Animal welfare, etológia és tartástechnológia

Animal welfare, ethology and housing systems

Volume 15 Issue 1

Gödöllő
2019

ESTRUS DETECTION AND ITS IMPACT ON REPRODUCTIVE AND ECONOMIC PERFORMANCE IN LARGE DAIRY HERDS

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Received – Érkezett: 02. 07. 2018.
Accepted – Elfogadva: 18. 02. 2019.

Abstract

Poor estrus expression is one of the major reasons of reproductive inefficiency on large dairy farms. Farm managers usually try to overcome this difficulty by using various estrus detection aids (e.g. pedometers, accelerometers, tail chalk), however, each method has its own limitations. Estrus detection aids generally lead to increased heat detection rate, better timing of inseminations relative to the time of ovulation, and ultimately, improved pregnancy rate. Some studies, however, did not find any benefit from the use of estrus detection aids, which is explained by (1) using the same rules on when to start inseminating heifers and cows as prior to the introduction of the new technology, and (2) by the widespread use of hormonal synchronization protocols that can potentially mask the effect of estrus detection aids. Economic outcome of the investment into estrus detection aids depends on the circumstances of the farm, although the reduction of labour cost can usually be expected. Despite efforts made towards the development of new estrus detection technologies, due to the high prevalence of anovular cows hormonal protocols are still required.
Keywords: dairy cattle, estrus detection, pedometer, activity monitoring, reproduction, economics

Az ivarzókeresés gyakorlata, ill. hatása a szaporodási és gazdasági eredményekre nagy létszámú tehenészetekben

Összefoglalás

Az ivarzási problémák jelentik az egyik legnagyobb akadályt a hatékony szaporodásbiológiai menedzselés előtt a nagy létszámú tejelő tehenészetekben. Ennek kiküszöbölésére a telepi menedzsment gyakran ivarzókeresési segédeszközöket (pl. lépésszámláló, aktivitásmérő, farokkrétázás) vezet be, azonban minden módszernek megvannak a maga korlátai. Az ivarzókeresési segédeszközök általában javítják az ivarzásmegfigyelési rátát, a termékenyítések időzítését az ovuláció időpontjához képest, ill. a vemhesülési rátát. Néhány kutatás azonban nem talált javulást az ivarzókeresési segédeszközök bevezetését követően, amit egyrészt annak tudtak be, hogy az üszők és tehenek termékenyítésére vonatkozó szabályokon nem változtattak az új technológia bevezetésével egyidőben, másrészt a hormonális ivarzás-szinkronizálási protokollok elfedhetik a segédeszközök nyújtotta előnyöket. Az ivarzókeresési segédeszközök beruházás-gazdaságossági vizsgálatai változatos eredményeket hoztak, mivel ezek jelentősen függnek az adott tehenészet körülményeitől, viszont általában várható a bérköltség csökkenése. Napjainkban is jelentős erőfeszítéseket tesznek új ivarzókeresési segédeszközök kifejlesztése érdekében, azonban az anovuláció gyakori előfordulása miatt továbbra is indokolt a hormonális ivarzás-szinkronizálási protokollok alkalmazása.
Kulcsszavak: tejelő szarvasmarha, ivarzókeresés, lépésszámláló, aktivitásmérő, szaporodás, gazdasági elemzés

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The importance of estrus detection

Poor estrus expression is a major contributor to the decline in reproductive efficiency (*Lucy*, 2001). Efficient and accurate estrus detection is a key management factor in the success of reproductive programs using artificial insemination and in achieving acceptable reproductive results in the herd (*Heersche and Nebel*, 1994). Problems in estrus detection lead to increased days to first service and breeding interval, and will ultimately result in reduced pregnancy rate (*Fricke et al.*, 2014*; Michaelis et al.*, 2014). In their simulation study, *De Vries and Conlin* (2003) found that the temporary decrease of estrus detection rate affected the economic performance of the herd even several years later.

The cow in estrus

The name estrus comes from Greek and refers to the gatfly (member of the Family *Oestridae*). The buzzing of this insect during summer causes that cows become hyperactive and show frenzied behaviour. The behavioural signs of estrus in cows are similar and can be classified as primary and secondary signs (*Roelofs et al.*, 2010).

Standing to be mounted is the primary sign, as this is the most definite and accurate indicator of estrus. During standing estrus, cows stand to be mounted by other cows or more forward slightly with the weight of the mounting cow (*Diskin and Sreenan*, 2000).

However, various behavioural signs are displayed more (or more intensively) during estrus compared to those periods when the cow is not in estrus; these are the secondary signs of estrus. Secondary signs are often seen in those cows, as well, which come into estrus (in this case closer attention should be given to these cows in the next 48 hours), and in those that have been in estrus recently (in this case more attention should be paid to her 17-20 days later). Secondary signs increased significantly 1-3 hours before the beginning of standing estrus (*Sveberg et al.*, 2011). The secondary signs of estrus include restlessness, increase in activity (in >90% of the estrus periods), mounting (in approximately 90% of the estrus periods), being mounted but not standing, hair loss and dirt marks caused by the frequent mounting by herdmates, decreased milk production (at the first milking after the onset of estrus, followed by a compensatory increase at subsequent milking), decreased feed intake, sniffing the vulva of another cow, flehmen, resting with the chin on the back of another cow, licking, rubbing, aggression, swelling and reddening of the vulva, discharge of clear mucus, and increase of the body temperature by 0.3-0.4°C (*Diskin and Sreenan*, 2000; *Roelofs et al.*, 2010; *Saint-Dizier and Chastant-Maillard*, 2018).

The detection of cows in estrus

Visual observation of estrus signs is one method of finding cows in estrus. However, many factors, such as the short duration and low intensity of estrus in modern dairy cows, increasing herd size, limited availability of labour time per cow, and the greatest activity of cows in estrus occurring in the early morning and late evening created the need for improving a wide variety of aids that may help the farm management to increase the success of estrus detection *(Fricke et al.*, 2014; *Saint-Dizier and Chastant-Maillard*, 2018). According to *Senger* (1994), the ideal system for the detection of estrus should have the following characteristics:

- continuous surveillance of the cow,
- accurate and automatic identification of the cow in estrus,

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- operation for the productive lifetime of the cow,
- minimal labour requirements, and
- high (95%) accuracy and efficiency for identifying the physiological events of estrus or ovulation or both.
-

Visual estrus detection

Modern dairy cows show fewer estrus signs with shorter duration, therefore, detecting cows in estrus is challenging (*Dobson et al.*, 2007). Timing, duration, frequency and the signs taken into account when observing cows for detection of estrus have large effect on estrus detection rate, moreover, record keeping of animals in estrus also plays a crucial role (*Roelofs et al.*, 2010). The rate of estrus detection based on the observation of standing estrus varies widely among farms (<50% to 90%). Since standing to be mounted can be observed only in 60% of estrus periods in recent studies, the secondary signs of estrus have to be taken into account, as well (*Roelofs et al.*, 2010). A scoring system was developed that enables farmers to detect cows in estrus without standing to be mounted (*Van Eerdenburg et al.*, 1996). Approximately one quarter of cows showed estrus with low intensity (<1.5 stands per hour) and short duration (<7 hours), therefore, detection of estrus is difficult if observed only twice daily for less than 30 minutes (*Dransfield et al.*, 1998). Thus, longer and more frequent observation is needed.

The role of the human factor in estrus observation is inevitable. Farm staff responsible for this activity should be fully committed to estrus observation and should understand signs of estrus (*Michaelis et al.*, 2014). Moreover, estrus observation is a very boring task, therefore, motivation of farm staff plays a crucial role, as well (*Heersche and Nebel*, 1994).

Estrus detection aids

Due to the impact of estrus detection rate on reproductive performance and to the problems with visual estrus detection, technologies have been developed and marketed to farmers. These technologies enhance the detection of estrus by the surveillance of behaviour in the absence or in addition to visual observation (*Fricke et al.*, 2014). Some of the available technologies for estrus detection are summarized in *Figure 1*.

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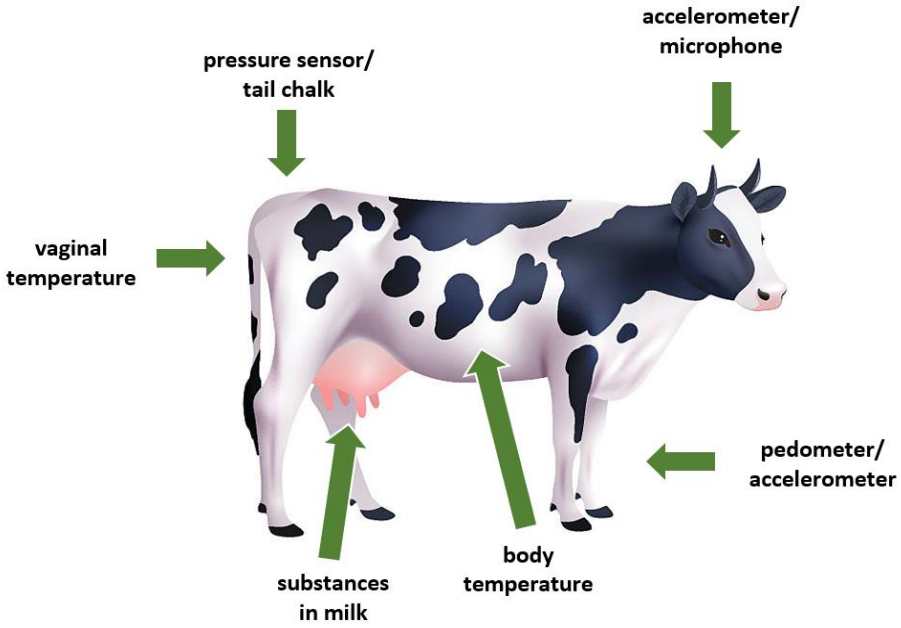
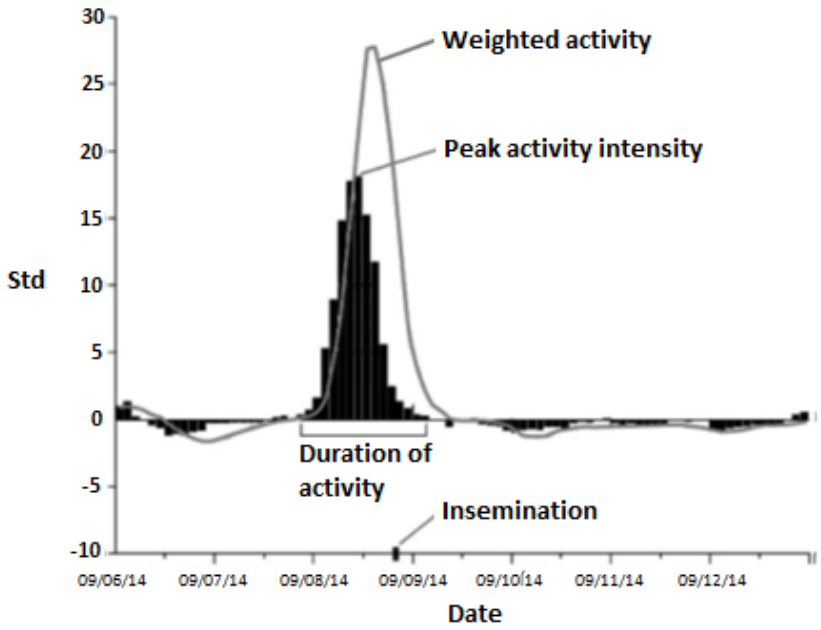
Figure 1. **Estrus detection aids for dairy cattle**



Increased activity of cows in estrus can be measured by pedometers and accelerometers (*Figure 2*). Pedometers calculate the change in the number of steps per unit of time. Accelerometers measure the acceleration forces in three dimensions (*Fricke et al.*, 2014). Above a certain threshold, these devices indicate that the cow is in estrus.

Figure 2. **Activity report for a cow in an activity monitoring system (Heatime; SCR Engineers Ltd, Netanya, Israel)**



Source: *Valenza et al. (2012)*

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The efficiency of pedometers and activity monitoring devices has been subject to intensive research. An estrus detection rate of >80% can be often achieved by using pedometers, but the efficiency is affected by the threshold used. Accuracy of these systems is 49-90% according to previous reports (*Roelofs et al.*, 2010). The large variation among farms was confirmed by *Galon* (2010), as well. Research conducted on Canadian dairy farms found that the major drivers for adopting an activity monitoring system were the desire to improve reproductive performance and the opinions and experiences of other farmers (*Neves and LeBlanc*, 2015).

Tail chalks are the non-electronic variants of mount detection devices (*Roelofs et al.*, 2010). The chalk is applied to the tailhead of cows, and when they are being mounted by their herdmates, the chalk is rubbed off. Detection rates using mount detection devices varies from <50% to >85%.

In the future, one of the possible ways of improving estrus detection can be inline milk sensors that measure hormones or substances secreted in milk. More than 40% of cows were inseminated at high progesterone levels (*Nebel et al.*, 1987). Although high progesterone levels indicate inappropriate time for insemination, low progesterone indicates only that the cow is in follicular phase, therefore, low progesterone levels should not be used to determine the time of insemination (*Heersche and Nebel*, 1994). The decrease of the level of progesterone indicates lutelysis, however, the interval from luteolysis to ovulation varies widely, therefore, this hormone is not a good candidate for determining the optimal time of insemination in itself. Combined measurements of progesterone and estradiol could improve timing of AI (*Fricke et al.*, 2014).

Several further possibilities exist for the detection of cows in estrus. Cow positioning can be measured by using ultra-wideband radio technology (UWB) that allows for the detection of both standing-to-be-mounted and mounting behaviours (*Homer et al.*, 2013). The rise of body temperature at the time of estrus can be monitored by temperature sensors either placed in the vagina or in the reticulum (*Saint-Dizier and Chastant-Maillard*, 2018). An estrus detection system measuring vaginal temperature outperformed pedometers in terms of heat detection rate (*Sakatani et al.*, 2016). Furthermore, a sound processing system has been developed that can detect estrus by >94% accuracy (*Chung et al.*, 2013). The great variety of possibilities regarding estrus detection is also indicated by dogs (with previous experience in detection of explosives) being capable of differentiating estrus vs. non-estrus cows with >80% accuracy (*Kiddy et al.*, 1978). However, most of these methods require further studies to evaluate their applicability and efficiency among practical circumstances.

Factors influencing estrus detection

Cow factors

1. *Heritability*. The degree of estrus expression has a low heritability (h^2=0.21) and varies individually, even from one estrus to another within the same cow (*Roelofs et al.*, 2010).
2. *Postpartum period*. In the US, 20-30% of high producing cows are anovular at 60-75 DIM (the time coinciding with the end of the VWP). These cows will not be detected by any means of estrus detection. Silent ovulations occur quite frequently, as well, since 35% of cows not detected in estrus had an ovulation. In few cases increase of activity is detected, but ovulation does not occur *(Fricke et al., 2014; Roelofs et al., 2010; Valenza et al.*, 2012).
3. *Number of lactations*. Behavioural scores and activity are higher in primiparous than in multiparous cows, however, the number of standing estrus events increases with parity *(Garcia et al., 2011; Madureira et al.*, 2015; *Roelofs et al.*, 2010; *Yániz et al.*, 2006).

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4. *Milk yield*. A weak antagonism between milk production and estrus expression exists (*Diskin and Sreenan*, 2000; *Yániz et al.*, 2006).
5. *Body condition score (BCS)*. Cows with higher BCS at the time of estrus are more likely to be detected (*Kovács et al.*, 2010; *Saint-Dizier and Chastant-Maillard*, 2018).
6. *Lameness*. Feet and leg problems lead to less mounting and fewer standing estrus events, but lame cows may well stand when not in estrus, if it is too painful for them to escape from the mounting cow (*Diskin and Sreenan*, 2000; *Roelofs et al.*, 2010). In the study of *Garcia et al.* (2011) no significant association between lameness and estrus intensity was found, however, lameness reduced the odds of pregnancy.
7. *Hormonal treatments*. A higher level of progesterone prior to estrus increases the sensitivity to estradiol, which, in turn, has a positive effect on estrus expression. No difference was found between the duration of PGF-induced and spontaneous estrus (*Roelofs et al.*, 2010).

Environmental factors

1. *Bull*. The interval between calving and the onset of estrus can be shortened by the presence of a bull (*Roelofs et al.*, 2010).
2. *Nutrition*. Negative energy balance has a negative effect on estrus expression. Similarly, lower body condition score decreases activity and the duration of estrus *(Madureira et al.*, 2015; *Roelofs et al.*, 2010).
3. *Weather*. Heavy rain, strong wind and high relative humidity suppresses estrus behaviour (*Roelofs et al.*, 2010; *Yániz et al.*, 2006).
4. *Circadian variation*. Estrus behaviour is more frequent from late evening until early morning, however, management has a large influence (e.g. feeding, milking) (*Diskin and Sreenan*, 2000; *Roelofs et al.*, 2010).
5. *Housing*. Confinement housing with concrete floors has reduced estrus expression of modern dairy cows. However, rubber mats on concrete promote estrus behaviour (*Lucy*, 2001; *Roelofs et al.*, 2010).
6. *Herdmates*. Estrus expression increases largely as the number of cows simultaneously in estrus increases (*Diskin and Sreenan*, 2000; *Roelofs et al.*, 2010; *Yániz et al.*, 2006).

Timing of insemination

The interval from insemination to ovulation is critical for optimizing conception risk (*Fricke et al.*, 2014; *Répási et al.*, 2014). Early studies based on frequent estrus detection (4-12 times per day) and insemination at standing estrus (not taking secondary estrus signs into account) found that the best conception risk was achieved when inseminations were performed a few hours after the end of the standing behaviour. Based on these results, the a.m.-p.m rule was developed as a guide for farmers. This means that if cows are observed in standing estrus in the morning, they should be inseminated in the afternoon, and if seen in estrus in the afternoon, they should be inseminated next morning. With proper estrus detection, the a.m.-p.m. rule can be used, however, if conception risk is not satisfactory, or estrus is not routinely detected, cows should be inseminated soon after they are first detected in estrus (*Roelofs et al.*, 2010). When cows are inseminated 0-12 hours after ovulation, fertilization rate and embryo quality are reduced due to the aging of the oocyte, however, when insemination is performed >24 hours before ovulation, fertilization rates are high, but embryo quality is low, possibly due to the aging of the sperm cells (*Fricke et al.*, 2014).

Automated estrus detection aids may help to optimize the timing of insemination (*Chebel and Ribeiro*, 2016). Cows ovulated 27-30 hours (range: 21-39 hours) after estrus detection by

activity monitoring systems, on average, whereas conception risk was the highest with inseminations performed 5-18 hours after the estrus alert (*Roelofs et al.*, 2015). For farms relying on activity monitoring for timing of insemination, *Fricke et al.* (2014) suggested that they generate list of cows and perform insemination twice per day rather than only once, to minimize variation from insemination to ovulation that could potentially reduce conception risk.

Impact of estrus detection aids and economic considerations

The most prevalent reason (81% of the responding herds) for introducing an automated activity monitoring system was the desire to improve reproductive performance. In the same study, 51% of the respondents indicated lack of time to detect estrus and 39% indicated the desire to reduce labour as the reason of adopting such a system (*Neves and LeBlanc*, 2015). Other studies found that the primary reasons for implementing sensor systems (e.g. for reproductive purposes) were the reduction of labour and the facilitation of management (*Steeneveld et al.*, 2015b). However, the lack of familiarity and the interpretation of the huge amount of data are the major obstacles to the uptake of these systems (*Saint-Dizier and Chastant-Maillard*, 2018).

Reproductive performance of the year before vs. the year after the implementation of automated estrus detection systems was compared in 505 dairy herds in Canada. The improvement of the heat detection rate (from 42% to 50%) led to the increase of pregnancy rate (from 15% to 17%) after the adoption of estrus detection aids, however, no change in the conception risk was detected (*Neves and LeBlanc*, 2015). In the Netherlands, the uptake of sensor systems did not have a positive effect on first calving age, days to first service and milk production *(Steeneveld et al.*, 2015b). On large Hungarian dairy farms, the use of estrus detection aids in heifers was related to reduced age at first service and age at first calving, and the probability of pregnancy at 20 months of age tended to be higher in these herds, as well (*Fodor et al.*, 2018b). However, no difference was found between those farms that used and those that did not use estrus detection aids in cows (*Fodor et al.*, 2018a). In a simulation study, however, it was found that the introduction of activity meters reduces calving interval and improves annual milk production (*Rutten et al.*, 2014). The lack of effect of estrus detection aids in some studies were explained by (1) using the same rules on when to start inseminating as before implementing the new technology and (2) the widespread use of hormonal synchronization protocols that can mask the effect of estrus detection aids (*Fodor et al.*, 2018a; *Steeneveld et al.*, 2015b).

When the dairy farms introduce a reproductive management tool, they have to take into account the costs related to the implementation of the technology and the cost of maintenance, as well (*Fodor and Ózsvári, 2018; Fodor et al., 2016*). *Chebel and Ribeiro* (2016) stated that the cost of estrus detection aids can be compensated for by the improvement of reproductive performance, especially in those herds where heat detection rate and conception risk are poor. In a simulated 130-cow herd the annual net cash flow increased by 2,827 EUR after the implementation of an activity meter system, and the internal rate of return (IRR) of the investment was 11% (*Rutten et al.*, 2014). On farms performing automated milking the total capital costs and total revenues increased after the adoption of sensor systems, however, labour costs and all variable costs did not change significantly (*Steeneveld et al.*, 2015a). In another study, the payback period of an automated estrus detection system ranged from 1.6 to >10 years (*Dolecheck et al.*, 2016). Labour cost is an important issue in the decision to invest into estrus detection aids (*Steeneveld et al.*, 2015a).

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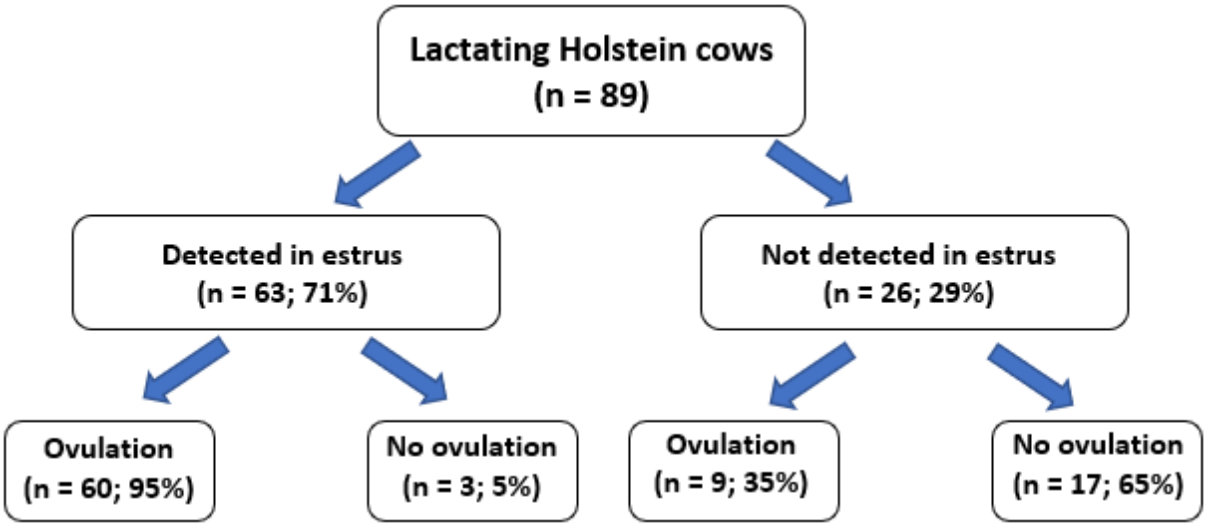
Estrus detection and hormonal synchronization

In practice estrus detection is often combined with synchronization protocols. The introduction of estrus detection aids influences the expenditures on hormonal synchronization protocols. Considering the hormonal protocols, the major cost factors are the cost of labour and the cost of drugs (*Fodor et al., 2014*). The use of estrus detection aids could be an alternative to hormonal synchronization, however, those cows that do not display estrus will not be detected by these methods (*Chebel and Ribeiro*, 2016; *Saint-Dizier and Chastant-Maillard*, 2018). Activity monitoring systems do not detect two subpopulations of cows: anovular cows and those cows that ovulated but their activity did not increase detectably (*Figure 3*) (*Fricke et al.*, 2014).

Until the mechanisms causing anovulation and silent ovulation are understood and effective preventive measures are introduced, hormonal therapy will be required to deal with these cows (*Fricke et al.*, 2014). The economic outcome of the combined synchronization and estrus detection programmes depends on the conception risk to estrus detection and to timed insemination, as well as on the proportion of cows being inseminated to detected estrus (*Fricke et al.*, 2014; *Giordano et al.*, 2012). However, farm managers are often not aware of the economic losses stemming from the suboptimal reproductive parameters, and are, therefore, unable to weigh the costs of investment or change in management against its potential benefit (*Tóth et al., 2006*). When conception risk to detected estrus is poor, involving cows in a hormonal synchronization protocol can be a profitable approach.

Figure 3. **Distribution of cows by estrus activity and ovulation**



Based on the results of *Valenza et al.* (2012)

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Acknowledgements

The Project was supported by the European Union and co-financed by the European Social Fund: (1) EFOP-3.6.1-16-2016-00024 'Innovations for Intelligent Specialisation on the University of Veterinary Science and the Faculty of Agricultural and Food Sciences of the Széchenyi István University Cooperation'; (2) EFOP-3.6.2-16-2017-00012 'Development of a product chain model for functional, healthy and safe foods from farm to fork based on a thematic research network'; and (3) EFOP-3.6.3-VEKOP-16-2017-00005 'Strengthening the scientific replacement by supporting the academic workshops and programs of students, developing a mentoring process'.

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