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Once-daily milking of dairy cows : an appraisal

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ABSTRACT

Once-daily milking offers the opportunity for a quantum change in the operation of the dairy farm. In particular, once-daily milking provides the major opportunity to reduce costs and increase labour productivity. New Zealand cows (particularly Jerseys) already possess an advantage in favour of once daily milking -that they produce a relatively concentrated milk and therefore have the capacity to accumulate >24 hours-worth of milk production. Nevertheless, short-term trials indicate an average production loss of 21% for once-daily relative to twice-daily milking. Full-lactation trials suggest greater losses of 35-50%, although the productivity of commercial farms milking once-daily throughout lactation is consistent with much smaller losses. There is evidence that cows can adapt to longer milking intervals and this coupled with increased herd size and care to maximise milk removal may restrict yield losses on the farm to less than 10%.

Apart from the production loss, other negative consequences of once-daily milking include changes in milk composition, a reduction in milk processing quality and increased somatic cell count. Further, it is not known to what degree, if any, cow comfort is compromised by once-daily milking.

If it becomes possible to identify more tolerant breeds or individuals, it may be feasible to reduce milk yield losses still further and ameliorate the changes in milk composition.

Keywords: milking; milking frequency; dairy cows; milk quality.

INTRODUCTION

The need to milk dairy cows twice-daily dominates dairy farming. In capital-intensive dairying systems with high milk prices it can be economical to increase milking frequency to capture an increase in milk yield. In contrast, in a low-cost/low milk price industry such as that in New Zealand there is no economic benefit to be derived from more frequent milking. Indeed, many farmers have found merit in reducing milking frequency to once-daily (ODM) either as part of early- or late-lactation management, or more rarely, as a strategy for the whole of lactation. In spring, ODM may reduce the metabolic stress on cows during periods of feed shortage. In late-lactation the switch to ODM may be driven by lifestyle advantages. In both cases, short periods of ODM, while reducing milk yield during ODM, do not result in any measurable carry-over effects (Carruthers, *et al*., 1993a).

Potential benefits accruing from ODM include a quantum leap in labour productivity, better utilisation of milking plant - particularly if sheds are shared between farms - and obvious lifestyle advantages. The actual benefit will depend upon individual circumstances. On a national basis there is the added bonus that ODM could lead to the unleashing of several thousand agricultural entrepreneurs into the rural environment, with time on their hands!

There are few, if any, forecasts of increasing returns for dairy products. Indeed it is more likely that relative returns for dairy products will be static or in decline. In any possible scenario there remains the need to reduce industry costs to maintain competitive advantage (and farm profitability). While there are a range of possibilities to reduce farm costs, the use of ODM probably provides the major opportunity. What is required to capture the full benefit of ODM is the development of appropriate strategies to minimise the yield loss. Of importance in this regard is that cows in New Zealand (especially Jersey cows) have a unique advantage in that they can accumulate >24 hours-worth of milk production, by virtue of the fact that they produce a relatively concentrated milk, i.e. high fat and protein content (Fig. 1; L'Huillier *et al*., 1989; Morris *et al*., 1991;). Some types of cow, such as the American Holstein are unsuited to ODM because the large volume production of dilute milk fills the udder too rapidly. Udder capacity in mature Holstein cows in North America has been measured as equivalent to 19 hours-worth of production (Fig. 1; Davis, S.R. unpublished data).

This review evaluates the concept of ODM, examines current knowledge about the causes of production loss and explores the potential to overcome the loss.

Yield loss during once-daily milking

There have been several trials undertaken in New Zealand which have measured the level of production loss as a result of ODM during part-lactations and, in one case, over a full lactation.

Yield loss ranged from 7-38% in the part-lactation studies (Table 1) and the loss tended to be lower in late lactation in absolute and percentage terms (Carruthers *et al*., 1993a; Stelwagen & Knight, 1997). Yield losses were usually unrelated to the level of production but several authors commented on the variability of the yield loss among cows.

FIGURE 1: Variation of total udder capacity (at peak lactation) with milk protein content (used as a marker of relative concentration of milks). Total udder capacity was measured after 40h of milk accumulation (Friesian, High-protein (HP) and Low-protein (LP) Jerseys; Carruthers *et al*., 1993). American Holstein capacity was determined after 30h accumulation (unpublished data; n=11). In both cases udders had been full for several hours. Hours-worth of secretion was calculated as capacity divided by the previous hourly secretion rate during twice-daily milking. Variation in milk protein reflects differences in lactose production (and hence volume secretion). Cows producing more lactose relative to protein will produce a more dilute milk (and vice versa) because lactose is the major osmole in milk

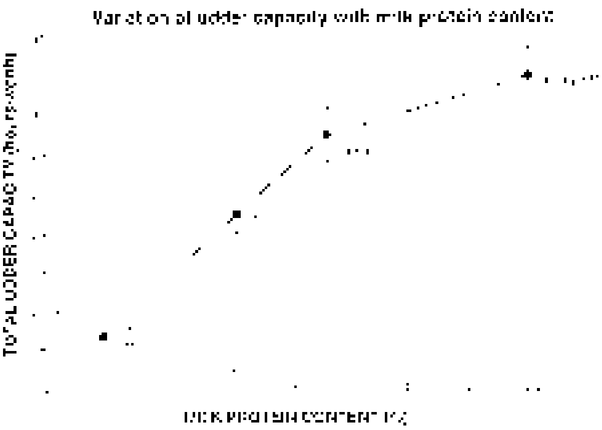

TABLE 1: A summary of levels of milk yield loss on once-daily milking (ODM) during part-lactation studies

Reference	% loss	Stage of Lactation	ODM Duration
Wilson (1965)	27	late	5-7 weeks
Parker (1966)	37	late	12 weeks
Bryant (1978)	18	late	5 weeks
Carruthers *et al*. (1993)	16	early/mid	2 weeks
	12	late	2 weeks
Kamote *et al*. (1994)	14	late-low SCC	4 weeks
	26	late-high SCC	4 weeks
Stelwagen & Knight (1997)	38	early (UK)	3 weeks
	28	late (UK)	3 weeks
Stelwagen & Lacy-Hulbert (1996)	15	peak	5 days
Stelwagen *et al*. (1994)	7	late	2 weeks
Knutson *et al*. (1993)	27	late	1 week
Lynch *et al*. 1991	11-15	late	5-13 weeks

An average figure for the yield loss during the short-term trials in Table 1 was 21% which contrasts with full lactation studies reported by Claesson *et al*. (1959) and Holmes *et al*. (1992) where losses were 50% and 35% respectively. Claesson *et al*. (1959) suggested yield losses were compounded with increased time on ODM. In support of this observation, Carruthers *et al*. (1993a) noted that ODM induced a more rapid decline (relative to TDM) in functional udder capacity over a 12-week period suggesting that there was a greater loss of secretory cells during ODM, as the functional udder capacity is determined by the internal surface area of the udder (Davis & Hughson, 1988). Turner (1955) came to a similar conclusion attributing an 'increased loss of secretory potential' to ODM.

Those farmers who have reported on long-term use of ODM have production figures similar to the district average (e.g. Attrill & Holmes, 1993) which indicates that the yield loss is less than the 35-50% stated in the literature. Indeed one such report states that the total farm production varied by less than 5% during the transition from TDM to ODM (Harding & Harding, 1990), albeit with an increase in stocking rate of 8%. Further, the distribution of production throughout the season was changed, with peak yield lower and production greater in later lactation, relative to peak.

It is likely that cows can adapt to less frequent milking. Woolford *et al*. (1985) showed that for cows milked 3 times in 2 days (19, 19, 10h intervals), yield losses were 17% in the first season falling to 7% for the second.

A prolonged period of infrequent milking may lead to stretching of the cisterns and ducts and, consequently, to increased tolerance. Indeed, some studies in Scotland have shown a link between cisternal milk volume and yield loss (Knight & Dewhurst, 1994; Stelwagen & Knight, 1997), although this relationship was not as strong among New Zealand cows (Carruthers *et al*., 1993a).

Heifers (which tend to have small cisterns) are less tolerant of ODM than mature cows suggesting a requirement for maturation of the cisterns to accommodate the increased milk storage during ODM (Attrill & Holmes, 1993; Carruthers *et al*., 1993a).

Overcoming the production loss during ODM

For the development of strategies to overcome the production loss during ODM it is necessary to understand the triggers that initiate the decline in milk secretion. As yet such knowledge is incomplete.

Certainly, the regulation of yield according to reduced milking frequency is determined by a local (intramammary) mechanism (Claesson *et al*., 1959; Stelwagen & Knight, 1997) as the yield loss occurs only in the treated gland.

The primary requirement, that the udder should possess enough capacity to accumulate 24 hours-worth of secretion is met in most New Zealand cows (especially Jerseys) because they produce a relatively concentrated milk (Fig 1; L'Huillier *et al*., 1989; Morris *et al*., 1991). Nevertheless, cows with >24 hours-worth of udder capacity still show a loss in production during ODM (Carruthers *et al*., 1993a).

Having established that the primary requirement of udder capacity was met, we have taken three approaches towards devising a strategy to overcome the production loss.

1. Search for a marker to select cows (more) tolerant of ODM.
2. Evaluate options to enhance production by hormonal treatment - oxytocin, bovine somatotropin.
3. Understand the physiological processes which constrain production during ODM.

Early studies failed to find a suitable marker for tolerance of ODM among a wide range of milk yield, composition and udder parameters investigated (Carruthers *et al*., 1993a). The highest correlation (r = 0.55) between parameters and yield loss on ODM was achieved with residual milk (that portion of milk retained in the alveoli after milking and removed following oxytocin injection).

This observation was extended during a study on the site of milk accumulation which suggested that the rate of drainage of milk from the alveolus to the cistern is a key factor in yield loss (Davis *et al*., 1998). Evidence for this stemmed from the observation that those cows which showed a smaller proportion of milk in the cistern at 24h post milking relative to 40h (full) showed the greatest loss of production. The rate of drainage from the alveoli between milkings is determined largely by the milk ducts, the tone of which is regulated by (adrenergic receptors (Bruckmaier *et al*., 1997). The ability to overcome milk retention through sympathetic nerve action on the milk ducts may be an important aspect in overcoming the yield loss. However, one study explored the notion that deliberate transfer of milk from alveoli to cistern (through induction of milk ejection at the time of the afternoon milking) might be advantageous. It was not. In fact, yield was reduced to an even greater extent (Copeman, P.J.A. & Woolford, M.W., unpublished data).

There may be a genetic component in tolerance of ODM but the lack of repeatability and poor correlation of yield loss within twin sets (Davis *et al*., 1998) indicates that a breeding strategy will be difficult to devise (see Morris *et al*., 1991). In a comparison of two Jersey strains (differing in total solids concentration) with Friesians, all types lost similar amounts of yield during ODM (Carruthers *et al*., 1993a) with some suggestion that there may have been a relative advantage for Jerseys in the long term. Such an advantage remains to be proven.

The yield loss can be totally overcome (at least in the short term) with bovine somatotropin, although the stimulated yield is likely to be 15-20% less than the stimulated yield on TDM (Stelwagen *et al*., 1994). This experiment confirmed that NZ cows have the udder capacity to produce milk at TDM rates during ODM.

Oxytocin has also been used to enhance milk production during ODM, the resulting increased efficiency of milk removal leading to a total (Woolford *et al*., 1982) or partial (Carruthers *et al*., 1993b) stimulation of yield. Stripping of milk has also been shown to enhance yield (Carruthers *et al*., 1993b) suggesting that some amelioration of the yield loss can be obtained if more attention is paid to maximising milk removal. In this regard, increasing the rate of milking was without effect on the milk yield during ODM (Carruthers *et al*., 1993b).

Studies at the Hannah Research Institute in Scotland have indicated the existence of an inhibitor of milk secretion in the milk of many species, including cows (Peaker & Wilde, 1996). The role of such an inhibitor in coordinating milk yield and milking frequency has yet to be established. Milk accumulation results in changes in the 'synthetic machinery' of the mammary gland (Farr *et al*., 1995; McFadden *et al*., 1995), which can only be reversed, relatively slowly, by frequent milking (Farr *et al*., 1998). It is likely that critical changes in mammary gene expression occur 12-18h after milking. Identification of the critical genes is a major challenge for the future.

Interaction of yield loss with nutritional status has been reported (Bryant, 1978; Lacy-Hulbert *et al*., 1995). One full-lactation study indicated that the yield loss was associated with decreased feed intake and increased body weight (Holmes *et al*., 1992). Hence an increase in stocking rate may be a simple strategy to ameliorate the yield loss, on a whole farm basis.

Cows with a high somatic cell count (SCC) show a relatively greater loss in yield on ODM (Kamote *et al*.,1994; see Table 1) and it was suggested that there was a multiplicative effect between ODM and SCC related to exacerbation of the inflammatory process.

In summary, yield loss during ODM can be substantial but the few documented reports of the productivity of those farms using ODM suggests that yield losses are less than the 35-50% reported in the scientific literature and may be as low as 5-10%. A combination of breed selection (Jersey?), increased stocking rate, improved udder health and increased care to maximise milk removal could provide the means to reduce yield loss during ODM to 0-5%. In future, depending upon market acceptance, strategic use of bovine somatotropin could even permit ODM with yield enhancement.

Changes in milk composition and somatic cell count during ODM

A range of changes in milk composition occur during ODM and are attributable to increased exchange of milk and extra-cellular fluid. This exchange occurs through an increase in gland permeability which becomes apparent after about 17-18h of milk accumulation (Stelwagen *et al*., 1997) and is thought to occur because the tight junction between cells of the mammary epithelium become leaky. This increased permeability is sustained during ODM such that, after the gland is milked out, an enhanced flow of extra-cellular fluid into milk occurs. These changes are most commonly measured as increased concentrations of immunoglobulin, serum albumin, milk sodium and protease activity but decreased milk lactose content (Stelwagen *et al*., 1994; Auldist & Prosser, 1998). There may also be small increases in milk fat and protein content.

Of most importance is the change in SCC which has been reported in several studies examining the consequences of ODM. Kamote *et al*. (1994) observed that ODM significantly increased the SCC of milk from cows with high initial cell counts. Others have noted that the SCC response is very variable among cows with some animals showing no change in SCC. Interestingly there is a 24h lag from the onset of ODM before an increase in SCC can be observed. Much of the increase in SCC can be accounted for by a "concentration effect" as milk yield falls while the number of secreted cells remain constant (Kamote *et al*., 1994). However, Stelwagen & Lacy-Hulbert (1996) measured a substantial increase in yield of cells in milk from cows with very low initial cell counts. In addition, ODM changed the relative proportions of macrophages, lymphocytes and neutrophils.

Holmes *et al*. (1992) reported that SCC was significantly higher in cows on ODM throughout lactation even though there appeared to be no increase in the incidence of mammary infections. Significantly, from January onwards cell counts in the ODM group were greater than 400,000 per ml, sufficient to incur financial penalties under the current penalty scheme. Indeed it is likely that use of ODM on commercial farms is declining because of the risk of SCC penalties. The available evidence suggests that, provided cows with existing high SCC are removed, ODM should result in only small changes in SCC, insufficient to incur any penalty.

There is no evidence that ODM increases the incidence of mastitis (eg Holmes *et al*., 1992). However, it is likely that, when mastitis does occur, it will progress more rapidly because of the less frequent milk removal.

Animal welfare

The issue of cow comfort and well-being will become increasingly important. Relevant to ODM is the question of whether the cow feels pain or discomfort in the later stages of milk accumulation. Certainly the human breast can become painfully engorged within 12h after suckling. Cows produce a more concentrated milk than humans and can utilise cisternal storage. Nevertheless, cows do exhibit enthusiasm to be milked during TDM as well as ODM. Left to a free choice with robotic milking some cows prefer to be milked (and fed concentrates) 4-6 times per day (Bieber & Kaufmann , 1990) and spend more time lying down (Rossing *et al*., 1997).

The question of matching management to the preferences of the cow must be addressed in the future. At this point, it is pertinent to note that considerably more milk is accumulated in the udder of a Holstein cow during 12 hours than in Jersey cows milked once-daily.

What is the opportunity?

While there are certain fixed costs associated with milking, including consumables, detergents and power, a major saving with ODM is in the labour cost. If the afternoon milking takes 2 hours and the lactation length is 250 days, 500 hours are saved per farm per season. Of most significance is that these hours provide considerable flexibility to the farm operation which, for example, would allow part-time employment off the farm, or the development of new ventures. The true value of the 500 hours can only be assessed by individual farmers to which can be added a few thousand dollars of shed cost savings per season.

ODM offers the opportunity for a quantum change in the operation of the dairy farm, not only in terms of labour productivity but also, for example, in utilisation of capital where, in some circumstances, it might be possible to share milking sheds.

Current knowledge suggests that increasing herd size, paying more attention to the efficiency of milk removal and udder health and the ability of cows to adapt to ODM will restrict yield losses to less than 10%. At this level of loss, it is possible that change in SCC will be insignificant. If more tolerant breeds or individuals can be identified, it may become possible to reduce yield losses still further.

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