Rates of recovery of milk yield and composition following milking intervals of varying length

V.C. FARR, K. STELWAGEN AND S.R. DAVIS

Dairy Science Group, AgResearch, Ruakura Research Centre, Private Bag 3123, Hamilton, New Zealand

ABSTRACT

In order to examine the rate of recovery of milk yield and composition following an extended milking interval, 20 cows were milked out with the aid of oxytocin and subjected to single intervals of either 16, 24, 32 or 40h. Cows were then milked frequently with the aid of oxytocin during the subsequent 26h. Milk secretion rate was depressed to 67 and 56% of pre-treatment (twice-daily milking) rates by the 32 and 40h treatments, and rates of recovery were slow, extending beyond 26h post-treatment.

Milk fat and protein contents did not differ significantly among treatment groups while lactose content was reduced by the 32 and 40h intervals, recovering by 26h post-treatment.

It was concluded that the udder is particularly sensitive to milk accumulation beyond 24h and that this leads to impairment of the 'synthetic machinery' in the udder. The prolonged effect on milk lactose concentrations with the longer intervals suggests that there was a sustained change in the integrity of tight junctions between secretory cells, leading to increased permeability of the mammary gland. Rates of recovery of yield and composition were relatively slow, taking >24h in spite of enhanced rates of milk removal.

Key words: Milking interval, once-daily milking, milk yield, milk lactose

INTRODUCTION

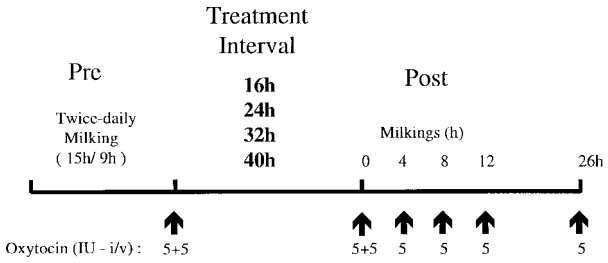
Experiments designed to examine variation in the rate of milk secretion with time post milking, have established that, while milk secretion rate may begin to decline after about 16h of accumulation, there was also a decline in the rate of secretion in the succeeding milking interval, the 'preceding milking interval effect' (Elliott *et al*., 1960). The preceding interval effect appears to operate at the onset of once-daily milking (ODM) as the rate of milk secretion declines over the first 48h of ODM (Carruthers *et al*.,1993). In order to further understand the mechanisms responsible for yield loss during ODM, this study examined the changes in milk secretion rate and composition after extended periods of milk accumulation and the rates of recovery.

MATERIALS AND METHODS

Twenty early lactation (61 ± 3d) cows in their second or third lactation were used. Cows were grazed on ryegrass/ white clover pasture and, before the experiment, were milked twice-daily (TDM) at 7.00 am and 4.00 pm. Four treatment groups, each of 5 cows, were exposed to milking intervals of 16, 24, 32 and 40h, following which all cows were milked at 4h intervals, for 12h and then again after a further 14h interval (total 26h). At every milking, including that at the start of the treatment interval, cows were milked out after injection of oxytocin (see Fig.1). All cows then returned to TDM.

Milk yield was recorded, and samples were analysed for fat, protein and lactose by infra-red spectroscopy (Foss Electric, Hillerød, Denmark). Data were analysed by regression analysis and Students' paired t-test as indicated in the text.

FIGURE 1*:* Scheme of experimental design.



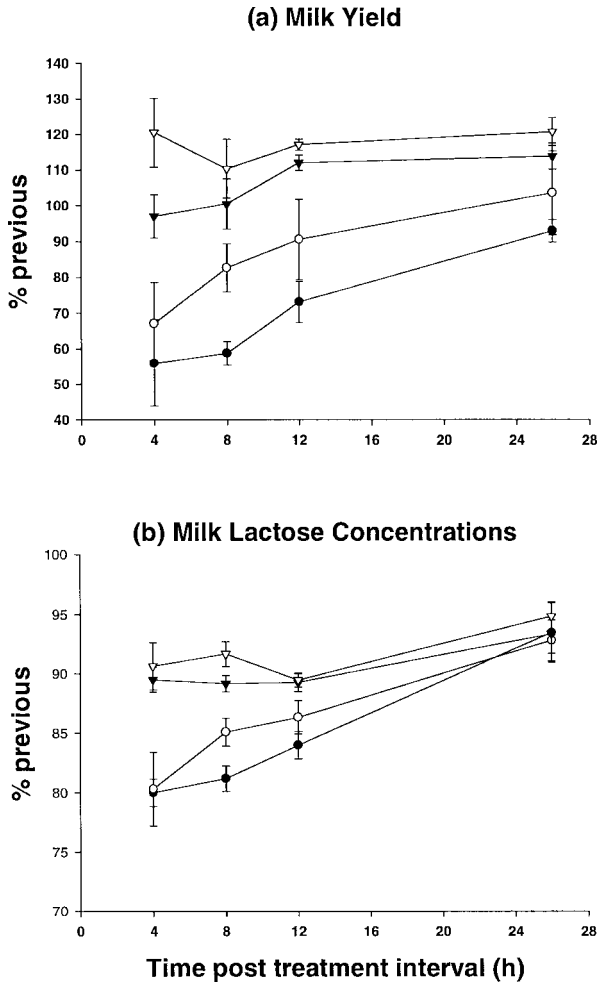
RESULTS

During the first 4h interval post treatment, milk secretion rates were reduced, relative to previous milk yield, by the 32 and 40h (67 ± 11 and 56 ± 12%, both $p<0.05$) but not the 16 and 24h treatment intervals (120 ± 10 and 96 ± 6%, both $P>0.05$) (see Fig. 2a). In the 16 and 24h groups, after 12h of frequent milking post-treatment, milk secretion rate (as % pre-treatment TDM) was significantly higher (117 ± 2 and 112 ± 2% respectively, both $P<0.01$) whereas secretion rate had still not recovered to its pre-treatment value in the 40h treatment group after 26h post treatment (Fig 2a).

By fitting regression lines to the milk yield data, the estimated time to recover to previous milk yield differed between the interval groups (16 vs 24 vs 32 vs 40h : 0^{a} vs 7 ± 3^{ab} vs 18 ± 4^{bc} vs $31 \pm 3h^{c}$, abc $P<0.01$).

Milk lactose content was reduced by the 32 and 40 h intervals ($P<0.05$) but did not differ among treatment groups after 26h post-treatment (Fig 2b). Milk fat and protein contents did not differ significantly among the treatment groups.

FIGURE 2: Recovery of milk yield (a) and milk lactose concentration (b) over 26 h following 16,(▽), 24 (▼), 32 (○) and 40 (●) hours of milk accumulation. Cows were milked out with oxytocin before the accumulation period began and at every interval post-treatment (see Fig. 1)



DISCUSSION

Milk secretion rate was reduced by both the 40 and 32h preceding milking interval but not the 24h interval. In the latter case the removal of residual milk at the start of the experiment probably acted to enhance milk secretion initially, as seen by the 20% increase in secretion rate for the 16h group. Hence, the 24h treatment is not comparable to the first day of ODM because of the removal of residual milk. Frequent removal of residual milk for the 12h following the treatment interval did not restore milk secretion to pretreatment values in the 32 and 40h interval groups. Regression analyses estimated that it would have taken 18h and 31h respectively for the 32 and 40h groups to have returned to pre-treatment rates of secretion.

Milk yield of cows on short-term ODM can decrease by 10-35% (Davis *et al*., 1998). The current data suggest that some of this decrease can be attributed to the 'preceding interval effect' corroborating in vivo measurements which showed impairment of synthetic machinery during ODM (Farr *et al*., 1995) and in vitro data demonstrating impairment of lactational performance by 40h milk stasis in ovine mammary tissue (McFadden *et al*., 1995).

In goats, Stelwagen *et al*. (1994) have shown that a decrease in milk secretion following an extended period of milk accumulation coincides with the loss of integrity of the tight junctions. Similar observations have been made in cows (Stelwagen *et al*., 1997). In the present experiment there was a significant and sustained decrease in milk lactose content following the longer preceding intervals. The effect on milk lactose is sustained following the recommencement of milk removal which indicates that the integrity (and permeability) of the tight junctions has been modified and that the recovery of 'tightness' takes several hours. This observation indicates that the effect of milk accumulation on mammary tight junctions is not merely a pressure-mediated effect leading to efflux of lactose from the udder and is corroborated by a parallel finding in cows based on the kinetics of lactose disappearance from blood (Stelwagen *et al*., 1997).

In conclusion, we have demonstrated that the bovine udder is sensitive to milking intervals beyond 24h and that effects of milk accumulation on tight junctions (as indicated by a decrease in milk lactose content) are sustained and not solely due to the development of a pressure differential between the milk space and extracellular fluid during the accumulation of milk. Rates of recovery of yield following the 32 and 40h intervals were relatively slow, taking >24h despite frequent and oxytocin-assisted milk removal.

REFERENCES

Carruthers, V.R.; Davis, S.R.; Bryant, A.M.; Henderson, H.V.; Morris, C.A.; Copeman, P.J.A. 1993. Response of Jersey and Friesian cows to once a day milking and prediction of response based on udder characteristics and milk composition. *Journal of Dairy Research* **60:** 1-11.

Davis, S.R.; Farr, V.C.; Stelwagen, K. 1998. Once-daily milking of dairy cows: an appraisal. *Proceedings of the New Zealand Society of Animal Production* **58:** (in press).

Elliott, G.M.; Dodd, F.H.; Brumby, P.J. 1960. Variation in the rate of milk secretion in milking intervals of 2-24 hours. *Journal of Dairy Research* **27:** 293-308.

Farr, V.C.; Stelwagen K.; Kerr, M.A.; Davis, S.R.; Eichler, S.J. 1995. Effect of once daily milking (ODM) on enzyme activities in the bovine mammary gland. *Proceedings of the New Zealand Society of Animal Production* **55:** 12-13.

McFadden T.B.; Callaghan, M.R.; Davis, S.R. 1995. Regulation of lactose production by ovine mammary acini in culture. *Proceedings of the New Zealand Society of Animal Production* **55:** 17-20.

Stelwagen, K.; Davis, S.R.; Farr, V.C.; Prosser, C.G.; Sherlock, R.A. 1994. Epithelial cell tight junction integrity and mammary blood flow during an extended milking interval in goats. *Journal of Dairy Science* **77:** 426-432.

Stelwagen, K.; Farr, V.C.; McFadden, H.A.; Prosser, C.G.; Davis, S.R. 1997. Time course of milk accumulation-induced opening of mammary tight junctions, and blood clearance of milk components. *American Journal of Physiology* **273:** R379-R386.