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BRIEF COMMUNICATION: Considerations to cost-effectively automate batch milking in pastoral dairy systems without distributing milkings over 24 h.

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Abstract

Current technological limitations mean that to cost-effectively automate batch milking, without distributing milkings over 24 h, a rethink of the farm and milking system is required. A model and a range of non-optimised scenarios were developed for a 300-cow herd to illustrate the trade-offs between the number of automated milking points required (cost) and the duration of 'on-call' time for the person overseeing milking. Compared to the base scenario of 30 milking points (equivalent to conventional milking), by milking the herd in three groups of 100 and adjusting the twice-a-day milking interval from 9-15 h to 6-18 h, the number required could be reduced to 12, with a similar 'on-call' time. Further adjustments could reduce the number of milking points to 7 by milking once-a-day, although five groups of 60 cows would be required to keep cow waiting time below 2 h. These results demonstrate the potential flexibility of current automated milking technology for batch milking.

Keywords: dairy farm systems; automated milking; batch-milking

Introduction

Labour efficiency on New Zealand dairy farms has plateaued at ~150 cows/full time equivalent since 2010/11 (Edwards et al. 2015; DairyNZ 2022). Milking is a time-consuming task, requiring on average 19 h/person/week, excluding herding and cleaning time, at peak lactation when 92% of herds were milked twice-a-day (Edwards et al. 2020). While there are options to adjust the twice-a-day milking interval and/or reduce time spent milking (Edwards et al. 2022), a large proportion of farm labour is occupied for fixed periods of the day, reducing flexibility and restricting the time available for non-milking tasks. Reducing milking frequency is an option but milking would still occupy a large proportion of the workforce for fixed periods in the day. Therefore, automating milking, in particular cluster attachment, could reduce peaks in daily workload and enable an increase in labour efficiency. This could also improve workplace attractiveness by removing a repetitive task, reducing unsociable working hours, and increasing workplace flexibility.

Typically, in automated milking systems, milkings are distributed over a 24 h period and cows voluntarily present for milking (John et al. 2019). This pattern of milking distribution minimises the number of automated milking points required and therefore capital expenditure. This approach has seen limited adoption in pasture-based systems, partly because it introduces complexity in managing voluntary cow traffic and pastures and necessitates someone 'on-call' outside of standard work hours. Milking cows in a group or batch could help alleviate this challenge and may be more easily integrated into existing farm practices.

To automate milking in batches, a robotic arm would be required at each milking stall due to the speed limitations of current automated cluster attachment technology (i.e. costly). Consequently, to cost effectively automate batch-milking a rethink of the farm and milking system is required. To quantify the trade-offs between the number of automated milking points required (cost) and the duration of milking or 'on-call' time (important for workplace attractiveness) a model was developed and the effect of changing aspects of the farm and milking system tested via scenarios.

Materials and methods

A model of milking was developed in Excel (Microsoft, Redmond, WA, USA) and contained 8 input variables that affect the number of milking points or the duration of milking. 1) the duration of the longest milking interval (h), 2) the maximum duration between the start of the first milking and end of the last milking (h), i.e. 'on-call' time, 3) the utilisation of the milking points (% of time, to allow for failed milkings or unoccupied stalls), 4) the size of the milking group(s), 5) the number of milking groups, 6) the time between each milking group (min), 7) the maximum time a group can be at the dairy (h; not including time to/from the paddock) and 8) the maximum group average milk yield in the lactation (kg/cow/day). Note that for a given herd size, the number of groups determines the group size and vice versa. The duration of each milking was proportional to the input milking interval (i.e. milk flow rate was assumed constant). Inputs referred to in the methods hereafter are italicised.

The time that each group was required to be milked within was determined by the minimum of three constraints, i) that the first milking (all groups milked) must be completed before the start time of the second milking in order to maintain the *milking interval* (if twice-a-day milking), ii) the second milking must be finished in time to satisfy the *maximum 'on-call' duration* and maintain the *milking interval* of each group, or iii) the *maximum time a group can be at the dairy* being milked.

The milk yield per cow at each milking was estimated using the *milking interval* and the *maximum group* *average milk yield*. This was further converted to the time required to milk each cow assuming a maximum milking time was used (Jago et al. 2010). This value was divided by the *utilisation* to determine an average milking point occupancy time and multiplied by the input *group size* to calculate the accumulated milking time. Finally, this was divided by the time the group was required to be milked in (determined above) and rounded up to estimate the number of automated milking points needed.

The model was used to determine the number of automated milking points required under a range of non-optimised scenarios with differing constraints for a 300-cow herd (Table 1), starting from a base scenario that was similar to conventional milking.

Results and discussion

There were an estimated 30 milking points (~NZ$250,000/point) required for the base scenario (A), with one milking group and a maximum time at the dairy of 2 h. Despite the maximum allowable 'on-call' time being set to 12 h, the maximum group milking time constraint of 2 h meant that the actual 'on-call' time was 10.4 h. Increasing the number of groups from one to three (100 cows/group) removed this constraint, allowing the majority of the 12 h period to be utilised and the number of milking points to decrease to 20 (scenario B). Increasing the number of groups to four was not beneficial because each group had to be milked in a shorter duration to maintain the milking interval. To ensure that increasing the number of groups would not create additional workload elsewhere and that people would not be required outside of milking, technology such as virtual herding would need to be investigated. From scenario B, increasing the utilisation of the milking system had a small effect on reducing the number of milking points required to 18 (scenario C). Less 'on-call' time is likely to be more attractive to people on-farm. From scenario B, changing the milking interval to 6-18 h (scenario D) decreased the 'on-call' time to 10.6 h (similar to the base scenario), maximised the duration the milking system was operating and reduced the number of milking points required to 12. The key driver of this was allowing for the second milking to begin immediately after the first milking was finished. Extending scenario D, if the objective was to reduce the 'on-call' time to under 9 h, then a milking interval of 5-19 h and 15 milking points would be required. This illustrates the importance of milking interval to 'on-call' time.

The purpose of scenarios E and F were to minimise the number of milking points further. In both scenarios, the number of milking points required was reduced to 10 (compared to base scenario of 30). The trade-off for this reduction was either an increase in 'on-call' time of 3.3 h or a requirement to reduce peak milk yield by 6 kg/cow/d, for example autumn calving has a flatter lactation curve than spring calving (Jarman et al. 2020). The advantage of the latter approach was a similar 'on-call' time to the base scenario. A variation to scenario F showed that if the reduced peak milk yield was achieved by reducing milking frequency to once-a-day, the number of milking points could be reduced to seven within the same 'on-call' time. However, this would require an increase in the number of groups to five and a reduction in group size to 60 to ensure the maximum group milking time constraint of 2 h was not limiting.

Table 1. Estimated number of milking points and operator day length ('on-call' time) from start of first milking start to end of last milking for a range of scenarios. In all scenarios the maximum duration each group could be at the dairy was 2 h and the time allowed between each group was 10 min.

Scenario name	Base	Increase groups	Increase utilisation	Increase milking interval	Increase day length	Lower peak milk yield
Scenario	A	B	C	D	E	F
Peak milk yield (kg/cow/day)	28	28	28	28	28	22
Milking interval (h)	9-15	9-15	9-15	6-18	8.4-15.6	6-18
Group size (cows)	300	100	100	100	100	100
Number of groups	1	3	3	3	3	3
Milking point utilisation	80%	80%	90%	80%	80%	80%
Maximum 'on-call' time (h)	12	12	12	12	15	12
Required time per group (min)	120	59	59	113	120	113
Milking points required	30	20	18	12	10	10
Actual 'on-call' time (h)	10.4	11.7	11.7	10.6	13.7	10.6
Machine operating time (h)	3.4	6.0	6.0	10.6	11.6	10.6

Overall, these results demonstrate the complex interactions that exist between the model inputs and the tension between the number of milking points required and the length of 'on-call' time. The scenarios are illustrative and are not necessarily optimised. Further work should be conducted to determine farmer preferences for this trade-off, and the impact of stacking complimentary technologies. This analysis demonstrates the flexibility afforded by current automated cluster attachment technology when the farm system design is re-imagined thereby increasing the economic feasibility of batch automatic milking without needing to distribute milkings over 24 h.

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