The Key to a Successful Reproductive Management Program

Ray L. Nebel

Department of Dairy Science, Virginia Tech, Blacksburg, Virginia 24061
Email: rnebel@vt.edu

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.
- Management must set standard operating procedures for all aspects of the reproduction program such as, heat detection, artificial insemination techniques, hormone injection protocol for synchronization program, and treatment of problem cows and policy established by management must be followed by all.
- 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.
- The goal of any program should be to have 100% of the cows inseminated within 24 days of the voluntary waiting period.
- Pregnancy rate is the benchmark that incorporates service rate and conception rate in a timely fashion and should be the cornerstone of performance monitoring.

Introduction

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. 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.

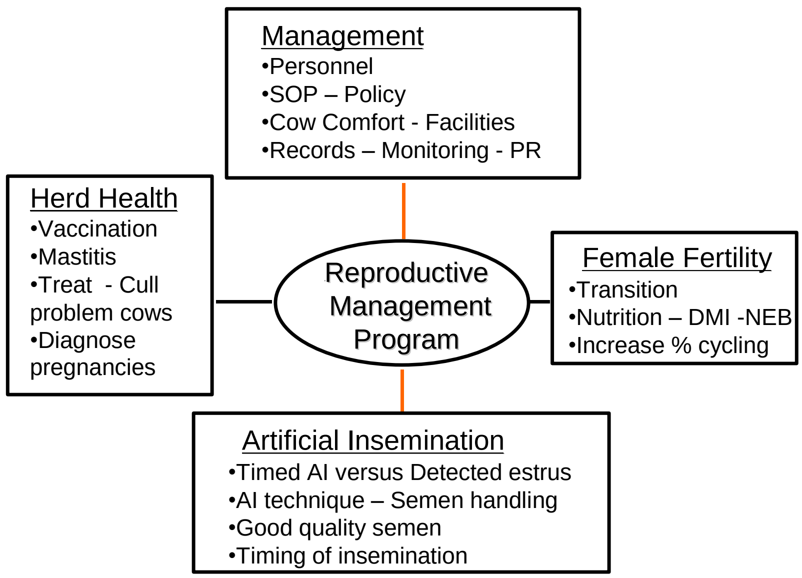

Figure 1. The four major components that should comprise the reproductive management program of dairy herds.

▪ What Should be the Goal for Reproductive Performance of Dairy Herds?

Table 1 was constructed using DairyMetrics reports from DRMS (Raleigh, NC). In Table 1, herds were stratified by calving interval with daily milk yield, Projected 305 day ME milk, days in milk, and various reproductive performance variables listed. Using daily milk yield as an indicative variable a calving interval of less than 14 months should be the goal. Using Projected 305 day ME milk yield as the controlling variable the ideal calving interval could be narrowed to 13 to 13.9 months. With each monthly increase above a 13.9-month calving interval daily milk yield dropped 1.5 to 2 kg and projected ME milk dropped almost linearly from 10,750 kgs for a 13- to 13.9-month calving interval to 9,450 kgs for herds having a calving interval greater than 16.9 months. Approximately one-third of the Holstein herds (n=1545) had a calving interval less than 14 months, so a calving interval < 14 months is an achievable goal that will produce higher daily milk yield and higher milk yield over the length of the lactation.

Calving interval is determined by days to first service, heat detection efficiency and conception rate. Herds that obtained a calving interval less than 14 months averaged less than 83 days to first service identified approximately 50% of the expected estrus periods and achieved conception rates above 40% on first service. It is interesting that conception rates at first service ranged from 40 to 47% with herds with both the shortest or longest calving interval having a first service conception rate of 47%. The variables that really determine calving interval are days to first service and heat detection, with heat detection having a strong influence of days to first service.

There are consequences to lowering the voluntary waiting period from 60 to 45 days. Conception rates are usually (almost always) lower when first service occurs less than 60 days in milk and days open are not reduced the expected 12 to 15 days because of this. Additionally, if a cow becomes pregnant at 45 days in milk she will have a very short calving interval of 10½ months, which equals a 265-day lactation period. Only cows with below average milk production should be considered for breeding with a voluntary waiting period of 45 days. All cows should have at least one service prior to 100 days in milk. The primary reason for extended days to first service is poor heat detection efficiency. As seen in Table 1 the real problem on most farms is heat detection or putting semen in cows either for first service or once breeding has been initiated for return or repeat services. However, conception rates have declined over the past 20 years, approximately 10 percentage points for a 20% decline from about 50% in 1982 to 40% in 2002.

Table 1. Change in daily milk yield, days in milk, 305 day ME milk, and reproductive performance for Holstein herds (n=4771) processed by DRMS and stratified by calving interval[1].

	Calving Interval (months)					
Item	**<13**	**13 to 13.9**	**14 to 14.9**	**15 to 15.9**	**16 to 16.9**	**>16.9**
Number of herds	129	1416	1856	919	290	161
Average herd size	83	159	160	157	125	165
Daily milk yield (kgs)	30.2	30.5	29.2	27.4	26.1	24.3
Days in milk	156	178	197	216	236	262
Voluntary waiting period (d)	56	57	56	57	56	55
Days to 1st service	74	82	93	105	120	140
Conception rate 1st service	47	41	40	40	42	47
% heat observed	53	50	44	38	33	26
Projected 305 day ME milk (kgs)	10,320	10,729	10,553	10,162	9,794	9,431

[1] DairyMetrics reports were generated on September 11, 2002 using current DHI information for Holstein herds that have a twice daily milking schedule and 25% or less of the services were to non-AI sires.

■ Management

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 (SOPs) 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 newly released NRC guidelines (2001) 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 those good managers "know it when they see it". Today's dairy cow may face a wide variety of environmental stressors. 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 present performance is recommended.

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. The ability to use records effectively is one of the cornerstones of reproductive management. Table 2 list current levels of five reproductive management benchmarks for Virginia DHI herds consisting of Holstein cows that that have a rolling herd average for milk greater than 10,000 kgs. My goal level and a level where I recommend a management change or intervention is warranted is also listed.

Table 2. Five benchmarks with goals and intervention levels for monitoring the reproductive status compared with current levels for selected Virginia DHI herds. Days open and calving interval are the same parameter expressed in days from calving to conception or from one calving to the next.

Parameter	Goal	Intervention level	[1]VA DHI herds >10,000 kgs RHA milk
Days open	140	175	156
Calving interval, months	13.5	15	14.4
Days to first service	75	100	91
Conception rate, first service, %	45	30	39
Heat detection rate, %	60	40	48
Pregnancy Rate	22	12	16

[1] DairyMetrics report was generated on November 26, 2002 using current DHI information for Virginia Holstein herds that have greater than 10,000 kgs rolling herd average for milk (n = 156 herds).

Pregnancy Rate. Many different measurements have been employed to assess reproductive performance. Some commonly used measurements include average days open, first service conception rate, annual services per conception and calving interval. Unfortunately, these measures can fail to detect changes in performance on a timely basis. Ultimately, the question of interest to dairy producers is “How many of the cows eligible to become pregnant actually became pregnant in a given time frame?” Since the value is in the pregnancy, a measurement is needed to detect the rate that pregnancies are occurring in eligible cows.

Recently, there have appeared articles in the popular press about using pregnancy rate to assess reproductive performance. Pregnancy rate can be defined as the percentage of cows eligible to become pregnant, in a given time frame that actually do become pregnant. A logical time frame would be 21 days, the typical length of an estrous cycle. The pregnancy rate calculation allows an assessment to not only determine how well cows are conceiving but also how quickly they are conceiving. Furthermore, by subdividing the breeding program into twenty-one day intervals, it can determine the effect of any recent changes on the breeding program. Pregnancy rate has often been defined as heat detection rate multiplied by conception rate. In many instances this will give a reasonable approximation of the actual pregnancy rate.

▪ Female Fertility

Fertility is a board 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. The risk for death is greater at calving than at any other period of the life cycle (Mather and Melancon, 1981). 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.

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 body condition score less than 2.5, compared to cows with a body condition score 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 55 kgs 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 (Figure 2). 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.

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 negative energy balance 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 negative energy balance and 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 negative energy balance, 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 negative energy balance, 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.

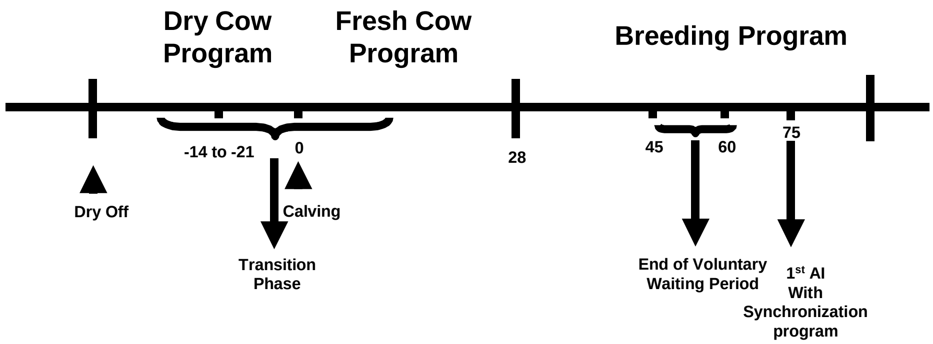

Figure 2. Timeline from the close-up dry period to first service that composes the '100 day contract' period in respect to the reproductive management events.

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 negative energy balance is exacerbated by excess intake of rumen degradable protein (Butler, 1998) and extreme loss in body condition after calving (Broster and Broster, 1998).

▪ Artificial Insemination

The greatest limiting factor to successful fertilization is associated with detection of estrus. Timed AI for dairy cattle is an important change in reproductive management because cows are inseminated without estrous detection. The discovery that a follicular wave could be synchronized to improve the consistency of the follicular development around PGF2a injection was an important step forward because it improved the responses to timed AI and enabled the widespread implementation of the method. Timed AI is a good approach on first service but calving rates after timed AI are approximately 20 to 40%. The fate of the 60 to 80% of dairy cows that are open after first insemination usually depends on detecting the return to estrus. The timing of second estrus after insemination is variable because many cows have an embryo that dies around the time of maternal recognition of pregnancy and the return to estrus is delayed. The fact that inseminated cows represent a mixture of pregnant and non-pregnant cows and that non-pregnant cows have a variable return to estrus complicates methods that can be used to synchronize second service.

Very few reliable methods are available for re-synchronizing of repeat service. A combination of timed AI and heat detection may be a solution for many herds. Figure 3 illustrates the survival curve for a 14% pregnancy rate and a survival curve if Timed AI with a 30% pregnancy rate was used for first service with a 14% pregnancy rate following first service. Instituting a timed AI program only for first service reduces days open by 30 days and simplifies the breeding protocol.

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.

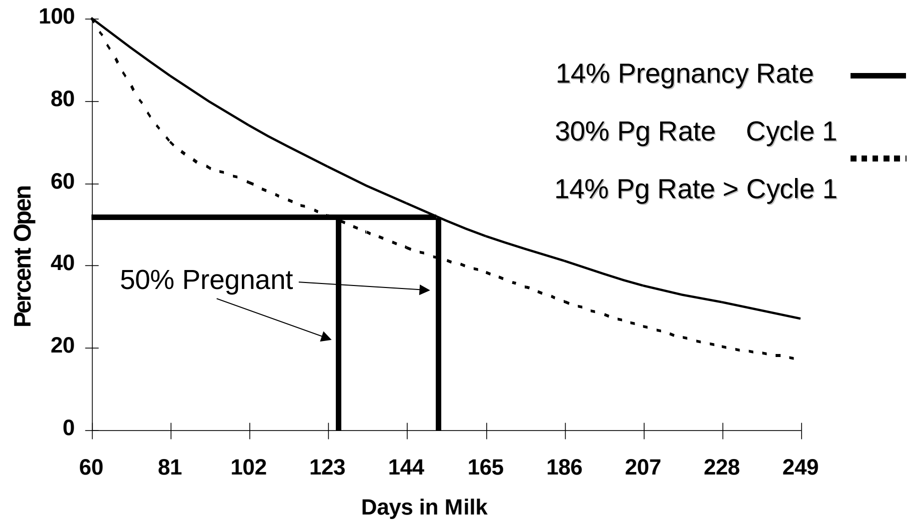

Figure 3. Survival curve for a 14% pregnancy rate compared to a survival curve where timed AI was used for first service only, with a 30% pregnancy rate initially and a 14% pregnancy rate following first service.

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.

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

More than 800 dairy producers surveyed in Alberta reported that their most frequent herd health concerns were mastitis, foot problems, and silent estrus (Spicer et al., 1994). 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).

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).

▪ Summary

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. This management should include treatment of anestrus, synchronization of first service, 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 will reveal critical pieces to this puzzle that can help improve reproductive efficiency in dairy cattle.

References

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.

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.

Mather, E., and J. Melancon. (1981) The periparturient cow – A pivotal entity In dairy production. J. Dairy Sci. 64:1422-1430.

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.

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.

Spain, J.M. and W.A. Scheer. (2002) The 100-day contract with the dairy cow: 30 days prepartum to 70 days postpartum. Advances in Dairy Technology. 14:1-15.

Spicer, H.M., L.A. Goonewardene, A.O. McNeil, and W.L. Slack. (1994) Alberta dairy farm survey response. J. Dairy Sci. 77:3460-3472.

Staples, C.R., W.W. Thatcher, and J.H. Clark. (1990) Relationship between ovarian activity and energy status during the early postpartum period of high producing dairy cows. J. Dairy Sci. 73:938-947.

Wells, W.J., S.L. Ott, and A.H. Seitzinger. (1998) Key health issues for dairy cattle new and old. J. Dairy Sci. 81:3029-3035.

Williams, B.L., F.C. Gwazdauskas, W.D. Whitter, R.E. Pearson, and R.L. Nebel. (1988) Impact of site of inseminate deposition and environmental factors that influence reproduction of dairy cattle. J. Dairy Sci. 71:2278-2283.

Zurek, E., G.R. Foxcroft, and J.J. Kennelly. (1995) Metabolic status and interval to first ovulation in postpartum dairy cows. J. Dairy Sci. 78:1909-1920.