RELATIONSHIP BETWEEN MILKING FREQUENCY AND UDDER CAPACITY IN FRIESIAN AND JERSEY COWS

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Summary

The relationship between udder maximum capacity (36-h accumulated milk yield) and the response of dairy cows (average producers) to thrice-daily milking was studied in 25 Friesian and 15 Jersey cows using the technique of half-udder study. Maximum half-udder capacity (acual yield) as well as whole udder capacity (estimated by udder measurements) was not altered significantly after 12-day thrice-daily milking period compared with a similar twice-daily period, although there was a positive response to increased milking frequency on secretion rate during this period. No effect of breed, season of the year or stage of lactation was observed on the above relationship. Hours-worth of capacity was higher with increased milking frequeny, with Jersey than Friesian. These results suggest that udder capacity is not a limiting factor in increased milk production.
(**Key Words** : Udder Capacity, Milking Frequency, Season and Stage of Lactation)

Introduction

The maximum amount of milk the udder can produce or hold until milk secretion ceases, namely the functional udder capacity, is an index of the internal surface area of the udder. This surface is both secretory (alveoli and fine ducts) and non-secretory (cisterns and large ducts) in nature. The high correlation of functional udder capacity and milk yield (Davis and Hughson, 1988) suggested that cisternal capacity is relatively constant among cows, making functional udder capacity one of the simplest methods available for comparing secretory cell numbers among cows. There is a stimulatory effect of increasing the frequency of milking on cell number as well as efficiency (Wilde et al., 1987). However, reducing milking frequency to once a day decreased the rate of milk secretion. Cisternal capacity could play a role in the latter effect (Whittlestone, 1951; Knight and Dewhurst, 1992; Stelwagen et al., 1993). However, treatment with bST during once daily milking increased milk yield by 13 to 20% (Carruthers et al., 1991; Knight, 1992; Stelwagen et al., 1994a), suggesting that mammary gland capacity was not limiting. Evidence is also accumulating that an autocrine inhibitor, present in the alveolar milk fraction, may be at least partly responsible for this loss of milk yield (wilde et al., 1990; Wilde and Peaker, 1990). However, whether the production loss is due to a lack of udder capacity and/or a chemical inhibition of secretion has not been determined.

This study was conducted to study the relationship between milking frequency and the capacity of the udder in Friesian and Jersey cows raised under semi-arid climate, and if season of the year and stage of lactation will affect this relationship.

Materials and Methods

Animals and Design

During the winter (3 stages of lactation) and early summer (2 stages of lactation) seasons of the year 1992, a total of 25 multiparous Friesian cows, from the herd of the Animal Production Farm of King Saud University, were used to study the effect of season of the year and stage of lactation on the relationship between udder capacity and the response of dairy cows to thrice daily milking. The effect of the breed was studied during the early summer season by using 15 Jersey cows (3 stages of lactation).

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Each stage of lactation (Early: wk 2-8; Mid: wk 9-15 and Post-Peak: wk 21-27) was divided into three experimental periods of 13.5 days with milking each half of the udder separately. The right hind with the left front glands were chosen randomely as the 'test half' and the left hind with the right front glands as the 'control half'. During the first and third periods both halves were milked twice daily at 08:00 h and 16:00 h for the first 12 days and then milking was ceased for 36 hours. The second period was as the other two periods except that the milking for the first 12 days for the test glands only was thrice daily instead of twice, the extra milking being at 00:00 h.

The animals were housed, individually, in a semi-closed concrete barn, with a good ventilation and constant lighting. Concentrate mixture (16% CP) was given during milking time according to milk yield of the previous day, in equal portions, either twice or 3 times per day. Also animals were given about 5 kg fresh fodder (*alfalfa*) after the morning milking only, while they received water and hay *adlibitum* as were salt licks.

Two mobile milking machines (Mungitrise Royal, Italy) were used for milking. Practically, one half of the udder was milked first before the other half; the former was chosen randomly to be the test half. Udder was flushed with water just before milking, wiped dry with cleaned towel, then teat cups were applied. Milking time was between 3-5 minutes per half. Machine stripping (with the aid of hand squeezing) was done first for the test glands after the milking of the control glands, then the later stripped. No oxytocin injections were used in this study. Total milk yield per each milking for each udder's half was recorded. After stripping, teats were dipped in iodine solution and the milking machines were cleaned. All the experimental work was started on all animals at the same time within each season of the year.

During winter, the average minimum and maximum ambient temperatures of the barn were 8.5 and 22.4℃ with the relative humidities in the range of 30.1 to 88%. The corresponding values during the early summer season were 18.6, 38.4℃ and 17 to 51%, respectively.

Calculation of Udder Volume and Capacity

Whole-udder volume was calculated from measurements made immediately after the last (morning) milkings of each of the three 12-day experimental periods (0 h, empty udder volume) and immediately before obtaining the accumulated milk yield of the 36-hour period full udder volume). Such udder measurements (see Davis and Hughson, 1988) included length, L; depth, D; width from the front, W1 and from the hind, W2, and were taken to calculate udder size (e.g., volumn = $1/2 \times L \times D \times (W1 + W2)/2$), where udder height or depth is from rear surface of rear quarter to base of rear teat; udder length is from base of rear teat to anterior junction of udder with abdomen; and average udder width is approximately 5 cm above the front and rear teats (calipers). Total milk accumulated in the udder throughout 36 hours (*estimated* udder capacity) was calculated from the difference between full udder volume and empty udder volume. The residual milk was calculated by subtracting the 36-h total milk yield obtained by milking (with no aid of oxytocin) from the estimated yield obtained by udder measurements. Only the milked yield was used for half-udder capacity. The secretion rate of milk obtaind during the 12-day twice or thrice daily milking (without oxytocin injection; see Salah et al., 1994) was used in calculating the hours-worth of secretion of this later capacity, viz. hours-worth of capacity was functional udder capacity (liters) divided by previous hourly yield (liters/h).

Statistical Analysis

Data obtained during the 1st and 3rd periods were pooled (control period), to be compared statistically with the 2nd period (treatment period) using the GLM, fixed-model procedures (SAS, 1986). A least-squares model, including breed of the cow, season of the year when experiment was made, udder's half, stage of lactation, treatment (twice vs. thrice daily milking) and all possible interactions with the treatment, was used after absorption of the cow's effect. Correlations among udder capacity and average daily milk yield of the 12-day period preceded the 36-h milking interval was made using the CORR procedure of the same system.

Results and Discussion

Maxiumu milk yields (functional udder capacities) obtained after the 36-hours milking interval, from the test as well from the control glands at different stages of lactation are shown in table 1 for the Friesian cows (winter and early summer seasons) and table 2 for the Jersey cows (early summer only).

Maximum half-udder yield during the control period (twice-daily milking) was higher ($p < 0.01$) for the test glands over the control glands, due to milking the former glands first (Elliott, 1961; Rotenberg and Swora, 1967). For the treatment period, maximum half-udder capacity increased significantly due to both increased milking frequency and milking the test glands first. These capacities did not change significantly when comparing the control and test periods for the same udder's half, an effect of milking frequency only. The same trend was also noticed during both the winter and early summer season as well as during each stage of lactation (tables 1 and 2).

TABLE 1. UDDER CAPACITY AND ASSOCIATED PARAMETERS IN FRIESIAN COWS AT DIFFERENT STAGES OF LACTATION DURING WINTER AND EARLY SUMMER SEASONS

	Winter			Summer	
	Early	Mid	Late	Early	Late
Capacity (l)					
Control period					
Control glands	5.0 ± 0.84^{Aa}	6.8 ± 0.54^{Ab}	5.6 ± 0.59^{Ac}	4.2 ± 0.77^{Ad}	4.3 ± 0.59^{Ad}
Test glands	5.8 ± 0.92^{Ba}	7.6 ± 0.61^{Bb}	6.5 ± 0.67^{Bc}	4.8 ± 0.87^{Bd}	4.9 ± 0.67^{Bd}
Treatment period					
Control glands	5.0 ± 0.94^{Aa}	6.6 ± 0.54^{Ab}	5.5 ± 0.59^{Aa}	4.2 ± 0.59^{Ac}	4.5 ± 0.55^{Ac}
Test glands	5.9 ± 0.96^{Bac}	7.7 ± 0.61^{Bb}	6.4 ± 0.67^{Ba}	5.1 ± 0.67^{Bc}	5.5 ± 0.72^{Bc}
Capacity (h)					
Control period					
Control glands	19.0 ± 4.11	21.5 ± 2.37	22.5 ± 2.60	17.6 ± 3.36	23.9 ± 2.60
Test glands	19.8 ± 3.81	21.2 ± 2.20	22.2 ± 2.41	18.0 ± 3.11	23.7 ± 2.41
Treatment period					
Control glands	19.5 ± 4.11	21.9 ± 2.37	22.5 ± 2.60	18.1 ± 3.36	23.5 ± 2.60
Test glands	16.5 ± 3.81	18.4 ± 2.20	17.3 ± 2.41	15.9 ± 3.11	19.6 ± 2.41

Different superscripts (small among the same raw; capital within the same column) indicate significant difference ($P < 0.01$) between means; otherwise indicate similarity.

TABLE 2. UDDER CAPACITY AND ASSOCIATED PARAMETERS IN JERSEY COWS AT DIFFERENT STAGES OF LACTATION DURING THE EARLY SUMMER SEASON

	Stage of lactation		
	Early	Mid	Late
Capacity (l)			
Control period			
Control glands	4.1 ± 0.51^{Aa}	4.4 ± 0.52^{Aa}	3.5 ± 0.37^{Ab}
Test glands	4.5 ± 0.61^{Aab}	4.7 ± 0.61^{Aa}	4.1 ± 0.57^{Bb}
Treatment period			
Control glands	4.3 ± 0.52^{Aa}	4.6 ± 0.49^{Aa}	3.4 ± 0.37^{Ab}
Test glands	4.7 ± 0.51^{Aab}	5.0 ± 0.65^{Aa}	4.4 ± 0.47^{Bb}
Capacity (h)			
Control period			
Control glands	22.6 ± 2.47	23.9 ± 2.40	25.7 ± 2.66
Test glands	22.4 ± 2.40	23.4 ± 2.51	25.3 ± 2.51
Treatment period			
Control glands	22.3 ± 2.47	23.7 ± 2.50	24.5 ± 2.66
Test glands	19.8 ± 2.40	21.2 ± 2.44	20.9 ± 2.71

Different superscripts (small among the same raw; capital within the same column) indicate significant difference ($P < 0.01$) between means; otherwise indicate similarity.

These results were also found when comparisons were made among the different groups of the study using the full udder capacity measured by the difference between udder volumes when empty ant full (table 3). There was some reduction in residual milk during the treatment period when only one half of the udder was milked thrice daily. Conclusively, summer season showed lower capacities than winter season, with significant differences ($p < 0.05$) among stages of lactation, and the two breeds (later stage during the summer season). Jersey cows reached its peak of lactation during the 9th week, while the Friesian peaked at the 11th week. Half-udder capacities were related to the average daily milk yield of the previous 12-day period ($r = 0.58$, 0.51 and 0.48 for the Friesians during the winter and summer seasons and the Jerseys during the summer season, respectively; $p < 0.05$).

We observed that the capacity of each udder exceeded the amount of milk obtained from the udder at any milking. This was also the case with the study of Matthews et al. (1949). However, the maximum milk accumulated within the mammary glands after 36 h (hours worth of capacity less than 24) was less than the averge daily yield of the 12-day milking period (see Salah et al., 1994), indicating a loss in milk yield with extending milking interval as it was reported with once daily milking in cows (Carruthers et al., 1993; Holmes et al., 1992), goats (Wilde and Knight, 1990), and Sheep (Morag, 1968). The exact reasons for this loss of yield are not known, but various factors may play a role. Preliminary data by Knight and Dewhurst (1992) and Stelwagen et al. (1993) indicate that mammary gland cisternal capacity may be limiting in cows milked once daily. Increased milking frequency in the present work did not alter significantly the maximum udder capacity during the short period of study, although the increased rate of milk secretion during this period, only in the udder's half that milked thrice daily, by over 15% (Salah et al., 1994). However, treatment with bST during once daily milking increased milk yield by 13 to 20% (Carruthers et al., 1991; Knight, 1992; Stelwagen et al., 1994a), suggesting that mammary gland capacity was not limiting. Evidence is also accumulating that an autocrine inhibitor, present in the alveolar milk fraction, may be at least partly responsible for this loss of milk yield (Wilde et al., 1988, 1990; Wilde and Peaker, 1990). Therefore, the reduction

TABLE 3. CHANGES IN UDDER VOLUME BETWEEN IMMEDIATELY AFTER MILKING (EMPTY UDDER, 0 h) TO 36 h LATER (FULL UDDER CAPACITY) FOR FRIESIAN (TWO SEASONS) AND JERSEY COWS (ONE SEASON) AT DIFFERENT STAGES OF LACTATION

	Twice-daily milking					Twice-and thrice-daily milking				
	Time 0 h	Time 36 h	Estimated capacity	Residual milk Amount	Residual milk %	Time 0 h	Time 36 h	Estimated capacity	Residual milk Amount	Residual milk %
Friesian (winter season):										
Early lactation	14.5 ±2.13	26.8 ±4.19	12.3 ±2.01	1.5 ±0.02	12.3 ±1.9	14.8 ±2.39	26.8 ±4.24	12.2 ±1.96	1.3 ±0.01	10.4 ±1.6
Mid lactation	14.8 ±2.02	31.1 ±4.29	16.2 ±1.81	1.8 ±0.03	11.2 ±1.8	14.8 ±2.21	30.8 ±4.13	16.0 ±1.88	1.7 ±0.02	10.8 ±1.7
Late lactation	14.4 ±1.93	28.4 ±4.05	14.0 ±2.21	1.9 ±0.03	13.4 ±1.9	13.9 ±2.11	27.2 ±4.17	13.3 ±1.92	1.4 ±0.01	10.8 ±1.6
Friesian (summer season):										
Early lactation	10.4 ±1.53	21.2 ±3.49	10.8 ±1.85	1.8 ±0.03	16.6 ±2.3	10.1 ±1.59	20.9 ±3.1	10.8 ±1.76	1.5 ±0.02	13.6 ±1.9
Late lactation	10.2 ±1.59	21.1 ±3.39	10.9 ±1.61	1.7 ±0.03	15.5 ±2.1	10.0 ±1.79	21.4 ±3.21	11.4 ±1.67	1.4 ±0.02	12.2 ±1.8
Jersey (summer season):										
Early lactation	10.6 ±1.23	20.6 ±3.49	10.0 ±1.21	1.4 ±0.01	13.6 ±1.9	10.9 ±1.79	21.3 ±4.21	10.4 ±1.55	1.4 ±0.02	13.5 ±1.9
Mid lactation	10.8 ±1.83	21.3 ±3.36	10.5 ±1.15	1.4 ±0.02	13.6 ±1.9	11.1 ±1.29	22.1 ±3.64	11.0 ±1.68	1.4 ±0.02	12.7 ±1.8
Late lactation	11.0 ±1.41	20.3 ±3.56	9.4 ±1.25	1.8 ±0.03	18.3 ±2.3	10.2 ±1.69	19.6 ±3.84	9.4 ±1.57	1.6 ±0.03	17.2 ±2.3

in milk yield due to the long milking interval in the present study suggests the autocrine regulation of milk secretion. It is the presence of milk itself, not the physical distention of the udder, that cause the inhibition of milk secretion (Henderson and Peaker, 1984). Most milking interval studies have demonstrated that 18-20 h is the maximum period between milkings which can tolerated without loss of production (Elliott, 1959a; Wheelock et al., 1966). Recently, Stelwagen et al. (1994b) found a disruption in the tight junctions of the mammary secretory cells in Saanen goats after 36 h milk accumulation, which actually began after 21 h of milk accumulation; also at the same time mammary blood flow started to decline. They reported that mammary impairment of mammary tight junction integrity is associated with decreased milk secretion during an extended milking interval. The decline in mammary blood flow may be the result of a negative feedback response to a reduced demand for metabolites, which is due to a reduced rate of milk secretion. Injection of bST (Carruthers et al., 1991; Stelwagen et al., 1994a), may somehow sustain the mammary demand for metabolites overcoming this negative response.

The results of Swett et al. (1932) in estimating udder capacities post mortem gave a slight positive correlation between capacity and stage of lactation, but Matthews et al. (1949), adopting the same technique, found a decrease in capacity with advancing lactation. Also, Turner (1955) using repeated udder measurements throughout lactation, indicated a decline in capacity (increased hour-worth of capacity) as lactation advanced. Our result showed the later trend. Whittlestone (1951) assumed constant udder capacity when daily milkings reduced to one time a day instead of two. If capacity were constant, an inhibitory amount of milk would accumulate much less rapidly in late lactation than in early lactation.

In term of hours worth of capacity, Friesian cows utilized capacity ahead of Jerseys (tables 1 and 2) by about 3.5 hours, with a few hours more in late than early stage of lactation in both breeds. Therefore, Jersey cows could be milked once a day without significant loss in milk production. This considerd to be a greater milk ability. Therefore, the higher percentage butterfat breeds would require less capacity for milk yield than the low percentage butterfat breeds to produce the same amount of butterfat. Both breeds expressed lower (non-significant) hours worth of capacity when milked thrice instead of twice daily due to higher rate of milk secretion. Cows of present study are average producers, which may otherwise have affected significantly the latter results.

In conclusion, the significant effects of increased milking frequency to three times a day on milk yield in one half of the udder with non-significant change in its capacity compared with the other half milked twice daily, suggested the possibility of some type of chemical inhibition of secretion may occur in cows (Hillerton et al., 1990), as it indeed evidenced in goats (Henderson and Peaker, 1984; Wilde and Peaker, 1990). Cow can hold milk more than its apparent full capacity, but reducing rate of secretion after a longe interval of milk accumulation due to one factor or another may prevent reaching the supposily maximum capacity.

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