Effect of Milking Frequency on DHI Performance Measures

J. W. Smith, L. O. Ely, W. M. Graves, and W. D. Gilson

Department of Animal and Dairy Science
The University of Georgia, Athens 30602

ABSTRACT

Increasing production by increasing milking frequency (MF) is a management option available to dairy producers. This study examined effects of MF and interactions with region and herd size on measures of herd performance. Dairy Herd Improvement (DHI) Holstein herd summary records ($n = 10,754$, $10,550$, and $10,438$) for the years 1998, 1999, and 2000 were classified by MF: two times a day (2X) milking vs three times a day (3X); herd size: small (< 250 cows) and large (≥ 250 cows); and region: North and South. Percentage of herds milking 3X by year were 7.0, 6.7, and 7.1. Rolling herd average milk production was 16, 16, and 15% higher for herds milking 3X than herds milking 2X for the respective years. Herds milking 3X in the North region outproduced herds milking 3X in the South region. Milk fat and protein percentages were lower for herds milking 3X during all 3 yr. Differences in energy-corrected milk production between herds milking 3X and herds milking 2X were 14.5, 13.4, and 13.4% during the respective 3 yr as a result of lower component percentages for herds milking 3X. Herds milking 3X had more days open and higher actual calving intervals than herds milking 2X. Services per pregnancy for herds breeding primarily by artificial insemination were higher for herds milking 3X than for herds milking 2X. Somatic cell scores and weighted somatic cell counts were lower for herds milking 3X than herds milking 2X. Herds milking 3X had a higher percentage of somatic cell scores in the low range (0 to 3) and a lower percentage in the high range (7 to 9). Mean percentages of cows entering and leaving the herd were higher for herds milking 3X during all 3 yr.

(**Key words:** Dairy Herd Improvement, frequency, management, milking)

Abbreviation key: CMT = California mastitis test, ECM = energy-corrected milk, MF = milking frequency, 3X = three times a day, 2X = two times a day.

INTRODUCTION

Many dairy producers seek higher levels of production in response to increased costs of production and a tendency for static or lower milk prices. Increasing production by increasing milking frequency (MF) to three times a day (3X) is one management option. Increased efficiency through parlor automation and mechanization have made 3X milking an attractive option for some herds.

Most studies conducted on MF have measured the effect of milking 3X on milk yield and components. Total milk yield is higher from cows milked 3X (Amos et al., 1985; DePeters et al., 1985; Allen et al., 1986; Gisi et al., 1986; Barnes et al., 1990). Higher production from 3X milking is usually expressed as a percentage (Gisi et al., 1986; Campos et al., 1994). However, an analysis of previously published reports found that increasing MF from two times a day (2X) to 3X resulted in a fixed increase of 3.5 kg/d in milk yield and 92 g/day in fat yield independent of parity (Erdman and Varner, 1995).

Some studies (Allen et al., 1986; Barnes et al., 1990; Speicher et al., 1994) reported a lower concentration of milk components from cows milked 3X, whereas others (Amos et al., 1985; DePeters et al., 1985) did not report any significant changes. The percentage of CP was lower for cows milked 3X than cows milked 2X during each lactation stage (Klei et al., 1997). A lower concentration of fat and casein from cows milked 3X could result in lower cheese yield. (Sapru et al., 1997).

Reproduction performance was not altered by 3X milking in some studies, whereas others have shown a trend for reduced reproductive performance. Barnes et al. (1990) concluded that MF did not alter days to first service, inseminations per conception, or days open. Reproductive performance was not influenced by MF, but there was a trend for increased days open in a study by Amos et al. (1985). They concluded that further research with larger numbers of cows may be required to define more clearly the influence of 3X milking on total reproductive performance. DePeters et al. (1985) reported a trend for poorer reproductive performance of cows milked 3X than cows milked 2X. Gisi et al. (1986) found no effect of 3X milking on calving interval, days open, or services per conception, but reproductive

Received April 19, 2002.

Accepted June 20, 2002.

Corresponding author: J. W. Smith; e-mail: jimsmith@uga.edu.

indexes on a herd basis tended to increase as milking 3X increased. In a California study, 3X milking was associated with more days open in first-lactation cows and a greater number of breedings per conception in both first- and second-lactation cows (Allen et al., 1986).

Most studies have reported little or no effect of 3X milking on udder health (DePeters et al., 1985; Gisi et al., 1986). A trend for lower SCC in cows milked 3X (Klei et al., 1997), and a reduction in Wisconsin mastitis test scores and a slightly lower incidence of mastitis in 3X milked cows was reported (Pearson et al., 1979). Cows milked 3X up to the third lactation had higher California mastitis test (CMT) scores than cows milked 2X. Fourth and later lactation cows milked 3X had lower CMT scores than cows milked 2X (Allen et al., 1986). Bulk tank SCC declined from 193,000 to 162,000 cells/ml when cows were changed to 3X milking (Hogvee et al., 2001). The number of cows with SCC greater than 250,000 cells/ml also decreased. When herds resumed 2X milking the trends reversed.

Reports of the effect of 3X milking on other herd management factors are limited. Allen et al. (1986) reported that fewer cows were culled from herds milking 3X across all parities. Gisi et al. (1986) reported that the response to 3X milking in 28 California herds was not related to herd size or production level when on 2X milking.

The decision to begin or continue 3X milking should be based on profitability. Culotta and Schmidt (1988) concluded from an economic evaluation that with their current milk and feed prices, 3X milking would be profitable only if the increased cost of labor were very low, large percentages in milk yield due to 3X milking were obtained, or if high milk yield per cow already existed on 2X milking.

The objective of this study was to determine the effect of MF and the interaction of MF with herd size and region on DHI measures of performance.

MATERIALS AND METHODS

Herd summary records from DHI for the years 1998, 1999, and 2000 were obtained from Dairy Records Management Systems (Raleigh, North Carolina). Holstein herds with 30 or more cows, a minimum rolling herd average of 6350 kg, and a last test date between November 1 and December 31 were included. Herd size groups were small (<250 cows) and large (≥ 250 cows). Herds within a state were assigned to North and South regions as shown in Figure 1. Energy-corrected milk (ECM) production was calculated as $ECM = (0.3246 \times \text{kg of milk}) + (12.86 \times \text{kg of fat}) + (7.04 \times \text{kg of protein})$. Herds were classified for analysis of reproductive variables. The All class included all herds regardless of percentage

Figure 1. Assignment of states to north and south regions.

of AI service sire usage. The AI class was limited to herds using 70% or more AI service sires and an average services per pregnancy ≥ 1.5 . Bovine somatotropin usage is not routinely reported on DHI records. An equal distribution of bST usage across all herd groups regardless of region and MF was assumed in this study.

Data were analyzed using SAS PROC GLM for main effects (MF, size, region) and two-way interactions (MF $\times$ size, MF $\times$ region) (SAS, 1996). Least squares means were compared by the Tukey option of SAS PROC GLM (SAS, 1997). The level of significance used was $P < 0.05$. Only significant main effects for MF and MF interactions are reported and discussed.

RESULTS AND DISCUSSION

The distribution of herds by MF, MF by herd size, and MF by region is shown in Table 1. The percentage of herds milking 3X was similar across years. The percentage of large herds milking both 2X and 3X increased by year, whereas the percentage of small herds milking 3X declined. The trend of 3X milking was similar across regions.

Milk Production and Composition

Milk production was significantly higher for herds milking 3X for all years ($P < 0.05$; Table 2). Herds milking 3X produced 16, 16, and 15% more milk than herds milking 2X during the respective years. Small and large herds milking 3X did not differ in production except in the year 2000. Herds in the North significantly outproduced herds in the South in 1998 and 1999 irrespective of MF ($P < 0.05$). The higher milk yield by cows and herds milked 3X agrees with other studies (Amos et al., 1985; DePeters et al., 1985; Allen et al., 1986; Gisi et al., 1986; and Barnes et al., 1990). Reviews of previous

Table 1. Percentage and number of herds for milking frequency (MF), MF by herd size, and MF within region for 1998, 1999, and 2000.

MF		1998		1999		2000	
		Percent	No.	Percent	No.	Percent	No.
2X		93.0	9999	93.1	9819	92.9	9701
3X		7.0	755	6.9	731	7.1	737
	Herd Size ¹						
2X	Large	3.9	417	4.2	449	4.7	487
2X	Small	89.1	9582	88.8	9370	88.3	9214
3X	Large	3.2	339	3.4	360	3.8	397
3X	Small	3.8	416	3.5	371	3.2	340
	Region ²						
2X	North	76.9	8274	77.4	8165	76.9	8024
2X	South	16.0	1725	15.7	551	16.1	570
3X	North	5.4	579	5.2	1654	5.4	1677
3X	South	1.6	176	1.7	180	1.6	167

¹Herd sizes are large (≥ 250 cows) and small (< 250 cows).

²Regions are North and South (see Figure 1).

reports by other researchers (Campos et al., 1994; Klei et al., 1997) suggest an average expected increase of about 12 to 15% when herds change from 2X to 3X milking. Milk yield increased 12% above previous 2X production on 28 California Holstein herds based on DHI herd summary records (Gisi et al., 1986). Herds in our study are designated 3X if the cows were milked 3X for all or any part of the yearly period. True 3X milk yield is probably higher than that shown in Table 2 because an unknown number of herds were milked 2X for part of the year, but production records for those herds were included in the summarized 3X yield. Because 3X herds in the current report averaged 15 to 16% more milk compared with studies reporting

slightly lower percentage differences, undefined management factors other than MF may account for some of the observed milk yield differences.

Milk fat and protein percentages were significantly lower for herds milking 3X during all 3 yr ($P < 0.05$; Table 3). Although milk from herds milking 2X in the North had a higher percentage of milk fat than herds milking 2X in the South, herds milking 3X did not differ by region. Herds milking 2X and 3X in the South had a significantly higher protein percentage in two out of the three years ($P < 0.05$). Milk composition was not affected by MF in studies by Amos et al. (1985) and DePeters et al. (1985). Milk fat percentage was not affected by MF (Gisi et al. (1986). Allen et al. (1986)

Table 2. Effect of milking frequency (MF) and interactions of MF with herd size and MF with region on herd average milk production¹ for 1998, 1999, and 2000.

MF		1998	1999	2000
2X		8698 ^b	8853 ^b	9013 ^b
3X		10,086 ^a	10,163 ^a	10,386 ^a
Difference, %		16	16	15
SEM		44	43	44
	Herd Size ²			
2X	Large	8732 ^b	8942 ^b	9081 ^c
2X	Small	8663 ^b	8764 ^b	8946 ^c
3X	Large	9994 ^a	10,057 ^a	10,170 ^b
3X	Small	10,179 ^a	10,268 ^a	10,603 ^a
SEM		57	57	58
	Region ³			
2X	North	9089 ^c	9289 ^b	9423
2X	South	8307 ^d	8416 ^c	8604
3X	North	10,654 ^a	10,806 ^a	10,891
3X	South	9518 ^b	9519 ^b	9882
SEM		59	59	60

^{abcd} Least squares means within a column for main effects or interaction with the same superscripts do not differ ($P < 0.05$).

¹DHI rolling herd milk production.

²Herd sizes are large (≥ 250 cows) and small (< 250 cows).

³Regions are North and South (see Figure 1).

Table 3. Effect of milking frequency (MF) and interaction of MF with region on milk fat and protein percentages¹ for 1998, 1999, and 2000.

MF		Fat			Protein		
		1998	1999	2000	1998	1999	2000
		(%)					
2X		3.64 ^a	3.64 ^a	3.67 ^a	3.19 ^a	3.22 ^a	3.10 ^a
3X		3.54 ^b	3.57 ^b	3.58 ^b	3.15 ^b	3.19 ^b	3.08 ^b
SEM		0.01	0.01	0.01	0.004	0.004	0.003
	Region ²						
2X	North	3.72 ^a	3.70 ^a	3.74 ^a	3.19	3.20 ^b	3.09 ^b
2X	South	3.56 ^b	3.57 ^b	3.61 ^b	3.19	3.24 ^a	3.12 ^a
3X	North	3.58 ^b	3.59 ^b	3.61 ^b	3.14	3.15 ^c	3.05 ^c
3X	South	3.50 ^b	3.56 ^b	3.55 ^b	3.16	3.24 ^a	3.12 ^a
SEM		0.01	0.01	0.01	0.005	0.005	0.005

^{abc}Least squares means within column for main effects or interaction with the same superscript do not differ ($P < 0.05$).

¹DHI rolling herd average milk fat and milk protein percentages.

²Regions are North and South (see Figure 1).

reported a slightly lower milk fat percentage from cows milked 3X compared with cows milked 2X. Increasing MF from 2X to 3X reduced milk fat percentage from multiparous cows and reduced protein percentage from multiparous and primiparous cows (Speicher et al., 1994). In a study by Barnes et al. (1990), cows milked 3X had a lower fat percentage and tended to weigh less than cows milked 2X. This suggested that more body tissue was catabolized for milk production because DMI was not different between the MF groups. Klei et al. (1997) reported a lower percentage of CP in milk from cows milked 2X during all lactation stages. Milk from cows milked 3X had a lower concentration of milkfat and casein than milk from cows milked 2X in a study by Sapru et al. (1997).

ECM production for herds milking both 2X and 3X followed a trend similar to actual milk production (Table 4). However, the difference between the ECM production of herds milking 2X and herds milking 3X was less than the difference between 2X and 3X actual milk production during all 3 yr. The smaller difference for ECM production is the result of the significantly lower fat and protein percentages for herds milked 3X. The effect of MF on ECM has not been reported previously.

Reproduction

Projected days open were significantly higher ($P < 0.05$) for both All herds and AI herds milked 3X across all 3 yr (Table 5). Herds milked 3X in the South tended to have the most days open, but this was significant only in the year 2000 ($P < 0.05$). The effect of MF on actual calving interval followed the same trend as projected days open (Table 6). The actual calving interval was significantly higher for herds milked 3X each year ($P < 0.05$). Milking frequency did not significantly affect

days to first service for AI herds. The number of services per pregnancy was significantly affected by MF ($P < 0.05$; Table 7). The number of services per pregnancy for all cows and for pregnant cows was significantly higher for herds milked 3X during all 3 yr ($P < 0.05$). Large-size herds milked 3X tended to have the most services per pregnancy, but the interaction was significant only in the year 2000 for the pregnant cows category ($P < 0.05$).

Other studies generally have not reported a significant effect of 3X milking on reproductive efficiency. Increased MF did not significantly affect conception rates or days open in a study by Barnes et al. (1990). Amos et al. (1985) reported that reproductive performance was not significantly altered by MF as measured by days to first estrus, days open, and services per conception. However, days open for cows milked 3X were longer by a numerical average of 18.1 d. Gisi et al. (1986) also did not find a significant difference in reproductive indexes with 3X milking, but there was a trend for the indexes to increase with 3X milking. The influence of 3X milking on reproductive performance may be related to parity. Allen et al. (1986) concluded that milking cows 3X had no adverse effect on reproductive efficiency. However, first-lactation cows milked 3X had more days open compared with cows milked 2X. Milking frequency did not affect days open for second-lactation cows. Third, fourth, and later parity cows milked 3X had fewer days open than cows milked 2X. The number of breedings for first- and second-lactation cows milked 3X was significantly higher than for cows milked 2X. There was no difference for cows in their third or later lactations.

Reproductive performance of cows milked 3X was not significantly different from cows milked 2X as reported by DePeters (1985). However, all indices of reproductive

Table 4. Effect of milking frequency (MF) and interactions of MF with herd size and MF with region on herd energy-corrected milk (ECM) production¹ for 1998, 1999, and 2000.

MF		1998	1999	2000
2X		8959 ^b	9131 ^b	9270 ^b
3X		10,264 ^a	10,360 ^a	10,517 ^a
Difference, %		14.5	13.4	13.4
SEM		52	50	51
	Herd Size ²			
2X	Large	9095 ^b	9454 ^c	9438 ^b
2X	Small	8822 ^c	8972 ^b	9102 ^c
3X	Large	10,220 ^a	10,314 ^a	10,358 ^a
3X	Small	10,308 ^a	10,406 ^a	10,677 ^a
SEM		66	64	64
	Region ³			
2X	North	9369	9539 ^b	9640
2X	South	8549	8724 ^c	8900
3X	North	10,740	10,924 ^a	10,940
3X	South	9789	9796 ^b	10,094
SEM		69	68	149

^{abc}Least squares means within column for main effect or interactions with the same superscripts do not differ ($P < 0.05$).

¹Calculated using DHI rolling herd average milk, fat, and protein production ($\text{ECM} = [0.346 \times \text{kg of milk}] + [12.86 \times \text{kg of fat}] + [7.04 \times \text{kg of protein}]$).

² Herd sizes are large (≥ 250 cows) and small (< 250 cows).

³Regions are North and South (see Figure 1).

Table 5. Effect of milking frequency (MF) and the interaction of MF and region on projected days open for All herds and AI herds.¹

MF		All herds			AI herds		
		1998	1999	2000	1998	1999	2000
2X		163.0 ^b	164.4 ^b	162.4 ^b	157.7 ^b	158.8 ^b	157.3 ^b
3X		169.4 ^a	171.2 ^a	168.6 ^a	164.8 ^a	164.4 ^a	165.9 ^a
SEM		1.2	1.2	1.2	1.3	1.3	1.3
	Region ³						
2X	North	155.7 ^a	156.9 ^a	154.4 ^c	149.5 ^a	150.8 ^a	149.8 ^c
2X	South	170.2 ^a	171.9 ^a	170.4 ^b	166.0 ^a	166.9 ^a	164.9 ^b
3X	North	159.4 ^a	161.5 ^a	156.2 ^c	155.4 ^a	156.7 ^a	152.8 ^c
3X	South	179.4 ^a	180.8 ^a	180.9 ^a	174.1 ^a	172.1 ^a	179.0 ^a
SEM		1.7	1.7	1.7	1.7	1.8	1.7

^{abc}Least squares means within column for main effect or interactions with the same superscripts do not differ ($P < 0.05$).

¹All herds includes herds regardless of AI service sire usage. AI herds are limited to herds using 70% or more AI service sires and services per pregnancy ≥ 1.5 .

³Regions are North and South (see Figure 1).

Table 6. Effect of milking frequency (MF) on actual calving interval for All herds and AI herds.¹

MF	All herds			AI herds		
	1998	1999	2000	1998	1999	2000
	months					
2X	13.77 ^b	13.97 ^b	14.02 ^b	13.86 ^b	14.07 ^b	14.11 ^b
3X	13.95 ^a	14.20 ^a	14.25 ^a	13.98 ^a	14.27 ^a	14.29 ^a
SEM	0.03	0.03	0.03	0.04	0.04	0.04

^{ab}Least squares means within a column with the same superscript do not differ ($P < 0.05$).

¹All herds includes herds regardless of AI service sire usage. AI herds are limited to herds using 70% or more AI service sires and services per pregnancy ≥ 1.5 .

Table 7. Effect of milking frequency (MF) and the interaction of MF and herd size on services per pregnancy.

MF		Services per pregnancy (pregnant) ¹			Services per pregnancy (all) ²		
		1998	1999	2000	1998	1999	2000
2X		3.79 ^b	3.76 ^b	3.69 ^b	2.36 ^b	2.42 ^b	2.40 ^b
3X		4.17 ^a	4.09 ^a	4.17 ^a	2.45 ^a	2.52 ^a	2.53 ^a
SEM		0.05	0.04	0.04	0.02	0.02	0.02
	Herd Size ³						
2X	Large	4.12 ^a	4.08 ^a	3.97 ^b	2.47 ^a	2.52 ^a	2.50 ^a
2X	Small	3.46 ^a	3.44 ^a	3.42 ^c	2.26 ^a	2.32 ^a	2.30 ^b
3X	Large	4.39 ^a	4.33 ^a	4.29 ^a	2.53 ^a	2.59 ^a	2.58 ^a
3X	Small	3.96 ^a	3.85 ^a	4.05 ^b	2.37 ^a	2.44 ^a	2.48 ^a
SEM		0.06	0.05	0.05	0.02	0.02	0.02

^{ab}Least squares means within a column with the same superscript do not differ ($P < 0.05$).

¹Services per pregnancy for pregnant cows.

²Services per pregnancy for all cows.

³Herd sizes were large (≥ 250 cows) or small (< 250 cows).

performance were poorer for cows milked 3X compared with cows milked 2X with the greatest effect on first lactation cows. The authors concluded that the poor reproductive performance of cows milked 3X may be related to large changes in BW over the lactation in response to milk yield.

Butler and Smith (1989) evaluated the loss in BCS during the first 5 wk postpartum as well as reproductive performance. Days to first ovulation, days to first estrus, and days to first service increased whereas first-service conception rate decreased with greater loss in BCS. Spaulding et al. (1975) reported that the level of milk production had an inverse relationship with fertility and reproduction for given ages and herd sizes.

Udder Health

SCC score and weighted SCC were significantly lower ($P < 0.05$) for herds milked 3X compared to herds milked 2X during all 3 yr (Table 8). Herds milked 3X had a significantly higher percentage of SCS in the low (0 to 3) range, and a lower percentage in the high range (7 to 9) during the 3-yr period ($P < 0.05$; Table 9). Information on the effect of 3X milking on udder health is limited. Udder health was not affected by 3X milking based on California mastitis scores (Gisi et al., 1986) and the

incidence of clinical mastitis cases (DePeters et al., 1985). Allen et al. (1986) found that udder health as measured by California mastitis test (CMT) scores was lower for cows milked 3X. Cows milked 3X up to the third lactation had higher CMT scores than cows milked 2X. Fourth and later lactation cows had lower CMT scores. Klei et al. (1997) reported slightly lower SCC for cows milked 3X. Hogeveen et al. (2001) used data from 57 herds and observed that changing from 2X to 3X milking resulted in a bulk tank SCC decrease from 193,000 to 162,000 cells/ml. The authors also reported a decrease in the number of cows with cell counts greater than 250,000 cells/ml. When herds resumed milking 2X the trend reversed.

Entering and Leaving the Herd

The percentage of cows entering the herd and the percentage leaving the herd were significantly higher for herds milked 3X during all 3 yr ($P < 0.05$; Table 10). The percentage of cows leaving the herd and milked 3X in the South was significantly higher than the North only in 1998 ($P < 0.05$). The higher culling rate for herds milked 3X in our study is in contrast to other studies. Allen et al. (1986) reported fewer cows culled from herds milked 3X and concluded that there appeared to be no

Table 8. Effect of milking frequency (MF) on SCS and weighted somatic cell counts (WSCC).

MF	SCS			WSCC		
	1998	1999	2000	1998	1999	2000
2X	3.23 ^a	3.22 ^a	3.21 ^a	368 ^a	356 ^a	352 ^a
3X	3.03 ^b	3.05 ^b	3.08 ^b	331 ^b	332 ^b	341 ^b
SEM	0.03	0.02	0.02	5	5	5

^{ab}Least squares means within a column with the same superscript do not differ ($P < 0.05$).

Table 9. Effect of milking frequency (MF) on the percent of high (0 to 3) and low (7 to 9) SCS by year.

MF	SCC 0 to 3			SCC 7 to 9		
	1998	1999	2000	1998	1999	2000
2X	58.0 ^b	58.4 ^b	58.4 ^b	8.8 ^a	8.4 ^a	8.3 ^a
3X	62.1 ^a	61.4 ^a	61.2 ^a	7.9 ^b	7.9 ^b	8.3 ^a
SEM	0.43	0.42	0.42	0.15	0.15	0.15

^{ab}Least squares means within a column with the same superscript do not differ ($P < 0.05$).

Table 10. Effect of milking frequency (MF) and interaction of MF with region on the percentage of cows entering and leaving the herd.

MF		Entering			Leaving		
		1998	1999	2000	1998	1999	2000
2X		38.4 ^b	38.5 ^b	38.7 ^b	35.6 ^b	34.9 ^b	35.5 ^b
3X		41.4 ^a	43.2 ^a	42.3 ^a	37.2 ^a	36.6 ^a	37.7 ^a
SEM		0.5	0.5	0.5	0.4	0.4	0.4
	Region ¹						
2X	North	39.1 ^{ab}	39.3	39.3	35.4 ^b	35.0	35.3
2X	South	37.6 ^b	37.6	38.0	35.9 ^b	34.8	35.8
3X	North	40.2 ^a	43.4	43.2	35.6 ^b	36.6	36.1
3X	South	42.6 ^a	43.0	41.4	38.8 ^a	36.5	39.2
SEM		0.7	0.7	0.7	0.5	0.5	0.5

^{ab}Least squares means within column for main effect or interaction with the same superscripts do not differ ($P < 0.05$).

¹Regions are North and South (see Figure 1).

adverse effect on longevity by milking cows 3X. Culling rate was not related to the production response that occurred with 3X milking according to Gisi et al. (1986). In our study, herds milked 3X increased in size more rapidly than herds milked 2X. The net change (% of cows entering – % of cows leaving) was 2.8, 3.6, and 3.2% for herds milked 2X, and 4.2, 6.6, and 4.6% for herds milked 3X for 1998, 1999, and 2000, respectively.

CONCLUSIONS

Previous studies on MF have been limited to a relatively few herds. Our study is the first to investigate MF with a large number of herds sorted by region. Milk yield, as expected, was higher for herds milked 3X. However, milk fat and milk protein percentages were significantly lower for herds milked 3X. As a result of lower milk component percentages, the milk production advantage of herds milked 3X was reduced when yields were measured by ECM. When evaluating the economics of milking 3X, an analysis beyond the scope of this report, consideration should be given to the lower component percentages, especially for herds paid for both milk fat and protein.

Based on this study, those contemplating milking 3X should expect an increase of approximately 13 to 14% in ECM. Reproductive efficiency is slightly lower for

herds milking 3X compared to herds milked 2X, but udder health as measured by SCC may be improved. Culling rates are slightly higher for herds milked 3X.

REFERENCES

- Allen, D. B., E. J. DePeters, and R. C. Laben. 1986. Three times a day milking: Effects on milk production, reproductive efficiency, and udder health. *J. Dairy Sci.* 69:1441–1446.
- Amos, H. E., T. Kiser, and M. Loewenstein. 1985. Influence of milking frequency on productive and reproductive efficiencies of dairy cows. *J. Dairy Sci.* 68:732–739.
- Barnes, M. A., R. E. Pearson, and A. J. Lukes-Wilson. 1990. Effects of milking frequency and selection for milk yield on productive efficiency of Holstein cows. *J. Dairy Sci.* 73:1603–1611.
- Butler, W. R., and R. D. Smith. 1989. Interrelationships between energy balance and postpartum function in dairy cattle. *J. Dairy Sci.* 72:767–783.
- Campos, M. S., C. J. Wilcox, H. H. Head, D. W. Webb, and J. Hayen. 1994. Effects of production of milking three times daily on first lactation Holstein and Jerseys in Florida. *J. Dairy Sci.* 77:770–773.
- Culotta, C. P., and G. H. Schmidt. 1988. An economic evaluation of three times daily milking of dairy cows. 1988. *J. Dairy Sci.* 71:1960–1966.
- DePeters, E. J., N. E. Smith, and J. Acedo-Rico. 1985. Three or two times daily milking of older cows and first lactation cows for entire lactations. *J. Dairy Sci.* 68:123–132.
- Erdman, R. A., and M. Varner. 1995. Fixed yield responses to increased milking frequency. *J. Dairy Sci.* 78:1199–1203.
- Gisi, D. D., E. J. DePeters, and C. L. Pelissier. 1986. Three times daily milking of cows in California dairy herds. *J. Dairy Sci.* 69:863–868.

- Hogeveen, H., J. D. Miltenburg, S. den Hollander, and K. Frankena. 2001. Milking three times a day and its effect on milk production health. *International Dairy Federation. Mastitis Newsletter*. 24:7.
- Klei, L. R., J. M. Lynch, D. M. Barbano, P. A. Oltenacu, A. J. Lednor, and D. K. Bandler. 1997. Influence of milking three times a day on milk quality. *J. Dairy Sci.* 80:427–436.
- Lacy-Hulbert, S. J., M. W. Woolford, G. N. Nicholas, C. G. Prosser, and K. Stelwagen. 1999. Effect of milking frequency and pasture intake on milk yield and composition of late lactation cows. *J. Dairy Sci.* 82:1232–1239.
- Pearson, R. E., L. A. Fulton, P. D. Thompson, and J. W. Smith. 1979. Three times a day milking during the first half of lactation. *J. Dairy Sci.* 62:1941–1950.
- Sapru, A., D. M. Barbano, J. J. Yun, L. R. Klei, P. A. Oltenacu, and D. K. Bandler. 1997. Cheddar Cheese: Influence of milking frequency and stage of lactation on composition and yield. *J. Dairy Sci.* 80:437–446.
- SAS/STAT User's Guide: Statistics, Version 6.12 Edition. 1996. SAS Inst., Inc., Cary, NC.
- SAS/STAT Software: Changes and Enhancements through Release 6.12. 1997. SAS Inst., Inc., Cary, NC.
- Spaulding, R. N., R. W. Everett, and R. H. Foote. 1975. Fertility on New York artificially inseminated Holstein herds in dairy herd improvement. *J. Dairy Sci.* 58:718–723.
- Speicher, J. A., H. A. Tucker, R. W. Ashley, E. P. Stanisiewski, J. F. Boucher, and C. J. Sniffen. 1994. Production responses of cows to recombinantly derived bovine somatotropin and to frequency of milking. *J. Dairy Sci.* 77: 2509–2517.
- Waterman, D. F., R. J. Harmon, R. W. Hemken, and B. E. Langlois. 1983. Milking frequency as related to udder health and milk production. *J. Dairy Sci.* 66:253–258.