Modelling the impact of increasing herd size on milking interval, milk yield and profit in a forage based automatic milking system

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ABSTRACT

The aim of this modelling study was to investigate the effect of herd size on walking distances and milking interval (MI), and their impact on milk yield (MY) and profit when 50% of the total diet was provided from home grown feed either as pasture or grazeable complementary forage rotation (CFR) in an automatic milking system (AMS). Twelve scenarios consisting of 3 AMS herd sizes (400, 600, 800 cows), 2 levels of pasture utilisation (15.0 t dry matter [DM]/ha, termed as 'moderate' and 19.7 t DM/ha, termed as 'high') and 2 rates of incorporation of grazeable complementary forage system (CFS [pasture+CFR], % farm planted into CFS; 0, 30%) were investigated. Modelled results showed that increased herd size and associated increased walking distances, resulted in increased energy loss and MI of cows, and reduced MY in a pasture-based AMS. However, modelling the integration of grazeable CFR showed the potential to increase MY and financial performance compared to the pasture only, large herd, AMS.

Keywords: Automatic milking system; land areas; milk yield; milking interval; walking distances.

INTRODUCTION

Pasture-based automatic milking system (AMS) farms rely upon voluntary cow traffic where the cows largely move themselves around the farm without human intervention. In any pasture-based system, maintaining a sustainable stocking rate requires larger farm areas for larger herds and by default longer average distances between paddocks and the parlour. In an AMS increased distances between paddocks and the parlour are associated with increased MI (Lyons 2013), and ultimately are likely to result in reduced milk yields (MY) and a reduced profit. (Islam *et al*. 2013) reported that a large herd of 800 cows require 200 ha grazing area (when pasture utilisation levels were set at 15 t DM/ha) in a modelled AMS farm; 60% of which was located more than 1-km from the parlour. Negative impacts on MY and profitability (associated with scale of operation) may be partly mitigated in pasture-based systems by utilizing more pasture/ha and/or by incorporating high yielding, grazeable forage crops based on the principles of CFR (Garcia *et al*. 2008). The aim of this study was to model the effect of herd size (and grazing area) on walking distances, MI, milk yield and profit when 50% of the total diet was provided from either as pasture or grazeable CFR in pasture-based AMS.

MATERIALS AND METHODS

Twelve theoretical scenarios consisting of 3 AMS herds (400, 600, 800 cows), 2 levels of pasture utilisation (15.0 t DM/ha, termed as 'moderate' and 19.7 t DM/ha, termed as 'high') and 2 rates of grazeable CFS (0, 30%) were investigated in this modelling study. The assumptions developed were based on reported studies/literature and did not incorporate 'new' field data. The assumptions made in this modelling study were developed to allow comparative differences in MY loss between larger and smaller herd sizes.

A desktop model was developed *ad hoc* in MS Excel to determine the effect of the 12 scenarios on walking distances, MI, MY and economic losses. The impact of walking distance (distance from parlour to paddock) on MI was shown to be 0.1 h (6 minutes) per additional 100 m when the walking distance was between 100 m and 1 km (MI increased from 14.24 to 15.16 h; Lyons 2013). On this basis and in the absence of any additional published data, for modelling purposes it was assumed that no additional human intervention was involved in encouraging cow traffic and therefore that MI would increase (from 14 h) by 1 h for every 1 km increase in walking distance from the parlour to the paddock (one-way). Thus, a MI of 14 h was considered as the baseline for paddocks immediately adjacent to the parlour, MI extended to 15 h at 1 km distance, and so on to 20 h at 6 km. Milking frequency was calculated as: MF = 24/MI). In order to consider return times from the paddock to the parlour as Lyons (2013), each MF was multiplied by 2 to calculate the number of 'trips' or trafficking events (i.e. from paddock to parlour and from parlour to paddock for each milking event) required to achieve a milking. Actual or total walking distances were calculated as total walking = walking distance from the parlour to paddock × number of trips). Land area requirement for walking distances from 1 to 6 km from the parlour to the paddock (total distances ranged from 0 to 14.4 km respectively) were taken from (Islam *et al*. 2013).

The relationship between MI and MY was developed using data available in the literature (Erdman and Varner, 1995; K. Kerrisk, unpubl. data; Stockdale 2006) as:
MY (kg/cow/d) = -0.594 × MI + 32.91 (R^2 = 0.99; equation 1).

Milk yield loss (kg/cow/d) due to extended MI from 14 h to 20 h was calculated using equation 1. At a MI of 14 h, MY was calculated to be 24.6 kg/cow/d, whilst a MI of 20 h MY was calculated to have a daily milk yield of 21 kg/cow/d. Net MY loss at each MI was calculated by the difference between yield at 14 h MI and yield at the MI of interest.

A total of 50% of the metabolisable energy (ME) requirement of cows was supplied to modelled cows either from pasture only or from CFS. Metabolisable energy expended on walking to and from the parlour, and simultaneous grazing and walking, against each total distance walked was calculated using CSIRO (2007). Milk yield loss caused by walking and grazing was calculated from the energy loss attributed to simultaneous grazing and walking, and total distances walked for each MI. Energy loss was divided by 5.7 (as 5.7 MJ ME is required to produce 1 kg milk; Nicol and Brookes, 2007) in order to calculate MY loss directly attributed to simultaneous walking and grazing and total walking distance. The net MY loss (kg/cow/d) against each MI or walking distance was multiplied by \$0.38 (\$/L milk; Fariña *et al*. 2013) in order to calculate an economic loss per cow/d resulting from extended MI or walking distances.

Relationship between land areas, total walking distances between the parlour and the paddock or MI and all parameters mentioned above were developed. These relationships were used to calculate all parameters against scenarios related to herd sizes, pasture utilisation and rates of CFR utilisation in pasture-based AMS.

RESULTS

Increasing herd size was associated with increased walking distances of cows in the AMS farm (Table 1). Our results showed that energy and MY loss could be 3.5 MJ ME/cow/d and 0.86 kg of milk for every km increase in total walking distances between the parlour and the paddock, which resulted in an additional loss of \$0.32/cow/d for every km increase in total distance walked (data not shown in table). Our results also indicate 0.42 h increase in MI for every km increase in total walking distances (i.e. walking distance from the parlour to paddock × number of trips), which incurred 0.6 kg reduction in MY for each h increase in MI and \$0.22 loss (data not shown in table).

With moderate pasture utilisation and 0% CFR, increasing the herd size from 400 to 800 cows resulted in an increase in total walking distances between the parlour and the paddock from 3.5 to 6.3 km (Table 1). Consequently, MI increased from 15.2 to 16.4 h. High pasture utilisation allowed for an increased stocking density and resulted in a reduction in the total walking distances up to 1 km, thus reduced the MI by up to 0.5 h compared to the moderate pasture and 800 cow herd combination. The high pasture utilisation combined with 30% of the farm in CFR (plus 70% high pasture) in the farm increased milk yield by up to 1.5 kg/cow/d, thereby reducing loss by up to \$0.50/cow/d (c.f. the moderate pasture and 800 cow herd scenario) (Table 1).

Table 1: Effect of herd sizes, pasture utilisation (P) and rates of grazeable complementary forage system (CFS) use on walking distances, energy loss, milking interval (MI), milk yield (MY) and economic profit or loss

Herd size (*n*)	**P (t DM/ ha)**	**CFS[a] (%)**	**Area (ha)**	**Distance walked (km/d)**	**MI (h)**	**ME loss/ cow/d**	**MYL GW (kg/cow)**	**MYL MI (kg cow)**	**Loss GW (\$/cow)**	**Loss MI (\$/ cow)**	**TML (kg/cow)**	**TL (\$/ cow)**
400	15.0	0	100	3.5	15.2	11.0	1.9	0.7	0.7	0.3	2.6	1.0
		30a	80	2.9	14.9	9.1	1.6	0.6	0.6	0.2	2.2	0.8
	19.7	0	80	2.9	14.9	9.1	1.6	0.5	0.6	0.2	2.2	0.8
		30b	70	2.7	14.8	8.1	1.4	0.5	0.5	0.2	1.9	0.7
600	15.0	0	150	4.9	15.8	16.0	2.8	1.1	1.1	0.4	3.9	1.5
		30	120	4.1	15.4	13.0	2.3	0.8	0.9	0.3	3.1	1.2
	19.7	0	120	4.1	15.4	13.0	2.3	0.8	0.9	0.3	3.1	1.2
		30	110	3.8	15.3	12.0	2.1	0.8	0.8	0.3	2.9	1.1
800	15.0	0	200	6.3	16.4	20.9	3.7	1.4	1.4	0.5	5.1	1.9
		30	160	5.2	15.9	16.9	3.0	1.1	1.1	0.4	4.1	1.5
	19.7	0	160	5.2	15.9	16.9	3.0	1.1	1.1	0.4	4.1	1.5
		30	140	4.6	15.6	15.0	2.6	1.0	1.0	0.4	3.6	1.4

[a]CFS 0 represents 100% pasture and CFS 30 represents 30% complementary forage rotation and 70% pasture; ME = metabolisable energy; MYL GW, milk yield loss due to grazing and walking (GW); MYL MI, milk yield loss due to MI; TML, total milk yield loss, TL, total loss in \$.

DISCUSSION

Our study revealed that as herd size and walking distances increased, so did energy expenditure. Our study also indicated that the energy loss of cows across all scenarios increased on average by 87% (9.3 to 17.4 MJ ME; calculated based on the average energy loss from 11.0 to 8.1 MJ ME for 400 cows and from 20.9 to 15.0 MJ ME for 800 cows in Table 1), with the increase in herd size from 400 to 800 cows. Thus, the net reduction in MY could also be as high as 87% (on average from 1.6 to 3.1 kg milk reduction/cow/d; calculated based on the average MY loss from 1.9 to 1.4 kg for 400 cows and from 3.7 to 2.6 kg for 800 cows in Table 1) with the increase in herd size from 400 to 800 cows, when the base MY was considered as 25 kg/cow/d. Our results also indicated that the loss in energy and MY would be 3.5 MJ ME and 0.86 kg for every additional km walked. Thus, walking long distances may impact negatively on MY; directly through the energy costs associated with the extra walking; and through physiological impacts inhibiting MY (e.g. increased milking interval).

Our results indicate 0.42 h increase in MI for every 1 km increase in total walking distances. However, an increase in the distance between the paddock and the parlour up to 0.5 km appeared to be unrelated to a change in MI (Lyons 2013). There is no literature to support the assumption that the impact of walking distance on MI is a linear relationship, which is one of the limitations of this study. We recognise the possibility that the negative impact of walking distance may in fact be significantly higher at extreme distances. Furthermore, it is possible that the number of cows that voluntarily traffic back to the parlour from furthermost paddocks may in fact be significantly reduced. If a large number of cows do not return to the parlour then it is possible that MI will extend dramatically if farm staffs do not intervene to encourage cows to traffic to the parlour at regular intervals. However, integration of grazeable CFR (30%) with pasture (70%) has the potential to increase milk yield and financial performance by reducing walking distances and MY in all herd sizes compared to the pasture-based only AMS.

CONCLUSION

Our study revealed that increased herd size and the associated increased walking distances, which led to increased energy loss, MI of cows, and impacted negatively on MY and economic cost in pasture-based AMS. Modelled reductions in MY in cows were predominantly explained by the energy expenditure directly associated with walking and grazing as opposed to those created through the resultant increases in MI. However, grazeable CFS (CFR:pasture 30:70) have the potential to reduce walking distances, MI, energy loss, financial loss and increase MY of a large AMS herd compared to pasture-based AMS only.

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