FUTURE TRENDS IN REPRODUCTIVE MANAGEMENT

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Introduction: Reproductive decline in dairy cows

Lactation and the reestablishment of pregnancy overlap in most dairy production systems. Unfortunately, recent changes in the genetics and productivity of dairy cows have led to a decline in reproductive efficiency during lactation. Reproductive decline in dairy cows began in the mid-1980's and may be continuing on modern dairy farms. An examination of records from 143 dairies in the Eastern United States showed that calving interval averaged about 13.5 months until the mid-1980's and then subsequently increased to greater than 14.5 months by the late 1990's (Lucy, 2001). Butler (1998) presented data showing a decline in first service conception rate from approximately 65% in 1951 to 40% in 1996 (New York State dairy cows). Declining first service conception rates have also been reported in Ireland, the United Kingdom, and Australia. The North American dairy industry consists primarily of continuously calving herds and reproductive efficiency can be sacrificed for gains in productivity when cows calve year-round. In seasonal calving herds, however, the decline in reproductive efficiency of dairy cows represents a tremendous challenge.

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 (Hansen, 2000). However, the effects of increased milk production on reproduction are relatively minor compared to the effects of other factors. In their paper on the epidemiology of reproductive performance in dairy cows, Gröhn and Rajala-Schultz (2000) reported that the hazard ratio for conception was near 1.0 (neutral effect) for most levels of milk production (i.e., milk production was not a major factor for determining whether dairy cows will conceive). Their conclusions agreed with those from an Australian dairy study (the InCalf Study; http://www.drdc.com.au) where the authors found minor effects of milk production on conception. Studies of European cattle have also failed to create a definitive link between milk production and reproduction (Loeffler et al., 1999).

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 (Stevenson, 1999). Services per conception increase 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.

Possible Causes of Reproductive Decline in Dairy Cows

The previous studies suggest that the effects of milk production on reproduction are minor. Nevertheless, there is a slight antagonistic relationship between level of production and reproduction and the trend for poorer reproduction will continue as cows achieve greater production. Other changes within the dairy industry, however, probably have equivalent or greater effects on reproduction in dairy cows. The relative contribution of the various physiological, genetic, environmental, and management factors toward the decline in dairy reproduction is not known. Some of the factors that are potentially affecting reproduction in dairy cattle are discussed below.

Growth of the Large Herd Dairy Industry. Within the United States, the total number of dairy farms is decreasing while the total number of herds with more than 200 cows is increasing. Nearly 30% of all dairy cows in the United States are found on farms with more than 500 cows. Reproductive rates on large dairies are similar to those on small dairies (Oleggini et al., 2001). Therefore, the consolidation of the dairy industry cannot be blamed for the decline in reproductive efficiency of dairy cows.

Modern Housing and Methods of Animal Management. Stahl et al. (1999) studied 50 Minnesota herds that increased milk output by 90%. The herds increased output by adding cows. At the same time, the use of free stalls, milking parlors and full-time/part-time hired labor increased. The greater use of free stall housing with concrete floors may be contributing to reproductive loss. The frictional properties of flooring affect cow comfort and wearing of concrete floors creates a slippery surface that predisposes cows to injury (Phillips and Morris, 2001). Concrete flooring has also been blamed for a higher incidence of lameness in modern dairy cows. Hernandez et al. (2001) studied the effects of lameness on reproduction. They found that lame cows with claw lesions (approximately 18% of the herd) were half as likely to conceive when compared to healthy cows.

Stahl et al. (1999) reported that fifty-two percent of herd growth was achieved by purchasing pregnant heifers that later calved and had their first lactation on the farm. First lactation cows have lower energy balance because they eat less and have energy requirements for growth in addition to lactation. Lower energy balance in first lactation cows was associated with delayed intervals to first ovulation and this may explain why some studies have identified first parity as a risk factor for conception failure at first AI. Mixing primiparous and multiparous cows affects social statuses within the herd. Changing social status affects behavior and leads to a decrease in milk yield (Phillips and Rind, 2001) and reduced reproductive performance (Dobson and Smith, 2000). Dairy herd expansions also compromise biosecurity leading to subsequent disease problems (Faust et al., 2001). The increase in disease may ultimately affect reproductive rates.

Traditional methods of visual estrous detection followed by artificial insemination do not work well when cows are managed in large groups. Large herds require more time for heat detection, identification, sorting, insemination, and record keeping simply because there are more cows. The responsibility for reproduction also falls on employees (instead of the owner) that may be overwhelmed by the number of cows that they manage. In some herds, non-electronic estrous detection aids (tail chalk, patches, etc.) have replaced visual detection of estrus and cows are inseminated based on rubbed tail heads, activated tail patches or the appearance of vaginal mucous. Less definitive signs of estrus lead to poorly timed inseminations and poorly timed inseminations lead to lower conception rates (Dalton et al., 2001). The misidentification of estrus may be a big problem in today's herds. In a study of a research herd of 242 Holsteins, Sturman et al. (2000) found that 19% of inseminations were performed on cows in the luteal phase or early phases of pregnancy. Inseminations of pregnant cows led to 17% embryonic loss.

Timed AI programs are popular because herds with poor estrous detection rates can achieve superior intervals to first insemination and pregnancy when compared to cows inseminated at an observed estrus (Pursley et al., 1998). Dairy cows inseminated within timed AI programs, however, have a lower conception rate when compared to dairy cows inseminated at an observed estrus (Nebel and Jobst, 1998). Therefore, traditional reproductive indices such as services per conception and conception rate are negatively affected when timed AI is implemented. Interval to first service and overall pregnancy rate may improve with timed AI.

Genetics of Modern Dairy Cows. Selection indices for dairy cattle are heavily weighted for milk production. By selecting for milk production, we created dairy cows that undergo a high level of nutrient partitioning and adipose tissue mobilization during early lactation. An essential question that must be addressed is whether or not modern dairy cows are inherently less fertile or if their infertility is simply a function of their level of milk production and nutrient partitioning. The current perspective is that infertility in North American dairy cows is secondary to negative energy balance during early lactation. In other words, the reproductive genotype of dairy cows is normal and their reproductive phenotype is a function of lactation. Although difficult to prove either way, most investigators would cite the fact that reproduction in virgin heifers has not changed during the period of declining fertility in lactating cows.

Studies in New Zealand have attempted to address the question of whether or not infertility in North American cows is caused by inadequate energy during lactation. New Zealand Friesian cows (believed to have high fertility) and North American Holstein cows (believed to have low fertility) were compared when they were either grazing (grass) or fed a TMR (Kolver et al., 2000). Regardless of feeding systems, the North American cows produced more milk and had lower body condition score. The infertility in North American cows was greater and body condition was lower even when feeding was similar to that used in the United States (TMR). The infertility in cows with North American genetics was not caused by anestrus because North American cows ovulated earlier postpartum than grass-fed New Zealand cows. It appears that cows with North American genetics will partition energy toward lactation at the expense of reproduction. This nutrient partitioning leads to lower body condition score even when a high energy TMR is fed. Thus, feeding more energy will probably not solve infertility problems in cows with a high percentage of North American ancestry.

Inbreeding. One consequence of selection pressure in North American Holsteins has been a dramatic increase in inbreeding in the past 20 years. Hansen (2000) predicted that levels of inbreeding will be 10% by 2020. Inbreeding depression negatively affects both milk production and reproduction in dairy cows. Hermas et al. (1987) concluded that every 1% increase in inbreeding led to a .17 increase in services per conception, a 2-day increase in days open, and a 3.3% decrease in conception rate. Their estimates suggest that inbreeding alone could account for much of the reproductive decline since 1980.

Recombinant bovine somatotropin (bST). Administration of bST to United States dairy cows for the purpose of increasing milk production began in 1994. Administration of bST causes a decrease in reproductive performance but the effects are relatively minor (Collier et al., 2001). The current period of reproductive decline began well before the introduction of bST in 1994 and countries that do not use bST (Ireland, the United Kingdom, and Australia) are experiencing reproductive problems in dairy herds. Therefore, the introduction of bST into the United States does not explain the current rate of reproductive decline.

How Has Reproductive Physiology Changed in Modern Dairy Cows?

Interval to First Ovulation. Interval to first ovulation is an important measure of reproductive efficiency because cows must be cyclic before breeding. The average interval to first ovulation is probably about 30 days and the percentage of anestrus cows at the start of breeding may be close to 50% on modern dairy farms. Most investigators suggest that the reason for the delay in interval to first ovulation is greater negative energy balance in modern dairy cows. Negative energy balance delays the resumption of ovarian activity (Butler, 2000). In addition to negative energy balance, however, other factors are probably contributing to the increase in the interval to first ovulation in modern dairy cows. deVries and Veerkamp (2000) found that only 3 to 4% of the variation in interval to first ovulation was explained by total energy deficit or energy balance nadir in early lactation. Furthermore, doubling the mean energy balance nadir for cows on the study lengthened the predicted interval to first ovulation by only 4 days.

Function of the Corpus Luteum. The corpus luteum produces progesterone for the maintenance of pregnancy. Pregnant cows have higher concentrations of blood progesterone than open cows within the first week to ten days after insemination. High-producing dairy cows have lower blood progesterone concentrations and the lower blood progesterone concentrations may lead to infertility (Lucy, 2001). In addition to lower progesterone, modern dairy cows also have a higher proportion of abnormal luteal phases. Holstein cows were nearly seven-times more likely to have a prolonged luteal phase than traditional Friesian cows (Opsomer et al., 1998). Laming and Darwash (1998) found similar patterns of abnormal progesterone in cows from the United Kingdom. Opsomer et al. (2000) concluded that negative energy balance, periparturient disorders, and postpartum diseases were risk factors for delayed cyclicity and prolonged luteal phases. Therefore, common ailments of early postpartum cows caused luteal phase abnormalities. A change in luteal phase length in modern-day dairy cows is an important observation because it changes the approach used for reproductive management in dairy cattle. Cows that are not in controlled breeding programs will have delayed breeding because their estrous cycles are longer. Abnormalities in luteal phase length also make it more difficult to predict when cyclic cows will return to estrus.

Function of Ovarian Follicles. Negative energy balance and weight loss have an inhibitory effect on ovarian follicular growth and development. Beam (1995) studied the effects of negative energy balance on follicular growth in early postpartum cows. He observed that the dominant follicle in cows in negative energy balance required more time to develop and reached a larger size before ovulation. Data from Beam (1995) agree with a recent report that compared the estrous cycle of lactating cows and heifers (Sartori et al., 2000). Lactating cows had larger preovulatory follicles than heifers but lower preovulatory concentrations of estradiol in blood. Whether lower blood estradiol concentrations are a consequence of lower steroidogenic capacity of the follicle or enhanced estrogen metabolism (caused by higher metabolic rate in high-producing cows) is not known.

Estrous Expression. Detection of estrus and the accuracy with which estrus is detected is an area of increasing concern. Dransfield et al. (1998) analyzed data generated from electronic mount detectors. The average dairy cow had 8.5 stands per estrus with an estrus duration of 7 hours. Nearly one-quarter of the cows had estruses that were classified as low intensity (< 1.5 stands/hour) and short duration (< 7 hour). Few studies have systematically evaluated the causes of poor estrous expression in dairy cows. The intensity and the duration of estrus depends on behavior of individual cows as well as social interactions among cows. Britt et al. (1986) concluded that milk yield did not influence the intensity of estrous expression. Their original study, however, demonstrated the importance of surface because duration of estrus, mounting activity, and standing activity were greater on dirt than on concrete. If a decrease in estrous expression is occurring in modern dairy cows then the most likely cause is the increased utilization of dairy confinement housing with concrete floors.

Oocyte Quality. Diseases and disorders will negatively affect follicles and oocytes that develop during the early postpartum period. Snijders et al. (2000) found that the ability of an oocyte to be fertilized and develop to the blastocyst stage in vitro was not affected by the milk production of the donor cow. Body condition, however, influenced oocyte competence because in vitro fertilized oocytes from cows in low body condition had a lower cleavage rate and a lower developmental rate when compared to oocytes from cows in better body condition. Lower body condition may be negatively affecting the follicle, decreasing oocyte health and causing infertility.

Uterine Function. There are high rates of embryonic loss between the period of conception and maternal recognition of pregnancy (about 17 to 19 days after insemination) (Mann et al., 1999). Losses after this early period are considerably less but nevertheless influence pregnancy rates. When reciprocal embryo transfer was done between repeat breeder and normal cattle, the repeat breeder cattle failed to achieve normal pregnancy rates even though an embryo from a "normal" cow was implanted (Gustafsson and Larsson, 1985). Conversely, normal cattle had normal rates of pregnancy when implanted with an embryo from a repeat breeder cow. These data suggest that repeat breeders and perhaps modern dairy cows fail to establish pregnancy because of a suboptimal uterine environment. The reason that embryos fail to develop within the uterus of otherwise normal cows is not known. The uterus may fail to synthesize adequate amounts of an embryotrophic growth factor that is required by filamentous embryos. Secretion of embryotrophic growth factors into the uterine lumen may be controlled by nutritional status because embryo transfer pregnancy rates are less in recipients with low body condition score (Mapletoft et al., 1986).

Ways to Improve Reproduction on Modern Dairy Farms

Reproduction is a complex process. Successful herd reproduction requires meticulous attention to detail. Estrous detection, time of insemination relative to estrus, semen handling, AI technique, and pregnancy diagnosis are important. Minor mistakes in these procedures have cumulative effects on herd reproduction. Progress in improving reproduction can only be made after these basic methods are practiced correctly. Producers should take advantage of the Estimated Relative Conception Rates (ERCR) that are now available for dairy sires (Clay and McDaniel, 2001). The effective use of the ERCR in sire selection could improve herd conception rates by several percentage points. Application of any new reproductive technology should be made after it is thoroughly tested. Recently, an early pregnancy test for cattle was found to be completely unreliable (Cordoba et al., 2001). The pregnancy test was an unfortunate example of an unsound reproductive method marketed to the dairy industry.

Genetic Selection for Improved Reproduction. Selection of cows for improved reproductive efficiency is a possible solution to reproductive decline. Careful genetic selection may allow dairy producers to use the genetics of high milk production and still maintain acceptable reproductive rates. Reproductive traits have low heritabilities but the coefficient of variation for reproductive traits is very large. Therefore, it should be possible to identify sires whose daughters have excellent fertility and to identify sires whose daughters have poor fertility (Weigel and Rekaya, 2000). Simply avoiding those sires whose daughters have poor fertility may lead to significant reproductive progress. Scandinavian breeding programs include functional non-production traits (fertility, mastitis resistance, etc.) in addition to production traits in their selection indices for total merit (Philipsson et al., 1994). Although progress toward greater milk production may be less, their models suggest better economic efficiency when functional non-production traits are included in selection programs.

Other present-day reproductive problems can be managed through appropriate sire selection. Modern dairy cows have an ovulation rate of approximately 1.25 and a twinning rate of approximately 5%. Twinning is undesirable because milk production and fertility after a twin birth are decreased (Beerepoot et al., 1992). The predicted transmitting ability for twinning ranges from 1.6 to 8.0% (Johanson et al., 2001). Appropriate sire selection can reduce herd-twinning rates. Longevity is also moderately heritable and breeding values for longevity can be used to select sires whose daughters will stay in the herd longer (Vukasinovic et al., 2001).

There is a strong link between body condition score and reproductive performance. Pryce et al. (2001) examined changes in body condition in cows selected for either high or average genetic merit for milk fat plus protein. They concluded that high genetic merit cows lost more body condition and that the reproductive performance of high merit cows was more dependent on their body condition than their level of production. There is a negative genetic and phenotypic relationship between body condition and milk production but the relationships are modest. Strong positive genetic trends exist between body condition and reproductive performance (Dechow et al., 2001; Veerkamp et al., 2001). Selection programs based on postpartum body condition score should lead to superior reproductive performance.

The high level of inbreeding in North American Holsteins should be addressed. One method is the implementation of computerized mate selection programs that control the level of inbreeding in herds (Weigel and Lin, 2000). These programs can control inbreeding within herds but a broader, industry-based approach will need to be implemented so that genetic diversity within the Holstein breed is maintained (Weigel, 2001).

Pharmacological Intervention of Reproductive Cycles. The best way to immediately reverse current declines in reproduction is to intensively manage the reproductive biology of the dairy cow. The dairy industry has very few tools for the pharmacological control of the estrous cycle. There is an immediate need for new methods and new tools for estrous cycle control.

Progestogens are the best treatment for anestrus is dairy cows. Unfortunately, progestogens are not approved in the United States for use in lactating dairy cows. The lack of an approved progestogen represents a severe limitation to reproductive management in herds with a high percentage of anestrus cows. The other option for anestrus treatment is a synchronization protocol that employs GnRH. Some anestrus cows will ovulate in response to GnRH but the response rate depends on the timing of the injection relative to the follicular wave and the depth of anestrus. Anestrus cows may become pregnant following a GnRH-based synchronization protocol but early embryonic loss may be greater for anestrus compared to cyclic cows treated with the same protocol.

Most cows are either untreated (inseminated at spontaneous estrus) or treated with biweekly injections of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) followed by estrous detection (Nebel and Jobst, 1998). Insemination at spontaneous estrus and the use of $PGF_{2\alpha}$ is a good management option but cows must be detected in estrus. Combining regular $PGF_{2\alpha}$ injections with some type of estrous detection aid (tail chalk, patches, electronic devices, etc.) improves the overall response but requires additional management and attention to details.

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 $PGF_{2\alpha}$ injection was an important step forward because it improved the responses to timed AI and enabled the widespread implementation of the method. Most producers use the standard "Ovsynch" protocol of GnRH (wait seven days), $PGF_{2\alpha}$ (wait two days), GnRH (wait one day), and then insemination (Pursley et al., 1998). Timed AI is a good approach but rates of embryonic loss after timed AI are high and calving rates for dairy cows after timed AI are approximately 25 to 30%. Therefore, there is still a need to optimize methods for timed insemination of dairy cattle.

Timed insemination and regular $PGF_{2\alpha}$ injections are good ways to control the time of first insemination. Only 20 to 40% of dairy cows, however, will be pregnant after first insemination. The fate of the 60 to 80% of dairy cows that are open after first insemination usually depends on detecting the return to estrus after the pregnancy fails. 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 normal luteolytic mechanisms are delayed. The fact that inseminated cows represent a mixture of pregnant and nonpregnant cows and that nonpregnant cows have a variable return to estrus complicates methods that can be used to synchronize second service. Very few reliable methods are available for resynchronizing second service in United States dairy cattle. A hormonal approach involving a progesterone insert, estradiol benzoate injection, and $PGF_{2\alpha}$ injection was developed in Australia for the purpose of synchronizing three inseminations in a 56-day period (Cavalieri and Macmillan, unpublished). Similar methods need to be developed for North American dairy cows.

Conclusions

There are no magical solutions to reproductive decline in high-producing dairy cattle. 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 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 resynchronization of second and third services. In the longer term, a genetic approach that incorporates reproductive and health traits in selection indices will correct some of the reproductive decline. It is also likely, that continued research in the area of postpartum reproduction of dairy cattle will reveal critical control points that can be manipulated to improve reproductive efficiency in dairy cattle.

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