Understanding the Estrous Cycle and Fundamentals of AI

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ABSTRACT

The estrous cycle is a series of ovarian events and hormonal changes that repeat every 21 days in non-pregnant, estrual cows. Enabling cattle producers to envision the critical events that occur during the cycle places them in a better position to make decisions that will improve their estrus synchronization programs or enhance their success with AI. The timing of insemination is considered to be a key to achieving maximum pregnancy rates following AI. Numerous studies have been performed to characterize the relative timing of estrus behavior and ovulation or to determine the fertilization rate, embryo quality or pregnancy rate following AI at various times relative to estrus and ovulation. While the results indicate that the "window of opportunity" for timing of AI may be longer than commonly believed, several well-controlled studies indicate breeding cows 12 hr after estrus detection, as prescribed by the traditional AM-PM rule, still represents the optimum timing for AI.

INTRODUCTION

Understanding the events and hormonal changes that occur during the estrous cycle is critical for beef and dairy producers using AI and estrus synchronization. To most producers the estrous cycle is an abstract concept. Any methods that enable producers to envision the critical events that occur during the cycle places them in a better position to make decisions that will improve their estrus synchronization program or enhance their success with AI. The purpose of this paper is to describe the important events and hormonal changes of the estrous cycle, with particular emphasis on the period from the initiation of standing estrus until the time of ovulation. Understanding the timing of events that occur during this segment of the cycle is particularly important for optimizing the timing of AI.

ESTROUS CYCLE – ovarian events and hormonal changes

A series of ovarian events and hormonal changes repeats in non-pregnant, estrual cows every twenty-one days. This regular repetition is called the estrous cycle (Figure 1).

Most descriptions of the estrous cycle begin with a cow in heat, or estrus, on Day 0. Several ovarian and hormonal events happen during standing estrus. One ovary has a large, pre-ovulatory follicle present on the surface. This follicle, filled with a fluid, contains a maturing ovum (egg) preparing to be released at the time of ovulation.

The maturing follicle produces the hormone estrogen. Estrogen, transported in the blood to all parts of the cow's body, causes the exhibition of estrous behavior (standing to be mounted). Standing estrus has been reported to last 9 to 12 hr in dairy cattle and 10 to 18 hr in beef cattle (see Table 1). Elevated estrogen concentrations in the blood on Day 0 also cause secondary signs of estrus, such as a red swollen vagina, going off feed, bellowing and increased movement. The cervix is stimulated by estrogen to secrete viscous mucus that lubricates the vagina and estrogen effects of the oviducts and uterus to aid in the transport of semen at the time of insemination.

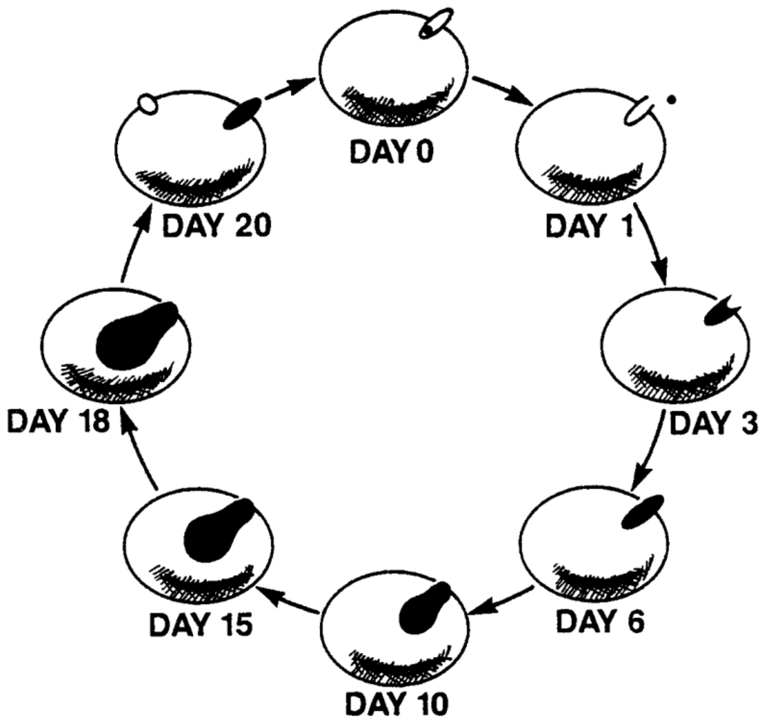

Figure 1. Ovarian events occurring during the estrous cycle

Walker et al. (1996) reported that ovulation occurred an average of 27.6 hr after the initiation of standing estrus in dairy cows housed in a free-stall barn. Timing of ovulation in beef cows on pasture was reported to occur 31.1 or 32.0 hr after the onset of estrus (White et al., 2002; Utt et al., 2003). Hence, in both beef and dairy cattle a mature follicle ovulates on Day 1 of the cycle, releasing the ovum into the oviduct. In the oviduct the ovum awaits sperm for fertilization. By the time the follicle has ovulated, estrogen secretion will have diminished and the cow no longer displays standing estrous behavior or secondary signs of estrus.

In the void on the ovary where the follicle has ovulated luteal cells begin to develop from the cells that made up the wall of the follicle. Quite rapidly over the 3 to 5 days after ovulation, the corpus luteum (CL) grows. The CL reaches its maximum diameter between Days 12 and 16 of the estrous cycle (Kot and Ginther, 1999).

The CL produces the hormone, progesterone. Progesterone released by the CL into the bloodstream prepares the uterus to accept and nourish a fertilized egg and keeps the cow from coming into heat. At the same time, a thick mucous plug forms in the cervix, preventing any bacteria or viruses from entering the uterus.

If fertilization occurs and a viable embryo is present in the uterus by Day 16 to 18 of the cycle, the CL is maintained. Continued secretion of progesterone from the CL keeps a pregnant cow from developing another ovulatory follicle and returning to heat. On the other hand, if the cow does not establish a pregnancy and the uterus fails to detect a growing embryo, it begins to produce prostaglandin. Prostaglandin released from the non-pregnant uterus regresses (destroys) the CL.

When the CL regresses in the non-pregnant cow, progesterone no longer is secreted and a new ovulatory follicle develops, producing large amounts of estrogen and bringing the cow back into standing heat. Upon the return to estrus, a full cycle has been completed. The average total time is about 21 days with a normal range of 18 to 24 days.

If fertilization occurs following ovulation of a follicle on Day 1 and a cow becomes pregnant, the events of the cycle would be the same as that of the non-pregnant animal until day 16 or 17. An embryo present in the uterus at that time will produce a substance which interferes with the ability of the uterus to release prostaglandin. In a pregnant animal prostaglandin is not secreted, the CL is not destroyed. Instead, the CL remains on the ovary producing large amounts of progesterone to support embryo development and prevent the cow from returning to standing estrus. The CL remains functional until the pregnant cow approaches the time of parturition.

Standing Estrus to Ovulation – optimum timing of insemination

Characterization of events occurring during the period of standing estrus have become more accurate since the development of an automatic system for detection of estrus utilizing radio telemetry (HeatWatch®, CowChips, LLC, Manalapan, NJ). When a cow is mounted, a battery-powered, pressure-sensing device placed on the tailhead transmits a radio signal to a receiver linked to a personal computer. The data collected includes: date, time and duration of mounting events.

Several studies combining HeatWatch® electronic estrus detection or frequent visual evaluation with ultrasonagraphy of ovaries have been conducted to describe the behavior of dairy and beef cattle during estrus, as well as to determine the timing of ovulation relative to the onset of estrus (Table 1). In general, dairy cattle have a shorter duration of estrus and exhibit fewer mounts during estrus than beef cattle. Despite differences in behavior patterns, the average timing of ovulation reported for dairy cattle (27 to 30 hr after the onset of estrus) has been similar to that reported for beef cows or heifers (31 to 32 hr).

Table 1. Behavior during the period of standing estrus and the timing of ovulation in dairy and beef cattle.

Dairy/ Beef	Duration of estrus (hr)	Total mounts during estrus	Interval from start of estrus to ovulation (hr±s.e.m.)	Reference
Dairy	9.5	10.1	27.6±5.4	Walker et al. 1996
Dairy	7.1	8.5	NA*	Dransfield et al., 1998
Dairy	11.8	NA	30.0±5.1	Roelofs et al., 2005
Beef	14.0	50.1	NA	Stevenson et al., 1996
Beef	10.1	35.1	NA	Rorie et al., 2002
Beef	13.9 to 17.6	38.2 to 59.0	31.1±0.6	White et al., 2002
Beef	15.3	36.5	32.0±4.4	Utt et al., 2003

*NA – data not available for this endpoint

Timing of ovulation relative to estrus has been considered the key variable to consider when determining the timing of AI needed to maximize pregnancy rate. Trimberger (1948) and Trimberger and Davis (1943) were among the first to report that maximum conception rates occurred when insemination was performed from mid-estrus until a few hours after the end of standing estrus. Their work led to the development of the AM-PM rule in which 1) cows observed in estrus during the AM were assigned to be inseminated during the next PM, and 2) cows observed in estrus during the PM were assigned to be inseminated during the next AM. More recently, Dransfield et al. (1998) conducted a large field trial (2,661 inseminations) during which the effect of differences in the timing of insemination relative to the onset of estrus detected with HeatWatch® was evaluated. The highest pregnancy rates following AI occurred when cows were inseminated between 4 and 12 h after the onset of standing activity (Figure 2).

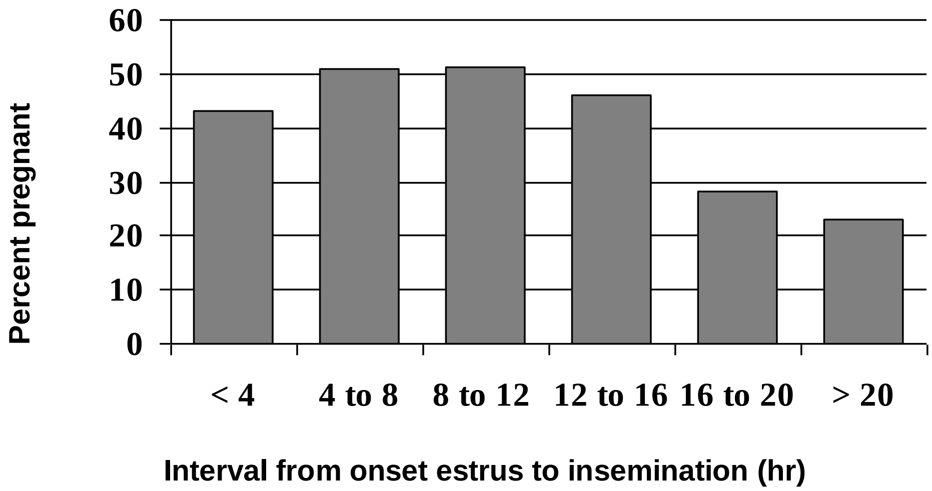

Figure 2. Pregnancy rates following AI in lactating dairy cows detected in estrus by HeatWatch® (adapted from Dransfield et al. 1998).

White et al. (2002) conducted a trial designed to determine the timing of ovulation in non-lactating beef cows relative to detection of estrus with HeatWatch®. Although they did not inseminate the cows, they speculated, based on the timing of ovulation, that optimal timing for insemination should be 14 to 20 hr after the onset of estrus in beef cows. Their recommendation to inseminate beef cows later than the times recommended by Dransfield et al. (1996) for dairy cattle was based on: 1) the longer interval from onset of estrus to ovulation recorded in their study (31.1 hr) than that reported by Walker et al (1996) for dairy cattle (27.6 hr); and 2) the belief that the number of sperm available for fertilization declined the longer sperm resided in the female reproductive tract prior to ovulation. However, they recognized the need for the sperm to be in the reproductive tract a minimum of 8 hr prior to ovulation in order to reach the upper oviduct and be capable of fertilizing the ovum.

Dalton et al. (2001) employed a different approach to determine the optimum timing for insemination relative to the onset of estrus. They inseminated single-ovulating, non-lactating dairy cows with semen at 0, 12 or 24 hr after the onset of estrus was detected using HeatWatch® and evaluated the quality of embryos recovered by flushing the uterus 6 d after insemination. Fertilization rate tended to increase as inseminations were performed later after the onset of estrus and closer to the time of ovulation: 0 hr (66%); 12 hr (74%) and 24 hr (82%). However, the quality of the embryos recovered was greatest (77% excellent/good) when cows were inseminated at 0 hr, intermediate (52% excellent/good) when inseminations occurred at 12 hr and lowest (47% excellent/good) when cows were inseminated at 24 hr after the onset of estrus. Likewise, the percentage of poor quality embryos was highest (34%) in the cows inseminated 24 hr after the onset of estrus. These and other experiments caused this research group to hypothesize that the optimum timing of AI may be a “compromise” between the quest to attain high fertilization rates or the desire to enhance embryo quality. They suggested early inseminations may result in lower fertilization rate, but produce embryos with higher quality, whereas, late inseminations may result in a higher fertilization rate, but poor embryo quality. Their recommendation was to follow the traditional AM-PM rule and breed cows approximately 12 hr after detection of estrus.

Conclusion

Once-daily insemination regimens have been reported to results in pregnancy rates equal to breeding by the AM-PM rule (Foote 1978; Nebel et al., 1994). Likewise, pregnancy rates following a single, timed insemination of cows coincident with the administration of GnRH to induce ovulation 30 hr later have been reported to be similar to those recorded when breeding after estrus detection (Larsen et al., 2006). These results indicate that the "window of opportunity" for timing of AI may be longer than commonly believed. They also indicate that satisfactory pregnancy rates can occur following insemination up to 30 hours prior to ovulation. Nonetheless, in well-controlled studies, using electronic devices to detect the exact time of the onset of estrus relative to time of AI, the data on fertilization rate, embryo quality and pregnancy rates indicate the time-tested AM-PM rule, which assign cattle to be bred 12 hr after detection of estrus, still represents the optimum timing for AI.

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