sows visited an individual electronic feed station according to a feeding order. Sows of subgroups which were introduced from the service house into a larger group in the gestation house generally fed after those sows that had been introduced earlier. This behaviour was stimulated by training the sows in the service house to feed after 15:00 h, when most sows in the gestation house had already eaten. This training was given with the aim to reduce competition for the use of the feed station. The stability of this feeding order on a day to day basis did not meet the high demands necessary to be able to use deviations from this order to detect reproduction or health problems (chapter 5).

Combining parameters into one resulting index could lead to higher specificity and sensitivity of detection methods for reproduction and health events. Maatje et al. (1987) showed that this was the case for oestrus detection in dairy cattle. An automated oestrus detection system for sows can probably be based on visits of sows to a boar. Combining this parameter with a parameter based on physical activity (chapter 3) might lead to an oestrus detection system with better predictive results than a system based on any of the separate parameters.

6. MAIN CONCLUSIONS

Group-housing is likely to become more common in the Netherlands under influence of public opinion upon future health and welfare policies. Group-housing systems can make it more difficult for stockpersons to examine and evaluate individual sows. On the other hand, group-housing systems offer possibilities not available in individual-housing systems. New skills and expertise will likely be required of the stockperson. Automation of individual sow monitoring may be useful to focus the stockperson's attention on those animals which need it most (chapters 1 through 4). Instead of replacing the stockperson, automated individual-animal decision support systems allow stockpersons to budget their time more effectively. An example is automation of oestrus detection in group-housed sows. Recording of boar visits made by sows was demonstrated to be technically feasible. By accepting a 5 % limit on false-negative sows for oestrus, the number of times sows which are not (yet) in oestrus have to be checked by the stockperson can be reduced by more than 90 %, compared to the situation where no automated system is used (chapters 1 and 2). Monitoring physical activity has also potential as an aid for oestrus detection in sows, but further research is necessary before practical application is possible (chapter 3).

Around farrowing, ear base temperature follows a pattern similar to that previously reported for deep body and rectal temperatures. This indicates that recording ear base temperature can be used to monitor (patho-)physiological processes which are associated with clear changes in sow body temperature (chapter 4).

Sows visit an individual electronic feed station according to a fairly stable feeding order. On a day to day basis, the stability of this feeding order does not meet the high demands necessary to be able to use deviations from this order to detect reproduction or health problems (chapter 5).

From chapters 1 through 4 it is concluded that the automation of individual sow monitoring in group-housing systems could be an important aid to the stockperson.

7. RECOMMENDATIONS FOR FURTHER RESEARCH

Sufficient space seemed required in front of the boar-pen (chapter 2) for automated oestrus detection with the use of a ticket-window to give good results. If space is limited, the results might be negatively affected. Further research on the influence of the size or shape of the area in front of the boar-pen can provide useful information on the design requirements of an automated oestrus detection system based on visits to a boar.

More research is needed on both the collection and the processing of physical activity data to use it in a practical oestrus detection system (chapter 3). Attachment of the measuring device to or into the animal is another topic which requires further study. A method has to be found to determine a threshold value for parameters on physical activity on basis of the activity of the sow before oestrus. Identification of specific behavioural elements on basis of their measured activity patterns could benefit the development of automated oestrus detection based on physical activity.

Incorporating sensors for measuring parameters on health and reproduction in sows into an injectable electronic identification device will require further research and development on technical (e.g., power source, miniaturising elements of the device) and physiological aspects. For example, *in vivo* measurement of hormones with an implantable device will require much more research both in the field of (bio)sensors and with respect to a suitable way to implant such a device.

Considerations should be given to whether it would be best to use internal or external devices. Technical, physiological and economic factors are important for this evaluation.

The consequences of adopting new technologies in animal husbandry on the well-being of animals and the potential effects on the public opinion should also be evaluated. This is especially the case if these technologies involve the injecting or implanting of devices into animals.

Extensive cost/benefit economic analysis of automated monitoring of reproduction and health was not within the scope of this research. It will be necessary when developments in this field are to be transferred to practical swine husbandry.

The choice of the parameters studied in this thesis was based on existing knowledge. Other parameters which could have been studied with existing technologies, such as heart rate and respiration rate, were not examined. Further research is required on these parameters. Fundamental biological research might contribute to the identification of new parameters for health and reproduction. Furthermore, a better understanding of the causes of individual animal differences might give a better basis for determining threshold values for parameters measured in sows.

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SUMMARY

Introduction

The number of sows per Dutch sow herd has increased dramatically from an average of 27 sows in 1975 to 112 in 1990. It is likely that EC regulations will foster group-housing of sows and reduce individual housing, which is currently common on Dutch farms. Stockpersons might find it difficult to monitor individual sows in a group-housing system. Because of the improving price/performance ratio of computers and sensors, the possibilities to facilitate the stockperson's management capabilities with automated decision aids has increased. Research into various aspects of automated monitoring of individual sows is presented in this thesis. The emphasis was on group-housed sows.

Automation of oestrus detection

The research described in chapters 1, 2 and 3 was conducted using groups of sows in a service house. For all sows, the piglets had been recently weaned. In general, sows come into oestrus within 10 days after weaning the piglets.

Pro-oestrual or oestrual sows will visit a boar more often than sows not in oestrus, if given the opportunity. This behavioural characteristic was the starting point for the research described in chapters 1 and 2. These chapters deal with methods to evaluate visits of sows to a boar. In a group of sows of which the piglets are recently weaned, often more than one sow will be in oestrus at the same time and they may compete for a good spot near the boar. This was taken into consideration in the present research project when devising ways to record visits of sows to a boar. Studies were made on how the data on sow visits can be processed into information for the stockperson. Twice daily, attention lists for the stockperson were simulated. On such a list the stockperson can see which sows in particular have to be checked for oestrous symptoms.

In chapter 1, the identity of sows was recorded when they entered or left a detection area in front of the boar-pen. This detection area was large enough

to permit all sows to be inside at the same time. Formulae for oestrus detection were derived based on visits of sows to the detection area. In scientific literature, the use of a ticket-window in a partition of the boar-pen has been reported. In the study described in chapter 2, sows were housed in a service house with a large area in front of the boar-pen. A ticket-window was located in the front partition of the boar-pen. Formulae for oestrus detection based on visits of sows to the ticket-window were derived and evaluated for two situations. In one situation, the area in front of the boar-pen was divided into a detection area and a dunging area by a passage-way. The passage-way was not present in the second situation. In the first situation, visits of sows to the detection area were recorded when sows went through the passage-way. Formulae for oestrus detection were based on these recordings too. Additionally, formulae were evaluated in chapter 2 on other sows than were used when deriving these formulae in chapter 1.

Both duration and frequency of visits to the boar were analyzed. If the value of the formula [Duration + (X * Frequency)] exceeded a threshold T, the sows could be listed for attention. Duration and Frequency were determined over a period of 24 hours before the (simulated) creation of each list. A threshold was determined in such a way that 95 % of sows that came into oestrus would be listed at least once during oestrus. The study focused on reducing the number of false-positive listings.

The behaviour of the sows depends on the time of the day. In general, sows rest during part of the afternoon and during the night. This will depend on factors such as the feeding and light regime. The results of the detection system improved if visits to the boar during those times with general activity were omitted.

From these experiments, it can be concluded that utilization of an automated oestrus detection system based on visits of sows to a boar was able to reduce the number of unneeded check-ups on dioestrous sows by more than 90 %. However, about 5 % of the sows that do come into oestrus would not be detected by the system. The results of an oestrus detection system based on visits to a detection area in front of the boar-pen were somewhat better than those obtained by using a ticket-window inside the detection-area. A system based on visits to a ticket-window with more space in front of it seemed to yield better results than those obtained by using a detection area. The number of sows studied in the latter situation was quite small, so more research is needed with this pen design.

In chapter 3, a study was described on the use of a prototype activity sensor for evaluating oestrus-associated physical activity. Physical activity increases around oestrus in many species. A signal transmitted by an accelerometer device, which was attached to the sow using a collar, was continuously recorded and processed. Different methods of data processing could be studied. Mercury switches with different sensitivities were simulated. The results suggest that the use of a relatively sensitive mercury switch would result in detection of an increase in physical activity associated with oestrus. It also became clear that more research is needed before oestrus detection on basis of physical activity is ready for practical use. When a suitable parameter for physical activity has been established, a good method has to be found to determine a threshold value for the values of this parameter above which sows should be listed for attention. The possibilities for oestrus detection based on the monitoring of physical activity can probably be improved when separate oestrus-associated behaviours can be identified, but this would most likely require alternative methods of attaching the activity sensor to the sow.

Monitoring of other aspects besides oestrus

Oestrus detection is not the only area in which the stockperson can be assisted. The monitoring of gestation, farrowing and health status of the animals is also important. Chapter 4 describes a study of radiotelemetric body temperature recording for individually housed sows around farrowing time. Temperature was measured in 7 sows under the skin, just behind the base of the ear. The study showed that ear base temperature increased at about 12 hours before farrowing, decreased after farrowing, but remained higher than before farrowing until the piglets are weaned. A similar temperature pattern has been described for measurements at other body sites. Therefore, monitoring ear base temperature of sows with the use of radiotelemetric devices can provide the stockperson with similar information as can be obtained by measuring at less desirable or inconvenient sites.

Previous research has shown that the ear base is a suitable spot for injecting an electronic identification device, to be used as a life number for permanent animal identification. The device is a small tube, closed at both ends, containing a passive transponder. With the use of a reader, a number can be read from such a device. When sensors for recording relevant physiological parameters are added to such a device, its value for the stockperson could be increased.

In this research project, stability of sow feeding order was analyzed for an individual electronic feed station. The sows were introduced into the gestation house as part of subgroups of 10 sows. At any time, 3-4 subgroups were present in the gestation house. Sows have been reported to visit the feed station in quite a stable order. Chapter 5 describes a study on the stability of this feeding order. Although the feeding order was not random within subgroups, it did not remain stable over the study period of several weeks. In general, sows from the most recently added subgroup fed later than sows introduced earlier. Increasing feed station learning time in the service house reduced the time required by sows to become accustomed to the feed station in a new environment. Sufficiently stable feed station usage patterns could not be identified to monitor the sows by analysing deviations from such patterns.

Main conclusions

Group-housing is likely to become more common in the Netherlands under influence of public opinion upon future health and welfare policies. Group-housing systems can make it more difficult for stockpersons to examine and evaluate individual sows. On the other hand, group-housing systems offer possibilities not available in individual-housing systems. New skills and expertise will likely be required of the stockperson. Automation of individual sow monitoring may be useful to focus the stock-person's attention on those animals which need it most (chapters 1 through 4). Instead of replacing the stockperson, automated individual-animal decision support systems allow stockpersons to budget their time more effectively. An example is automation of oestrus detection in group-housed sows. Recording of boar visits made by sows was demonstrated to be technically feasible. By accepting a 5 % limit on false-negative sows for oestrus, the number of times sows which are not (yet) in oestrus have to be checked by the stockperson can be reduced by more than 90 %, compared to the situation where no automated system is used (chapters 1 and 2). Monitoring physical activity has also potential as an aid for oestrus detection in sows, but further research is necessary before practical application is possible (chapter 3).

Around farrowing, ear base temperature follows a pattern similar to that previously reported for deep body and rectal temperature. This indicates that recording ear base temperature can be used to monitor (patho-)physiological processes which are associated with clear changes in sow body temperature (chapter 4).

Sows visit an individual electronic feed station according to a fairly stable feeding order. On a day to day basis, the stability of this feeding order does not meet the high demands necessary to be able to use deviations from this order to detect reproduction or health problems (chapter 5).

From chapters 1 through 4 it is concluded that the automation of individual sow monitoring in group-housing systems could be an important aid to the stockperson.

SAMENVATTING

Inleiding

Het aantal zeugen per zeugenbedrijf is sterk toegenomen van gemiddeld 27 in 1975 tot 112 in 1990. Mede onder invloed van EG-maatregelen is het waarschijnlijk, dat groepshuisvesting van zeugen terrein zal winnen ten koste van de nu gebruikelijke individuele huisvesting. Daardoor kan het voor de verzorger van de zeugen moeilijker worden, om ieder individueel dier voldoende in de gaten te houden. Door de verbeterende prijs/kwaliteit-verhouding van computers en sensoren nemen de mogelijkheden toe om het werk van de verzorger te ondersteunen met behulp van automatisering. In dit proefschrift wordt onderzoek naar een aantal aspecten (bijv. bronstdetectie) van het automatiseren van de bewaking van individuele zeugen in groepshuisvesting beschreven.

Automatische bronstdetectie

Het onderzoek beschreven in hoofdstuk 1, 2 en 3 werd uitgevoerd in een dekstal bij in groepen gehouden zeugen. Van alle zeugen werden de biggen gespeend op de dag dat de zeugen in de dekstal werden geplaatst. Over het algemeen worden zeugen dan binnen 10 dagen berig, dat wil zeggen, ze komen in bronst.

Uit vroeger onderzoek bleek dat loslopende zeugen, die in bronst komen of zijn, vaker naar een beer toegaan dan zeugen die niet in bronst zijn. Van dit gegeven wordt in hoofdstuk 1 en 2 van dit proefschrift gebruik gemaakt. In het onderzoek, dat in deze hoofdstukken wordt beschreven, werd onderzocht hoe bezoeken van in groepen gehouden zeugen aan een beer geregistreerd en verwerkt kunnen worden. In een groep zeugen waarvan de biggen net zijn gespeend zal vaak meer dan één zeug tegelijk in bronst zijn. Hiermee dient bij de wijze van registreren van bezoeken van deze zeugen aan een beer rekening gehouden te worden. Verder werd onderzocht, hoe de gegevens over bezoeken van zeugen aan een beer omgezet kunnen worden in informatie voor de verzorger van de zeugen. Er is in deze hoofdstukken van uitgegaan, dat er twee keer per dag een lijst beschikbaar wordt gesteld. Op een dergelijke lijst kan de verzorger zien, welke zeugen op bronst onderzocht moeten worden.

In hoofdstuk 1 wordt beschreven hoe de dieren werden geregistreerd als ze een bezoek brachten aan een detectieruimte vóór het berehok. Deze detectieruimte was groot genoeg om alle 10 zeugen, die in de dekstal aanwezig waren, tegelijk toe te laten. In ander onderzoek is gebruik gemaakt van een loket in de wand van het berehok. In het onderzoek dat in hoofdstuk 2 is beschreven waren de dieren gehuisvest in een dekstal met een grote ruimte vóór het berehok. In de wand van het berehok was een loket aangebracht. Formules voor bronstdetectie, gebaseerd op bezoeken van zeugen aan het loket, werden ontwikkeld voor twee situaties. In de eerste situatie was de ruimte voor het berehok door middel van een sluis verdeeld in een detectieruimte en een mestruimte. Deze sluis was niet aanwezig in de andere situatie. In de eerste situatie werden bezoeken van de zeugen aan de detectieruimte geregistreerd op het moment dat de dieren door de sluis liepen. Ook op basis van deze gegevens werden formules voor bronstdetectie ontwikkeld. Verder wordt in hoofdstuk 2 beschreven hoe formules werden geëvalueerd, die werden ontwikkeld in het onderzoek dat in hoofdstuk 1 is beschreven op basis van andere zeugen.

Zowel de duur als de frequentie van de bezoeken van de zeugen aan de beer werden in het onderzoek betrokken. Zodra de waarde van de formule: [Duur + (X * Frequentie)] groter was dan een grenswaarde T, konden de dieren op een lijst worden geplaatst. Hierbij werden Duur en Frequentie van bezoeken bepaald over perioden van 24 uur, voorafgaand aan het tijdstip dat een lijst beschikbaar zou worden gesteld. Er werd een zodanige grenswaarde vastgesteld, dat 95 % van de dieren minstens één keer tijdens de bronst op een dergelijke lijst werden geplaatst. In het onderzoek werd er naar gestreefd om zo min mogelijk niet-berige dieren op een lijst te laten zetten.

Het gedrag van de dieren is afhankelijk van de tijd van de dag. In het algemeen rusten de zeugen gedurende een gedeelte van de middag en gedurende de nacht. Wanneer de uren waarin de dieren over het algemeen het meest actief waren niet werden betrokken in de analyse, verbeterden de resultaten van het detectiesysteem.

Uit deze experimenten kwam naar voren, dat geautomatiseerde bronstdetectie met behulp van bezoeken van zeugen aan een beer een geschikte methode is om het aantal bronstcontroles aan zeugen die niet berig zijn, met meer dan 90 % te kunnen verminderen. Wel zullen dan ongeveer 5 % van de zeugen die *wél berig zijn*, niet door het systeem worden opgemerkt. De resultaten die verkregen werden wanneer de dieren werden geregistreerd als ze een detectieruimte vóór het berehok bezochten, waren iets beter dan bij registratie met behulp van een loket binnen deze detectieruimte. Wanneer echter vóór het loket veel ruimte beschikbaar was, leken de resultaten nog beter. Omdat dit laatste echter bij een klein aantal dieren werd onderzocht, is meer onderzoek nodig om hier harde uitspraken over te kunnen doen.

In hoofdstuk 3 wordt een onderzoek beschreven naar het gebruik van een prototype van een activiteitsmeter voor het meten van met bronst samenhangende lichamelijke activiteit. Uit eerder onderzoek bij diverse diersoorten is bekend, dat tijdens de bronst de lichamelijke activiteit toeneemt. Het signaal van een versnellingsmeter, die aan een halsband van de zeug was bevestigd, werd continue geregistreerd en bewerkt. Hierdoor konden verschillende methoden van dataverwerking worden bekeken. Zo werden kwikschakelaars met verschillende gevoeligheden nagebootst. Uit het onderzoek bleek dat met een relatief gevoelige kwikschakelaar een vrij duidelijke verhoging van de lichamelijke activiteit van zeugen tijdens de bronst is vast te stellen. Ook werd duidelijk, dat nog veel onderzoek nodig is om bronstdetectie op basis van de parameter lichamelijk activiteit in de praktijk toe te kunnen passen.

Als een geschikte parameter voor lichamelijke activiteit is bepaald, moet er een goede methode worden gevonden om een drempelwaarde voor deze parameter vast te stellen. Als de waarde van de parameter boven deze drempelwaarde uitkomt, kan de zeug vervolgens op een attentielijst vermeld worden. De mogelijkheden voor bronstdetectie met behulp van het meten van lichamelijke activiteit kunnen waarschijnlijk worden verbeterd als afzonderlijke, met bronst geassocieerde, gedragselementen kunnen worden onderscheiden maar dit vereist waarschijnlijk een andere bevestiging van de activiteitsmeter aan het dier dan in dit onderzoek is toegepast.

Bewaking van andere aspecten dan bronst

Niet alleen ondersteuning bij de bronstdetectie is van belang voor de verzorger. Ook ondersteuning bij de controle op het verloop van de dracht en het werpen en bij de detectie van gezondheidsproblemen is belangrijk. In hoofdstuk 4 is een onderzoek beschreven naar radiotelemetrische temperatuurmetingen bij individueel gehuisveste zeugen rond het werpen. Daarmee is dit het enige deel van het huidige onderzoek, dat niet bij zeugen in groepshuisvesting is geschied. Voor het onderzoek werd bij 7 zeugen de temperatuur gemeten dicht onder de huid, vlak achter de oorbasis. Uit het onderzoek bleek, dat de temperatuur op deze plek toeneemt vanaf ongeveer 12 uur voor het werpen, na het werpen weer wat daalt, maar tot het spenen van de biggen hoger blijft dan deze voor het werpen was. Een soortgelijk verloop was al bekend voor lichaamstemperatuur gemeten op andere plaatsen in het lichaam. Daaruit volgt dat uit temperaturen gemeten achter de oorbasis vergelijkbare informatie kan worden afgeleid als uit temperaturen die op andere plekken in het lichaam worden gemeten.

Eerder onderzoek wees uit, dat de oorbasis een geschikte plek is voor het injecteren van een elektronisch "levensnummer". Dit is een glazen of kunststof buisje met een passieve zender, waaruit door middel van uitleesapparatuur een nummer kan worden opgevraagd. Indien aan zulk een apparaatje sensoren voor het meten van relevante fysiologische parameters worden toegevoegd, kan dit het nut van een dergelijk apparaatje voor de verzorgers van zeugen verhogen.

Aan de zeugen in dit onderzoek werd krachtvoer verstrekt met behulp van een automatisch voerstation. Ze werden in de dragende-zeugenstal gebracht in (sub)groepen van 10 dieren, waarbij er steeds 3-4 subgroepen tegelijk in de stal aanwezig waren. De zeugen bezoeken een voerstation in een vrij vaste volgorde. In hoofdstuk 5 wordt een onderzoek beschreven, waarin de stabiliteit van deze rangorde werd onderzocht. Hoewel de voervolgorde binnen subgroepen niet willekeurig was, bleef ze niet stabiel over een periode van meerdere weken. Als de dieren in de dekstal langer de tijd kregen om het gebruik van voerstation aan te leren, hadden ze minder tijd nodig om het voerstation in een nieuwe situatie te leren gebruiken. Ten aanzien van de voervolgorde konden geen voldoende stabiele patronen in het gebruik van het voerstation worden onderscheiden om bewaking van zeugen met behulp van analyse van afwijkingen van deze patronen mogelijk te maken.

Belangrijkste conclusies

Groepshuisvesting zal in de toekomst waarschijnlijk vaker worden toegepast onder invloed van toekomstig EG- en nationaal beleid. Toepassing van groepshuisvesting kan het voor de verzorger moeilijker maken om zeugen individueel in de gaten te houden en hun reproduktie en gezondheid te bewaken. Ook het toenemende aantal zeugen per bedrijf draagt bij aan dit probleem. Dit zal nieuwe kennis en vaardigheden vereisen van de verzorger. Automatische, beslissingsondersteunende systemen gebaseerd op individuele bewaking van zeugen kunnen bruikbaar zijn om de aandacht van verzorger te richten op de dieren die dat het meest nodig hebben. Een voorbeeld is de automatisering van de bronstdetectie bij zeugen in groepshuisvesting. Uit hoofdstuk 2 blijkt dat registratie van bezoeken van zeugen aan een beer technisch mogelijk is. Vergeleken met de situatie waarin geen geautomatiseerd systeem wordt toegepast, kan het aantal bronstcontroles aan dieren die (nog) niet in bronst zijn met meer dan 90 % worden gereduceerd, als daarbij 5 % vals-negatieve zeugen wordt geaccepteerd. Ook het vervolgen van lichamelijke activiteit biedt mogelijkheden voor automatisering van de bronstdetectie, maar verder onderzoek is nodig voordat toepassing in de praktijk gerealiseerd kan worden.

Bij meting dicht onder de huid, vlak achter de oorbasis laat de temperatuur rond het werpen veranderingen zien die vergelijkbaar zijn met die van de rectaal en kerntemperatuur. Dit geeft aan dat meting van de oorbasistemperatuur een bijdrage kan leveren aan het bewaken van (patho-) fysiologische processen die tot een duidelijke verandering in lichaamstemperatuur leiden (hoofdstuk 4).

Zeugen bezoeken een elektronisch voerstation voor individuele voedering volgens een bepaalde volgorde. Van dag tot dag kan de stabiliteit van deze volgorde niet voldoen aan de hoge eisen die gesteld moeten worden om afwijkingen van deze volgorde te gebruiken voor detectie van problemen met betrekking tot reproduktie of gezondheid (hoofdstuk 5).

Op basis van hoofdstukken 1 tot en met 4 kan worden geconcludeerd dat de automatisering van bewaking van individuele zeugen in groepshuisvesting een belangrijk hulpmiddel voor de verzorger kan zijn.

CURRICULUM VITAE

Henricus Petrus Maria Bressers werd geboren op 25 april 1961 te Gemert (N.Br.). In 1978 werd het havo-diploma behaald aan het Dr. Knippenberg College te Helmond. Aan ditzelfde college werd in 1979 het diploma van het ongedeeld VWO behaald. Hierna volgde de biologiestudie aan de Landbouwunivers-titeit te Wageningen, waar in januari 1987 met goed gevolg het doctoraalexamen werd afgelegd. Als hoofdvakken tijdens de doctoraalfase van deze studie werd gekozen voor de ethologie en de dierfysiologie. Verder werd een bijvak informatica en een extra vak onderwijskunde gevolgd. Van maart 1987 tot en met mei 1988 werd de vervangende dienstplicht vervuld aan het DLO-Instituut voor Veeteeltkundig Onderzoek "Schoonoord" te Zeist. Hierna volgde tot december 1988 de opleiding tot systeemanalist van de SAVAG te Wageningen. Vanaf december 1988 werkte hij als DLO-AIO verbonden aan de vakgroep Veehouderij van de Landbouwuniversiteit, gedetacheerd op het DLO-Instituut voor Veeteeltkundig Onderzoek "Schoonoord" te Zeist. Het daar uitgevoerde onderzoek leidde tot het proefschrift, dat thans voor u ligt.