Increasing platform speed and the percentage of cows completing a second rotation improves throughput in rotary dairies

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Abstract. This study sought to improve milking efficiency in rotary dairies by modelling the effect of increasing platform speed on the percentage of cows requiring multiple rotations to complete milking, i.e. ‘go-around’ cows, and cow throughput. Milking data, including 376 429 milking event records from 44 530 cows, were collected from 62 commercial farms with rotary dairies in New Zealand. Average rotation time, a function of platform speed and rotary size, was 10.0 ± 1.5 min, mean milking duration 383 ± 129 s, and mean milk yield 11.9 ± 3.8 kg per milking session. Milking duration data were normalised using a log10 transformation. An estimate of the percentage of ‘go-around’ cows and potential throughput over a range of platform speeds were made using the NORMDIST function of Microsoft Excel 2010. Results indicate that throughput continues to increase with increasing platform speed, despite a greater number of ‘go-around’ cows. If a potential shadow effect (whereby a ‘go-around’ cow may cause the following bail to be unoccupied) is considered, the optimum percentage of ‘go-around’ cows was ~20%. Accordingly, a change of operating practices in many rotary dairies is justified as the current target of 10% ‘go-around’ cows may limit throughput. In order to achieve greater cow throughput, platform speed should rather be set based on the capability of the operator attaching clusters. The difference between the current average rotation time and milking duration indicates that many dairies can increase platform speed and thus throughput. Furthermore, many work routines can be accelerated so faster platform speeds can be achieved without increasing labour requirements. The increased throughput potential of larger dairies is only realised when operated at fast platform speeds.

Introduction

Milking is the most time-consuming task on pasture-based dairy farms, accounting for between 33 and 57% of time annually (O’Brien et al. 2004; O’Donovan et al. 2008; Taylor et al. 2009). In the future, milking times will increase due to the continued expansion of herd sizes (DairyNZ and LIC 2011), exerting pressure on labour resources if changes to milking routines and dairy size are not made. Large herds (>500 cows) in New Zealand and Australia tend to be milked through rotary dairies, for example 40% of cows, accounting for only 25% of herds, are milked through rotary dairies in New Zealand (Cuthbert 2008). Therefore, the rotary dairy is likely to become the dominant technology for milking cows as herd size increases.

The operating efficiency of rotary dairies is important in determining herd milking times and thus labour requirements for the milking process. Operating efficiency is determined by three factors (Copeman 1985): (i) the number of bails on the platform, which is determined at the time of construction and cannot be easily changed, (ii) the distribution of individual cow milking times (determined by milk yield, milk flow rate and end of milking criteria), and (iii) the speed at which the platform is rotating. The speed of the rotation is the only factor directly controlled by the operator at the time of milking.

Rotation or platform speed (for practical purposes defined as s/bail) is difficult to measure and thus a more common term used on farm is rotation time, defined as the rotation speed multiplied by the number of bails on the platform, or simply the time taken to complete one rotation. Cows with milking durations greater than the rotation time will remain on the platform and complete a further revolution. Thus, rotation time directly affects the number of cows requiring more than one rotation to complete milking (Nitzan et al. 2006). The number of cows requiring a second rotation (‘go-around’ cows) is obvious to the operator attaching clusters, and is thus the cue most operators use to set platform speed. The effect of platform speed on the efficiency of small rotaries was examined by Copeman (1985), who reported that the maximum throughput...
(cows milked per hour) was achieved when the speed was set so that 8–16% of cows were sent around on a second rotation. Since the 1980s there has been an increase (~25%) in per cow production (DairyNZ and LIC 2011), potentially altering the distribution of individual cow milking durations. Additionally, rotary sizes have increased from the 17 to 36 bails examined by Copeman (1985) up to as large as 80–100 bails today and pre-milking routines are no longer common practice (Phillips 1987). Therefore, setting platform speed using the common target of 10% ‘go-around’ cows may no longer be appropriate.

It was hypothesised that the highest cow throughput would be achieved with 10% cows ‘going-around’ on a second rotation. A simple model was developed using data collected from commercial farms. This model was used to determine the effect of varying platform speed on the number of cows requiring a second rotation and cow throughput.

Materials and methods

Data collection

Sixty-two farmers throughout New Zealand participated in a study to provide benchmark data for a range of milking efficiency measures. Farmers were selected for their ability to record milking data automatically and all dairies were equipped with a minimum level of technology including electronic identification, milk meters, automatic cluster removers and herd management software that recorded individual milking events. A range of dairy sizes, and milking plant manufacturers were included to represent rotary milking systems in use. Milking data were collected from ~10 milkings between the end of calving and start of mating (September–November 2010). Additionally, a phone survey was conducted to determine the number of herds being managed and the number of operators attaching clusters in the dairy.

Measurements and calculations

Each herd management system, DairyMaster (Causeway, Ireland), DeLaval (Tumba, Sweden), GEA (Bönen, Germany), Milfos (Hamilton, New Zealand), and Waikato Milking Systems (Hamilton, New Zealand), was programmed to produce similar reports. Variables recorded included cow number, identification (ID) time, bail number, milk yield, and milking duration. Bails not occupied by new cows were calculated by sorting data by ID time for each milking session and counting the number of times bail numbers were not sequential. The number of rotations during the session was calculated by adding the number of cows milked and the number of bails not occupied by new cows and dividing by the number of bails in the rotary. An estimate of average platform speed was calculated by subtracting the last ID time from the first ID time and removing the largest time gap(s) during a milking session if more than one herd(s), then dividing this value by the number of rotations and then by the number of bails.

Model development

Milking duration data from the morning and afternoon session were combined. Data were examined and found to be skewed (Fig. 1a) so were normalised using a log10 transformation (Fig. 1b). The normalised mean milking duration and standard deviation of the benchmark data were used with the NORMDIST function of Microsoft Excel 2010 (Redmond, WA, USA) to estimate the percentage of cows that would have completed milking in each rotation for a given platform speed and rotary size (rotation time is platform speed multiplied by rotary size). Subtracting the percentage finished milking from 100 leaves the percentage of cows that would not have finished milking before the end of that rotation. This calculation was repeated for five rotations to account for cows with longer milking durations that may require more than two rotations to complete milking at faster platform speeds (shorter rotation times). For example, a cow with a 20-min milking duration would occupy a bail for four rotations at a 6-min rotation time. The percentage of ‘go-around’ cows at each of the five rotations was summed to give an overall percentage of bails occupied by ‘go-around’ cows on the platform at any given time in a steady-state situation. An estimate of throughput for a given platform speed and its corresponding ‘go-around’ percentage was calculated using Eqn 1. It was assumed that there were six unutilised bails over the entry and exit to the platform and that there were no unoccupied bails. A second scenario was developed to determine the effect of a potential shadow effect whereby a...
‘go-around’ cow may increase the chances the following bail is unoccupied. In this scenario it was assumed that half the bails following a ‘go-around’ cow were unoccupied.

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\text{Throughput (cows/hour)} = \frac{3600 \times \left(\frac{\text{go-around} \% + 100}{100}\right)}{\text{platform speed (s/bail)}}
\]

**(Results)**

**Commercial farms**

A total of 376,429 milking event records from 44,530 cows were extracted from the 62 commercial farms. The average milking duration was 383 ± 129 s (Fig. 1a) and average session yield 11.9 ± 3.8 kg, or a total daily yield of 23.8 kg/cow. The log\(_{10}\) transformed milking duration data had a mean of 2.56 and a standard deviation of 0.14 (Fig. 1b).

Single operator dairies (n = 57) achieved platform speeds of up to 6.4 s/bail. Mean platform speed was 11.3 ± 2.4 s/bail, and the slowest was 22.0 s/bail. The speed of dairies with two operators (n = 2) attaching clusters ranged from a maximum of 5.5 s/bail to as slow as 8.5 s/bail, mean platform speed was 6.8 ± 1.1 s/bail. The remaining dairies operated with between one and two operators (n = 3). Smaller dairies tended to operate at slower speeds than larger dairies. Mean rotation time was 10.0 ± 1.5 min, minimum 6.4 min and maximum 16.1 min.

**Modelling**

Increasing platform speeds resulted in higher percentages of ‘go-around’ cows (Fig. 2a). A greater number of ‘go-around’ cows did not result in reduced potential throughput for all dairy sizes. Eighty bail rotary dairies operating at 5 s/bail achieved the highest potential throughput, 484 cows/h, when an estimated 49% of cows required a second rotation (Fig. 2b). Potential throughput was constrained by dairy size. Additionally, potential throughput was reduced when a shadow effect was included and an optimum percentage of ‘go-around’ cows, ~20% (Fig. 2c), was created. Modifying the shadow effect from 50 to 25 or 75% achieved similar results for optimum platform speed at each dairy size. The effect of platform speed on milking performance for a 718-cow herd, the average herd size of the 62 farms, milked through a 60-bail rotary, is shown in Table 1. Decreasing rotation time from the average 10 to 8 min could result in a saving of 8.6 min per milking.

**Discussion**

The hypothesis that 10% is the optimum percentage of ‘go-around’ cows to achieve maximum throughput was rejected. The percentage of ‘go-around’ cows increased with faster platform speeds, however, throughput continued to increase without maxima. This result is consistent with Nitzan et al. (2006) as the combination of a greater number of bails presented per hour and the time saved by cows waiting less time to exit the platform after rotation one is greater than the negative effect of more cows requiring multiple rotations, thus, an increased throughput is achieved. Greater throughput with

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**Table 1. Effect of three platform speeds on milking performance for a 718-cow herd milked through a 60-bail rotary**

<table>
<thead>
<tr>
<th>Item</th>
<th>8 s/bail</th>
<th>9 s/bail</th>
<th>10 s/bail</th>
<th>11 s/bail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotation time (min)</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>‘Go-around’ (%)</td>
<td>30</td>
<td>18</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Rotations</td>
<td>15.5</td>
<td>14.2</td>
<td>13.3</td>
<td>12.7</td>
</tr>
<tr>
<td>Total milking time (h)</td>
<td>2.1</td>
<td>2.1</td>
<td>2.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Difference (min)</td>
<td>8.6</td>
<td>5.3</td>
<td>0</td>
<td>7.2</td>
</tr>
<tr>
<td>Throughput (cows/h)</td>
<td>347</td>
<td>338</td>
<td>325</td>
<td>308</td>
</tr>
</tbody>
</table>

*Difference relative to mean rotation time of benchmark farms, 10 min.*
more ‘go-around’ cows was not reported by Copeman (1985). However, Copeman (1985) made the assumption that at least 20 s was required to prepare a cow and therefore did not examine faster speeds. Examining the current results in the 20–60 s/italic bail range produces a similar figure to that reported by Copeman (1985). The current results indicate that throughput is highest when platform speeds are set to the maximum physically achievable by each dairy size or, if a potential shadow effect was included, when ~20% of cows were sent on multiple rotations. However, faster platform speeds require good cow flow onto and off the platform and the milking goals of farmers may vary, for example, feeding in bail may be the primary objective in which case a slower speed is appropriate to allow sufficient feeding time. Additionally, increasing the number of ‘go-around’ cows may result in more cows experiencing extreme overmilking (clusters remaining attached after the cessation of milk flow) when clusters are not removed by the operator normally attaching clusters in dairies not fitted with automatic cup removers, although cows exiting after a single rotation would be less likely to be overmilked. Furthermore, increased speeds and thus rotations may increase maintenance costs, so the increase in throughput should be considered with this in mind. Nevertheless, the current target of 10% ‘go-around’ cows will limit throughput in many situations. Thus, a major change in philosophy for the operating procedures of rotary dairies is justified.

Increasing platform speed has consequences for work routines and thus labour productivity and sustainability. Surveys in the USA suggest a work routine or platform speed of 8–12 s/italic bail is a common rate at which to attach clusters (Armstrong and Quick 1986). The mean platform speed for single operator dairies was 11.3 s/italic bail, indicating platform speeds could be increased. Furthermore, mean rotation time was 10 min despite an average milking duration of 6.4 min. Rotation times of 10 min or greater will likely result in operator idle time in dairies of 60 bails or less. The dataset provided examples of dairies with a single milking operator attaching clusters at a rate which allowed a platform speed of 6.4 s/italic bail. Alternatively, dairies were identified where two milking operators attached clusters with a platform speed of 8.5 s/italic bail. Thus, indicating that at ~7.5 s/italic bail the platform speed becomes too great for a single operator to attach clusters and two operators are necessary. Therefore, if increasing platform speed beyond the capabilities of one operator cow throughput should be measured in cows per hour per operator. The increase in throughput may not justify the greater labour input. Thus, platform speed should be set based on the abilities of the operator instead of the number of ‘go-around’ cows, which is used currently.

The rotary dairy is an efficient design because cow movement is largely automated, where cows enter and exit the platform at a constant rate, leaving the operator little time to rest between cows (Douphrâte et al. 2009). Additionally, milking tasks are highly repetitive, thus putting the operator at risk of injuries such as carpal tunnel syndrome (Stål et al. 2003). Operators looking to improve throughput by increasing platform speed will reduce the time available to rest the wrists and hands further, potentially increasing the chances of developing injuries (Stål et al. 2003). To reduce repetitiveness and increase rest time Stål et al. (2003) advocated the use of job rotation, for example the swapping of operators during the changeover between herds. A task rotation strategy in rotary dairies has been linked with fewer repetitions, and higher opportunities for rest/recovery compared with herringbone dairies (Douphrâte et al. 2012). Job rotation has the added benefit of increasing variety, likely leading to greater job satisfaction and improved staff retention. Therefore, on large farms, with considerable herd milking times, operators should be changed after each herd.

The throughput performance of all dairy sizes was similar at slower platform speeds. At these slower speeds, few bails will be occupied by ‘go-around’ cows so the majority of bail presented will be available for new cows. However, the rotation time will be significantly longer than individual cow milking durations in larger dairies and the bail will be occupied for a greater proportion of the rotation without harvesting milk. Conversely, faster platform speeds in larger dairies achieve greater throughput and therefore take less time to milk a herd than smaller dairies. So, if platform speed was limited, for example by a pre-milking routine that required 20 s to apply, then there is little justification for constructing a rotary of more than 40 bails (Fig. 1b), unless labour is increased, because at this point routine time is the limiting factor. Similarly, routine time has been reported to limit the number of clusters that should be handled by a single operator in herringbone dairies (O’Brien et al. 2012). Additionally, regardless of pre-milking routine, dairies with more than 60 bails are likely to require more than one operator to achieve the desired speed, thus reducing labour efficiency. This is relevant for very large herds (e.g. >1500 cows) where total time to milk the herd may be of greater importance than labour efficiency. Therefore, larger dairies (>60 bails) are best suited to properties where overall milking time is important and must be operated at fast platform speeds to justify the investment over a smaller rotary.

In conclusion, aiming for 10% ‘go-around’ cows will limit rotary performance in many circumstances. Instead, platform speed should be set to match the abilities of the operator attaching clusters and job rotation strategies should be employed. Larger dairies need to be operated at faster platform speeds to justify the additional investment over a smaller rotary.

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References


Platform speed, go-around cows and rotary throughput


