THIS ARTICLE IS SPONSORED BY THE
MINNESOTA DAIRY HEALTH CONFERENCE.

UNIVERSITY OF MINNESOTA

College of Veterinary Medicine

VETERINARY CONTINUING EDUCATION

ST. PAUL, MINNESOTA
UNITED STATES OF MINNESOTA

Production and Reproduction in Dairy Cows

James D. Ferguson, VMD, MS
New Bolton Center
School of Veterinary Medicine
University of Pennsylvania

Introduction

Hormonal changes at parturition initiate lactation, thus milk production is inherently associated with reproduction. Milk yield follows a predictable function; the shape influences profit from sale of milk. If milk yield was constant after calving, profit/day from milk sales would be constant, and the time interval to subsequent calving would not influence profit from milk sales. However, production peaks around 6 weeks in milk and then declines at a constant rate. Fifty percent of the total profit produced in one lactation is realized in the first 100 days of lactation. Milk produced per day declines as days open increase (Figure 1). To maximize profit, cows must have successive lactation cycles occurring at an optimal frequency. Intervals to first and between successive calvings determine total profit produced by a cow during herd lifetime. Thus milk produced by a cow over her lifetime is influenced by her reproductive efficiency.

Economic models suggest maximum income is realized when cows calve every 12 to 13 months (2,3,19). Increasingly, farmers have questioned the feasibility and economic justification of achieving a 12 to 13 month calving interval in cows producing over 9,000 kg of milk. Concerns have arisen over two issues. One is biological: are higher yields of milk associated with reduced conception rate (CR); the other is managerial: are longer calving intervals more profitable in higher producers. Breeding is often delayed in high producing cows, particularly when expensive semen is used, because managers feel CR is reduced at days in milk that correspond to a yearly calving interval. Additionally, the impression exists that higher producing cows make more money when calving intervals are longer than average producing herd mates. This paper will examine the biological and managerial relationships between milk yield and reproduction.

Milk Yield and Fertility

If milk yield is antagonistic to fertility, then achieving a 12 to 13 month calving interval with increasing yields of milk would be unrealistic. Thus some description of the magnitude of association between milk and fertility is necessary to examine the feasibility of management recommendations. Fertility may be measured as days open and calving interval, but these measures are subject to management policy and are influenced by heat detection rate, voluntary wait period and CR. Thus days open and calving interval are confounded as measures of fertility. Although influenced by many factors, CR is more inherently associated with cow factors that influence fertility than interval measures, particularly across a large number of herds.

Some researchers have associated a negative relationship between higher milk production and fertility (13) and others have not (15). Hanson et al. (7) and Faust et al. (4) found milk yield to be antagonistic for fertility in first lactation animals. Selection for higher milk production may have a very slight negative association with fertility, but does not appear to be directly antagonistic, as evidenced by similar CR in virgin heifers now and in 1952 (1). Reproductive traits have a low heritability, thus associations between increased milk yield and fertility may be related to factors associated with increased milk production and not increased milk yield per se.

Many factors influence fertility in dairy cows. Interactions between cow-management-bull-inseminator determine CR in a dairy herd. By far management practices, particularly those associated with heat detection and overall breeding policy influence fertility in dairy herds to the greatest degree. However, fertility is lower in higher producing herds than in lower producing herds (CR=49% in herds>8,597 kg milk vs CR=55% in herds<6,783 kg milk) (1). Management practices are usually better in higher producing herds, thus it is unlikely management contributes to this decline.

Since multiple factors may confound the relationship between milk yield and fertility. Since days in milk when inseminated (20,21), age of cow (6), season(6), and service number (6) influence CR, these factors must be controlled to study milk yield-fertility relationships.

We have examined fertility-production relationships in several data sets from DHIA records, 191,165 cow records from the Northeast DHIA system and 5,249 cow records from a data base of 39 herds we maintain at New Bolton Center. Overall first service CR was 40.9% in the Northeast and 36.9% in the NBC data. First service CR decreased with increaseing test milk closest to breeding in both data sets, however, the decline was not steep, about 2 to 3% per 10 pound increase in milk at insemination. Delay in first service (days in milk when inseminated (DIM)) was associated with higher CR but not dramatically, about 1.7 to 1.8% per 21 day delay. Increased frequency of milking (3x vs 2x) was associated with reduced CR (40.7% vs 37.8%).

From this data, it appears that higher yields of milk are associated with lower CR for cows in the Northeast. The magnitude of decrease is small, 2% for every 10 lbs increase in milk yield at breeding. In the New Bolton Center data we found a similar decline in fertility for increased milk yield. This slight declines in fertility with increased milk production should not be apparent within farm data. Thus, farms should not be eperiencing a dramatic decline in CR with increasing milk production or improving CR with increasing days in milk.

If the 39 herds in the NBC data set are stratefied into high producing cows and low producing cows based on median milk production, 10 of these farms have significantly lower first service CR (FSTCR) in high producing cows. This should not be apparent and suggests some problems in nutritional management of these cows.

In addition 3x milking is associated with a larger reduction in CR than increased milk production. Factors associated with increased milk yield, but not milk yield per se may be responsible for the reduction in CR. Errors in semen handling and insemination technique will also lower CR, but these again are not likely to be management errors occurring only in high producing cows.

Improvements in CR with time postcalving after 40 to 50 days, signficant differences in second service CR versus FSTCR, and decreased in CR in higher producing cows suggest energy balance may be influencing fertility in the herd.

Energy Balance and Fertility

It is well established that cows in early lactation cannot consume enough energy-yielding nutrients to meet the needs of production and maintenance. Body tissue, primarily adipose stores, provide energy-yielding nutrients sufficient to supply the energy deficit incurred in early lactation, resulting in weight loss. Investigators have correlated weight loss with reduced fertility (8,15,23), but correlations are usually only significant when weight loss is extreme.

Body weight and weight change are influenced by dry matter intake, growth, and frame size. The magnitude of body weight change is relative to size of the animal. Thus it is not surprising weight change is not a sensitive indicator of fertility potential. Wildman et al. (22) proposed a body scoring system, independent of frame size, age and dry matter intake, which has proved useful for monitoring depletion and repletion of body tissue reserves in dairy cows.

Table 1 presents data from 531 cows. Cows were examined every two weeks and heart-girth and body condition score were measured. The relationship between CR and body condition change from calving to breeding, FCM, age, body weight and weight change from calving (estimated from heart girth diameter) and DIM when inseminated was analyzed using a logistic model. Cows which had lost one condition score from calving to breeding had lower CR than cows with no condition score difference from calving (Table 1). Further reduction in condition loss was associated with further reduction in CR (Table 1). Weight change was not significant as a predictor of conception. Increased FCM at breeding was marginally associated with lower CR ($p<.11$) when controlling for body condition change and DIM when inseminated. Age did not significantly influence the relationship between body condition and CR.

Perkins (16) observed similar magnitudes of CR decrease in cows which lost moderate (0.5 to 1.0 condition loss) to severe body condition (>1.0 condition loss) in the first five weeks of lactation compared to cows with minor condition loss (<0.5 condition loss) (First service CR: minor 65%, moderate 53%, and severe 17%).

Huszenicza et al. (9) observed that first lactation cows, poorly grown and in poor body condition or poorly grown and in excessive over condition due to over feeding late in gestation, were more likely to experience delayed first ovulation, first breeding, and low CR. A similar relationship between body condition at calving and postpartum ovarian function and fertility was observed in multiparous beef cattle (12). This same group of researchers also observed that dairy cattle, well fed throughout the lactation and dry period, experienced fewer retained placentas, had fewer days to first ovulation and conception, and had higher CR than cows underfed protein and energy during lactation (10). Effects of milk yield on reproductive function were most dramatic in the cows which were underfed (10) or in first lactation cows which lost excessive body condition (9). First lactation cows in good condition at calving or cows which were fed to proper standards (NRC, 1978) had poor correlations between milk yield and days open and duration of the acyclic period postpartum (9,10). This data is suggestive that body condition loss and not milk yield per se accounts for negative impacts of production on reproduction.

Cows which lose more body condition in early lactation appear to be at risk for delayed ovulation, delayed first insemination, and low conception. It may be that increased yields of milk and 3x milking are associated with greater loss in body condition and thereby reduce fertility.

Energy Balance

Energy balance (EB) is defined as the difference in net energy consumed minus the net energy required for maintenance and production (EB = Nel (consumed) - Nel (required)) (1). Condition loss correlates positively with increased negative EB and increased plasma concentrations of nonesterified fatty acids (NEFA) (11). EB usually reaches the lowest absolute value during the second week after calving and then begins to recover. Both the nadir and the rate of recovery are important in determining time to first ovulation during the postpartum period in dairy cows (1). Time to first ovulation may influence CR by effecting the number of estrous cycles prior to first breeding, which appears to influence CR (1,9,10,20).

Similarly, the magnitude of negative EB and rate of recovery determine cumulative negative energy balance (CNEB). In a study from Israel (5), conception to first service in cows with CNEB which exceeded -50 Mcal was impaired with time postpartum compared with cows that did not exceed -50 Mcal CNEB (Table 2). Fertility was low in both groups of cows when first inseminated less than 90 DIM. However, in cows with less negative CNEB, CR improved when inseminations occurred after 90 DIM. This did not occur in the more negative energy balance group. The cows less negative in energy balance returned to positive EB by 50 days postpartum compared with 97 days for the more negative energy balance group ($p<.0004$). Time to cumulative EB of zero was 14.3 weeks and 35.9 weeks for the less negative and more negative energy balance groups, respectively ($p<.0004$).

Although producing higher yields of milk, the more negative CNEB group was primarily lower in EB as a result of reduced dry matter intake relative to milk yield. These cows did not increase as rapidly in dry matter intake as cows of comparable milk yield. This necessitated increased tissue mobilization to support milk yield in early lactation and mobilization continued over a longer period of time compared to the less negative CNEB group.

Body tissue mobilization and negative energy balance have been correlated with increased serum NEFA concentration. Recently work from Hungary correlated plasma NEFA concentration and the time postpartum that it was elevated with ovarian and reproductive function (11). Sixty multiparous cows, who had no clinical signs of postpartum complications, were used to correlate plasma metabolites over the first 10 weeks postpartum with reproductive function. Milk samples were collected twice a week to monitor progesterone. Plasma elevation of NEFA for more than 1 week postpartum was associated with longer days to first ovulation, irregular estrous cycles (as determined by changes in milk progesterone concentration), and cessation of cyclic activity. Number of pregnant animals was lower in cows with longer periods of NEFA elevation. These data imply that the duration, rather than depth of negative EB can influence resumption and control of ovarian cycling.

Energy restriction has been shown to decrease luteinizing hormone (LH) pulse frequency (13). Energy restriction in beef animals inhibits the release of LH at time of calf removal (17). Hypoglycemia blocked the release of LH in response to calf removal and period of repression related to depression of serum insulin (17). Exact mechanisms which conjoin EB and reproductive function are not clear, but it is interesting to speculate that insulin concentration may play a role in communicating metabolic status to hypothalamic centers that control reproductive function via LH release (1).

Conclusions

Data from DHIA records suggest higher milk production is associated with lower CR in the Northeast. However, effects of milk yield on reproduction per se may be minor if body condition change can be controlled. The data from DHIA records suggest that higher yields of milk are achieved via increased tissue mobilization, resulting in lower CR in higher producing cows. This is especially suggestive in data from 3x cows.

Increased tissue mobilization is correlated with increased negative EB and higher levels of plasma NEFA. Increased CNEB appears to correlate more with constraints on energy intake than higher milk yield. Deficiencies in ration content or total dry matter intake may result in unacceptable consumption of energy-yielding nutrients and result in more negative EB for longer periods of time, delaying first ovulation and decreasing reproductive efficiency.

Fat in rations to dairy cows increases energy density. The use of fats in rations of high producing cows may benefit reproduction or production, but not both (Table 3). In one trial in 3 herds CR was 61% in cows receiving 0.5 kg fat/day compared to 42% in herdmates not receiving fat. In another trial, inclusion of rumen inert fat increased milk yield by 4 kg compared to herdmates not receiving fat, but fertility was unaffected.

Monitoring body condition and body condition change throughout lactation and the dry period would appear to be a useful management tool to assess antagonism between milk yield and fertility. Based on the small survey of literature in this report, body condition monitoring should be a routine management practice. Changes in condition from calving to breeding may provide a useful monitor to assess fertility potential.

References

1. Butler, WR and RD Smith. 1989. Interrelationships between energy balance and postpartum reproductive function in dairy cattle. J. Dairy Sci. 72:767.

2. Dijkhuizen, AA and JA Renkema. 1984/5. Economic aspects of reproductive failure in dairy cattle, I. Financial loss at farm level. Prev. Vet. Med. 3: 251.

3. Dijkhuizen, AA and JA Renkema. 1984/5. Economic aspects of reproductive failure in dairy cattle, II. The decision to replace animals. Prev. Vet. Med. 3: 265.

4. Faust, MA, BT McDaniel, OW Robinson, and JH Britt. 1988. Environmental and yield effects on reproduction in primiparous holsteins. J. Dairy Sci. 71:3092.

5. Ferguson, JD, RH Foote, S. Eger, TJ Reimers, H Schindler, S Amir. 1989. The Influence of cumulative negative energy balance on conception rate with time postpartum in dairy cows. J. Dairy Sci. 72:Supplement 1. Abstract in press

6. Gwazdauskas, FC, WD Whittier, WE Vinson, and RE Pearson. 1986. Evaluation of reproductive efficiency of dairy cattle with emphasis on timing of breeding. J. Dairy Sci. 69:290.

7. Hanson, LB, AE Freeman, and PJ berger. 1983. Yield and fertility relationships in dairy cattle. J. Dairy Sci. 66:293.

8. Heinonen 1988. Effect of postpartum live weight loss on reproductive functions in dairy cows. Acta. Vet. Scan. 29:249.

9. Huszenicza, Gy, S Fekete, J Haraszti, L Molnar and L Solti. 1988. Ovarian activity after the first calving in cows reared under different farm conditions. Acta. Veterinaria Hungarica 36:153.

10. Huszenicza, Gy, S Fekete, L Molnar, J Haraszti, and L Solti. 1988. Postpartal ovarian function in dairy cows kept on different feeding regimes. Acta Veterinaria Hungarica 36:143.

11. Huszenicza, G, J Haraszti, L Molnar, L Solti, S Fekete, K Ekes, and AC Yaro. 1988. Some metabolic characteristics of dairy cows with different postpartum ovarian functions. J. Vet. Med. 35:506.

12. Huszenicza, G, S Fekete, L Molnar, J Haraszti, L Solti, Gy Bicserdy, L Czaban, K Korffy, G Bulla, AC Yaro, and A Zwillinger. 1987. Influence of the body condition, body mass change and different levels of energy intake on the postpartal ovarian activity of beef cows. Acta Veterinaria Hungarica 35:359.

13. Imakawa, K, ML Day, DD Zalesky, A Clutter, RJ Kittock, and JE Kinder. 1987. Effects of 17beta-estradiol and diets varying in energy on secretion of luteinizing hormone in beef heifers. J. Anim. Sci. 64:805.

14. Lean, IJ, JC Gallard and JL Scott. 1989. Relationships between fertility, peak milk yields and lactational persistency in dairy cows. Theriogenology 31:1093.

15. McClure, TJ. 1970. An experimental study of the causes of a nutritional and lactational stress infertility of pasture-fed cows, associated with loss of bodyweight at about time of mating. Res. Vet. Sci. 11:247.

16. Perkins, B. 1985. Production, Reproduction, Health and Liver Function Following Overconditioning in Dairy Cattle. PhD Thesis.
Cornell University.

17. Rutter, LM and JG Manns. 1987. Hypoglycemia alters pulsatile luteinizing hormone secretion in the postpartum beef cow. J. Anim. Sci. 64:479.

18. Schindler, H, RH Foote, S Eger, and S Amir. 1986. Breeding efficiency and milk yield of dairy cows in relation to nutritional status and planned differences in conception intervals. Final Report, Project n.1/106/79, Submitted to BARD.

19. Schmidt, GH. 1989. Effect of length of calving intervals on income over feed and variable costs. J. Dairy Sci. 72:1605.

20. Thatcher, WW and CJ Wilcox. 1973. Postpartum estrus as indicator of reproductive status in the dairy cow. J. Dairy Sci. 56:608.

21. Trimberger, GW. 1954. Conception rates in dairy cattle from services at various intervals after parturition. J. Dairy Sci. 37:1042.

22. Wildman, EE, GM Jones, PE Wagner, RL Boman, HF Troutt, Jr., and TN Lesch. 1982. A dairy cow condition scoring system and its relationship to selected production characteristics. J. Dairy Sci. 65:495.

23. Youdan, PG and JOL King. 1977. The effects of body weight changes on fertility during the postpartum period in dairy cows. Bt. Vet. Journal 133:635.

Table 1. Body Condition Change From Calving to Breeding: Effect on CR

Condition change	CR (95% Confidence Limit)
+1	61.7 (53.9,68.9)
0	50.0 (47.9,63.6)
-1	38.3 (31.1,46.1)

N=531 cows
Scale of condition score 1 to 5 (20)

Table 2. Effects of Cumulative Negative Energy Balance on Conception with Time Postpartum.

Insemination Period Balance (days)	Cumulative Negative Energy >-50 Mcal	< -50 Mcal
<90	30%	43%
>90	83%	36%

Interaction CNEB*Period p<.05
N= 40 multiparous cows

Table 3. Reproductive Responses to Ruminally Inert Fats

	FAT (kg)	
	0	0.5
Hard Fats		
Cows	110	91
CR	42	61**
Preg Cows	76	74*
Days Open	118	105
S/C	2.41	1.66
Ca-LCFA		
Cows	46	52
CR	47	34
Preg	34	32
Days Open	89	98
S/C	2.15	2.44
Comparison of Diets		
Protein (kg)	3.6	3.7
CP %	16.8	17.2
UIP (kg)	1.32	1.41
NEl/UIP(Mcal/kg/kg)	1.32	1.23
Increase		
Milk Yield kg/day	0	+ 4
Fertility	+2.22	0

Cows fed 0.5 kg supplemental fat through 150 days of lactation
Breeding information only for the supplemental period
** $p<.02$
* $p<.01$