Managing Milking Frequency

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Take Home Messages

- The mammary gland has the capacity to respond to increased demand by increasing milk yield
- Increasing milk yield per cow increases efficiency of production
- Milk yield responses to increased milking frequency are well-established
- Mechanisms of action are not well understood
- Recent studies have shown that increased milking frequency during early lactation causes an immediate increase in milk yield as well as a significant carry-over effect, even after extra milkings are stopped
- There is some flexibility in timing and duration of the extra milkings that can still elicit a carry-over response and increased persistency of lactation
- Early frequent milking can be a profitable management technique for increasing milk production efficiency

Introduction

Increasing milking frequency from two- to three- or more times daily is an effective management tool that allows dairy farmers to increase milk production efficiency. That the cow and its mammary glands can respond to more frequent milking has been reported since the late 1800's (reviewed by Wall and McFadden, 2008). The most common on-farm application of this concept has been to increase milking frequency from twice-daily (**2X**) to thrice-daily (**3X**), although other frequencies, from 1X to 6X, have been reported. More frequent milking is profitable when the value of the extra milk produced exceeds the costs associated with the extra milkings. Because the milk yield response to 3X milking is fairly consistent given adequate management, the profitability of adopting it depends mainly on labor and other costs as well as current milk prices. Cows milked 3X generally produce about 15% more milk than those milked 2X, and four times daily (**4X**) milking increases yield by a further 7%, relative to 3X (reviewed by Wall and McFadden, 2008). Currently, factors of 12-14% are used to adjust 3X milking records to 2X equivalence (VanRaden et al., 1999).

Table 1. Summary of literature reports on the milk yield response to increased milking frequency in dairy cows

Paper	Parity	2X vs. 3X	Reference
1	2+	(+) 1.34 kg/d	Rao and Ludri, 1984
2	2+	(+) 17%	DePeters et al., 1985
	1	(+) 6% (NS)[1]	
3	2+	(+) 18.5%	Amos et al., 1983
	1	(+) 25.2%	
4	2+	(+) 13.4%	Allen et al., 1985
	1	(+) 19.4%	
5	2+	(+) 12%	Gisi et al., 1986
	1	(+) 14%	
6	1	(+) 14%	Barnes et al., 1990
7	1+	(+) 17.3%[2]	Campos et al., 1994
	1+	(+) 6.3%[3]	
8	1+	(+) 10.4%	Klei et al., 1997
9	1+	(+) 16%	Smith et al., 2002

[1]NS = not significant; [2]Holstein, [3]Jersey

Many authors have reported on milk yield response to frequent milking (Table 1) and others have attempted to identify mechanisms of action behind the response. So far, the results have provided some insights but also raised new questions about the regulation of milk production efficiency. One more recent approach has been to impose extra milkings (4X or even 6X) only during the first 3 to 6 weeks of lactation (Bar-Peled et al., 1995; Hale et al., 2003; Dahl et al., 2004; VanBaale et al., 2005). The advantage of this approach is that not only is there an immediate milk yield response during the time of extra milkings but there is also a carry-over response such that part of the increase in milk yield remains through the rest of the lactation, even after cows are returned to normal, 2X milking (see Figure 1). Thus, managing milking frequency, especially early frequent milking, offers an attractive method to increase profitability and improve milk production efficiency.

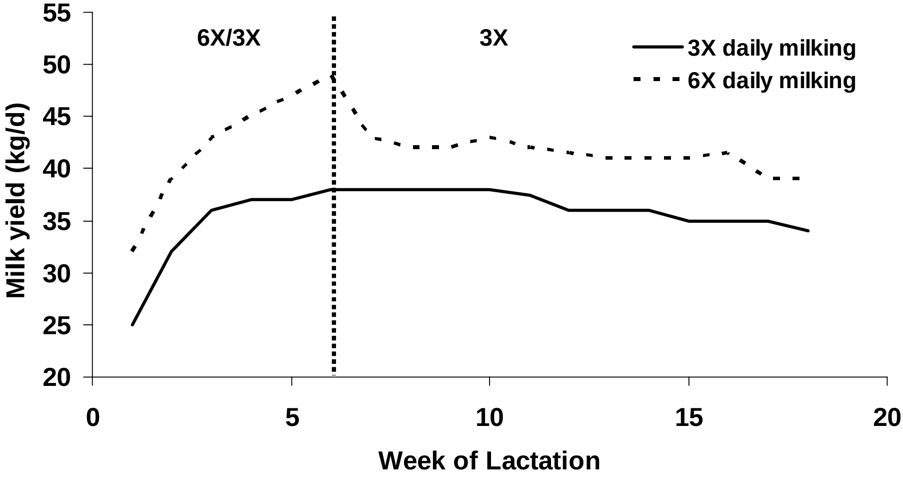


Figure 1. Frequent milking during early lactation increases milk production for the remainder of lactation (Bar-Peled et al., 1995)

■ Frequent Milking Increases Milk Production

There have been many studies on the milk yield response of dairy cows to frequent milking, as summarized in Table 1. Many studies were conducted during the 1980's and 1990's, when there was high interest in switching milking regimes from 2X to 3X in order to increase milk production efficiency. In summaries of DHIA records, the increase in milk yield of cows milked 3X compared to those milked 2X was 13, 12, and 16% (Allen et al., 1986; Gisi et al., 1986; Smith et al., 2002). These reports consisted of mostly Holstein herds, or mixed herds of Holsteins and Jerseys. Culotta and Schmidt (1988) suggested that smaller dairy breeds do not respond as well to frequent milking as larger breeds. Consistent with that prediction, Campos et al. (1994), reported that 3X increased milk yield by 17.3 and 6.3% relative to 2X in Holsteins and Jerseys, respectively. In contrast, Copeland (1934) found that Jerseys milked 3X produced 21% more milk and 19% more milk fat, than those milked 2X. They also found a positive correlation (+.64) between the amount of milk the cows produced prior to frequent milking and the magnitude of their response to frequent milking. That led to speculation that high producing cows respond better to increased milking frequency than lower producers. However, such a relationship was not conclusively established. More recently, Erdman and Varner (1995) reviewed the literature on frequent milking and found no correlation between prior milk yield and the response to frequent milking. Instead, they suggested that the milk yield response to increased (or decreased) milking frequency is incremental rather than proportional. They reported fixed milk yield responses of: -6.2, +3.5 and +4.9

kg/d for once daily milking (1X), 3X, and 4X, respectively, relative to 2X yields.

▪ Effects of Frequent Milking on Milk Composition and Cow Health

Reports on the effects of frequent milking on milk composition, SCC and herd health have been inconsistent. Many researchers have observed no effect of frequent milking on milk composition (Poole, 1982; Rao and Ludri, 1984; Amos et al., 1985; DePeters et al., 1985; Gisi et al., 1986), whereas some have observed a decrease in fat percentage (Allen et al., 1986; Smith et al., 2002), and others have observed an increase in fat and protein yield (Klei et al., 1997; Dahl et al., 2004b). With respect to SCC, some reports have indicated an association between frequent milking and decreased SCC, resulting in lower incidence of mastitis (Poole, 1982; Armstrong et al., 1985; Smith et al., 2002; Dahl et al., 2004b), whereas others have reported no effect of frequent milking on SCC (reviewed in Wall and McFadden, 2008). Discrepancies also exist in the reported effects of frequent milking on reproductive performance and herd health. Some researchers have observed decreased reproductive performance in 3X cows compared to 2X cows, whereas others have observed no effect or an improvement in reproductive performance with 3X (reviewed in Wall and McFadden, 2008). Armstrong et al. (1985) suggested that any negative effects of frequent milking on herd health or reproductive performance may be associated with poor herd management.

▪ Frequent Milking During Early Lactation: a Window of Opportunity

It has been established that the stage of lactation can influence the milk yield response to frequent milking. For example, switching from high to low milking frequency during middle to late lactation results in an immediate decrease in milk production (Morag, 1973; Svennersten et al., 1990). In contrast, frequent milking during early lactation can stimulate milk production through the remainder of lactation. This was originally observed in experiments designed to determine the milk yield loss associated with the use of nurse cows. Using identical twin cows, Everitt and Phillips (1971) discovered that allowing cows to nurse their calves, in addition to being machine milked, during the first 8 to 10 weeks of lactation resulted in higher milk yield after weaning and throughout the remainder of lactation, in both first calf heifers and mature cows. Similar observations were made by other researchers and many subsequent experiments have found that increased milking frequency during early lactation is associated with both acute and persistent increases in milk production (Wall and McFadden, 2008).

Pearson et al. (1979) and Poole (1982) compared 2X to 3X during the first half of lactation, followed by 2X. They observed that relative to 2X, 3X during early lactation resulted in an acute increase in milk yield, as well as a carry-over effect and greater persistency in the 3X cows and heifers (Pearson et al., 1979; Poole, 1982). These findings presented an exciting opportunity for dairy producers, such that an initial investment in labor could increase milk production efficiency for the remainder of lactation. Poole (1982) speculated that the practice may not be adopted, however, because producers would be discouraged by the decrease in milk production upon cessation of frequent milking, despite the significant carry-over effect.

In an attempt to minimize additional costs associated with frequent milking, and to investigate the response of dairy cows to frequent milking or suckling during a short interval of time in early lactation, Bar-Peled et al. (1995) compared 3X to 6X or 3X+suckling for the first 6 wk of lactation, followed by 3X of all cows. Relative to 3X during the entire lactation, 6X and 3X+suckling increased milk production by 7.3 and 14.7 kg/d, respectively (Figure 2; Bar-Peled et al., 1995). Cessation of frequent milking or suckling was associated with a decline in milk production, however a carry-over effect was observed in 6X cows (+5.1 kg/d relative to 3X; Bar-Peled et al., 1995). In a similar experiment, Sanders et al. (2000) observed an acute increase of 6 kg/d and a carry over response of 3.7 kg/d in 6X cows relative to 3X cows. In heifers, the acute response to 6X was lower in magnitude (+1.7 kg/d), and no carry effect was observed (Sanders et al., 2000).

The results of subsequent experiments have further narrowed down the "window" during early lactation wherein frequent milking can increase milk production for the remainder of lactation. Hale et al. (2003) assigned cows to 2X or to 4X for the first three wk of lactation, followed by 2X thereafter. Four times daily milking was associated with an acute increase of 8.8 kg/d and a carry over effect of 2.6 kg/d for the remainder of lactation (Hale et al., 2003). This time interval of 1 to 21 DIM was also used in a field study by Dahl et al. (2004b), and the observed effects of frequent milking during early lactation were consistent with those of Hale et al. (2003). In contrast, VanBaale et al. (2005) reported that 3X was associated with increased milk production relative to 6X. In this field study, cows were assigned to 3X or 6X for the first 7, 14, or 21 days of lactation. Their observations were inconsistent with previous reports, as 3X cows produced more than 6X cows both during and after 6X (VanBaale et al., 2005). The authors speculated that facility logistics may have influenced their results, because 6X cows were housed farther away from the milking parlor and spent a considerably longer time away from their pen than 3X cows.

With few exceptions (VanBaale et al., 2005), a positive effect of frequent milking on milk yield of dairy cows has been established and it is widely accepted that increased milking frequency during early lactation increases milk yield for the remainder of lactation. It has been suggested that this may reflect an evolutionary adaptation to match milk yield to demands of the offspring (Dahl et al., 2004a), but the mechanistic basis for the milk yield response is poorly understood.

■ Cellular Response to Frequent Milking

Several authors have speculated that frequent milking increases milk yield via an increase in mammary cell number and/or secretory activity (see Wall and McFadden, 2008). Stelwagen (2001) suggested that the acute response to frequent milking may be the result of increased secretory cell activity, whereas the long term response may be due to an increase in cell number. Hale et al. (2003) observed an increase in mammary cell proliferation at 7 DIM when cows were milked 4X for the first 3 wk of lactation. We observed an increase in proliferation only in nonsecretory cells in response to 4X, and no effect on mammary cell death (Wall et al., 2006). There were also changes in mammary expression of genes such as suppressor of cytokine signaling (SOCS) -2 and SOCS-3 in response to 4X. The SOCS genes regulate tissue responses to cytokines and hormones such as prolactin, and their function in mammary tissue has been linked to milk stasis and mammary cell proliferation and death (Wall et al., 2006). The role of SOCS in the bovine mammary gland is still unclear, but the response of these genes to frequent milking is intriguing and further investigations are warranted.

■ Local Regulation of Milk Production

Milk secretion is partially regulated by local factors within the udder, independent of systemic factors (Wilde et al., 1995). Local regulation could involve changes in udder pressure or factors present in milk that alter mammary function and milk production. Increased mammary pressure due to prolonged milking intervals may result in decreased blood flow to the gland, or (more likely) breakdown of tight junctions and loss of secretory function (Knight et al., 1998). However, when mammary pressure was maintained during frequent milking by infusion of sucrose into the mammary gland, milk yield was not affected (Henderson and Peaker, 1984). They proposed an alternate hypothesis: that milk contains a chemical factor that signals the gland to reduce milk secretion as it accumulates between milkings. A small glycoprotein in milk that was shown to reversibly inhibit casein and lactose synthesis was named ‘feedback inhibitor of lactation’ (FIL), and was proposed to be involved in autocrine regulation of milk secretion (Wilde et al., 1995). After a prolonged period of study there has been little further progress reported on this topic recently. However, the concept remains intriguing and our current research has discovered several novel factors that may be local regulators of milk secretion.

■ Unilateral Frequent Milking

The concept of unilateral frequent milking (UFM), in which one udder half is milked at a given frequency and the other half is milked at a different one was introduced shortly after a report in the 1930's that frequent milking increased milk yield. Half-udder designs are extremely powerful because they eliminate variation between animals due to environment, nutrition, and genetics. In addition, both udder halves are exposed to the same systemic factors, hence responses to frequent milking are strictly at the level of the mammary gland. A summary of the milk yield response to frequent milking in half-udder experiments is presented in Wall and McFadden (2008). Early reports provided strong evidence for local regulation of milk production and indicated that the increase in milk yield in response to UFM occurs within 24 h, and the magnitude of the response was independent of previous milk production.

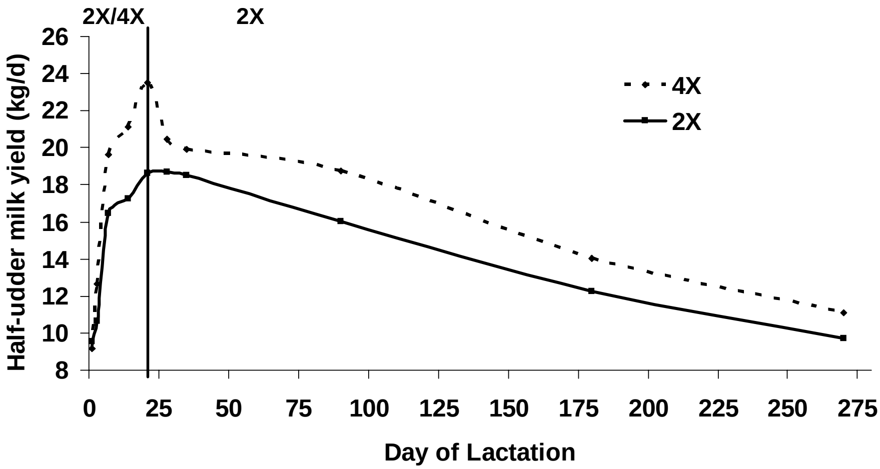
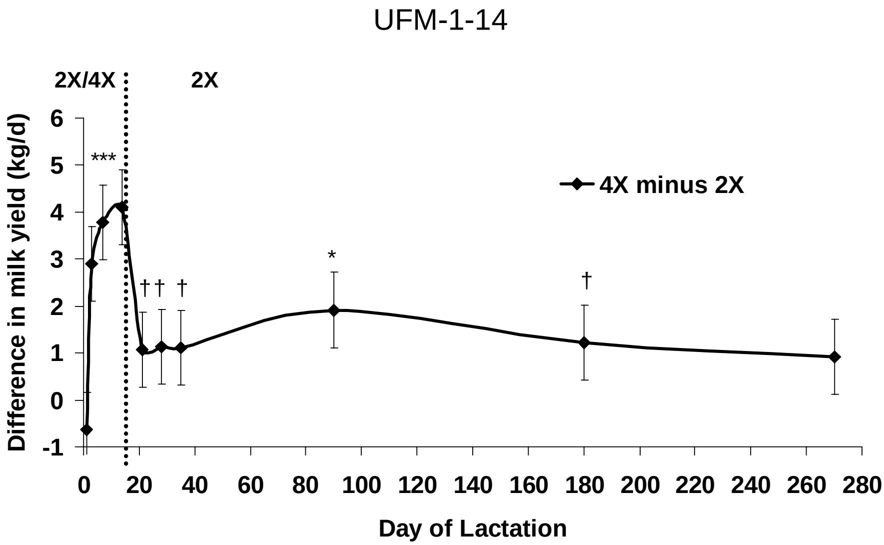


Figure 2. Milk yield response to unilateral frequent milking on days 1 to 21 of lactation. Milk production of udder halves milked 4X increases during frequent milking and remains elevated even after returning to 2X milking for the remainder of lactation (Wall and McFadden, 2008).

In a mechanistic experiment, Hillerton et al. (1990) used a UFM model and milked udder halves 2X or 4X for 4 wk during mid-lactation. In both cows and heifers, milk production of 4X udder halves increased by 10% relative to 2X udder halves. The authors also reported an increase in activity of mammary enzymes, and more protein and lactose synthesis (in heifers only), DNA synthesis, and alveolar area in 4X glands (Hillerton et al., 1990). They speculated that cellular differentiation and proliferation were optimized with frequent milking. Conversely, Norgaard et al. (2005) found no effect of UFM on cell death, proliferation, or enzyme activities, despite an increase in milk yield in the 4X udder half. They reported that frequent milking caused an increase in mammary gland size, and suggested that negative feedback/pressure in the udder may regulate the effect of frequent milking on milk production. Others (Knight et al., 1992) had also observed an increase in epithelial cell size in heifer mammary glands milked 4X compared to glands milked 2X.

▪ Optimizing the Implementation of Frequent Milking

The research reviewed above clearly shows the potential for manipulating milking frequency to improve milk production efficiency and, potentially, on-farm profitability. The greatest opportunity is offered by the early frequent milking approach, which features an immediate milk yield response and, more importantly, a carryover effect that persists even after the return to normal, 2x milking. We have sought to optimize these responses by studying the timing and duration of the period of 4X milking, using the UFM (half-udder) experimental model. After establishing that milk yield responses in the half udder model were essentially identical to those found in cow trials (see Figures 1 & 2; note that the difference in milk yield of udder halves in Figure 2 must be doubled to be comparable to whole udder yields in Figure 1) we reduced the duration of 4X milking to 14 days and implemented it from days 1-14 or days 7-21 of lactation (Wall and McFadden, 2007a, b). The difference in milk yield of udder halves milked 4X for the indicated interval, relative to udder halves milked 2X throughout the trial, is shown in Figure 3. In both trials, milk yield increased when 4X milking was imposed and the peak response on day 21 was similar but the response was more rapid when 4X milking was initiated on day 1 rather than on day 7. The amount of extra milk produced in the 1st 21 days was similar in these two trials but less than that obtained after 3 weeks of 4X milking (Figure 2) due to the shorter duration of extra milking.



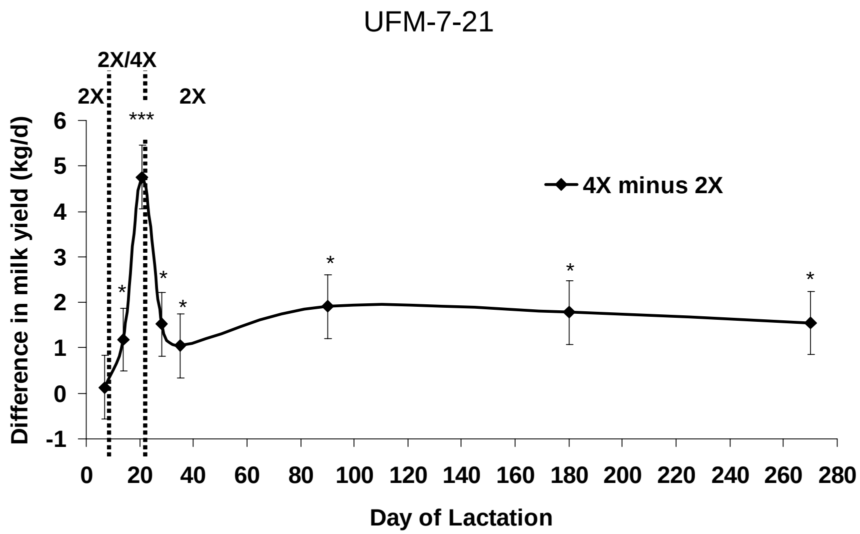


Figure 3. Difference in milk yield of udder halves milked 2X or 4X for A. days 1-14 of lactation, or B. days 7-21 of lactation. Dotted vertical lines indicate duration of UFM. Milk yield of the 2X side was subtracted from that of the 4X side. In both treatments, milk production from the 4X udder half increased dramatically during UFM ($P < 0.001$). For the remainder of lactation, milk production from the 4X udder half was greater than that of the 2X udder half ($P < 0.05$).

More importantly, although much of the milk yield differential was lost after resuming 2X milking, a significant carryover effect was found in both trials. Although the magnitude of the carryover response appears small, when doubled to put it on a whole udder equivalent basis, then multiplied over the remaining 284 days of a normal 305-day lactation, it amounts to a substantial increase in total milk yield (Wall and McFadden, 2007b). Because one of our objectives was to assess the predicted profitability of these milking routines, we calculated the economic returns based on calculated milk yield and estimated costs, assuming a milk price of USD$12/100 lb of milk. As seen in Table 2, projected net income ranged from USD$40 – 90 per cow per year, or USD$4,000 - $9,000 for a 100-cow herd.

Assuming a milk price of CAD$70/hL, and milk composition of 3.3% protein and 4.0% fat, the comparable values in Table 2 for extra milk income/cow/yr would be CAD$781, CAD$557 and CAD$634 for 4X milking on days 1-21, 1-14, and 7-21, respectively. Total net income per cow/yr in CAD can be calculated by estimating costs of the listed items and subtracting from extra milk income.

While actual costs of feed, labor and materials, as well as milk prices will vary across farms and years, the potential returns of managing milking frequency are readily apparent.

Table 2. Potential economic return of milking four-times daily during early lactation. Costs and income are in US Dollars.[1]

Milking routine[2]	Feed cost during FM[3]	Feed cost after FM[4]	Labor[5]	Misc. cost[6]	Extra milk income /cow/yr[7]	Total net income /cow/yr
4X 1 to 21	$19.28	$98.00	$84.00	$0.50	$294.75	$92.94
4X 1 to 14	$12.86	$100.75	$56.00	$0.34	$210.29	$40.33
4X 7 to 21	$12.86	$98.00	$56.00	$0.34	$239.33	$72.12

[1]From Wall and McFadden (2007b) J. Dairy Sci. 90:5042-5048.
[2]Four times daily milking for days 1 to 21, 1 to 14 or 7 to 21 of lactation, followed by twice daily milking for the remainder of lactation.
[3]Additional feed to support increased milk production during frequent milking (**FM**), estimated at $0.92/cow/d.
[4]Additional feed to support increased milk production after frequent milking, estimated at $0.39/cow/d.
[5]Additional labor associated with extra milkings and animal handling during 4X milking, approximately $4/d
[6]Cost associated with extra milkings, including inflation replacement, teat dip, and towels; approximately $0.025/d
[7]Extra milk income is based on $12/100 lb of milk.

Summary

A number of research groups have attempted to characterize the economic return of frequent milking. Factors contributing to the profitability of frequent milking were labor, herd size, herd health, management, feed costs, and milk price (Armstrong et al., 1985; Culotta and Schmidt, 1988). Rao and Ludri (1984) reported that 3X increased net income by 21% relative to 2X. More recently, we estimated a net increase of approximately $93/cow/yr when cows were milked 4X for the first 3 wk of lactation, followed by 2X (Wall and McFadden, 2007b). Therefore, we conclude that managing milking frequency has strong potential for increasing milk production efficiency and farm profitability.

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