# Postpartum factors and fertility in dairy cows

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## Abstract

Normal reproductive function should return by 50 days postcalving and depends on complete uterine involution, clearance of uterine pathogens, and resumption of ovarian cycling. Delays in resumption of ovarian cycling beyond 35 days postcalving, failure to clear uterine pathogens, excessive adipose tissue mobilization and body condition loss, increased blood ketones, and decreased serum glucose are associated with decreased pregnancy to first insemination and increased pregnancy loss in cows that do conceive. Overall, health issues and delays in ovulation have an odds ratio of conception to first insemination of 0.54 - 0.39 relative to cows with early ovulation and no infectious or metabolic health problems. Embryonic losses are approximately 16.5% in cows with no health problems and 27% in cows with postcalving health problems. Significant proportions of cows with health problems challenge the ability of farm managers to achieve pregnancy rates that result in economic optimal reproductive performance.

**Keywords:** Postpartum cows, fertility, postpartum health

## Reproductive Goals

Birth of a calf initiates lactation. Ideally, dairy cows would begin to produce milk at 22 - 24 months of age and calve every 11 - 13 months until replaced by a genetically superior female.[1] However, removal may occur for nongenetic purposes, such as for health problems, reproductive failure, or injury. Typically, cows remain in a herd for 2.5 - 3 lactations[2] until replaced by a younger female, but health and reproductive failure may influence the age at which a cow leaves the herd. Herd profitability is influenced by the dynamics of age at first calving, age of cow at replacement, annual rate of replacement, genetic intensity of replacement, and the annual frequency of animals recalving.[1] A successfully managed reproductive program controls the age at first calving (22 - 24 months), the period of annual recalving (calving interval, 11 - 13 months), the reason for herd removal (primarily low production), and the sale of female and male animals.

Annual recalving should occur every 11 - 13 months, with a rest period of 40 - 60 days between sequential lactations.[1] Since pregnancy is ~280 days in *Bos taurus* cows (range; 270 - 295 days), to maintain 11 - 13 month calving intervals requires that cows become pregnant 55 - 115 days postcalving. Since annual replacement (culling) rates are typically about 25 - 35% in a dairy herd, 65 - 70% of cows which calve should become pregnant within this interval, with new replacements maintaining the dairy population. Management practices that control insemination have a major influence on achieving this goal.[1-3] However, cow physiology also has a role determining if pregnancy will be achieved within economically optimal intervals. The economic success of herd reproductive programs depends on successful integration of management practices and cow physiology.[1,4-5]

Pregnancy rate (PR) is a metric that captures management (insemination rate) and cow fertility (conception rate) in one variable.[1-3] It represents the proportion of nonpregnant (open) cows that become pregnant every 21 days.[2,3] The average estrous cycle of the cow, 21 days (range; 18 - 24 days), delineates the time period for determining rates of insemination and conception. For this paper, conception will be defined as cows diagnosed as pregnant between 30 - 45 days postinsemination, relative to a particular time period of insemination. True, physiologic conception (fertilization of an ovulated oocyte) are close to 85 - 90% in dairy cows but are not observable on dairy farms.[5] Embryonic loss of fertilized oocytes prior to 35 days are high (40 - 60% of fertilized oocytes) and still significant up to 45 days postinsemination (10 - 15% of pregnancies from 28 to 45 days).[5]

Pregnancy rate depends on insemination rate (IR) and conception rate (CR). Insemination rate is calculated as nonpregnant (open) cows inseminated within a 21-day period, divided by the proportion of nonpregnant cows available to inseminate. Conception rate is calculated as the proportion of cows diagnosed as pregnant, divided by the total cows inseminated within the concurrent 21-day interval. Every 21 days following the voluntary waiting period (VWP), the proportion of open cows that become pregnant are determined by the PR. Pregnancy rate is the combination of IR (heat detection rate) times CR. Survival curves of pregnancy with days postcalving describe overall PR for a herd.

For optimal economic returns, PR needs to be ≥ 25% (Figure 1). Pregnancy rates < 25% have 6-fold economic loss compared to PR ≥ 25% (Figure 1). To achieve a PR ≥ 25%, insemination rates need to be ≥ 70%, and CR needs to be at least ≥ 35%. Management controls IR. Cow fertility is the major controller of CR. This paper will examine cow factors influencing PR. A companion paper will examine management factors influencing insemination rates.

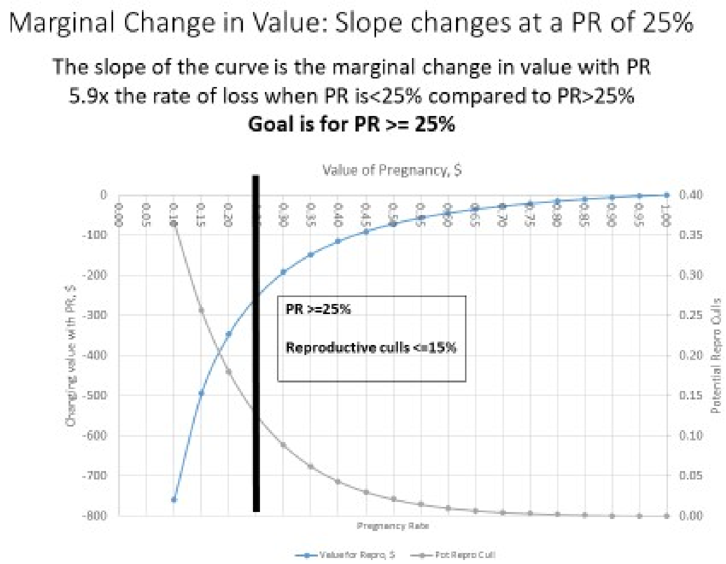


**Figure 1**. Pregnancy rate (PR) on the X-axis and change in economic value (losses) relative to a pregnancy rate of 1.00 on the left Y-axis, with potential reproductive culls on the right Y-axis. Cows that become pregnant in the first 21 days after the voluntary waiting period have a pregnancy rate of 1.00. With each successive 21 days, PR declines proportionally. The distribution of cows within each 21-day window determines the herd overall PR. Cows not pregnant by 150 days, typical for most herds, are at risk for culling, the proportion on the right Y-axis. Reproductive losses are much greater when the mean herd PR is below 25% and potential reproductive culls increase.

## Parturient cow

Ideally, by 50 days postpartum, a cow is fully capable of becoming pregnant and carrying a pregnancy to term.[6] This requires a fully regenerated and repaired uterus and resumption of estrous cycles prior to 50 days postpartum.[6-8] During this period, milk production increases to peak yield, prioritizing nutrient demands for glucose, amino acids, and minerals.[9] Peak milk production occurs by 30 - 50 days postcalving, yet feed intake will not peak until 100 - 120 days postcalving. This creates negative balances in energy, protein, and minerals, especially in the first 2 weeks postcalving.[10-17] Positive balances will not be realized until 8 weeks postcalving, as feed intake increases and milk production declines from peak.[16] At calving, homeorhetic signals coordinate nutrient flows to support lactation through alterations in tissue utilization of glucose, increased gluconeogenesis in the liver, mobilization of fatty acids from adipose tissue, and mineral mobilization from bone.[4,9,15] Central control centers in the arcuate nucleus of the hypothalamus sense the degree of disparity in nutrient balance and turn on, dampen, or shut down hypothalamic centers that control GnRH release, impacting the initiation of ovarian function.[14,18] Endocrine and metabolic signals influence central control centers that determine when reproductive function will commence. Endocrine and metabolic factors in the week prior to calving and in the first several weeks postcalving influence resumption of ovarian cycling and fertility at first insemination.[15,19]

During the first weeks postcalving, homeostatic processes may be disrupted, resulting in ill health in the postpartum period (milk fever, ketosis, fatty liver, displaced abomasum); furthermore, infectious diseases (metritis, mastitis) further impact the reproductive axis and influence ovulation and future fertility (Table 1).[19-21] In addition, elevations in nonesterified fatty acids (NEFA), serum beta hydroxy butyric acid (BHBA), and reductions in calcium have been associated with increased days to first ovulation, lower conception at first insemination, and reduced pregnancy rates.[22-26] Energy balance, metabolic stress, and infectious disease combine to reduce fertility in the postpartum cow.[19]

**Table 1.** Postpartum conditions and fertility in dairy cows measured as the odds of conceiving at first insemination (OR, odds ratio)[1].

| Item[4] | Signalment | Action Level (%)[2] | OR FSTCR[3] |
|---|---|---|---|
| Dystocia | Calving difficulty | > 10 | 0.80,0.75 |
| Twins | | > 5 | |
| Die | Death losses < 30 days | > 5 | |
| Culling first 60 days | | > 10 | |
| Milk Fever | Hypocalcemia | > 2 | 0.85 |
| Retained Placenta | > 24 hours | > 8 | 0.68 |
| Puerperal Metritis | Fever > 39.7°C, off feed | > 10 | 0.56,0.64,0.43,0.37 |
| Chronic Metritis | Purulent discharge > 30d | > 20 | 0.57, 0.68, 0.34, 0.24 0.381, 0.71, 0.70, 0.67 |
| Subclinical Endometritis | Proportion of neutrophils in uterine cytology | > 20 | <1.00 |
| Ketosis | b-OH butyrate > 1 mmol/l | > 10 | 0.69, 0.50, 0.79 |
| Displaced abomasum | | > 3 | |
| Anestrus | | | 0.47, 0.38, 0.42 |
| Ovulatory dysfunction | > 40 DIM first ovulation | > 20 | |
| Body condition loss | 30 DIM ≥ ¾ score loss | > 15 | 0.545,0.689 |
| Body condition postpartum | score < 2.5 at 30 DIM | > 15 | 0.650 |
| One clinical disease | in first 30 DIM | > 30 | 0.52, 0.79 |
| Two or more clinical disease | in first 30 DIM | > 10 | 0.57 |

[1]OR = odds ratio,
[2]Action Level = proportion of animals with the condition divided by the number calving
[3]FSTCR = first service conception rate
[4] Dystocia = based on calving difficulty score of 2 or greater
[4] DIM = days in milk
[4] Body condition based on a 5 point scale, 1 being emaciated, 2 thin, 3 adequate, 4 fat, 5 obese

Fertility is the outcome of multiple systems acting in concert in the postpartum dairy cow.[18,19] The immune, metabolic, endocrine, and gastrointestinal systems undergo adaptations following calving to coordinate lactation, uterine repair, feed intake and resumption of reproductive cycling.[15,19] Excessive inflammation and infection, increased metabolic disparity between nutrient intake and output in milk, and gastrointestinal upset can disrupt the coordination of nutrient flows and lead to impairment of health and fertility.[20,21,27] Homeorhetic controls are achieved through changes in somatomedins postcalving.[2,4,28,29] Serum insulin and insulin growth factor 1 (IGF1) decrease, whereas serum growth hormone, prolactin, parathyroid hormone, and glucocorticoids increase.[4,15,18,28,29] Immediately postcalving, serum glucose declines and serum NEFA increases, released from adipose tissue.[4,15,30] Amino acids are released from skeletal muscle. Plasma calcium declines precipitously on the day of calving and returns to homeostatic concentrations over next 4 days. Liver gluconeogenesis increases to meet the demand for glucose by the mammary gland using propionate absorbed from the rumen, and lactate and amino acids released from skeletal muscle.[17]

Serum BHBA increases due to incomplete beta oxidation of NEFA in the liver and peripheral tissues. Liver triglycerides increase due to incomplete incorporation of NEFA into triglycerides for export from the liver as low-density lipoproteins. Reduced serum insulin and increased insulin resistance in insulin-sensitive tissues direct glucose to the mammary gland and reduce glucose availability to muscle and adipose tissue. Increases in inflammatory cytokines from uterine endothelial cells, macrophages, and neutrophils in response to uterine infection stimulate the liver to produce acute phase proteins, such as haptoglobin, serum amyloid A, and ceruloplasmin, and decrease synthesis of negative acute phase proteins, such as albumin, and vitamin and hormone carriers.[20,21,27] Reactive oxidation compounds increase, increasing the demand for antioxidant protection.[31]

Decreases in plasma insulin, IGF1, calcium and glucose combined with increases in NEFA, BHBA, and inflammatory compounds influence the hypothalamic-pituitary-ovarian axis and may disrupt ovarian follicular growth, steroidogenesis, and ovulation.[4,18,29] In addition, failure to clear pathogenic bacteria from the uterus further impacts the ability of the cow to establish and maintain pregnancy.[7,8,32,33] Physical conditions at calving, such as dystocia, twin births, and uterine prolapse create risk factors for reduced fertility.[34-38] Disease in the postpartum period, the first 30 days in milk, such as metritis, ketosis, milk fever, displaced abomasum, mastitis, and lameness, increase the risk for low fertility.[34-42] Increased negative energy balance, calving problems, uterine disease and metabolic disease disrupt uterine involution, ovarian activity, and pregnancy maintenance.

**Cow factors influencing fertility**

Postpartum cows experience multiple challenges postcalving. Parturition is an inflammatory process and inflammatory cytokines increase, influencing hepatic function and exerting central influences on feed intake and reproductive control.[20,21,27] Uterine bacterial contamination is present in over 90% of cows in the first 3 weeks postcalving, further contributing to inflammatory challenges.[7,8] Parturition is associated with depression in innate immunity, increasing the risk of bacterial contamination becoming a significant infection.[7,8] Specific bacteria have a greater risk of causing uterine pathology.[7,8] Uterine infection may present as an acute puerperal metritis observed in the first 2 weeks postcalving. Puerperal metritis is characterized by a fetid, watery vaginal discharge, fever > 39.5ºC, and a depressed, anorexic cow. Failure to clear pathogenic bacteria by 3 - 4 weeks postcalving can result in a chronic endometritis or subclinical endometritis associated with purulent to mucopurulent vaginal discharge or an increased presence of polymorphonuclear cells in uterine lavages.[7,8,32,33]

Superimposed on inflammatory and infectious challenges are metabolic challenges associated with the negative energy balance postcalving.[4] In the first 3 weeks postcalving, significant elevations in serum NEFA (> 0.70 mEq/L), and BHBA (> 10 mg/dl), and reduced serum concentrations of glucose are associated with reductions in conception at first AI.[22-26] Serum glucose is important in coordinating insulin and IGF1 in the early postpartum period and low serum glucose in the first week postcalving is associated with lower FSTCR.[4] In addition elevations of NEFA in the week prior to calving are associated with reduction in FSTCR. Elevations in serum NEFA, BHBA and decreases in serum calcium and glucose have been associated with reduction in FSTCR in cows with no apparent clinical conditions postcalving.[22-26,30,40] Metabolic stresses late in pregnancy and early postcalving influence FSTCR.

Metabolic influences in early postpartum could alter follicular and ovum development which would reduce fertility at first insemination.[43] Changes in body condition (BC) postpartum seem to support this hypothesis, as cows with more extreme condition loss have lower fertility.[44-46] Similarly, cows with more body weight loss have fewer fertilized oocytes and transferable embryos.[47] Cows that experience more negative energy balance, more condition and body weight loss, and have greater serum NEFA in the first week postcalving have lower fertility at first insemination. Health problems postpartum exacerbate energy balance, as feed intake is often depressed, which may compound problems with fertility at first insemination.

Conception at first insemination postcalving for cows with various reproductive disorders is summarized (Table 2). Postpartum disorders have an odds ratio (OR) < 1, indicating a reduction in CR to first insemination. Cows with no health problems postcalving and that ovulate prior to first insemination have an odds ratio of first service of 1; they are the sentinel fertility group in a herd.

**Table 2.** Odds ratio of pregnancy at first insemination from various references

| Author | Group | Year / Condition | Herds | Cows | OR | SEM |
|---|---|---|---|---|---|---|
| Fourichon et al: | | 1999 | Meta-analysis | studies used varied with condition | | |
| | Physical | Dystocia | | | 0.802 | 0.025 |
| | Physical | Still birth | | | 0.739 | 0.081 |
| | Metabolic | Milk Fever | | | 0.852 | 0.483 |
| | Metabolic | Retained Placenta | | | 0.681 | 0.014 |
| | Infectious | Metritis | | | 0.563 | 0.036 |
| | Metabolic | Cystic Ovaries | | | 0.786 | 0.058 |
| | Metabolic | Anestrus | | | 0.471 | 0.022 |
| | Metabolic | Ketosis | | | 0.754 | 0.256 |
| | Metabolic | Displaced Abomasum | | | 1.000 | |
| | Physical | Lameness | | | 0.852 | 0.123 |
| Ribeiro et al: | | 2013 | 2 | 957 | | |
| | Physical | Dystocia | | | 0.460 | 0.128 |
| | Infectious | Metritis | | | 0.370 | 0.122 |
| | Infectious | Endometritis | | | 0.680 | 0.138 |
| | Infectious | Mastitis | | | 0.700 | 0.140 |
| | Infectious | Pneumonia | | | 0.490 | 0.255 |
| | Metabolic | Digestive Problem | | | 0.220 | 0.122 |
| | Physical | Lameness | | | 0510 | 0.235 |
| | Metabolic | 1 Subclinical Condition | | | 0.820 | 0.158 |
| | Metabolic | >1 Subclinical Condition | | | 0.520 | 0.105 |
| | Metabolic | NEFA > 0.70 mEq/l | | | 0.420 | 0.084 |
| | Metabolic | BHBA> 10 mg/dl | | | 0.690 | 0.112 |
| | Metabolic | Ca < 2.14 mmol/l | | | 0.890 | 0.153 |
| | General | 1 postpartum disease | | | 0.640 | 0.110 |
| | General | > 1 postpartum disease | | | 0.340 | 0.089 |
| Santos et al: | | 2009 | 8 | 5,719 | | |
| | Physical | Dystocia | | | 0.750 | 0.064 |
| | Infectious | Metritis | | | 0.660 | 0.056 |
| | Infectious | Endometritis | | | 0.620 | 0.056 |
| | Infectious | Fever >39.5°C | | | 0.600 | 0.043 |
| | Infectious | Mastitis | | | 0.840 | 0.117 |
| | Infectious | Pneumonia | | | 0.630 | 0.242 |
| | Metabolic | Ketosis | | | 0.500 | 0.082 |
| | Metabolic | Digestive Problem | | | 0.780 | 0.224 |
| | Physical | Lameness | | | 0.570 | 0.094 |
| | General | 1 postpartum disease | | | 0.790 | 0.056 |
| | General | > 1 postpartum disease | | | 0.570 | 0.054 |
| Toni et al: | | 2015 | 3 | 1498 | | |
| | Infectious | Metritis | | | 0.640 | 0.071 |
| | Infectious | Endometritis | | | 0.340 | 0.056 |
| | Metabolic | Cystic Ovaries | | | 0.260 | 0.037 |
| | Metabolic | Anestrus | | | 0.380 | 0.089 |
| | Physical | Lameness | | | 0.540 | 0.041 |
| Harman et al: | | 1996 | 6,227 | 44,450 | | |
| | Infectious | Endometritis | | | 0.235 | 0.036 |
| | Infectious | Other disease | | | 0.653 | 0.128 |
| | Infectious | Other infertility disease | | | 0.342 | 0.044 |
| | Infectious | Mastitis | | | 0.786 | 0.058 |
| | Metabolic | Anestrus | | | 0.418 | 0.026 |
| | Metabolic | Cystic Ovaries | | | 0.439 | 0.021 |
| | Metabolic | Ketosis | | | 0.786 | 0.041 |
| | Physical | Lameness | | | 0.515 | 0.172 |
| Francos and Mayer | | 1988 | NR | 14,573 | | |
| | Infectious | Metritis | | | 0.303 | 0.022 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Infectious | Endometritis | | | 0.381 | 0.012 |
| | Metabolic | Retained Placenta | | | 0.363 | 0.012 |
| | Metabolic | Anestrus | | | 0.431 | 0.008 |
| Lee et al: 1989 | | | 5 | 1,059 | | |
| | Infectious | Metritis | | | 0.538 | 0.177 |
| | Infectious | Endometritis | | | 0.709 | 0.103 |
| | Metabolic | Retained Placenta | | | 0.493 | 0.122 |
| | Metabolic | Cystic Ovaries | | | 0.538 | 0.137 |
| | Physical | Lameness | | | 0.527 | 0.165 |
| Leblanc et al. 2002 | | | 27 | 1,865 | | |
| | Infectious | Endometritis | | | 0.700 | 0.083 |
| Ferguson et al. 1995 | | | 4 | 566 | | |
| | Infectious | Fever > 39.5ºC | | | 0.350 | 0.075 |
| Ospina et al: 2010 | | | 91 | 2,770 | | |
| | Metabolic | NEFA > 0.27 1 week prior | | | 0.681 | 0.095 |
| | Metabolic | NEFA > 0.72 1 week after | | | 0.730 | 0.119 |
| | Metabolic | BHBA > 10 mg/dl 1 week | | | 0.873 | 0.176 |
| | BCS | BCS ≥ 3.75 | | | 1.041 | 0.239 |
| Chapinal et al: 2012 | | | 55 | 1,919 | | |
| | BCS | BCS ≥ 4 versus < | | | 1.00 | |
| | BCS | BCS 3.25-3.75 vs ≥ 4.0 | | | 0.710 | 0.089 |
| | BCS | BCS< 3.0 versus ≥ 4.0 | | | 0.540 | 0.084 |
| | Metabolic | Ca < 2.3 mmol/l week-1 | | | 0.670 | 0.105 |
| | Metabolic | Ca < 2.2 mmol/l week +1 | | | 0.770 | 0.096 |
| Kim and Jeong 2019 | | | 2 | 790 | | |
| | General | One disease postpartum | | | 0.550 | 0.089 |
| | BCS | BCS at AI <3 versus >3 | | | 0.640 | 0.119 |
| | BCS | BCS at 30 day < 2.75 versus >2.75 | | | 0.792 | 0.155 |
| Loeffler et al: | | | 43 | 9,369 | | |
| | Infectious | Metritis | | | 0.740 | 0.099 |
| | Infectious | Endometritis | | | 0.670 | 0.128 |
| | Infectious | Mastitis | | | 0.530 | 0.110 |
| | Metabolic | Cystic Ovarian Disease | | | 0.530 | 0.115 |
| | BCS | BCS ≤2.5 versus 2.75-3.25 | | | 0.650 | 0.117 |
| | BCS | BCS ≥ 3.5 versus 2.73-3.25 | | | 0.740 | 0.161 |
| Bruinje et al: | | 2017 | 2 | 748 | | |
| | Metabolic | no luteal phase versus 1 normal | | | 0.260 | 0.059 |
| | Metabolic | one abnormal luteal phase versus none | | | 0.746 | 0.119 |
| | Metabolic | no luteal phase versus 2 normal | | | 0.381 | 0.066 |
| | Metabolic | ovulation ≥ 63 days versus earlier | | | 0.461 | 0.115 |
| Barletta et al. | | 2017 | 1 | 232 | | |
| | BCS | BCS loss vs BCS gain | | | 0.198 | 0.068 |
| | BCS | BCS maintain versus BCS gain | | | 0.326 | 0.130 |
| Santos et al: | | 2009 | 4 | 6396 | | |
| | Anestrus | No ovulation 65 d versus ovn | | | 0.584 | 0.038 |
| | BCS Calving | BCS < 3 versus BCS 3 - 3.5 | | | 0.848 | 0.060 |
| | BCS Calving | BCS > 3.75 versus BCS 3 - 3.5 | | | 1.058 | 0.072 |
| | BCS at AI | BCS < 3 versus 3 - 3.5 | | | 0.727 | 0.403 |
| | BCS at AI | BCS > 3.75 versus 3 - 3.5 | | | 1.236 | 0.119 |

[1]Papers reporting hazard of pregnancy or relative risk converted to odds ratio using the formula
OR = (RR - RR*CR reference group)/ (1 - RR*CR reference group); CR = conception rate; RR = relative risk

Cows that had dystocia, 1 postpartum disease, multiple postpartum diseases, metabolic stress, lameness, and ovulatory dysfunction have reduced CR at first insemination.

Body condition at calving, BC at insemination, and BC loss have variable effects on CR to first insemination. In general, BC < 2.5 and BC loss ≥ 1 unit have lower odds of conceiving at first insemination. Cows with BC > 3.75 at calving and that have maintained BC from calving to first insemination have CR that are better or not different from cows with no health problems postcalving.

Milk production (Figure 2) for cows with no postpartum problem compared to cows that had a health issue or delivered twin calves (897 total calving, milk production was from 841 cows distributed as follows; normal (452) metritis (131), retained placenta (106), dystocia (168), milk fever (15), ketosis (57), displaced abomasum (85), twins (47)). Milk production was reduced in cows with problems in the first 10 weeks postcalving, reducing total lactation yield in 44 weeks by 439 kg of milk.

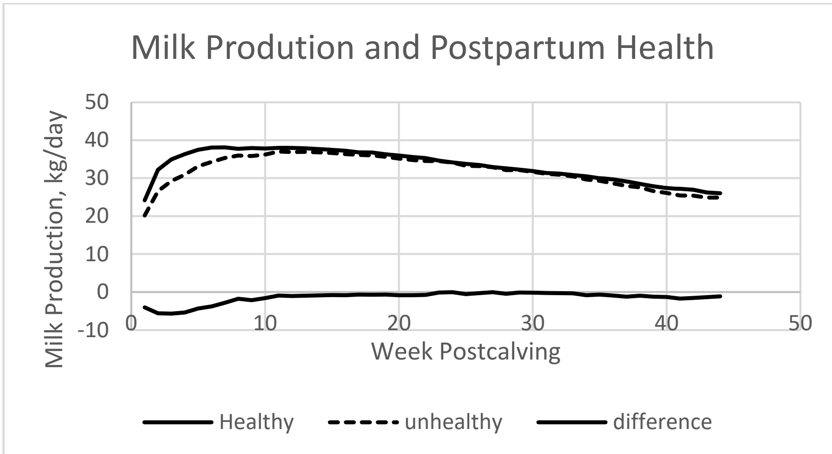


**Figure 2.** Milk production by week postcalving for cows with no postpartum disease and cows with a problems postcalving (metritis, retained placenta, dystocia, ketosis, displaced abomasum, and twins). Data from University of Pennsylvania Marshak Dairy, 900 cows. Total difference in milk -439 kg over 44 weeks postcalving.

A random effects model was used to calculate an overall OR of CR for cows with postpartum problems and BC change. General groupings were constructed for the data (Table 3).

**Table 3.** Random effects model across studies for the mean odds ratio (OR) for postpartum conditions.

| Condition postpartum | OR | SE | 95% Confidence Range | |
|---|---|---|---|---|
| anestrus, COD, nonovulatory | 0.466 | 0.048 | 0.373 | 0.559 |
| BC change <-1 unit from calving | 0.440 | 0.263 | -0.075 | 0.955 |
| BC change ≥ -1 unit from calving | 0.502 | 0.089 | 0.327 | 0.677 |
| BC at AI 2.75 - 3.25 | 0.581 | 0.665 | -0.722 | 1.884 |
| BC at calving 2.75 - 3.5 | 0.648 | 0.197 | 0.263 | 1.033 |
| BC at calving ≥ 3.75 | 0.936 | 0.083 | 0.774 | 1.098 |
| BC at calving < 3 | 0.616 | 0.117 | 0.387 | 0.846 |
| BC at AI ≥ 3.75 | 0.939 | 0.185 | 0.576 | 1.301 |
| BC at AI < 3 | 0.671 | 0.129 | 0.418 | 0.924 |
| One postpartum disease | 0.617 | 0.104 | 0.412 | 0.821 |
| More than one postpartum disease | 0.390 | 0.113 | 0.169 | 0.612 |
| Metritis, Mastitis postpartum | 0.478 | 0.043 | 0.394 | 0.561 |
| Postpartum ketosis, elevated NEFA | 0.499 | 0.044 | 0.413 | 0.585 |
| Two metabolic conditions | 0.502 | 0.216 | 0.080 | 0.925 |
| Dystocia, lameness, still birth | 0.610 | 0.063 | 0.487 | 0.732 |
| Overall Mean | 0.542 | 0.020 | 0.502 | 0.581 |

Cod = cystic ovarian disorder
Nonovulatory = no ovulation prior to first insemination
BC = body condition, scale 1 to 5, with 1 emaciated, 2 thin, 3 average, 4 fat, and 5 obese
AI = artificial insemination

Overall, having a postpartum problem, significant BC loss, or having thin BC at insemination had an OR of 0.542 (SE 0.020) on insemination to first insemination. If CR in normal cows is 50%, the CR in problem cows would be 35.1%. If heat detection (insemination rates) were similar in both groups of cows, which is unlikely as cows with reproductive problems often have delayed first ovulation, normal cows would achieve a PR of 25.0% if CR was 33.3% and insemination rates 75%. Cows with reproductive problems would have a CR of 21.3%, which would result in a PR of 16.0% if insemination rates were 75%. This would correspond to a hazard rate of pregnancy of 0.76 compared to normal cows. Effects on survival curves for normal cows and reproductive problem cows are shown (Figure 3). The lower PR reduces milk produced per day due to longer calving intervals, fewer calves born per year, and a higher risk of culling due to more open cows at or beyond 230 days postcalving. In addition, cows with reproductive problems due to health issues produce about 439 kg less milk over a 305 days lactation, primarily due to lower yields in the first 10 weeks postcalving. The result would be a reduction in income of $404.00 per cow per year (milk income, $0.17/lb; calf value, $150/head; replacement costs, $750/cull cow).

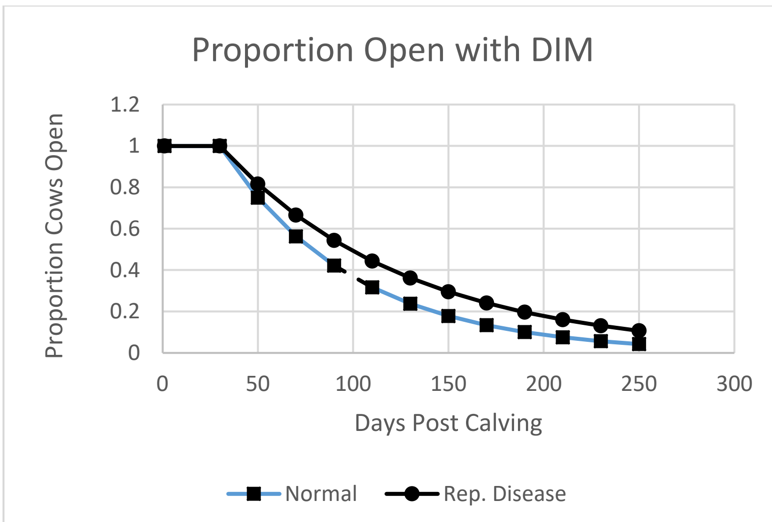


**Figure 3.** Failure time (pregnancy rate) curves for cows with normal postpartum conditions (■) versus cows with reproductive disease or late first ovulation (●). Normal cows have a pregnancy rate of 25.0% (Insemination rates of 75% and CR of 33.3%), whereas the reproductive disease cows have a pregnancy rate of 18.4% (insemination rate of 75% and CR of 24.5%, based on a mean OR of 0.65 compared to normal cows for reproductive disease). Voluntary wait period is 50 days. The hazard rate of pregnancy for the reproductive disease cows is 0.828 relative to the normal cows.

### Initiation of ovulation

Reinitiation of ovarian cycling early postpartum is critical for full restoration of fertility.[6,10-14,48] Ovulation of a healthy ovum capable of fertilization and normal embryonic development is essential for maintenance of pregnancy.[47] Follicular development affects the quality of the ovum and of the corpus luteum that develops following ovulation, influencing embryonic development, progesterone secretion, and the maintenance of pregnancy.[47] Typically, it has been observed that several estrous cycles prior to the breeding period are necessary to ensure a healthy ovum and sufficient progesterone secretion to support pregnancy.[6] To that end, earlier first ovulation and normal luteal phases prior to first insemination are associated with higher pregnancy rates.[49] The degree of energy balance nadir,[16] the days to energy balance nadir,[13] and uterine bacterial contamination can influence to day to first ovulation[50] and the quality of ovum and progesterone produced by the subsequent corpus luteum.[8]

Negative energy balance, the difference in energy output in milk minus energy intake from feed, is a factor influencing resumption of luteal activity postpartum and subsequent fertility.[13] Majority of cows experience negative energy balance postcalving, with the nadir typically occurring within the second week (Figure 4). Majority of cows return to positive energy balance by week 8, with a range from 4 - 12 weeks (Figure 4). Cows tolerate moderate degrees of negative energy balance in the early postpartum period, but there seems to be a threshold that impairs ovarian function and fertility.[16] Days to first ovulation were negatively correlated with the nadir of negative energy balance, rather than the time.[16] The greater the negative energy balance, the longer the days to first ovulation. The greater the degree of negative energy balance postpartum, the greater the serum concentrations of NEFA and BHBA, and the lower the concentration of glucose, insulin, and IGF-1.[10-12,15,19] Negative energy balance is greater in cows with greater BC loss over 30 days postcalving. Cows with NEFA > 0.7 mEq/L, BHBA >10 mg/dl had lower serum concentrations of insulin, IGF-1, and glucose in the first 1 - 3 weeks postcalving.

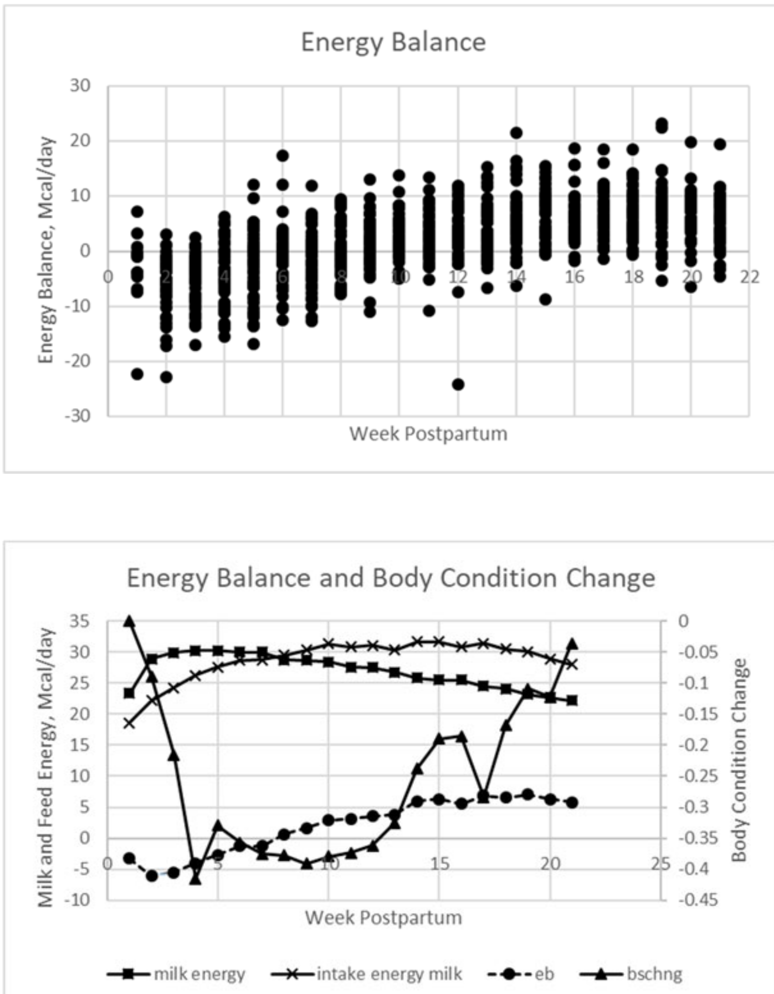


**Figure 4.** Daily energy balance (energy intake in feed - energy output in milk) by week postpartum in 40 lactating Holstein dairy cows (upper panel). Energy output in milk and energy intake from feed (Mcal/day) to energy balance (eb) and body condition change from calving body condition score (bschng) on a 5-point scale, using quarter-point increments, by week postcalving (lower panel).

It is not possible to measure energy balance on a farm, but body condition score (BCS) is a good estimator of body fat,[51] and change in BCS is a good estimate of fat mobilization and cumulative negative energy balance.[52,53] One unit of BC loss was associated with 42 or 54 kg of fat mobilized to support milk production, corresponding to 420 and 564 Mcal of net energy of lactation used for milk production from body fat.[52,53] These estimates of tissue loss and energy depend upon how fat the cow is; a cow with a BCS of 4 will lose more fat with a higher energy value when losing 1 unit of condition than a cow with a BCS of 3.[54] In addition, cows fat at calving will lose more BC than thinner cows. Generally, 1 unit of BC loss corresponds to -300 to -500 Mcal of cumulative negative energy balance for cows with a BCS of 2.5 - 4.0.

Body condition loss is greatest between calving and 30 days in milk, then tends to flatten over the next 4 - 8 weeks before increasing, as cows accumulate positive energy balance (Figure 4). Cows seem to tolerate up to ¾ of BCS loss before a reduction in first service conception rate is observed. When BC loss is > ¾ of BCS, the odds ratio of first service conception rate (FSTCR) is 0.34 - 0.50 relative to no change in BC in the first month postcalving. Meta-analysis (15 studies) of BC and BC loss observed heterogeneity of BC loss and FSTCR, with significant fertility reduction in cows with low BC at calving or at first AI (< 2.5) and in cows with BC loss > 1unit of BCS. [44] This would tend to support the observation that cows tolerate ¾ of BC loss. Thinner cows, particularly < 2.5 BC, had lower fertility than cows with greater BC.[44,45] Cows in thinner (≤ 3.0) or moderate BCS (3.35 - 3.75) at calving had a lower odds of pregnancy at first service (OR = 0.54, OR 0.71, respectively) compared to fat cows (≥ 4.0 BCS) at calving. [23] Body condition loss and BC at first insemination create the heterogeneity in associating condition score with conception rates.

The influence of energy balance on FSTCR may operate through delays in first ovulation. Cows that ovulate after 35 days postpartum have lower first service conception and lower pregnancy rates.[48] Longer days to first ovulation is associated with lower energy balance, later days to energy balance nadir, lower body condition score at 30 days postpartum, metritis, abnormal calving, ketosis, and increased serum NEFA in the first week postpartum.[10-14,16,40,41,46,49,50,56] Longer days to first ovulation postcalving is consistently associated with lower FSTCR.

Ovulation of the first dominant follicle occurred at 21 days postcalving in 30 - 50% of cows[10-14,16,40,41,46,49,50,56] (Figure 5). At 50 days postcalving, 20% of cows had not ovulated (Figure 5) resulting in lower first service conception rates. Cows that were in synchronized ovulation and timed artificial insemination program had a FSTCR of ~ 20% lower than cycling contemporary cows. Metritis,

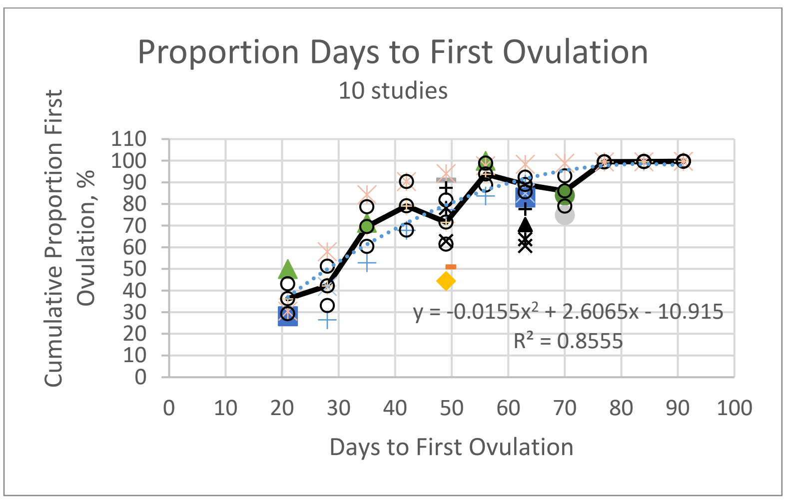


**Figure 5.** Cumulative proportion of cows with first ovulation by days postcalving across studies.[10-14,16,40,41,46,49,50,56]

ketosis, digestive upsets, and calving difficulties increased the proportion of anovulatory cows at 50 days postcalving to 30% and further reduction in FSTCR occurred in cows that had greater risk of endometritis.

**Embryonic mortality**

Postpartum conditions reduced conception at first insemination with higher pregnancy loss after insemination.[5,47,57] Losses in the first week were due to fertilization failure, from days 8 - 27 due to failure of maternal recognition of pregnancy, from 28 - 60 days due to improper placental development, and from 60 - 90 days, due to placental growth.[47] On dairy farms, fertilization failure and embryo losses are not apparent, except as return to estrus within 24 days from insemination. Losses from 8 - 27 days may only be apparent as returns to estrus between 25 - 35 days after insemination, but inseminations in this time period may be confounded with prior inseminations of cows that were not truly in estrus. Losses from 28 - 60 days and 60 - 90 days would be observable as cows checked pregnant at an examination from 28 - 42 days postinsemination then either returning to estrus after examination or not pregnant at a subsequent examination. These losses were characterized as late embryonic losses based on the classification; early embryonic loss (15 - 17 days postinsemination), late embryonic loss (17 - 42 days postinsemination), and fetal loss (after 50 days postinsemination).[57] Due to pregnancy losses and fertilization failure following insemination, it is estimated that only about 30 - 35% of inseminations result in a live calf.[5,47] With this degree of loss, it would require 5 or more inseminations to achieve 85% probability of inseminated cows recalving.

On most farms, with routine veterinary reproductive programs, pregnancy loss will be most apparent from 30 - 60 days after pregnancy examination. Typically, cows are first examined for pregnancy ~ 28 - 42 days postinsemination. Pregnancy loss was ~ 12% at 60 days postinsemination after a pregnancy examination at 30 days postinsemination.[47] However, this may be influenced by heat stress and prior postpartum conditions. Postpartum conditions will not only lower conception rates, they will also increase late embryonic loss.

Conditions (Figure 6) that result in pregnancy loss were classified.[45,49,59-84] Classifications were organized into two groupings: "no major problem:" (bcsmain = maintenance of body condition from calving; norm = cows with no health problems postcalving and ovulatory before insemination; bcsgain = cows gaining body condition from calving to insemination; bcsloss = cows with body condition loss from calving with no other identified health problems; tai = ovulatory cows inseminated on timed insemination; ov = cows that had ovulated prior to first insemination); "problem:" (dis = cows with 1 postpartum disease; met = cows with subclinical metabolic disease; phy = cows with a physical problem such as lameness or dystocia; inf = cows with metritis, endometritis, mastitis, pneumonia; multdis = cows with more than one condition post calving; abn = general classification for other abnormal conditions postcalving). Classes were examined using a random effects model in SAS model with study as random effect. A total of 94 observations were analyzed from 28 studies.

Data from cows classified as "no major problem" had a pregnancy loss of 16.5% (SEM $\pm$ 2.3%) similar to 12% reported.[47] However, cows with problems postcalving had a loss of 27.2% (SEM $\pm$ 3.1%). Cows that had not ovulated by the voluntary wait period had a pregnancy loss of 20.3%, intermediate to cows without a problem and cows with problems postcalving. This analysis should be viewed cautiously, as more descriptive analysis is needed. However, it points that the loss of pregnancy in cows with no problems are significant and losses in cows with problems are about double the loss in cows with no problems.

Proportion of pregnancy loss 30 days from first insemination (Figure 7) suggested wide variation, with higher losses in cows that had a lower CR at 30 days postinsemination.

**Overall impact on herd performance**

Most dairy farms calve cows year-round, have cows of multiple parities, and have a proportion of cows that experienced health problems postcalving. In addition, cows with no apparent health issues may

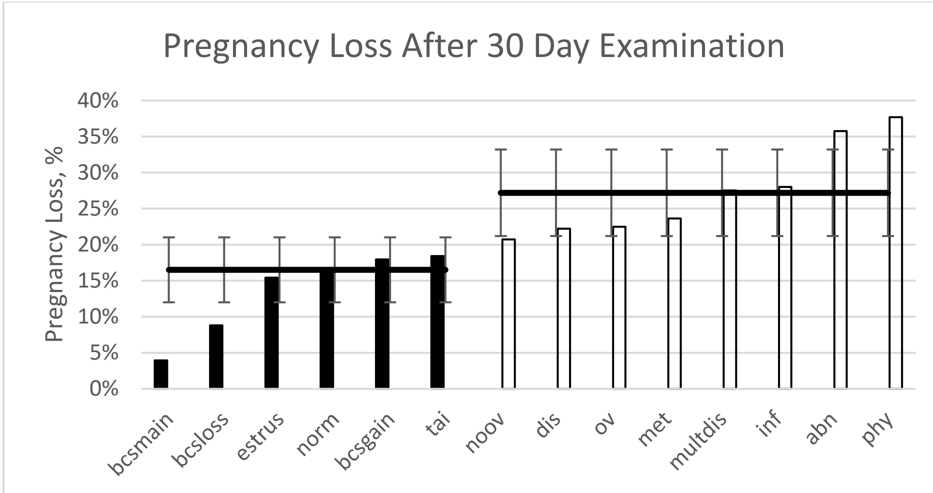


**Figure 6.** Random effects model of the proportion of pregnancies lost from first insemination after a "30" day initial pregnancy examination for categories of conditions: bcsmain = maintenance of body condition from calving; norm=cows with no health problems postcalving and ovulatory before insemination; bcsgain= cows gaining body condition from calving to insemination; bcsloss = cows with body condition loss from calving with no other identified health problems; tai = ovulatory cows inseminated on timed insemination; ov = cows that had ovulated prior to first insemination; dis = cows with one postpartum disease; met = cows with subclinical metabolic disease; phy = cows with a physical problem such as lameness or dystocia; inf = cows with metritis, endometritis, mastitis, pneumonia; multdis = cows with more than one condition postcalving; abn = general classification for other abnormal conditions postcalving. The lines represent a mean loss of 16.5% (SE 2.3%) and 27.2% (SE 3.1%), with error bars representing the 95% confidence range for the two estimates.

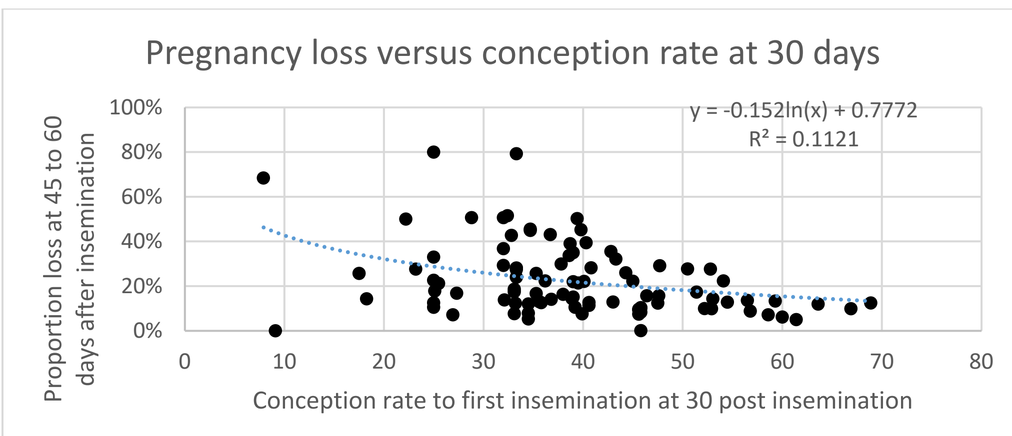


**Figure 7.** Proportion of pregnancies lost against the conception rate at 30 days after insemination.

not ovulate by 50 days postcalving. Healthy cows that ovulates prior to 50 days postcalving had the best fertility in the herd and the lowest pregnancy loss. Given the pattern of first ovulation (Figure 5), 81% of healthy cows would ovulate prior to 50 days postpartum and 19% of cows would not. For cows with health problems, 67% would ovulate by 50 days and 33% would not. Cows with delayed ovulation and health issues will have an OR of 0.54 for first service CR. Cows with more than one health problem or a health problem combined with delayed ovulation will have an OR of FSTCR of 0.29 (Table 3). The impact on FSTCR would be as follows: if healthy cows have a FSTCR of 50%, then healthy cows with ovulation later than 50 days would have a FSTCR of 35%, as would cows with one health problem that ovulated prior to 50 days. Cows with multiple health problems and with late first ovulation would have a FSTCR of 22%. Pregnancy losses will also be influenced by these conditions. Cows with no health problems that ovulated prior to 50 days would have a pregnancy loss of 16.5%, which would reduce

**Table 4.** Impact of heat detection rate (insemination rate), conception rate based on a pregnancy exam at 30 days postinsemination, OR of CR of 0.54 in cows with delayed ovulation after 50 days postpartum and with one health problem, and an OR of 0.28 in cows with two or more health problems or health problem and delayed ovulation. Pregnancy loss after 30 days was 16.5% for cows with no health problems and 27.2% for cows with delayed ovulation or one or more health problems. Break even dollars were calculated relative to a PR of 25%.

| HDR<br>% | Healthy Cows<br>% of cows calving | CR Needed to break even<br>% of insemination pregnant at 30 days |
|---|---|---|
| 50 | 50 | 76 |
| 50 | 60 | 73 |
| 50 | 70 | 69 |
| 50 | 80 | 66 |
| 60 | 50 | 70 |
| 60 | 60 | 67 |
| 60 | 70 | 63 |
| 60 | 80 | 60 |
| 70 | 50 | 64 |
| 70 | 60 | 61 |
| 70 | 70 | 57 |
| 70 | 80 | 54 |
| 80 | 50 | 58 |
| 80 | 60 | 55 |
| 80 | 70 | 51 |
| 80 | 80 | 48 |

pregnancy following first insemination from 50 to 42%. Healthy cows that ovulated after 50 days appear to have a pregnancy loss by 60 days of 20%, resulting in a pregnancy outcome at 60 days of 28%. Cows with health problems have a pregnancy loss of 28%; pregnancy at 60 days would be 25%. Pregnancy at 60 days in cows with multiple problems would be 20%.

Herd reproductive performance would be a composite of the proportion of healthy cows and cows with significant body condition loss and severe negative energy balance, infectious disease (metritis, endometritis, mastitis), metabolic disease (ketosis, displaced abomasum, lameness), subclinical metabolic conditions (elevated NEFA and BHBA, and hypocalcemia). The standard of fertility in the herd would be healthy cows with first ovulation prior to 50 days postcalving. All other groups of cows would have lower reproductive performance, both in terms of pregnancy at 30 days postinsemination and maintenance of pregnancy to 60 days postinsemination. Depending on the FSTCR in healthy cows and the proportion of healthy cows, the ability to achieve an optimal economic return on reproduction will be limited.

Impact of heat detection rate (HDR, insemination rate) on CR in healthy cows at 30 days postinsemination to achieve a PR of 25% is summarized (Table 4). It requires a herd with more than 50% of cows calving with no health problem and an insemination rate of 70% or better to have a CR in healthy cows below 55% to achieve a herd PR of 25%. This is a challenge on many dairy farms.

Typically, on most farms, only 50% of cows have no problems postcalving. Average HDR are below 50% according to DHIA summary statistics. Therefore, reproductive performance is below a pregnancy rate of 25% on most farms. This represents a significant loss of income. There are major opportunities to improve reproduction by improving health of cows in transition from the dry period to lactation and employing programs to ensure high rates of insemination.

## Conclusion

To prevent health problems postcalving in less than 50% of cows calving requires a sound management program prior to calving and in the first month postcalving. Housing, feed bunk access, and adequately formulated rations are a must for decreasing health conditions postcalving. It is beyond the scope of this paper to identify adequate rations for late pregnancy, but those are described elsewhere.[85-87]

## Conflict of interest

There are no conflicts of interest to declare.

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