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Milking regimes to shorten milking duration

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Four milking regimes using automatic cluster removers (ACR) were tested over a 19-week period, from mid to late lactation. Each treatment group consisted of 16 slow-milking cows. The milking regimes used were: an ACR setting of 200 ml/min (Control); raised ACR setting from 200 to 500 in steps of 100 ml/min (Raised ACR); raised ACR as above in conjunction with pre-milking teat stimulation (Raised ACR+Stim); and terminating the milking when an ACR threshold of 200 ml/min was reached or when a predetermined maximum milking duration was reached (Timer). All incremental treatments were applied in blocks of 6 or 7 weeks duration. ACR thresholds were raised from 200 to 500 ml/min without observed loss of milk production when compared with controls. However, even up to an ACR setting of 500 ml/min there was little reduction in the group milking duration even when used with teat stimulation. In contrast, the Timer treatment resulted in a 34% reduction of the maximum milking duration for the group without significant loss of milk yield. For all groups, including Control, strip yield was occasionally very high and highly variable. Willingness of cows to enter the milking platform, behaviour during milking, teat condition and incidence of mastitis were similar for all treatment groups. The results indicated that simple truncation of milking at a predetermined maximum duration could be a most potent and inexpensive method of milking a herd more quickly. Such a method could be employed by using a simple timer in any dairy regardless of the level of sophistication of the milking system.

Keywords: Milk production, economics, ACR, dairy cow.

The amount of labour required to milk cows is often the largest proportion (40–50%) of the total labour used for pasture-based dairy production (Mein & Smolenaars, 2001). Moran et al. (2000) showed that dairy farm labour costs ranged from 4·8 to 10·3 A¢/l of milk and was the strongest factor influencing farm profitability. An appreciable reduction in the labour associated with milking could provide economic or lifestyle improvements for dairy farmers.

Case studies from an Australian dairy labour productivity study highlighted the adverse impact that slow-milking cows have in many herds (Johnston & Klindworth 2000). Leaving clusters on cows can greatly increase milking labour costs and reduce the efficiency of use of capital equipment. It may also cause an increased risk of over-milking of other cows on the milking platform at the same time or cause cows to be held back to 'go around again' on rotary dairies. Negative effects of a reduced milking duration are also possible, e.g., incomplete milking, reduced milk yield and increased risk of mastitis.

Pioneering research on shortening milking (Rasmussen et al. 1992) has been successfully applied in early-adopting herds in the USA where careful pre-milking teat preparation is normally practised. It has been reported that milking clusters extract milk quickly and completely and the behaviour of cows in the dairy improved (D Armstrong & G Mein, personal communication). Rasmussen recommended thorough manual teat stimulation (15–30 s) and a 30-s delay before cluster attachment. Rasmussen (1993) also reduced milking duration by raising the threshold setting of the automatic cluster remover (ACR). The above research appeared to be based on the premise that thorough manual teat stimulation was a prerequisite for quick and complete milking. Such stimulation is not a normal part of the milking routine on most Australian and

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New Zealand dairy farms. Moreover, only 11% of Australian dairies are fitted with ACR equipment (Riley et al. 1999).

We aimed to evaluate shorter milking regimes for the Australian dairy industry to see whether it was possible to reduce milking duration without loss of milk production, particularly for those cows that have long milking durations. Our study was also designed to examine the effect of shortening of milking with raised ACR settings, with and without pre-milking teat stimulation. We also used an alternative milking regime (without pre-milking teat stimulation) that simply truncated milking at a predetermined maximum duration that would mimic the durations achieved with the new ACR settings. We considered that this treatment, if successful, would be immediately applicable to many dairy farms that do not yet have ACR fitted in their dairies.

Materials and Methods

Sixty-four of the slowest-milking Friesian cows were selected from the commercial herd of 450 multiparous cows at Agriculture Victoria, Ellinbank. The 64 cows were grazed as a single herd for the whole experiment. Cows were all milked the same way on the Control milking regime for a 2-week period, at the end of which, cows were allocated evenly to four groups. Allocation was based on milking duration, milk yield and parity. A covariate balance method (Harville, 1974) was implemented as the CDESIGN procedure (Baird, 1994). Following allocation, the four groups continued to be milked under the Control regime for a further 2 weeks, providing a 4-week covariate period. Pre-milking teat stimulation was introduced for the next 4 weeks only to those cows that were allocated to this treatment (Raised ACR+Stim group). It was applied immediately on entry to the milking platform and there was a lag time of about 1 min prior to cluster attachment.

The various milking regimes were applied in three experimental periods of 7, 6 and 6 weeks duration respectively (Table 1). Each experimental treatment period was further broken up into two sub-periods of 3 or 4 weeks duration, the first of each being considered as a period for adjustment to the increased ACR setting or reduced milking time threshold.

The four treatment groups were milked twice daily at approximately 7.00 and 16.00 according to the allocated regime over three experimental periods. All cows were given approximately 1 min to settle before clusters were attached. The control group was milked with ACR set at 200 ml/min (Control). One Raised ACR group was milked with ACR raised from 200 to 500 ml/min, in 100 ml/min steps, for each successive experimental period (Raised ACR). The other Raised ACR group received the same treatment, but each cow received 15 s of manual teat stimulation upon entry to the dairy (Raised ACR+Stim). The last group was milked until an ACR setting of 200 ml/min or a prescribed maximum milking duration was reached (Timer). For each cow in the Timer group we calculated the weekly average milking duration. In the first experimental period the maximum milking duration for this group was set weekly according to the value of the cow with the 4th slowest mean milking duration in the Timer group from the previous week. The 5th and 6th slowest milking durations were used respectively for each successive treatment period. A separate calculation of the prescribed maximum milking duration was made for a.m. and p.m. milkings respectively.

Originally the maximum milking duration per cow was to have been based on the maximum milking duration observed in the Raised ACR treatment. However, by the fourth week of the first treatment period, it was evident that this treatment did not appreciably reduce the milking duration of the slowest-milking cows in a batch or side of cows in the 16-aside doubled-up herringbone dairy. Consequently, a *post hoc* decision was made to change the Timer treatment to a defined maximum milking duration as described above.

The cows were drafted into treatment groups prior to milking and were allowed a minimum of 10 min to settle in their holding pens and an extra 1 min to settle on the milking platform before milking was started. Order of entry of groups into the dairy was changed each week so that all groups shared equally in their order of entry.

Cows were milked in a dairy fitted with electronic milk meters and samplers (FloMaster Pro meters, samplers, ACR and electronic cow ID tags; Alfa Laval Agri Box 39, 147 21 Tumba, Sweden). The ACR delay setting (time delay between detecting the low flow threshold and cluster removal) was set to 3 s (the lowest setting available). Cows were electronically identified on entry to the dairy. Milk yield and milking duration were recorded automatically for every cow at every milking. Separate a.m. and p.m. milk samples were collected approximately twice monthly. Samples were analysed for fat, protein and lactose using a Bently 2000 Infrared Milk Analyser and somatic cell count (SCC) was measured using a Bently Somacount 300 (Bentley Instruments Chaska, MN, USA). Data on animal behaviour in the dairy, quarter strip volume, teat condition score and herd test were collected twice during each treatment period.

The quarter strip volume was determined using a handheld device made from a liner and shell (P Hemming, personal communication). The short milk tube had an air admission vent in it and an internal weight was added to the shell so that it had a weight that was equivalent to a quarter of the effective weight of the cluster assembly with which the cows were milked. The liner and shell were connected to a pneumatic pulsator and the long milk tube had a transparent section to allow the cessation of milk flow to be observed. The long milk tube was connected to a 450-ml receiver flask, which was connected by a valved tube to an array of flasks in a crate. This apparatus allowed

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Table 1. Effect of various milking regimes on milking characteristics of cows

Period (date)	Co-variate 09/10–22/10/00	Stimulation 23/10–19/11/00	Period 1† 20/11–07/01/01	Period 2† 08/01–18/02/01	Period 3† 19/02–01/04/01
Raised ACR setting	200	200	300	400	500
Approximate timer setting p.m.+a.m. (min)	nil	nil	‡	10·5	8·7
Milking regime					
Mean sum of daily maximum of p.m. and a.m. milking duration (min) [% reduction *v.* Control]					
Control (ACR 200)	21·9	21·4	17·5	14·7	13·9
Raised ACR	22·4	21·5	19·4 [−11]	16·4 [−11]	14·1 [−2]
Raised ACR+Stim	21·2	19·9	17·1 [2]	13·9 [6]	13·1 [6]
Timer (ACR 200)	21·3	20·1	15·2 [13]	10·8 [26]	9·7 [30]
Mean milking duration (min/d), covariate adjusted [% reduction *v.* Control]					
Control (ACR 200)	13·5	13·0	11·5	9·7	8·9
Raised ACR	13·7	13·0	11·5 [0]	9·8 [−1]	8·6 [4]
Raised ACR+Stim	14·0	13·0	11·2 [3]	9·0 [7]	8·0 [10]*
Timer (ACR 200)	13·5	12·7	10·9 [5]	8·8 [9]*	7·8 [13]*
LSD (5% level)		0·72	0·70	0·71	0·71
Mean daily milk yield (l/d), covariate adjusted					
Control (ACR 200)	26·1	22·3	21·3	17·1	14·3
Raised ACR	25·7	22·6	21·7	18·1	14·9
Raised ACR+Stim	26·4	22·8	21·4	18·0	15·0
Timer (ACR 200)	26·4	22·3	20·8	17·2	14·4
LSD (5% level)	—	0·77	0·74	0·75	0·75
Mean milk flow rate (l/min) covariate adjusted [% increase *v.* Control]					
Control (ACR 200)	2·02	1·79	1·92	1·81	1·65
Raised ACR	1·95	1·87	2·02 [5]	1·97 [9]*	1·84 [12]*
Raised ACR+Stim	1·95	1·85	2·02 [5]	2·08 [15]*	1·95 [18]*
Timer (ACR 200)	2·06	1·81	1·94 [1]	1·95 [8]*	1·83 [11]*
LSD (5% level)	—	0·12	0·12	0·12	0·12
Mean quarter strip yield after am milking (ml/quarter), for quarters with strip yield over 99 ml					
Control (ACR 200)	—	—	451	345	195
Raised ACR	—	—	443	540	220
Raised ACR+Stim	—	—	251	268	234
Timer (ACR 200)	—	—	458	660	428
Percentage of udder quarters per am milking with strip yield over 99 ml					
Control (ACR 200)	—	—	6·77	10·2	10·2
Raised ACR	—	—	6·25	6·25	13·3
Raised ACR+Stim	—	—	7·29	3·91	11·7
Timer (ACR 200)	—	—	9·38	14·8	25·8
Bulk milk SCC, calculated from cow SCC (cells/µl)					
Control (ACR 200)	106	—	56	119	150
Raised ACR	69	—	67	117	196
Raised ACR+Stim	180	—	222	107	140
Timer (ACR 200)	284	—	292	417	209

† Periods 1, 2 & 3 Raised ACR and Timer treatments set respectively to: 300 ml/min or the fourth slowest cow's milking duration, 400 ml/min or the fifth slowest cow's milking duration, 500 ml/min or the sixth slowest cow's milking duration

‡ The truncation treatment was only introduced in the latter part of this sub-period

* Means are significantly different from the Control (LSD 5% level). Calculation of LSD excludes Timer group

us to collect the strip yield of each quarter and record the volume.

Each milking position was provided with an electronic programmable timer with a count-down function that caused a light to flash when the programmed maximum milking duration was reached. The device was sealed in a transparent waterproof plastic sachet that allowed convenient viewing of the light and control of the timer functions through the plastic membrane.

We observed cow behaviour, including willingness to enter the dairy (baulking and time taken to enter dairy) and restlessness during cluster attachment and milking by recording step-kick responses (Brightling et al. 2000). Observations were recorded the day after each new experimental treatment period started (for both p.m. and a.m. milkings) and again in the last week of each treatment period. Observations were also recorded during the covariate period.

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Milk samples for bacteriology were aseptically collected from individual quarters of cows that had high SCC. The samples were cultured aerobically on sheep blood and McConkey agar at 36·5 °C.

Teat condition of all cows was assessed in the covariate period and each of the experimental sub-periods. Teat scoring was done by two scorers who each scored all the cows at two pm milkings per treatment period using the methodology as described by Brightling et al. (2000).

Statistical methods

Daily milk yield and milking duration were averaged each week for each animal. Flow rate was calculated as the quotient of these average daily yield and daily duration values. A split-plot analysis of covariance (ANCOVA), with animal split for week, was used for these variables to account for the repeated-measures structure. The covariate employed was the variable analysed, averaged over the covariate period for each animal. The treatment structure specified week nested within sub-period nested within treatment period, all crossed with treatment group.

For milking duration, the LSD was derived with the Timer treatment excluded from the ANCOVA. This treatment imposes a milking duration reduction, by definition. Consequently, a test of whether or not the reduction is 'significant' (inconsistent with chance alone) is unnecessary. Furthermore, the Timer treatment may violate the ANCOVA distributional assumptions of equal variance and normality by virtue of having its range of observable milking durations artificially curtailed.

The average maximum milking duration per batch of 16 cows (i.e., the maximum milking duration for each milking, averaged over a period of time for each treatment group) is an important statistic. It reflects the typical minimum time required for milking the group and thus relates directly to the labour productivity of the milking regime. This quantity, however, is problematic to analyse statistically under the present design. As there is only one maximum for each group and one group of each treatment, there is no explicit replication for this variable. Techniques such as permutation tests and the bootstrap (making use of within-group variation) were investigated, but the group maximum is unsuited to these approaches (Efron & Tibshirani, 1993).

Permutation tests (Efron & Tibshirani, 1993) were used to test the differences between bulk milk cell counts for the treatment groups.

Willingness of cows to enter the dairy was recorded with the group as the experimental unit. Consequently, these data could not be statistically analysed. For all other behaviour observations the individual cow was considered the experimental unit.

Total restlessness counts were analysed using a generalized linear model having overdispersed poisson error distribution and log link (McCullagh & Nelder, 1983). Analyses were performed for each measurement occasion (from treatment period 1 onwards) and for the total number of counts in the last four measurement occasions. The restlessness count for the afternoon milking of the second observation of the covariate period was log(x+1) transformed and used as a covariate in these analyses. One cow was deleted from the analyses because its restlessness counts were atypical for that cow during the covariate period.

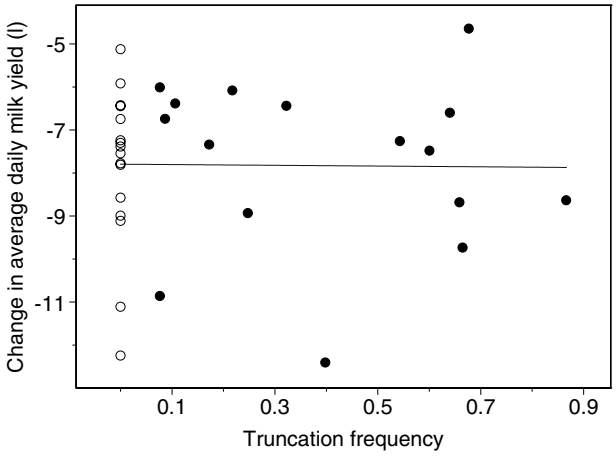

Fig. 1. Relationship between the change in the mean daily milk yield of individual cows and the frequency of truncation of milking of the same cows. The milk yield change (l/d) was calculated from the difference in the individual cow's average daily yield in the covariate period and the last two treatment periods (where the milkings were truncated to the duration of 5th and 6th slowest milkings respectively). Cows in Timer group, ●; ○, cows in Control group (for comparison). Linear regression slope 0·087 (SE 1·263).

Results and Discussion

Initial analysis of variance showed no significant differences in the response to treatments between sub-periods within treatment periods. As there were no observable 'adjustment to treatment' effects we subsequently reported results for whole treatment periods.

Mean milk yield per day ranged from 26 (October) to 15 l/d (March) and was not significantly affected by any of the treatments (Table 1). However, it was possible that the yield from the majority of less frequently truncated cows was masking a detrimental effect on the yield of those few cows that were truncated often. Consequently, we used regression analysis to examine the relationship between the decline of milk yield (difference between the covariate milk yield and the milk yield during sustained truncation treatment) and truncation frequency of individual cows during the last two experimental periods. The analysis showed a similar scatter for the Control and Timer cows and no association between milk yield decline and truncation frequency in any experimental period (Fig. 1). The analysis also showed that, for the last two treatment

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periods, most of the cows were truncated at one or more milkings.

We calculated the daily yield of milk solids from the yield of milk and the sum of the composition of fat, protein and lactose in the p.m. and a.m. test samples of each cow during the covariate and treatment periods. Analysis of variance revealed only small, non-significant, differences between the mean daily yield of milk solids for groups within periods.

Raising of the ACR threshold appeared to have only a small effect on reducing the mean milking duration. This effect was not statistically significant even when raised to 500 ml/min. For Raised ACR+Stim treatment there was a reduction in the mean milking duration which was significant ($P<0{\cdot}05$) in period 3 (Table 1). This 10% reduction at ACR setting of 500 ml/min was similar to that reported by Rasmussen (1993) who observed a 10% reduction for a change from 200 to 400 ml/min with pre-milking stimulation.

During the experiment, we visually estimated 'end of milking' flow rate from the time between 'dumps' (using a stop clock) and the incremental yield shown on the meter. When estimated in this crude way, the flow rate immediately prior to ACR activation was always substantially (approximately 100%) higher than the ACR setting. Consequently, we consider that the actual cut-off flow rates were probably considerably higher than their nominal values of 200, 300, 400 and 500 ml/min set on the system.

For our Timer group, negligible truncation of milking took place until the latter part of treatment period 1 when we changed the protocol to truncate at a time equal to the mean milking duration of the fourth slowest cow in the group during the previous week. Consequently, an appreciable effect of truncation could be observed only in periods 2 and 3 when the cows in this group had their milking truncated to the mean milking duration of the 5th and 6th slowest cows respectively, observed within the group during the previous week. This truncation of milkings caused a 26–30% reduction in maximum milking duration per batch of 16 cows. Over the same periods the reduction in maximum milking duration per batch of 16 cows for the Raised ACR+Stim treatment was only 10%.

After the completion of our experiment we became aware of an experiment that used truncation of milking duration which caused a 7·7% reduction in milk yield (Nielsen et al. 1983). However we note that in their experiment those workers applied a harsher timer/truncation treatment (5·5 min) and did not adjust truncation times for stage of lactation (or milk production as we did). Milking was not terminated according to an ACR-threshold as well as time, whichever came first (as we did in our experiment). Moreover, the mean milk yield was similar to ours, but they applied their treatment during the start of lactation (we did not) which, they assert, may have had an adverse effect on yield for the rest of the lactation. Lastly, they used 'average' cows in their experiment, whereas we used a selected group of the slowest milking cows from a large herd. The two findings are not inconsistent, given the differences between the two experiments. Together the experiments indicate that there is scope to find beneficial milking regimes that can save substantial milking time and cause little or no loss of milk production.

At the outset of the present experiment, we expected that a reduced milking duration for the group might cause a production loss for some cows, particularly as we had selected 64 of the slowest-milking cows from a herd of 450 cows. However, our results indicate that we could use considerably shorter milking regimes before such a loss would occur. Consequently we consider that there is considerable scope to reduce the maximum milking duration in order to find the optimum milking duration.

In period 3 the electronically recorded mean maximum milking duration for the Timer group was approximately 1 min more than the time set on the independent timer devices (Table 1). We consider that this discrepancy could have come about by the milking staff being otherwise occupied and allowing some cows occasionally to milk beyond their allocated maximum milking duration. If such errors had been avoided, by the full electronic automation of the truncation process, the saving in milking time would have been as high as 37%.

The average milk flow rate (l/cow per min of milking duration) was significantly greater than the Control group for all shorter milking regimes in some treatment periods. The largest and most consistent improvement in milk flow rate was for the group that had teat stimulation (ACR+Stim), although this was not significantly different ($P>0{\cdot}05$) from the other shorter milking regimes (Table 1).

The introduction of the pre-milking teat stimulation treatment was done with the ACR at the Control setting of 200 ml/min. We observed no significant increase of milk flow rate in this period. From this we can infer that there was probably a critical interaction of stimulation and ACR setting that caused the subsequent improvements in milk flow rate. Alternatively, the early null effect of stimulation (only) treatment could be because the cows required some time to become positively conditioned to teat stimulation.

Quarter strip yield was measured as the volume of 'strippings' that were removed from the quarter by re-attaching the teat cup stripping apparatus that is previously described in Methods. This strip yield represents the milk that was left behind and could have been removed by a more complete milking process. However, we expect that our stripping method may have removed more milk than 'hand stripping' or machine stripping (where the cluster is not removed-then-replaced). Even so, strip yield was within normal acceptable limits when assessed against recommendations by Brightling et al. (2000), i.e., not more than 20% of quarters with strip yields (hand) over 99 ml, except for the Timer group in the final period (Table 1).

Individual quarters in all groups, including the Control group, had strip yields >2000 ml/quarter, which was much higher than we expected. While some of the high strip

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yield could be attributed to the early cluster removal in our treatments, much of it was probably due to other factors. We observed many quarters that had strong milk flow as soon as the strip cups were re-attached. We speculate that these cows may have had a milking failure that was caused by 'teatcup crawl' and/or swelling of the tissue at the base of the teat within the zone surrounded by the liner mouthpiece. The resultant constriction could have effectively closed off the upper reaches of the teat cistern and caused the milk to stop flowing. If this were the case, then these slow milkings could be rightly viewed as deriving from imperfections in the milking process rather than from innate properties of the cow's anatomy.

Thiel & Dodd (1979) state that 'Contrary to popular belief the results of experiments on the effect of incomplete stripping indicate that its effect (on milk yield) is small'. They hasten to add that the most extensive experimental evidence for this small effect lacked a test of statistical significance. In our experiments, despite recording very high strip yields, production in all treatment groups was maintained relative to the Control. This phenomenon is consistent with there being a delay in milk harvesting rather than a loss of production, 'strippings' from one milking being harvested at the subsequent milking.

There is also a popular belief that incomplete milking of cows causes mastitis (Thiel & Dodd, 1979). They comment that this belief has little evidence to support it and suggest that infections may merely be less likely to show clinical signs if all available milk is carefully removed. We did not expect our shorter milking regimes to cause more mastitis. However, because our milking regimes could cause increased frequency of incomplete milking, we examined the apparent rate of new subclinical infections in each group. We assumed that there was a 'new' case of subclinical mastitis when SCC was >249 cells/μl for the first time in the lactation (in the absence of clinical signs). On this basis there were 5, 7, 3 and 5 new subclinical infections during treatment for the Control, Raised ACR, Raised ACR+Stim and Timer groups respectively. It appeared that the shortening of milking did not increase the incidence of subclinical mastitis. Of course a very large impact on mastitis frequency would be required to be detectable in a study of this size having 16 animals per treatment. We also noted that these 'new infections' did not particularly occur in cows that had a high frequency of truncation of milking. Rasmussen (1993) also found that raising the ACR threshold to 400 ml/min did not affect the incidence of subclinical mastitis.

Over the entire experiment there were five cases of clinical mastitis. There were two cases in the Raised ACR+Stim treatment group and one each for the other treatments. Two of these cases were in the covariate period and none of the other cases occurred in treatment periods 2 and 3 when milkings were shortened the most.

At the end of the experiment we obtained a general indication of the aetiology of mastitis infections that were in the herd. We aseptically sampled quarter milks from 17 cows that had high cell counts. The quarters were selected on the basis of a rapid California Mastitis Test. The samples were cultured and all growths were reported. A high number of cows were subclinically infected with minor pathogens (mainly *Corynebacterium bovis*).

The bulk milk SCC for each group was calculated from cow SCC and milk volumes (Table 1). Timer group tended to have higher bulk milk SCC than the other groups but this also was also evident in the covariate period.

Anecdotal reports from USA claim an improvement in teat condition from shorter milking regimes in very high yielding herds, but we found no significant improvement resulting from our regimes that shortened milking duration.

Cow behaviour at milking in all treatments was normal and there were no significant differences between treatments when all data were corrected for the covariate period.

Our 'proof of concept' experiment with small groups of slow-milking cows provided strong evidence that, under Australian dairying conditions, milking duration can be substantially reduced without incurring significant loss of milk production or increase in the incidence of mastitis.

Truncation of milking at a predetermined duration (Timer treatment) provided the most direct means of shortening milking and was considerably more effective than raising ACR settings. For example, in a herd of 200 cows milked in a 20-unit herringbone dairy, using milking truncation, it could save 50 min/d (4 min batch∗10 batches∗2 milkings/d∗0·66 flow on factor). The 'flow on factor' allows for the fact that the slowest-milking cows will not distribute themselves evenly across all batches entering the dairy and will have a random order of entry within the batch. Milking truncation will also be highly suited to milking in rotary dairies, the main benefit in these dairies being that high rotation speeds can be maintained with reduction or elimination of 'go round again' cows. Alternatively, farmers could save money by constructing smaller dairies whilst maintaining their milk harvesting productivity.

Pre-milking teat stimulation, when coupled with a raised ACR setting produced significantly reduced average milking duration relative to the Control group. However, the extra labour required for stimulation in our 16-aside dairy (16 cows∗0·25 min=4 min) grossly exceeded the milking time saved (1 min).

Failure of the Raised ACR treatment (without stimulation) to have an appreciable effect on the maximum or mean milking duration indicates that it is an ineffective tool to speed the milking process in an industry where pre-milking teat stimulation is not routinely practised. Possibly ACR settings above 500 ml/min would be more effective.

Our results indicate that Raised ACR+Stim treatment caused the highest average milk flow rates. However, in contrast to the Timer treatment, it did not effectively address the problem of protracted milking duration for individual cows. These contrasting findings indicate that probably the improved milk flow rate did not particularly

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occur in cows that had protracted milkings (where improved flow rates would be most beneficial).

We also speculate that slow-milking cows experience a damaging and building cycle of over-milking, with resultant physiological effects that perpetuate and extend slow milking. The regime of timed truncation of milking may have simply broken this cycle, reducing milking duration whilst maintaining production.

ACR technology, if only used to shorten milking duration, would be an expensive capital investment for many farmers and might prove ineffective. It also would need to be used in conjunction with teat stimulation to speed milking significantly. By contrast, the simple timer (as used in this research) could be extremely cheap (<A$100/dairy). A milking regime that uses timers requires no teat stimulation to have its effect of shortening milking duration. We also note that we have not tested the use of timers in the absence of ACR, but we can find no logical reason why the reduced milking duration benefits would not occur in the absence of ACR.

Having advocated the simple use of milking timers to shorten milking duration, we still consider that ACR is a valuable device for reducing labour costs (cluster removal) and preventing over-milking (timely cluster removal). If ACR is coupled with truncation timers then large savings in all three aspects of milking efficiency could be achieved.

Slow-milking cows must be rated highly for production and other desirable dairy characteristics if they are to be kept in the herd. If the truncation treatment can largely offset the effect of their protracted milking then this should be an attractive alternative to culling otherwise valuable cows.

Our use of predominantly slow-milking cows can be criticized as being atypical of a 'normal' herd. However, we justify this choice for our experiment on the grounds that the main benefit of our regimes will be expressed unequivocally by using such animals. However, even if in commercial herds the prevalence of slow milking is much lower, the slowest cows in each milking batch will determine the number of batches per hour that can be milked. Consequently the mean milking duration per cow is irrelevant. Dairy farmers often sum this issue up quite well by saying 'those few slow-milking cows seem to conspire to make sure there is one in every batch, just to slow the milking'.

The equations that can be used to determine milking efficiency for herringbone and rotary dairies have recently been revised (Johnston & Klindworth, 2000). They show that average maximum milking duration per batch (rather than the mean milking duration per cow) is the critical factor that should be used in such equations for both rotary and herringbone dairies. We also encourage other researchers to measure and report on mean maximum milking duration because it is critical to the true estimation of milking dairy throughput and labour productivity issues. Recent research by Stewart et al. (2002) showed that raising ACR settings marginally reduced the mean milking duration in five herds. However, there was not a commensurate increase in 'parlour turns/h'. This apparent contradiction might have been resolved if they had measured the average maximum milking duration (as we did). It is also possible that our postulated 'constriction of milk flow' mechanism could help to explain this counter-intuitive outcome.

In conclusion, the present experiment indicates that simple truncation of milking may be a potent and inexpensive method of milking a herd of cows more quickly and could be applied in all dairies regardless of the level of sophistication of the milking system. Although these are preliminary findings, we would encourage dairy industry to examine ACR systems to see if they can be adapted to this apparently simple yet efficient way of milking cows. On the other hand, where ACR systems are out of financial reach, farmers may consider the use of a simple electronic timer to objectively set and manage the maximum milking duration for batches of cows based upon their expected milk yield.

We recommend that these issues be examined further with more cows, particularly high yielding cows at peak of lactation, to verify our findings and to find possible optimum shortened milking regimes.

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References

Baird DB 1994 The design of experiments with covariates. PhD Thesis, University of Otago

Brightling P, Mein G, Hope A, Malmo J & Ryan D 2000 *Countdown Downunder, Technotes for mastitis control*. Dairy Research and Development Corporation, Level 3/84 William St, Melbourne 3000

Efron B & Tibshirani RJ 1993 *An Introduction to the Bootstrap*. New York: Chapman & Hall

Genstat 5 Committee 1996 Genstat 5 Release 3.2 Command Language Manual. Oxford: Numerical Algorithms Group

Harville DA 1974 Nearly optimal allocation of experimental units using observed covariate values. *Technometrics* **16** 589–599

Johnston M & Klindworth D 2000 *Working Smarter Not Harder* Agriculture Victoria Ellinbank, RMB 2460 Hazeldean Road, Ellinbank, Victoria, Australia, 3821. ISSN 0 731145100

McCullagh P & Nelder JA 1983 *Generalized Linear Models*. London: Chapman and Hall Ltd.

Mein G & Smolenaars F 2001 *Making the most of the milk harvest*. A prospectus for the milk quality and harvesting program. Dairy Research and Development Corporation, 3/84 William St, Melbourne, Victoria, 3000

Moran JB, Drysdale GR, Shambrook DA & Markham NK 2000 A study of the key profit drivers in the Victorian dairy industry. *Proceedings 9th Congress of the Asian-Australasian Association of Animal Production*

Nielsen SM, Rasmussen MD, Frimer ES, Madsen PS, Jensen NE & Keller P 1983 *Standardized machine milking*. National Institute of Animal Science, Denmark. Report 549

Rasmussen MD, Frimer E, Galton DM & Petersson LG 1992 The influence of premilking teat preparation and attachment delay on milk yield and milking performance. *Journal of Dairy Science* **75** 2131–2141

Rasmussen MD 1993 Influence of switch level of automatic cluster removers on milking performance and udder health. *Journal of Dairy Research* **60** 287–297

Riley D, Jennings J, Boero Rodriguez V & Hardcastle S 1999 Technology and farm management practices in the Australian dairy industry, Australian Bureau of Agricultural Resource Economics, Report to the Dairy Research and Development Corporation, 3/84 William St, Melbourne, Victoria, 3000

Stewart S, Godden P, Rapnicki P, Reid D, Johnson A & Eicker S 2002 Effects of automatic cluster remover settings on average milking duration, milk flow, and milk yield. *Journal of Dairy Science* **85** 818–823

Thiel CC & Dodd FH 1979 '*Machine Milking*' Technical Bulletin No.1, Reading, England: NIRD

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