Improving Dairy Cattle Reproductive Performance

Ray Nebel
Department of DairyScience, Virginia Polytechnic Institute and State University

Take Home Message

- A calving interval of 13.5 months is an achievable goal that will produce higher daily milk yield and higher milk yield over the length of the lactation. To achieve this goal average days to first service should be <80, yearly 21-day Pregnancy Rates should average >20% and culling for reproductive failure should not exceed 10%.
- Management must set standard operating procedures for all aspects of the breeding program, such as, heat detection, artificial insemination techniques, hormone injection protocol for synchronization program, and treatment of problem cows. The management team should established protocols and operating procedures to be followed by all involved.
- Intensive management of the nutrition, feeding system, and environment of the periparturient dairy cow during the transition period reduces the odds of disease and increases the odds of pregnancy in a timely manner. Average loss in body condition score (BCS) should be approximately one point. Cows should calve having a BCS ranging between 3.25 and 3.75.
- The goal should be to have 100% of the cows inseminated within 24 days of the voluntary waiting period.
- Pregnancy rate is the benchmark that incorporates submission rate and conception rate in a timely fashion and should be the cornerstone of reproductive performance monitoring.

Introduction

The artificial insemination of cattle has been important in reducing disease transmission, allowing for genetic selection, and ultimately increasing the health, longevity, and milk yield of dairy cattle. Increased milk yield, dependence on human labor for the detection of estrus, and increased herd size have combined to furnish an environment that challenges management's ability to maintain an acceptable level of reproductive performance. Under optimal conditions, the reproductive process is less than perfect because of the multitude of factors involved in producing a live calf. Reproductive decline in dairy cows began in the mid-1980's and may be continuing on today's dairy farms.

During the past 50 years that AI has been practiced in the U.S. the fertility of virgin heifers has remained relatively constant at approximately 65% first service conception; whereas, the first service conception rate for lactating cows has decreased approximately 33% from 60 to 40%. Most of the discussion about reproductive decline in dairy cattle has centered on the effects of milk production on reproduction. There is a long history of associating greater milk production with reduced reproductive performance in dairy cows. An antagonistic relationship exists between milk production and reproduction in dairy cows. However, the effects of increased milk production on reproduction are relatively minor compared to the effects of other factors. Practical experience also suggests a weak link between milk production and reproduction in dairy cows. Days open and interval to first service decrease for lowest to highest producing herds. Services per conception increases in high producing herds but so does estrous detection efficiency. The improved reproduction in high-producing herds probably reflects a higher level of management that includes better nutrition as well as greater cow comfort and cleanliness.

Better management compensates for a slight decline in reproductive efficiency caused by level of production in the best dairy cows. Figure 1 diagrammatically illustrates the major categories of the reproductive management program that will be discussed. **There are no magical solutions to the reproductive decline in high-producing dairy cows.** Cows selected for high milk production partition nutrients toward lactation. The partitioning of nutrients leads to cows with less adipose tissue mass (lower body condition) and greater infertility. Feeding more energy will probably not solve reproductive problems completely but do appear to lessen its impact because cows will partition the additional nutrients toward milk production. For the immediate future, the best approach will be to intensively manage the reproductive biology of the cow.

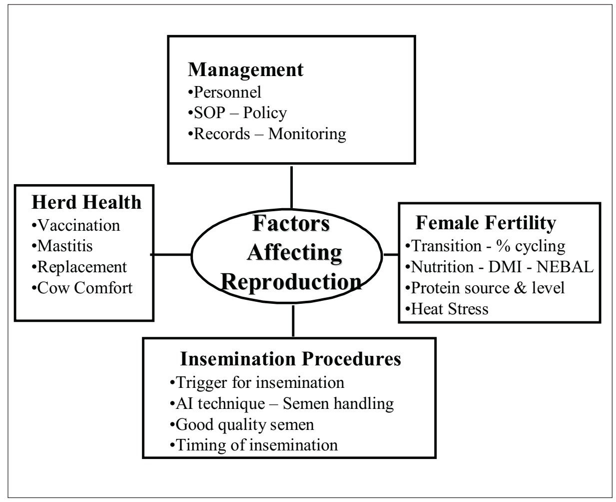

Figure 1. The four major components affecting the reproductive performance of dairy herds.

Management

Personnel and Standard Operating Procedures (SOP): Successful reproduction begins with dedicated knowledgeable personnel that are motivated and enjoy working with cattle. Factors governing successful reproductive performance are numerous and often complex in nature. Standard operation procedures (SOP) must be put in place for all tasks that are required to obtain and maintain pregnancy and high milk yield. Managers who recognize the importance of good performance usually have an understanding of the losses in potential income that occur when pregnancy rates are too low and when reproductive culling rates are too high. They are therefore motivated to develop and maintain an effective reproductive management program.

A feeding program that maximizes dry matter intake (DMI) and allows for a smooth transition from the dry period to peak milk yield with minimal body condition loss has the greatest beneficial effect on the reproductive process. The transition period is a time of considerable metabolic adjustment for dairy cows. Sub-optimal nutrition during this time period may convey nutritional stress on the cows that may be manifested as one or more of the common periparturient disorders. Attention must be given to formulating appropriate diets for cows during the far-off and close-up dry periods and for the fresh cow. The 2001 NRC guidelines provide a solid foundation for feeding close-up cows. In addition to ration formulation and monitoring, feeding management and grouping strategies may impact transition success.

Successful herd reproduction requires meticulous attention to detail. Heat detection, time of insemination relative to onset of estrus, semen handling, AI technique, and pregnancy diagnosis are examples of a few of the important task that must occur. Minor mistakes in these everyday jobs have cumulative effects on herd reproduction. Progress in improving reproduction can only be made after these basic tasks are practiced correctly and consistently. A primary function of management is to establish SOPs that work for that farm and employees, to obtain the desired reproductive outcome.

Cow Comfort: It is difficult to present scientifically defensible definitions and specifications for what constitutes "cow comfort", but there is no doubt that a good manager "knows it when they see it". These may include heat stress, overcrowding, infectious challenge, poor ventilation, poor footing, uncomfortable stalls, poor management of grouping and cow movement, and rough handling. Overcrowding is common in free-stall barns and moderate overcrowding has been reported not to affect milk production if feeding management is good;

however, overcrowding should be avoided in the close-up and just-fresh pens. Every cow needs to have a comfortable stall to lie in. Cows naturally seek to isolate themselves from other cows as parturition approaches; in such animals the inability to do so in confinement constitutes a major social stress.

The stress response consists of recognition of a stressor, the biological defense against the stressor, and the consequences of the stress response. It is this last stage that determines whether a cow's productivity and reproduction will be compromised (the stress becomes "distress") or whether the event passes without impact. In many cases the expedient response of an animal is behavioral, by attempting to remove itself from the vicinity of a stressor. For example, a timid cow will move away from the perceived threat of a "boss" cow. When this behavioral response is prevented or limited, say by overcrowding in confinement housing, then the impact on the timid cow may be more negative.

Records and Monitoring: Complete and accurate herd records should provide the tools necessary to define past herd performance, assist in establishing goals for the benchmarks being evaluated, and allow monitoring to determine the impact of the plan developed to reach an established goal. The first step in record analysis is to identify key benchmarks that reflect components of reproductive performance that affect the desired outcome or goal. In fact, on many farms data overload is the problem where too much information is available and decisions must be made on what parameters are really important and useful. Goals must be applied with caution and may not be appropriate for intervention on an individual cow basis. It is also important to be practical and reasonable in applying goals especially in cases where vast improvement in performance is needed.

What is the reproductive status of herds? What should be expected for dairy herds in the upper mid-west? Records for all Holstein herds (n = 1,745) that process their records at Dairy Records Management Systems (DRMS, Raleigh, NC) over the past 12 months is summarized in Table 1. The average Holstein herd had a rolling herd average for milk of 20,754 lbs but the ranged was 10,048 to 33,321 lbs. Daily milk yield averaged 68.7 lbs but ranged from 30 to 112 lbs. Yearly average pregnancy rate for the period of April 2004 to March 2005 was 14 ± 5%. Another Interesting statistic was herd size that ranged from 20 to 3,415 cows with an average of 100 cows per herd.

The production—reproduction debates may lead one to believe that herds with above average reproduction must be herds that have below average milk production. The right column in Table 1 list the 127 herds in IA, IL and WS that process their DHI records with DRMS and whose average yearly 21- day pregnancy rate was ³ 20%. Approximately 12% of all herds averaged ³ 20% pregnancy rate and interesting the daily milk production was 6 lbs greater for these herds. Day open was 56 day lower, day to first service 16 day lower, heat detection rate was 49 versus 40%, and conception rate at first service was 47 versus 33%.

Female Fertility

Transition from dry to milking herd: Fertility is a broad term that is a combination of factors such as, sperm transport, fertilization, the uterine environment, oocyte quality, hormone production, and embryo maintenance. One of the major factors influencing fertility in dairy herds is calving. Calving places the cow at risk for various disorders such as, metritis, retained placenta, dystocia, milk fever and may contribute to the decline in fertility of the population. Analysis of traditional production costs rank mastitis, reproductive problems, and lameness as the top dairy cattle diseases (Wells et al., 1998). However, when other important diseases are included, the top-ranked diseases change to Johne's disease, bovine viral diarrhea, and mastitis caused by salmonella.

Typically, cows that experience a postpartum problem will have conception rates one half that of normal cows. Ketosis and lameness do not appear to have the same effect as metritis in reducing conception rates; however, many studies have identified these conditions as having a significant impact on fertility. The impact of retained placenta on conception rate may be dependent upon the development of secondary disease, such as metritis or ketosis. Lameness has had varying impacts on fertility and may depend on the time postpartum when it occurs and the severity of the problem. Metritis and systemic metritis may be perceived as conditions associated with hygiene and stress at calving. Retained placenta, milk fever, uterine prolapse, and grass tetany are directly associated with dry cow feeding and mineral content in dry cow rations. Ketosis, laminitis, fatty liver, and ovulatory dysfunction, particularly anestrus, may be viewed as metabolic dysfunctions associated with energy balance. In addition, excessive body condition loss should be detected as a problem with energy management and will reduce fertility. The magnitude and duration of negative energy balance depends more on dry matter intake than milk yield.

Dry Matter Intake (DMI) and Negative Energy Balance (NEBAL): Prevention of excessive mobilization of body fat in the first 4 weeks of lactation is of primary importance for subsequent fertility. Cows will tolerate a loss of approximately 1 body condition scoring unit in the first 4 weeks after calving; more extreme condition loss will predispose her to lower conception rates at first service. Researchers at the University of Florida have shown that the pregnancy rates to timed AI was approximately 12% lower for cows with a BCS less than 2.5, compared to cows with a BCS greater than 2.5 (Moreira et al., 2000). The mobilization of body fat post-calving actually begins prior to parturition, as seen from profiles of serum lipids. One unit change in body condition score represents about 120 lbs of body weight change and about 400 Mcal of energy. Feeding management that maximizes DMI is also essential to minimize body condition loss and have ovarian cycles start back approximately 3 weeks after calving.

Ideally, the third ovulation will occur by 50 days postpartum when uterine involution and repair will also be complete. Increased negative energy balance may delay first ovulation 60 to 75 days or longer extending the postpartum effects and recovery of the uterine environment.

In evaluating the reproduction cycle of the dairy herd, a 100-day period of critical importance exists. This period has been coined the ‘100-day contract’ and begins 30 days before calving and continues through first breeding at approximately 70 days postpartum (Spain and Scheer, 2002). The terms of the contract include the birth of a live calf with the cow remaining healthy during the transition period, high peak milk production, controlled loss of body condition, and high fertility at first breeding. The momentum toward successful achievement begins in the close-up dry cow group and builds through calving to first breeding. Getting the cow off the track at any point disrupts the momentum and can lead to ‘wrecks’. Wrecks include metabolic disorders during the periparturient period that can have long-term impact on production and reproduction.

Percent cycling by 50 DIM: The stimulation of appetite to ensure adequate DMI in normal, healthy cows is essential to provide nutrients for maximum milk production, follicular growth, ovulation, uterine involution, and the initiation of pregnancy. However, lactating dairy cows experience a postpartum NEBAL that reaches its lowest point during the first or second week postpartum and recovers at a variable rate. First ovulation usually occurs approximately 10 to 15 days after the point of greatest NEBAL and

Table 1. Reproductive status, herd size, and the milk yield rolling herd average (RHA) for Holstein herds that use AI ³ 90% located in IL, IA, and WI, and processed by Dairy Records Management Systems (DRMS, Raleigh, NC) compared to all Holstein herds that process records at DRMS and Holstein herds that 21-pregnancy rate (PR) ³20. [1]

Item	All HolsteinHerds	Holstein Herds IA, IL, & WS	Holstein Herds IA, IL, & WS $\geq$ 20 PR
No. of herds	12,231	1,080	127
Herd size	12620 to 3,751	10020 to 3,415	8420 to 632
Daily milk, (lbs)	69 ± 11.6	68.7 ± 11.9	72.6 ± 12.5
Actual calving interval, (mo)	14.2 ± 1.2	14.3 ± 1.3	13.6 ± 0.8
Days to 1st service	95 ± 25	101 ± 20	85 ± 16
Heat detection rate, (%)	45 ± 13	40 ± 14	49 ± 11
1st Service Conception rate, (%)	38 ± 17	33 ± 25	47 ± 15
21-Day PR Year Average	15 ± 5	14 ± 5	22 ± 3

[1] DairyMetrics reports were generated on April 15, 2005 using current DHI information (drms.org).

sometime before the peak in daily milk secretion (Butler and Smith, 1989; Zurek et al., 1995). Nevertheless, dairy cows with greater DMI, despite having a NEBAL, produced more milk, lost less body weight, and ovulated earlier postpartum than those with lower intakes (Staples et al., 1990; Zurek et al., 1995). Additionally, cows with greater intakes also reached their low point of energy balance earlier and experienced a more severe, but shorter, period of NEBAL, suggesting that when cows are more efficient in partitioning dietary and stored nutrients toward milk synthesis, they are also better able to recover ovarian cyclicity.

Increased feeding frequency and better feed bunk management to maintain a fresh, adequate supply of feed and multiple sources of clean water are critical for stimulating appetite and maximal DMI (Grant and Albright, 1995). Normally, peak DMI are achieved just following or coincident with zero energy balance at approximately 7 weeks postpartum and after peak daily milk production (Ingvartsen and Andersen, 2000). Milk production and DMI are stimulated by increased dietary protein, but decreased fertility often is associated with excess feeding of ruminally degradable protein as assessed by elevated blood or milk concentrations of urea (Butler,1998).

Concentrations of milk urea nitrogen exceeding 19 mg/dl are associated with altered uterine pH (Butler, 1998) and reduced fertility (Butler et al., 1996). The latter occurs when the NEBAL is exacerbated by excess intake of rumen degradable protein (Butler, 1998) and extreme loss in body condition after calving (Broster and Broster, 1998).

Heat Stress: Fertility in dairy cows is depressed during the summer months in warm areas of the world (Hansen, 1997). This depression is caused essentially by heat stress. Experimental application of heat stress reduced fertility and increased embryonic mortality, while alleviation of heat stress during the summer increased fertility. The magnitude of the seasonal depression in fertility is influenced by environmental factors that define the extent of heat stress and internal factors of the cow that determine her ability to regulate body temperature during heat stress.

There is a greater reduction in fertility during the summer for lactating cows than for non-lactating heifers. High milk yield exacerbates the effects of heat stress on fertility. The major reason for high milk yield provoking the effects of heat stress on fertility is related to the increased metabolic rates and decreased thermoregulatory ability for cows with high milk yield. Berman et al., (1985) found that among cows exposed to temperatures within the range of 50 to 78°F, rectal temperature increased 0.03°F for each 2.2 lbs of fat-corrected milk a cow produced above 53 lbs per day.

Insemination Procedures

Trigger for insemination: The greatest limiting factor to successful fertilization is associated with detection of estrus. Accuracy of estrus detection is defined as the percentage of cows identified in estrus that are indeed in true estrus. Inaccuracies occur when cattle are inseminated at times other than true estrus. Examining the frequency distribution of inter-estrual intervals has been shown to be helpful in documenting errors in the detection of estrus. Two characteristics specific to estrus detection error are: (1) more than 10% of the inter-estrual intervals are between 3 and 17 days, and (2) cows are verified pregnant or to calve to breeding prior to the one last recorded.

In a large field study involving herds in the Northeast U.S., Reimers et al., (1985) reported that 5.1% of the cows presented for insemination were not in estrus based on high milk progesterone levels. The error rate varied from 0 to 60% among herds and 10% or more of the cows inseminated were not in estrus from 30% of the herds. Numerous other studies using milk progesterone analysis have shown that 5 to 15% of cows are inseminated when they are not in or near estrus.

Timed AI: Timed AI for dairy cattle is an important change in reproductive management because cows are inseminated without detection of estrus. The discovery that a follicular wave could be synchronized to improve the consistency of the follicular development around GnRH - $PGF2\alpha$ - GnRH injections was an important step forward because it improved the responses to timed AI and enabled the widespread implementation of Timed AI programs coined Ovsynch or Presynch/Ovsynch being the two most commonly used in the dairy industry.

Use of Timed AI programs such as Ovsynch or Presynch/Ovsynch for initiating first service at or every near the end of the voluntary waiting period (VWP) has consistently reduced days to first service and increased the pregnancy rate for the first 21 days following the VWP. Use of hormone injection protocols such as, Ovsynch or Presynch/

Ovsynch are excellent approaches to first service but calving rates after first service timed AI using these programs are approximately 25 to 40%. Therefore, it is very important to identify non-pregnant cows post-AI as soon as possible and return cows failing to conceive to a subsequent AI service. Thus, heat detection is still an important component of the reproductive program even when a Timed AI program is used for first service. However, in the best herds only 50 to 60% of the cows that did not conceive will be detected in estrus 18 to 24 days following insemination. Now that it is relatively easy to program cows to receive first service research is concentrating of methods to identify open cows to submit them to a subsequent AI service.

AI techniques: The highest quality semen placed in the healthiest cow at just the right time will not produce a calf if the breeding technique is not proper. Practice is required to develop the skill, which should be learned and periodically reviewed with the assistance of professionals. One of the most critical components of the insemination technique is depositing the semen anterior to the cervix. The major reason why sperm numbers can be markedly lower for frozen and thawed semen used in AI is that the cervix, which is the major barrier to sperm transport, is bypassed in correct semen deposition.

Many studies have compared semen deposition near the greater curvature of the uterine horns with conventional deposition into the uterine body. Although Senger et al. (1988) and Lopez-Gatius (1996) reported increased conception rates when semen was deposited in the uterine horns rather than the uterine body, Williams et al. (1988), McKenna et al. (1990), and Hawk and Tanabe (1986) found no difference in fertility when comparing uterine body and uterine horn inseminations. It is not clear why a few studies have shown fertility advantage following uterine horn insemination while others have not. A possible explanation for the difference may be related to the minimization or elimination of cervical depositions with horn placement. Cervical deposition accounts for approximately 20% of attempted uterine body depositions (Peters et al., 1984). Macpherson (1968) reported that cervical insemination resulted in a 10% decrease in fertility when compared with deposition in the uterine body. Clearly, all AI technicians must develop sufficient skills to recognize when the tip of the AI pipette remains in the cervix.

Good quality semen: What is the range in fertility of sires available from AI organizations? Estimated relative conception rate (ERCR), is a measure of conception rate of a service sire relative to service sires of herdmates and are calculated by the DHI processing center DRMS in Raleigh, NC. These conception rate summaries are available from the DRMS website at http://www.drms.org and updated twice yearly during May and November.

ERCR is expressed as a percent difference of conception rate from the average AI service sire of herdmates. For example, ERCR values published in the November 2004 summary for Holstein bulls ranged from -6 to +5. Holstein sires summarized between 1998 and 2000 ranged from -11% to +5%. This means that the average service to the most fertile bull produced a calf 5% more often than a service to the average AI service sire of herdmates. Similarly, a service to the least fertile bull produced a calf 11% less often. The average value was 0 and there were approximately equal numbers of positive and negative values. Although the values in 2004 had a range of 11 percentage points, 77% of the bulls were in the range of -1% to +2%.

AgriTech Analytics (Visalia, CA) calculates a relative conception rate for Holstein and Jersey sires from 595 herds located in the Western USA that use their DHI processing center. Their fertility index is based on actual veterinary confirmed pregnancies in contrast to ERCR values which are based on 70 day non-return calculations. The results from the most recent summary of 2,181,904 AI records between January 1, 2002 and November 30, 2004 for 1,355 bulls that had a minimum of 10 services in 10 herds ranged from a high of + 6.2% to a low of - 8.8%.

Timing of insemination: The key to proper timing of insemination and maximizing fertilization rates is to inseminate cows at a time to allow ovulation to occur when adequate numbers of motile sperm are present in the oviducts. Timing of insemination should be based on the frequency of heat detection. A general recommendation for timing of insemination is that when only one daily period is used for the detection of estrus, insemination should occur soon after the detection period has ceased, when two observation periods are used approximately 12 hours apart, insemination should occur 4 to 8 hours following detection. When three observation periods are used approximately 8 hours apart, insemination should occur 4 to 12 hours following detection (Nebel and Jones, 2002). Optimal timing of AI should occur between 4 and 14 hours after the first standing event detected by the HeatWatch system (Dransfield et al., 1998) or between 6 and 17 hours after increased pedometer readings (Maatje et al., 1997).

Herd Health

Vaccination program: Appropriate preventative herd health programs should include a vaccination program for cows and replacement heifers, deworming of animals on pasture, mastitis control, hoof care, reproductive exams for pregnancy and non-cycling cows. A comprehensive discussion and review of vaccines and vaccination programs should routinely occur with the herd practitioner. Vaccination programs for lactating cows should be centered around the dry period and during the first 30 day in milk to afford maximum protection (Hjerpe, 1990).

Mastitis: Evidence is mounting that cows with mammary infections are predisposed to early pregnancy losses because of disruption of normal luteal maintenance. Cows that had clinical mastitis during the first 45 days of gestation were at 2.7 times greater risk for abortion during the next 90 days than cows without mastitis (Risco et al., 1999). Several reproductive traits (days to first service, days open, and services per conception) were impacted negatively in cows with clinical mastitis of both gram-positive and gram-negative organisms when compared with healthy controls (Barker et al., 1998; Schrick et al., 2001).

Treatment or replacement of problem cows: The major factor influencing fertility in dairy herds is first calving. Heifers have conception rates close to theoretical optimal values. First calving reduces the conception rate 35 to 50%. The question is why this tremendous reduction after parturition. Every calving places the cow at risk for metritis, retained placenta, dystocia, milk fever and other metabolic diseases that contribute to the decline in fertility of the population. Typically cows that experience a postpartum problem will have conception rates one half that of normal cows. Ketosis and lameness do not appear to have the magnitude of metritis or abnormal lochia in reducing conception rate; however, many studies have identified these conditions as having a significant impact on fertility. The impact of retained placenta on conception rate may be dependent upon the development of secondary disease, such as metritis or ketosis. Lameness has had varying effects on fertility and may depend on the time postpartum when it occurs and the severity of the problem.

Metritis, abnormal lochia, systemic metritis may be perceived as conditions associated with hygiene and stress at calving. Retained placenta, milk fever, uterine prolapse, and grass tetany are directly associated with dry cow feeding and mineral content in dry cow rations. Ketosis, laminitis, fatty liver, and ovulatory dysfunction, particularly anestrus, may be viewed as metabolic dysfunctions associated with energy balance. In addition, excessive body condition loss should be detected as a problem with energy management that will reduce fertility. Reproductive replacement usually ranks as the first or at least second most common reason for voluntary disposal.

Conclusions

Throughout her herd life, a cow should calve without difficulty, experience little or no postpartum reproductive disease, breed back within an optimal time period, carry each fetus to term, and have a live birth. There are no magical solutions to the reproductive decline in high-producing dairy cows. Cows selected for high milk production partition nutrients toward lactation. The partitioning of nutrients leads to cows with less adipose tissue mass (lower body condition) and greater infertility. For the immediate future, the best approach will be to intensively manage the reproductive biology of the cow. This management should include synchronization of first service with timed AI and may include resynchronization of second and third services. A genetic approach that incorporates reproductive and health traits in selection indices will correct some of the reproductive decline, but this will be a long-term fix. It is also likely, that continued research in the area of postpartum reproduction of dairy cattle would reveal critical pieces to this puzzle that can help improve reproductive efficiency in dairy cattle.

References

Berman, A.,Y. Folman, M. Kaim, M. Mamen, Z. Herz, D. Wolfenson, A. Arieli, and Y. Graber. 1985. Upper critical temperatures and forced ventilation effects for high-yielding dairy cows in a subtropical climate. J. Dairy Sci. 68:1488-1495.

Barker, A.R., F.N. Schrick, M.J. Lewis, H.H. Dowlen, and S.P. Oliver. 1998. Influence of clinical mastitis during early lactation on reproductive performance of Jersey cows. J. Dairy Sci. 81:1285-1290.

Broster, W.H., and V.J. Broster. 1998. Body condition score of dairy cows. J. Dairy Res. 65:155-173.

Butler, W.R. 1998. Review: Effect of protein nutrition on ovarian and uterine physiology in dairy cattle. J. Dairy Sci. 81:2533-2539.

Butler, W.R., J.J. Calaman, and S.W. Beam. 1996. Plasma and milk urea nitrogen in relation to pregnancy rate in lactating dairy cattle. J. Anim. Sci. 74:858-865.

Butler, W.R. and R.D. Smith. 1989. Interrelationships between energy balance and postpartum reproductive function in dairy cattle. J. Dairy Sci. 72:767-783.

Dransfield, M.G.B., R.L. Nebel, R.E. Pearson, and L.D. Warnick. 1998. Timing of insemination for dairy cows identified in estrus by a radiotelemetric estrus detection system. J. Dairy Sci. 81:1874-1882.

Grant, R.J. and J.L.Albright. 1995. Feeding behavior and management factors during the transition period in dairy cattle. J. Anim. Sci. 73:2820-2833.

Hawk, H.W. and T.Y. Tanabe. 1986. Effect of unilateral corneal insemination upon fertilization rate in superovulating and single-ovulating cattle. J. Anim. Sci. 63:551-560.

Hansen, P.J. 1997. Effects of environment on bovine reproduction. In: Current Therapy in Large Animal Theriogenology, RS Youngquist, ed., W.B. Saunders, Philadelphia, pp 403-415.

Hjerpe, C.A. 1990. Bovine vaccines and herd vaccination programs. Vet. Clin. North. Am. Food Anim. Pract. 6:167-260.

Ingvartsen, K.L. and J.B. Anderson. 2000. Integration of metabolism and intake regulation. A review focusing on periparturient animals. J. Dairy Sci. 83:1573-1597.

Lopez-Gatius, F. 1996. Side of gestation in dairy heifers affects subsequent sperm transport and pregnancy rates after deep insemination into one uterine horn. Theriogenology. 45:417-425.

Maatje, K., S.H. Loeffler, and B. Engel. 1997. Predicting optimal time of insemination in cows that show visual signs of estrus by estimating onset of estrus with pedometers. J. Dairy Sci. 80:1098-1105.

Macpherson, J.W. 1968. Semen placement effects on fertility in bovines. J. Dairy Sci. 51:807-808.

McKenna, T., R.W. Lenz, S.E. Fenton, and R. Ax. 1990. Nonreturn rates of dairy following uterine body or corneal insemination. J. Dairy Sci. 73:1779-1783.

Moreira, F., C.A. Risco, M.F.A.. Pires, J.D. Ambrose, M. Drost, M. DeLorenzo, and W.W. Thatcher. 2000. Effect of body condition on reproductive efficiency of lactating dairy cows receiving a timed insemination. Theriogenology. 53:1305-1319.

National Research Council. 2001. Nutrient requirements of dairy cattle. 7th rev. ed. Natl. Acad. Sci., Washington, DC.

Nebel, R.L. and C. M. Jones. 2002. Detection of oestrus. In : Encyclopedia of Dairy Sciences, Eds. H. Roginski, J.W. Fuquay, and P. F. Fox. Academic Press, San Diego, CA, pp. 1757-1763.

Peters, J.L., P.L. Senger, J.L. Rosenberger, and M.L. O'Connor. 1984. Radiographic evaluation of bovine artificial inseminating technique among professional and herdsman-inseminators using .5-ml and .25-ml French straws. J. Anim. Sci. 59:1671-1683.

Reimers, T.J., R.D. Smith, and S.K. Newman. 1985. Management factors affecting reproductive performance of dairy cows in the northeast United States. J. Dairy Sci. 68:963-977.

Risco, C.A., G.A. Donovan, and J. Hernandez. 1999. Clinical mastitis associated with abortion in dairy cows. J. Dairy Sci. 82:1684-1689.

Schrick, F. N., M. E. Hockett, A. M. Saxton, M. J. Lewis, H. H. Dowlen, and S. P. Oliver 2001. Influence of subclinical mastitis during early lactation on reproductive parameters. J. Dairy Sci. 84:1407-1412.

Senger, P.L., W.C. Becker, S.T. Davidge, J.K. Hillers and J.J. Reeves. 1988. Influence of cornual inseminations on conception in dairy cattle. J. Anim. Sci. 66:3010-3016.