1. Reproductive management

Efficient and profitable reproduction management in a dairy herd requires routine and time-consuming manual heat detection and proper timing of artificial insemination. Failure to detect heat is a major factor contributing to low fertility. More than half of the heats are undetected on dairy farms today because of lack of time used for manual heat detection, and because high yielding cows exhibit weak and short lasting heat signs (Figure 1).

In addition, research based on levels of the hormone progesterone in milk shows that up to 15 percent of the cattle presented for insemination are not in heat (O’connor 1993). Failure to detect cows that are in heat and breeding cows not in heat result in economic loss for the producer because of extended calving intervals and additional semen expense. Research worldwide points to a loss of appr. 2 € per open day beyond the voluntary waiting period, which in larger herds can sum up to large monetary losses. Further, misclassified reproduction failures result in inappropriate cullings. Therefore, poor heat detection is costly to the producer and should be considered the critical component of reproductive management.

The more time spent on manual heat detection, the higher the heat detection rate (Eerdenburg, 2008), but in modern dairy production there is often little time to perform manual heat detection. Therefore, systems to monitor heat related behaviour have been developed (activity and combined activity/picture recognition systems). The major issue with these systems is the inferior sensitivity, because some cows do not show increased activity at the time of heat. Also, cows not in heat may show activity, despite no heat or because they are already pregnant.

Other solutions are to perform cowside tests for progesterone in focus cows. The problems with cowside tests are the work load incurred at milking, where farmers would like to concentrate on milking, and also the scarcity of test results. Further, manual heat detection and cowside tests of progesterone will not fully encompass heat detection, and not take in consideration other reproductive events as ovarian cysts, Post Partum Anoestrus, confirmation of pregnancy and detection of abortions.

Figure 1. High producing dairy cows show short and low activity heats (Lopez et al., 2004)

In addition, research based on levels of the hormone progesterone in milk shows that up to 15 percent of the cattle presented for
2. **Herd Navigator™ and reproductive management**

The Herd Navigator™ concept differs greatly from traditional reproduction management, where the detection of heats depends on visual observations and/or activity meters, and the diagnosis of other reproductive events depend on rectal examinations. The reproduction cycle in the dairy cow is controlled by a number of hormones, which control the development and release of an egg every ~21 days.

The Herd Navigator™ takes milk samples for analysis of the reproductive hormone progesterone, which is produced in the structure called the Corpus Luteum in the ovaries. The Corpus Luteum is developed soon after a heat, where an oocyte (egg) is released from the ovary. The corpus luteum will produce increasing amounts of progesterone after the heat. In cows that have not been bred the production will cease at around 19 days after the latest heat, and a new heat will appear. In pregnant cows the production of progesterone will continue in order to maintain the pregnancy (figure 2).

Right after a heat the model will ask for samples on appr. day 5, 9 and 14 in order to evaluate if the cow has become pregnant or has developed a follicular cyst (see section 5). Further, the model will ask for frequent samples after day 18 in the heat cycle in order to find the next heat.

The reproduction model assumes the cow to be in one of three states (see figure 3). After calving the cow will have low concentrations of progesterone, until she resumes cyclicity at 20–30 days after calving. This is status 0, Post Partum Anoestrus. Once the first ovulation happens, progesterone concentrations will increase, and the model will change to status 1, cycling, and will begin to look for the next heat. Once this has been detected, the status of the cow changes to status 2, potentially pregnant (even if there is no AI). If on day 5 after the heat the model learns that the cow was not bred, the model will switch back to status 1. If the cow was bred, the model will assess the probability of a prospective pregnancy.

Herd Navigator™ will take milk samples for progesterone analyses at varying intervals during the heat cycle, with particular emphasis on the period up to a new heat event. The model will not be able to pick up the first heat event in early lactation, where progesterone concentrations will go from very low concentrations and then rise. This heat is not used by the farmer, but the model will now know that the heat took place and look for the next heat around 21 days later.

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**Figure 2.**

![Figure 2. Milk progesterone concentrations before and after oestrus (day 0) for cows which did (solid line, filled squares) or did not (stippled line, open circles) conceive at that oestrus. (Friggens et al., 2007).](image)

**Figure 3.**

![Figure 3. The three states of reproduction of the cow. Status=0 is the post partum anoestrous period. When the cow moved to status=1 the cow has commenced cyclicity, and in Status=2 the cow is potentially pregnant. From here she can either stay in status=2 because she is pregnant, or fall back to Status=1. With Herd Navigator™, the sampling schedule will start 20 days before the end of the Voluntary Waiting Period, in order for the model to assess the present state of the cow.](image)
The basic model layout is shown in figure 4. The model is driven by the progesterone concentrations which are smoothed in order to take away natural biologically based occurrence of “noise” from the progesterone measurements. A number of manual inputs to the model will assist in keeping track of the cows’ reproductive status. In particular breeding data are essential, and therefore strict data management is important, and any event, in particular breeding should be reported to the herd management system immediately.

External Oestrus Detection can either be manual recording of a heat or activity meter input. The input will make the model perform a new run to either confirm the observation or to reject the information. Manual pregnancy determination can also be made. The outputs from the model are shown on the right side of the model, and will be described in detail below. The testing of the reproduction model showed a heat detection rate of more than 95 %.

Figure 4. Overview of the model to predict reproductive status. The biological module with components for each of the three reproductive Statuses is shown within the stippled box, the statistical module generating smoothed progesterone values is shown adjacent to the progesterone input. Inputs and outputs are circled. The arrow leaving “days to next sample” indicates that this value is fed back to the milk sampling software.
One should be aware that cows are biologically different creatures. Some cows will exhibit heat signs where the progesterone concentration is not very low. This can be seen from figure 5. In these cases, Herd Navigator™ will not issue a heat alarm. If the heat has been observed, a look at the progesterone curve will acknowledge the observation. On the other hand, an observed heat where there is no drop in progesterone can be rejected. These observations typically occur in cows that were bred in the previous heat, and are now pregnant. These cows should not be inseminated.

Figure 5. An example of a progesterone profile showing a high progesterone oestrus. In this case the reproduction model will not issue a heat alarm (Friggens et al, 2008).

3. Start of progesterone measurements
In most herds commencement of breeding will not start immediately after calving. This is especially the case in herds with high producing cows, where commencement of cyclicity can occur long after calving. Therefore, in the user interface settings of start of progesterone measurements can be set manually in order to suit the needs of the particular herd. We recommend a start time of 20 days before the end of the Voluntary Waiting Period, in order to have the reproduction model pick up the status of the cows before the first breeding. Further, a Standard Operations Procedure (SOP) can be built in the user interface, allowing for herd specific rules of insemination, based on Days from Calving and actual daily milk yield (see section 10).

4. Heat detection
Once progesterone concentrations have dropped below 5 ng/ml, the reproduction model will issue a heat alarm. At the same time the model will also issue a Likelihood of successful insemination (0-100%). This figure has been computed in the model on the basis of maximum progesterone concentration in previous cycle, previous cycle length, oocyte quality and uterine environment. A likelihood below 10 % is a non-productive heat, and the cow should not be inseminated.

Based on the experience from test herds, the insemination shall take place 24-36 hours after the heat alarm. A heat alarm occurring after the morning milking should result in an insemination the next day, and a heat alarm after the evening milking should result in an insemination the day after tomorrow. Figure 6 shows the ideal timing of events around a heat alarm.

Figure 6. Line graph showing the timing of events around a heat alarm. The graph shows the optimal timing for insemination, taking into account the life span of sperm in the female tract and the fertile life of the egg. The Herd Navigator™ alarm indicates the approximate time of the standing heat, allowing for a 24-36 hour window for insemination. (Redrawn from O’Connor, 1993).
5. Follicular cyst alarms
In some cows the heat event will be followed by continuing low concentrations of progesterone (happening in an average of 15% of heats), indicating that there was no ovulation taking place (figure 7). The majority of these cows will not exhibit clinical signs of the follicular cyst, and hence being classified as “silent heat cows” in traditional herd management. With Herd Navigator™, these cows will be detected, and a risk value higher than 90% (default risk value for an alarm) will appear on day 10 after the heat alarm, allowing early diagnosis and treatment (hormone treatment that will cause an ovulation). Based on the experience from testing, the heat following the treatment should not be used for breeding, as the conception rate is very low.

In very high producing animals, naturally occurring low values of progesterone can occur in early lactation, and until the daily milk yield drops to less than 40 kg. The chances of conception in these cows are very low, and we advise that the insemination Standard Operating Procedure (SOP) for these cows should be not to inseminate until milk yield has dropped.

Figure 7. Progesterone curve indicating a follicular cyst (DelPro user interface). There is a heat alarm January 5th, followed by low progesterone values: The red triangle indicates a heat alarm, and the blue diamond indicates an insemination.

6. Luteal cyst alarms
In some cows in early lactation, the normal regression of the corpus luteum doesn’t take place as expected at the end of a heat cycle (figure 8). This happens in approximately 5% of the cows. This means that the persistent corpus luteum produces high amounts of progesterone, and the progesterone curve stays high. The reproduction model expects a new heat 21 days after the latest heat, and if progesterone is still high on day 25, the model will issue a luteal cyst alarm.

The luteal cyst is often accompanied by an inflammation of the uterus (endometritis). Therefore, these cows should be rectally examined and treated with luteolytic hormone (prostaglandins).

If Herd Navigator™ issues a luteal cyst alarm in cows that were bred, the cow should be examined for pregnancy at the earliest convenience. If the cow is pregnant, the pregnancy should be reported to the system, as this will remove the luteal cyst alarm. This will happen from time to time, either because of a mistimed AI or late reporting of the insemination, or due to a slow development in progesterone, which makes the reproduction model assume that the chance of a pregnancy is low. We advise that in case of a luteal cyst alarm after breeding, the cow should be manually checked for pregnancy. In the herd management system, filters are available to sort potentially pregnant cows from luteal cyst cows.

Figure 8. Progesterone curve indicating a luteal cyst (DelPro user interface). There is a heat alarm November 20, 2009, followed by a luteal cyst. The cow was treated, and a new heat alarm came December 28, followed by an insemination.
7. Post Partum Anoestrus alarms
Dairy cows are expected to resume cyclicity 20-30 days after calving. If the progesterone measurements start at day 40 after calving, the first Post Partum Anoestrus alarm will be issued on day 50, allowing time for the model to recognize the development in progesterone (figure 9). In some cases progesterone concentration might be low in the first measurement days because the cow is in the middle of a heat period, and hence the alarm would be inappropriate.

Figure 9. An example of a Post Partum Anoestrus cow. The cow is supposed to commence cyclicity, but still up to 70 days after calving there is no increase in progesterone concentrations. At 70 days after calving the first ovulation took place, and the cow became cyclic.

In case of a Post Partum Anoestrus alarm the cow should be examined at the earliest convenience to determine whether she is not cycling or to determine if a follicular cyst is causing the alarm. In case of a true Post Partum Anoestrus very little can be done except waiting for the animal to commence cyclicity, and any attempts to breed the animal upon heat activity is non-productive.

8. Pregnancy attentions
In cows that were bred, the reproductive model will follow the development in progesterone. If at day 30 after breeding the progesterone concentration is high, the model will assume that the cow is pregnant, and issue a pregnancy attention.

The system will now follow the cow for additional 25 days to check for pregnancy. During this period, 95 % of all cases of early embryonic death and abortions will have taken place, and the cow is most certainly pregnant (Forar et al., 1996).

If the user suspects or observes an abortion after this time, and the cow is still in the measurement window (typically 40-240 days after calving), the system will restart progesterone measurements on the cow, in order to prepare for a rebreeding.

9. Early Embryonic Loss/Abortion alarms
In some cases (10-20 %) a pregnant cow will lose the embryo and revert to heat. The majority of these events happens around day 30 in pregnancy and can be caused by a number of factors, including mistimed insemination and a non-viable foetus. In traditional reproductive management these events will be classified as “prolonged heat cycles”, i.e. heats in the period 25-35 days since the last heat.

The Herd Navigator™ will detect these events and issue an Early Embryonic Loss or Abortion alarm, in order for the user to know that the cow was pregnant, but lost the foetus. The experience from Herd Navigator™ herds shows that the heat coming right after such an event should not be used for breeding, as the chances for conception are low (around 15 %).
10. Standard Operating Procedures (SOPs) for insemination

In the modern dairy herd the voluntary waiting period may depend on lactation number and the present milk yield of cows. The lactation curve is very flat, which makes it less important to breed cows early in lactation. Further, the very high milk yield in early lactation is compromising normal ovarial function. Therefore, many Herd Navigator™ users chose to develop SOPs that takes into consideration these factors. In the user interface one can develop SOPs suited for the herd policies for breeding. In case a heat alarm doesn’t meet the criteria for an insemination it will be shown, but there will be no “insemination” instruction with the alarm. In figure 10 is shown a typical example of an insemination SOP.

Figure 10. Example of a reproduction SOP. The SOP takes into consideration days in milk and the likelihood of success for insemination. The SOP can be developed in the user interface.

11. References


