Importance of monitoring the peripartal period to increase reproductive performance in dairy cattle

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Introduction

Successful genetic selection for higher milk production in Holstein cows has nearly doubled the average milk production in the United States since 1960, to over 11,000 kg/year. Over the same time period, there has been a dramatic decline in the reproductive performance of dairy cows (Butler, 2000; Samardžija et al., 2008). The average number of days open (calving to conception), the number of services per conception and the number of cows culled for infertility have increased substantially (Royal et al., 2000). It is important to emphasize that during this time period, reproductive performance in heifers was not affected (Silva, 2003). In order to decrease the longer lactations and the number of cows culled for reproductive reasons, it is very important to improve reproductive management practices (Silva, 2003). Achievement of optimum herd reproductive performance (a calving interval of 12 or 13 months with the first calf born at 24 months of age) requires concentrated management activities, especially during the first 100 days following calving. Early postpartum breeding of dairy cows results in more calves, with higher milk production per lactation (Britt, 1975). Poor reproductive performance can reduce the number of calves born and can reduce milk production, which may increase the cost of therapy and semen.

The following diagnostic activities should be pursued during the early postpartum period to achieve or approach the optimal calving interval: prediction of the onset of calving, monitoring for post parturient metabolic disease, early diagnosis of post parturient uterine diseases, accurate detection of oestrus, correct timing of insemination, and accurate diagnosis of early pregnancy and pregnancy loss.

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Importance of predicting the onset of calving in dairy cows

One of the most important breeding objectives is to reduce the need for calving assistance. This is even more important, as calving assistance in itself may negatively affect the acid-base balance in newborn calves (Szenci, 1983; Bleul and Götz, 2013; Vannucchi et al., 2013) and may subsequent affect the fertility of the dam. Therefore, the main emphasis should focus on the prevention of asphyxia of calves at birth, since instruments suitable for the reliable clearing of respiratory passages and artificial respiration of newborn calves are not yet widely available under practical conditions (Szenci, 2003).

In the case of dystocia, the mode and time of calving assistance should be selected with regard to profitability factors and in a manner that would allow for a minimum shift of the newborn calf's acid-base balance towards acidosis. Before applying traction, measurements of the soft birth canal should always be considered under insufficient dilatation of the soft maternal passages, and they must be expanded non-surgically or surgically (episiotomy lateralis) with the use of obstetric lubricants to avoid traction of longer than 2 to 3 minutes (Szenci et al., 1995) and rib and/or vertebral fractures due to excessive traction. If prolonged traction is expected, Caesarean section should be performed to save the calf and to prevent injuries of the maternal birth canal. Recent studies have shown that prior to selecting the mode of calving assistance in an animal hospital, the results of acid-base balance measurements from blood samples should be considered. The routine use of complex treatment of newborn calves born with severe asphyxia may reduce postnatal calf losses (Szenci, 2003). In addition to adequate therapy, in the case of calves with asphyxia, particular attention should be paid to the ingestion of sufficient quantities of colostrum, since deficient colostrum uptake is accompanied by an increased susceptibility to *E. coli* infections (Besser et al., 1990).

While it is not possible to eliminate dystocia, adequate management of heifers during development (adequate feeding, selection of a sire with a negative expected progeny difference for birth weight) and close observation of cows and heifers during calving are essential for reducing calf losses (Szenci, 2003). Since in many cases there are no visible clinical signs of the onset of calving, this can be difficult to recognise, especially on large dairy farms. Insertion of a vaginal thermometer into the vagina (Vel'Phone, Medria, Châteaugiron, France) may contribute to the decrease of stillbirth, delayed calving assistance and its consequences by providing daily text updates on changes in temperature, the imminence of calving, and rupture of the allantoic sac (Choukeir et al., 2013). In a recent experiment, 257 calvings were monitored using a vaginal thermometer, and the stillbirth rate was 1.7% for heifer calvings and 2.5% for cow calvings, respectively (Szenci et al., 2017). Similar results were reported by others (Paolucci et al., 2010).

It is also very important to avoid birth injuries and infection of the reproductive tract, which may more likely develop in cows with inappropriately timed obstetrical assistance and/or dystocia (Kovács et al., 2016). Dystocia can negatively affect the subsequent pregnancy rate of dams (Szenci, 2017).

Importance of monitoring post parturient metabolic disease in dairy cow

Dairy cattle are usually in a negative energy balance (NEBAL) in the initial weeks of lactation, as the energy intake during this period is less than half of the energy requirements for milk production (Kočila et al., 2009). Therefore, the gap between energy input and output during early lactation must be met through increased non-esterified fatty acid (NEFA) production (Kočila et al., 2013). On the other hand, some 60 to 70% of the energy requirements of dairy cows are met by volatile fatty acids (acetate, propionate and butyrate) fermented in the rumen, and as such, ruminal fluid is one of the most important sources of energy metabolism in dairy cow. In the periparturient period, feed intake is physiologically suppressed, causing a lack of dietary energy intake. This results in a lack of gluconeogenesis, which in turn causes a lack of glucose for complete oxidation of NEFA. The incomplete oxidation of fatty acids contributes to increased production of ketone bodies (β-hydroxybutyrate /BHB/, acetone, acetoacetate) which may cause ketosis and fatty liver (Oetzel, 2004; Folnožić et al., 2015). It is important to mention that primiparous cows are more susceptible to metabolic stress during the transition period than the multiparous cows (Folnožić et al., 2016).

According to Iwersen et al. (2009), the electronic hand-held BHBA measuring system using whole blood is a more useful and practical tool for diagnosing subclinical ketosis than the commonly used chemical dipsticks (e.g. Ketostix or Ketolac). Meanwhile, BHB concentrations measured at the farm by a portable hand-held device (Precision Xtra, Abbot Laboratories**)** showed a strong and significant correlation ($r>0.92$, $P<0.001$) with the results of samples evaluated in the laboratory before and after freezing (Szelényi et al., 2013).

Salivation is also decreased during calving due to breaking chewing or a reduced period and intensity of chewing. This may contribute to the development of clinical or subclinical rumen acidosis, especially when the ration of concentrate is not limited for the days surrounding calving. Ruminal acidosis may also negatively affect rumen motility and appetite. pH value of the rumen fluid collected using a stomach tube or by rumenocentesis can be measured in the field; however, the accuracy of diagnosing subacute ruminal acidosis is limited. Long-term measurement of reticuloruminal pH-value using an indwelling and wireless data transmitting unit enables the evaluation of dietary composition and allows for adjustments in feeding management in the field (Gasteiner et al., 2013).

As previously mentioned, a rapid increase in energy requirements at the onset of lactation results in a negative energy balance (NEBAL) that begins several days prior to calving and usually reaches its most negative level (nadir) about 2-3 weeks later and used to be extended 10-12 weeks until the beginning of the usual breeding period (Butler and Smith, 1989). The NEBAL that develops spontaneously in dairy cows represents a physiological state of undernutrition. The severity and duration of NEBAL is primarily related to differences in dry matter intake and its rate of increase during early lactation.

Body condition score (BCS) can be evaluated in the field using the 5-point condition scoring system (scale 0 to 5, in 0.2-point increments) (Mulvany, 1977). Calving in moderate condition (3-3.5) and maintaining feed intake during the periparturient transition period are key factors to reducing NEBAL and avoiding metabolic disorders (milk fever, acidosis, ketosis fat cow syndrome) that are deleterious to performance.

Following parturition, regardless of NEBAL, a wave of follicular development begins at 5 to 7 days after calving due to elevated plasma FSH concentrations. Three types of follicular development have been described and can be diagnosed in the field using ultrasonography (Beam and Butler, 1997):

1. Ovulation of the first dominant follicle (16-20 days after calving)
2. Non-ovulation of the first dominant follicle followed by turnover and a new follicular wave
3. The dominant follicle fails to ovulate and becomes cystic.

The development of non-ovulatory dominant or cystic follicles prolongs the interval for the first ovulation to 40-50 days after calving. Ovulation of a dominant follicle during early lactation depends on the re-establishment of pulsatile LH secretion (Butler, 2001). NEBAL, as a physiological state of undernutrition, may suppress pulsatile LH secretions and reduce ovarian responsiveness to LH stimulation, thereby deterring ovulation (Jolly et al., 1995; Butler, 2001).

It should be noted that prolonged anovulatory anoestrus may occur in 11 to 38% of dairy herds (Rhodes et al., 1998) and can be associated with reduced fertility caused by NEBAL (Rhodes et al., 1998). It seems that NEBAL can influence the timing of first postpartum ovulation, whereby negatively affecting fertility (Butler, 2001; Darwash et al., 2001). Cows remaining anovulatory for > 50 days of lactation are less likely to become pregnant during lactation and will be culled (Frajblat, 2000).

Plasma progesterone (P4) concentrations generally rise during the first two or three postpartum ovulatory cycles (Villa-Godoy et al., 1988; Spicer et al., 1990). The rate of increase in P4 is reduced or moderated by NEBAL (Villa-Godoy et al., 1988; Spicer et al., 1990). Meanwhile, high dietary intake (both energy and protein) may increase the metabolic clearance of P4 in high yielding dairy cows. P4 plays an important role in conceptus development and growth via its regulation of the uterine environment. A slower rate of increase in P4 after ovulation may decrease embryo growth by Day 16 and is associated with low fertility (Shelton et al., 1990; Butler et al., 1996).

Early postpartum NEBAL may adversely impact the quality of oocytes during the first 80-100 days after calving, which exerts another carryover effect on fertility (Britt, 1992; Kruip et al., 2001). However, it is very difficult to reconcile the effect of NEBAL on follicles and oocytes with the effect of high dietary energy on oocyte quality and development to blastocysts in dairy cows (Armstrong et al., 2001; Boland et al., 2001). It appears that extremes in energy status in either direction may negatively influence fertility (Butler, 2001).

Fertility in dairy cows reflects the cumulative influence of metabolic, endocrine, and postpartum health components. Energy imbalance seems to be one of the most important factors, though the complex interactions of the aforementioned factors should be considered in order to improve fertility (Butler, 2001). Similarly, BCS, glucose, NEFA or IGF-I concentration from calving to AI cannot explain the low fertility rate (Snijders et al., 2001).

Cows should be challenge-fed during the dry-off period and early lactation to prevent the prevalence of metabolic diseases of the puerperal period such as milk fever, acidosis, ketosis and fat cow syndrome. These diseases can increase the prevalence of reproductive diseases and reduce reproductive performance. Prevention is more preferable to treatment and requires close attention of nutrition and management. The maintenance of good body condition at calving and the provision of a high-density energy diet that does not produce a fatty liver in early lactation are also very important in minimizing the detrimental effects of NEBAL on the return of the oestrous cycle after calving.

Importance of diagnosing post parturient uterine diseases in dairy cow

Cows having dystocia, retained foetal membranes, metabolic disorders (hypocalcaemia), or twins are more likely to contract uterine infections than cows calving normally. Postpartum infection of the uterus has long been considered to have a deleterious effect on subsequent fertility (Erb et al., 1981). Thus, nutrition, population density, calving management (minimising stress), sanitation during calving, early diagnosis and treatment of uterine infections are of great importance. Clinical metritis and endometritis should be treated as early and as intensively as possible to keep the conception interval short. Recently, new cow programs have been developed based on monitoring cow temperatures each morning for the first 10 days after calving, thus allowing for early treatment (Belschner and Saltman, 2000). However, the results of routine treatment of clinical metritis with intrauterine antimicrobial agents (oxytetracycline; ampicillin and cloxacillin), antiseptic chemicals (iodine solutions: 500 mL of 2% Lugol's iodine immediately after calving and again 6 h later as a preventive measure), systemic antibiotics (penicillin or one of its synthetic analogues: 20,000 to 30,000 U/kg/cow; ceftiofur /third generation cephalosporin/: 2.2 mg/kg of body weight daily for 3 to 5 days; today double dose is recommended preferably a single dose of 6.6 mg ceftiofur/kg of body weight s.c. in the base of the ear within 24 h after abnormal calving), ozone i.u. treatment (Đuričić et al., 2012 and 2014; Đuričić et al., 2015; Samardžija et al., 2017), supportive therapy (nonsteroidal anti-inflammatory drugs such as flunixin meglumine, fluid therapy in case of dehydration, therapy with calcium and energy supplements in case of depressed appetite, and/or hormone therapy (oxytocin: 20 to 40 IU repeated every 3 to 6 h within 48 to 72 h after calving; $PGF_{2\alpha}$ or its synthetic analogues) are greatly variable (Szenci, 2016). According to our present knowledge, intrauterine antimicrobial and antiseptic treatments are not recommended as they irritate the endometrium. Routine use of hormone therapies (prostaglandin) is also controversial and requires further confirmation. It seems that presently systemic antibiotic (ceftiofur) and supportive therapy can be recommended for the field (Drillich et al., 2001; Dubuc et al., 2011).

Cows with clinical endometritis having a palpable CL, treated by intrauterine infusion of cephapirin or PGF2α, had no significant difference in time to pregnancy (Pécsi et al., 2007). Both groups tended to have a higher pregnancy rate than those in untreated cows. Numerous reviewers have concluded that $PGF_{2\alpha}$ appears to be at least as effective for the treatment of clinical endometritis as any available alternative therapy (Lugol's iodine, polyvinylpyrrlidone-iodine solution, metacresolsulphuric acid and Lotagen) and presents a minimal risk of harm to the uterus or presence of residues in milk or meat (Szenci, 2016).

In the absence of an active corpus luteum, the treatment efficacy of clinical endometritis solely with prostaglandin injection is limited; however, according to Lewis (2004), such a treatment may bring certain advantages by stimulating the self-defence mechanism. More detailed information about the diagnosis and treatment of post-parturient uterine diseases in dairy cows has been recently summarized (Szenci, 2016).

Importance of accurate oestrus detection in dairy cow

Oestrus detection is one of the major contributors to low fertility results in the field (Reimers et al., 1985). Until recently, it was believed that this was caused by the low management input, with priorities focused elsewhere on the farm. However, since the study made by Van Vliet and Van Eerdenburg (1996), it is clearer that cow factors are also part of the cause for low detection rates. One of the management related factors for the low number of standing heats in their studies might be the fact that there was only one cow in heat at any one time. Due to the size of the average dairy herd in several European countries (45 – 50 cows) and the year round calving pattern, the chances of having more than one cow in oestrus at the same time are rather limited. The number of cows in oestrus at the same time is of major influence to the intensity and length of the oestrus (Van Vliet and Van Eerdenburg, 1996). Another point of concern is the short duration of oestrus. In a recent study (Van Vliet and Van Eerdenburg, 1996) it was shown that a substantial number of animals (40%) showed oestrous signs for less than 12 h. The mean duration of oestrus was 13.7 h in their study, in which the cows were observed every two hours for 30 min. The short duration of oestrus on modern dairy farms makes it even more important to correctly determine the optimum time for artificial insemination (Trimberger, 1948). Simple observation of the herd for 30 minutes in the morning before and after milking, at midday, and late in the evening is recommended to determine oestrus accurately under usual management circumstances. The use of traditional aids such as pressure sensitive mount detectors, tailhead markings, and/or detector animals or recently developed aids like pedometry, electrical resistance measurements, and/or electronic pressure-sensitive mount detectors may improve the accuracy of oestrus detection. The combined use of monitoring of oestrous behaviour and one or more oestrus detection aids may improve its efficiency.

It is very important to emphasize that when standing heat is used as a predictor for time of ovulation (26.4±5.2 h), only a limited number of cows display standing heat (58%), especially when few animals are in oestrus at the same time. According to a recent study, the onset of mounting behaviour displayed in 90% of oestruses is the best predictor for time of ovulation (30.0±5.1 h); however, its limitation is that it cannot yet be assessed by oestrus detection aids (Roelofs et al., 2005a).

Importance of determining the optimal time for artificial insemination

A P4 assay of plasma or milk as an indication of true oestrus clearly demonstrated that 7 to 22% of cows showing oestrus had abnormal levels of P4 at the time of insemination. When such cows are inseminated, they do not conceive or it leads to abortion if they had been pregnant (Appleyard and Cook, 1975). Since the chances for pregnancy after insemination are much higher when ovulation occurs within the survival time of sperm (Trimberger, 1948), it is therefore important to inseminate the cow within 12 hours after the onset of oestrus.

According to Van Eerdenburg et al. (2002), 100 cows were detected in oestrus with a scoring system. Of these animals, 50% showed standing heat and of the 64 animals that were presented for insemination, 98% did indeed ovulate. There was no correlation between follicular size and ovulation time and oestrus detection score. The level of milk yield and parity were also not correlated with the oestrous behaviour score. The animals that ovulated 0-24 h after the first ultrasonographic examination scored more than twice the number of points than those that ovulated 24-48 h after the first scan (P=0.045). Ovulation > 48 h after

AI resulted in pregnancy in only 15% of the cows. Cows that did not show overt signs of oestrus and thus scored < 100 points in the scoring system, had a high chance of ovulating after 24 h and should therefore be inseminated again (Van Eerdenburg et al., 2002).

Ovulation can also be detected by ultrasonography, since it is characterised by the abrupt disappearance of the large ovulatory follicle (Larsson, 1987; Van Eerdenburg et al., 2002). Pedometers may detect oestrus accurately (83%) and appear to be a promising tool for predicting ovulation (duration between onset of increased number of steps and ovulation: 29.3±3.9 h; duration between the end of increased number of steps and ovulation: 19.4±4.4 h) in dairy cow (Roelofs et al., 2005b), while monitoring P4 alone is not sufficient to predict ovulation (Roelofs et al., 2005c).

Without oestrus detection, synchronization of ovulation can be achieved on the farm by using Pre-Synch-11 ($PGF_{2\alpha}$: Day 0 + $PGF_{2\alpha}$: Day 14 + GnRH: Day 25 + $PGF_{2\alpha}$: Day 32 + GnRH: Day 34 p.m. + timed AI: Day 35 a.m.), Double-Ovsynch (GnRH: Day 0 + $PGF_{2\alpha}$: Day 7 + GnRH: Day 10 + GnRH: Day 17 + $PGF_{2\alpha}$: Day 24 + GnRH: Day 26 p.m. + timed AI: Day 27 a.m.), or G6G ($PGF_{2\alpha}$: Day 0 + GnRH: Day 2 + GnRH: Day 8 + $PGF_{2\alpha}$: Day 15 + GnRH: Day 17 p.m. + timed AI: Day 18 a.m.), which provides similar pregnancy rates per AI when compared with those of classical reproductive management systems, based on oestrus detection and hormonal therapy when necessary (Wiltbank et al., 2006; Pursley and Martins, 2012). When oestrus detection on the farm is good, $PGF_{2\alpha}$ treatment and AI at the observed oestrus are recommended, while when oestrus detection is poor, Pre-Synch-11, double Ovsynch or G6G-protocol and a fixed time AI may be recommended (Mialot et al., 1999; Pursley and Martins, 2012).

Importance of diagnosing pregnancy and pregnancy loss in dairy cow

Accurate early detection of pregnant and non-pregnant cows, as well as cows with late embryonic/early foetal mortality, plays a key role in achieving an optimal calving to conception interval.

One of the most recent techniques for the diagnosis of early pregnancy in cattle on the farm is B-mode ultrasonography. Under field conditions, acceptable results may be achieved with ultrasonography (using 5 or 7.5 MHz transducers) from Days 25 to 30 (Pieterse et al., 1990; Szenci et al., 1998). The reliability of the test greatly depends on the frequency of the transducer used, the skill of the surgeon, the criterion used for a positive pregnancy diagnosis (Szenci et al., 1998) and the position of the uterus in the pelvic inlet (Szenci et al., 1995). More incorrect non-pregnancy diagnoses were made in cows between Days 24 to 38, in which the uterus was located far cranial to the pelvic inlet, in comparison with cows in which the uterus was located within or close to the pelvic inlet (Szenci et al., 1995).

Pregnancy protein (pregnancy associated glycoprotein, pregnancy specific protein B) RIA and/or ELISA assays may provide an alternative method to ultrasonography for determining early pregnancy in cows; however, the relatively long half-life after calving and pregnancy loss may limit the effectiveness of these laboratory methods for early pregnancy diagnosis in the field, especially when compared with a direct method such as transrectal ultrasonography (Szenci et al., 1998).

Abstract

Due to the successful genetic selection for higher milk production in Holstein dairy cows, a dramatic decline in fertility rates has been observed around in the world in recent decades. Therefore, herd management should focus the first 100 days postpartum to achieve optimum herd reproductive performance (calving interval less than 400 days). After calving, a cow has to overcome a series of physiological hurdles before becoming pregnant. The selection of timely diagnostic devices and methods, such as the calving alarm vaginal thermometer to predict the onset of calving, electronic hand-held BHBA measuring system to detect subclinical ketosis on the farm, long-term measurement of reticuloruminal pH by an indwelling and wireless data transmitting unit to monitor subclinical acidosis, monitoring rumination time to select cows for early treatment of subclinical metabolic diseases (subclinical ketosis, acidosis and/or hypocalcaemia) and/or clinical metritis, performing metabolic profile tests to detect subclinical metabolic diseases at the herd level, oestrus detectors and/or detection aids, on-farm P4 test to monitor specific events in the postpartum and service periods, early diagnosis of pregnancy and late embryonic/early foetal mortality by means of ultrasonography are vital to correctly identify problems and their potential causes to enable these issues to be rectified. The following monitoring and managing activities should be pursued during the early postpartum period to achieve or approach the optimal calving interval: monitoring the onset of calving and post parturient metabolic diseases, early diagnosis of post parturient uterine diseases, accurate detection of oestrus, correct timing of insemination, and accurate diagnosis of early pregnancy and embryonic loss. Despite higher milk production, acceptable fertility results can be achieved, even on large-scale dairy farms, if the impacts of the above factors that contribute to reduced fertility can be moderated.

Key words: *dairy cow, calving, metabolic disorders, uterine abnormalities, detection of oestrus, timing of insemination, pregnancy diagnosis*

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Značenje praćenja peripartalnog razdoblja u cilju poboljšanja plodnosti mliječnih krava

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Zahvaljujući uspješnoj selekciji gena za proizvodnju mlijeka u Holstein mliječnih krava, posljednjih je desetljeća u cijelom svijetu uočen dramatičan pad stope plodnosti. Stoga bi se upravljanje stadom trebalo usredotočiti na prvih 100 dana nakon porođaja kako bi se postigla optimalna reproduktivna učinkovitost stada (interval teljenja manji od 400 dana). Krava nakon teljenja mora prevladati niz fizioloških zapreka prije nego što postane gravidna. Odabir pravodobnih dijagnostičkih uređaja i metoda poput vaginalnog toplomjera s alarmom za teljenje za predviđanje početka teljenja, elektronički ručni mjerni sustav za mjerenje BHBA (beta-hidroksi maslačne kiseline) za otkrivanje subkliničke ketoze na farmama, dugoročno mjerenje retikuloruminalnih pH vrijednosti pomoću jedinice za odašiljanje i bežični prijenos podataka za praćenje subkliničke acidoze, praćenje vremena ruminacije za selekciju krava za rano liječenje subkliničkih metaboličkih bolesti (subklinička ketoza, acidoza i/ili hipokalcemija) i/ili kliničkog metritisa, ispitivanje metaboličkih profila za otkrivanje subkliničkih metaboličkih bolesti na razini stada, uređaji i/ili pomagala za detekciju estrusa, testovi za razinu progesterona za uporabu na farmama za praćenje specifičnih događaja u post porođajnom i aktivnom razdoblju, rana dijagnostika gravidnosti i kasne embrionalne/rane fetalne smrtnosti pomoću ultrasonografije od vitalne su važnosti za ispravno prepoznavanje problema i njihovih mogućih uzroka te načina na koji se mogu ispraviti. Aktivnosti praćenja i upravljanja navedene u nastavku potrebno je provoditi tijekom ranog post porođajnog razdoblja kako bi se dostigao ili optimalan interval teljenja ili kako bi mu se približilo: praćenje početka teljenja i post-porođajnih metaboličkih bolesti, rana dijagnostika post-porođajnih bolesti maternice, precizna dijagnostika estrusa, precizno tempiranje oplodnje i točna dijagnoza rane gravidnosti i gubitka zametaka. Unatoč većoj proizvodnji mlijeka, prihvatljivi rezultati plodnosti, čak i na velikim mliječnim farmama, mogu se postići ako se moderira utjecaj gore navedenih činitelja koji doprinose nižoj plodnosti.

Ključne riječi: *mliječna krava, teljenje, metabolički poremećaji, bolesti maternice, otkrivanje estrusa, vrijeme osjemenjivanja, dijagnostika gravidnosti*