Dairy cattle response to and learning of a virtual fence: Individual and herd

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Virtual fencing (VF) has the potential to revolutionise the control of livestock movement. Cattle can associate an audio cue (AC) with an electrical pulse (EP) however it is important to understand variation in response between individuals and how individual cattle learn within the herd. The aim of this study was to determine if there was a difference in learning and response to VF cues when cows were trained either as individuals or in groups, and how this was retained across contexts. Twenty-three Holstein-Friesian dry cows were fitted with Agersens eShepherd collars. Cattle were offered Lucerne cubes as a feed attractant at the end of 100x20m paddocks. For testing purposes, the VF was set halfway(50m). Cows received an AC when they reached the VF, which was paired with ana EP if they continued forward towards the feed. Tests were conducted once per day, either as individuals or in groups of six. After four tests, the cattle were crossed over, the individuals were tested in groups, and the groups tested as individuals for an additional two tests. The number of AC and EP received, and whether a cow reached the feed or not were recorded.

The probability of reaching the feed was similar between cattle trained as either individuals or groups, however the overall probability decreased to less than 10% after 4 tests (P<0.001). In addition to this reduced probability, there was a decrease in the mean number of cues across tests, reflecting animal learning. However, there was an interaction between crossover and training treatment, with 20% of cows trained in groups reaching the feed when tested as individuals, compared to 4% of individuals tested in groups (p=0.04). While there was a clear effect of learning, this result indicates not all cattle interact with the VF sufficiently in a group setting to reinforce the association of the cues. Ensuring that all cattle learn the VF within the herd is vital for the integration of this technology into the dairy industry.

Additional keywords: Virtual fencing (VF), Audio cue (AC), Electrical pulse (EP), Individual, Group.

Table 1: Probability of cows reaching feed per test. abc Values differ significantly at P<0.001.

Test #	Mean number of cues received	
	Paired audio + pulse	**Unpaired audio**
1	5.26^{ab}	10.21^{ab}
2	8.18^{a}	18.63^{a}
3	1.80^{b}	4.50^{b}
4	2.36^{ab}	5.28^{b}
P-value	0.02	0.04
Crossover		
5	0.531	1.373
6	2.513	6.955
P-value	0.46	0.54

Table 2: Mean number of cues received paired and unpaired. abc values differ significantly.

	Test #	Probability of reaching feed
Pre-crossover	1	0.98^{a}
	2	0.78^{b}
	3	0.18^{ce}
	4	0.07^{cf}
Post-crossover	5	0.01^{d}
	6	0.10^{ef}

Table 3: Probability of cows reaching feed pre-and post-crossover. abc values differ significantly at P= 0.04.

Treatment	pre-crossover	post crossover
Group	0.63^{a}	0.04^{b}
Individual	0.41^{c}	0.20^{b}
P-value	0.04	

Spatial, temporal and management drivers of field scale N_2O emissions and emission factors from pasture-based dairy systems

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Abstract

The emissions of the greenhouse gas nitrous oxide (N_2O) from intensively managed grazing soils typically exhibit a high spatial and temporal variability, which is attributed to uneven deposition of animal N excreta and heterogeneity in soil chemical and physical properties. A comprehensive understanding of these spatio-temporal dynamics is critical for developing effective N_2O mitigation strategies for fertilised pasture soils. We measured N_2O emissions from two dairy farms with different grazing intensity in subtropical Australia with a high spatial coverage over 3 years to assess the magnitude and controlling factors of soil-borne N_2O fluxes. The analysis highlighted a non-linear response of N_2O emissions to increasing soil nitrate availability and cumulative rainfall with higher N_2O emissions observed immediately after grazing, due to increased incidence of N deposition from animal excreta and low plant N uptake. The spatial distribution of N_2O fluxes and soil nitrate contents reflected the effect of animal treading and excreta N deposition with N_2O fluxes in the proximity of field gateways 11 times higher than the field average. Therefore, integrating the spatial management of N loads into improved farming practice has therefore significant scope to reduce N losses from dairy grazing systems. Additionally, average annual N_2O emissions were 7 times higher (12.54 ±4.38 kg N_2O-N ha^{-1} y^{-1}) in the high grazing intensity farm than in the low grazing intensity farm (1.51 ± 0.65 kg N_2O-N ha^{-1} y^{-1}). This corresponded to an emission factor (EF) of 1.07% and 0.16% for the high and low grazing intensity farm, respectively. However, the GHG intensity was lower in the high intensity system (0.68 vs 0.87 kg CO_2-eq per kg of fat and protein corrected milk y^{-1} for the high and low intensity system, respectively) suggesting a higher efficiency of the intensive system.

Keywords: Nitrous oxide; grazing systems, temporal variability, spatial variability, greenhouse gases

Lameness detection though classification of basic gait metrics

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Visual lameness scoring is a subjective method for assessing cattle mobility, which is time consuming, and requires training to perform systematically. Automatic lameness detection is desired to improve the level of accuracy and ability to detect small changes in locomotion that are critical for early detection of lameness. To this end, 73 cows (Holstein-Friesian, 1 to 7 lactation cycles, median 3 lactation cycles) were recorded by a system consisting of four 3D sensors placed alongside and overhead the exit of an automatic rotary milking dairy in Camden, NSW. A colour camera recorded cow passings from the side, which were scored by two skilled lameness scorers according to the Dairy Australia Healthy Hooves scoring system. The 3D positions of hooves were detected in each frame using a Convolutional Neural Network, resulting in a trajectory in space and time. Hoof placements were determined by thresholding hoof velocity, and subsequently 52 gait metrics were extracted, including stride length, step overlap, and maximum hoof velocities. 25 of these metrics were derived from only the static location and timing of each hoof placement, while the remaining 27 related to the trajectory of the hoof mid swing. Lameness scores were binarised into two classes, non-lame cows (score 0, n=36) and lame cows (scores 1, 2, 3, n=37). Linear discriminant analysis on the gait metrics was performed to classify each cow passing into a lameness score. Leave-one-out cross-validation was used, and a comparison was made between using only the static-hoof gait metrics (25 metrics), versus using all available gait metrics (52 metrics). The classification accuracy on static hoof gait metrics (0.59) was higher than when off ground hoof dynamics (0.51) were used. While the absolute accuracies are low, the relative performance difference indicates that a complete hoof trajectory is not required for visual lameness score prediction when linear discriminant analysis is used.

Additional keywords: lameness scoring, animal welfare, automation, precision agriculture

A financial assessment of pasture-based AMS

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Abstract

Adoption rates of Automatic Milking Systems (AMS) in Australia have been lower than in other developed countries. The reasons of this are unclear but could be related to greater initial investment, increased costs and/or lack of demonstration of the benefits of the technology in comparison to conventional milking systems (CMS). The aim of this study was to assess the current economic situation of pasture-based AMS in comparison to CMS and identify physical key performance indicators with a high impact on profitability of AMS farms. The database utilised included three financial years (15/16, 16/17, 17/18) of physical and economic information from 14 AMS and 113 CMS farms located in the main Australian dairy regions. For unbiased comparison, all CMS used were within the same range of herd size than AMS (120 to 360 cows). Data were analysed in R Software using linear mixed modelling. Gross income, variable costs, labour costs, earnings before interests & taxes (EBIT) and return on assets (ROA) were similar between systems. AMS farms had lower net income -i.e. profit available to pay tax when all cash and non-cash costs are covered- due to higher overhead costs, depreciation and finance costs. AMS had greater shed power, dairy supplies and repairs and maintenance, but lower artificial insemination and herd test costs (Table 1). Labour efficiency (Kg milk solids/full time equivalent) and robot efficiency (Kg milk solids/robot. day) were identified as two important determinants of profit in AMS. Both indicators were associated with lower overhead costs and higher EBIT and ROA. Some costs appear to be higher in AMS than in CMS, however some AMS farms are achieving good economic performance by reaching high labour and robot efficiency. Given the wide range of economic performance between AMS farms, there is a potential to make the system more profitable by improving technical efficiency.

Key words: economic analysis, automatic milking systems, key performance indicators

Table1. Predicted means of the main physical and economic indicators ($/Kg milk solids)

Item	Milking System		
	AMS	CMS	P-value
Total usable area (ha)	190	185	0.84
Milking area (ha)	95	116	0.061
Number of milking cows	221	255	0.051
Stocking rate (cows/usable area)	1.15	1.39	0.126
Milk production (kg MS)	105,924	128,563	0.034
Milk solids/ha	542	667	0.093
Solids/cow	487	506	0.33
Fat (%)	4.0%	4.2%	0.066
Protein (%)	3.3%	3.4%	0.009
Grazed pasture (t)	5.5	6.3	0.23
Cows/FTE	95	92	0.676
Solids/FTE	45,629	45,864	0.948
Gross farm income	7.18	6.91	0.153
Milk income	6.35	6.09	0.018
Total variable costs	3.60	3.54	0.78
Total herd costs	0.25	0.30	0.119
AI and herd test	0.06	0.12	0.001
Animal health	0.15	0.14	0.68
Calf rearing	0.04	0.04	0.894
Total shed costs	0.46	0.23	<0.001
Shed power	0.24	0.12	<0.001
Dairy supplies	0.23	0.12	<0.001
Total feed costs	2.86	3.00	0.419
Total overheads	3.31	2.53	<0.001
Cash overheads	1.28	1.24	0.785
Registration and insurance	0.12	0.12	0.736
Repairs and maintenance	0.53	0.37	<0.001
Other overheads	0.23	0.21	0.424
Employed labour	0.41	0.54	0.204
Imputed*	1.11	0.89	0.123
Depreciation	0.77	0.27	<0.001
Finance (interest+ lease)	1.19	0.61	<0.001
EBIT	0.31	0.75	0.079
Net farm income	-0.89	0.14	<0.001
Return on total assets	1.1%	2.3%	0.115

AMS- Automatic Milking Systems CMS- Conventional Milking Systems

*Imputed owner/operator and family labour

Timing of feed bunk access and the growth of cattle

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Abstract

Limited feeding space in feedlots and in freestall dairies can determine the eating pattern of cattle within a pen based on social rank. Our objectives were to determine the impact of feed bunk access timing relative to the timing that feed was offered on the behavioural pattern and average daily gain (ADG) of cattle. Accelerometer-based ear tag sensors were fitted to 100 cattle (mixed *Bos taurus* and *Bos indicus* breed, mixed colour and sex) at feedlot induction offered a high grain total mixed ration once daily at around 1000h. The time that feed was offered for days 3 to 6 post induction was recorded alongside the timing and duration of eating and rumination as determined by SCR eSense™ ear tags (SCR Engineers Ltd., Netanya, Israel). The liveweight of animals was determined on day 0 and 39 and 75 on feed. Animals were grouped according to their access to feed bunk at the time of feed offer as follows: animals that had no access (Group 0) -, had access for 1 day (Group 1) -, had access for 2 day (Group 2) -, had access for 3 day (Group 3) -, and had access for all 4 days (Group 4) - out of 4 observation days within 1h of feed offer. We analyzed data restricting only to heifers as they were represented across all group levels. Eating time, rumination time and mid-feed ADG (day 35) differed significantly (P<0.05) between groups. Group 0 had significantly reduced (P<0.05) eating time, rumination time and ADG compared to other groups. However, final ADG (day 75) of Group 1 to 4 did not differ significantly. Therefore, segregation of animals that are consistently late at feed and customized feeding regimes can improve feeding behaviour and performance of cattle in feedlot and in intensive freestall dairy systems.

Additional keywords: Cattle; feed access timing; animal segregation; ADG

Effect of Heat Stress on Milk Solids Production of Cows at Different Stages of Lactation

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Heat stress (HS) in dairy cows occurs when the animals body temperature exceeds its thermoneutral zone. The Temperature Humidity Index (THI) is commonly used to estimate the impact environmental conditions on cows. Heat stress has been shown to reduce feed intake and milk production of lactating dairy cows, but there is little information comparing the impact of heat stress on cows at different stages of lactation under the same weather conditions. In this study, data from The University of Melbourne Dookie robotic dairy in northern Victoria was used to investigate the effect of heat stress (HS) on the milk solids and liveweight of cows from three calving groups. The farm has a pasture-based production system with voluntary cow traffic. Daily production records of each cow were obtained from the Lely automatic milking machines and weather records at 15-minute intervals from a station on the farm. The analysis was performed on data collected from 1 to 25 February 2017, which included a 7-day baseline period (prior to HS event), a consecutive 4-day HS period (average THI of each day > 72), and a 14-day recovery period. Results showed that milk solids production decreased by 12% in mid (n= 70) and late (n= 18) lactation groups, and production of milk solids from both groups recovered to pre-HS level after 4 and 5 days respectively. In the early lactation group (n= 16), milk solids production was increased in the pre-HS period at a rate of 0.09 kg/day. However, the rate of increase slowed to 0.03 kg/day during the HS event. Importantly the cows in early lactation did not return to their pre-HS rate of production increase during the 14-day recovery period, indicating that the HS event had an on-going effect on milk production. Further research is required to determine the impact of HS over the whole lactation, with particular emphasis on cows in early lactation.

Additional keywords: automatic milking system, heat stress, milk solids, liveweight

Total dry matter intake response of dairy cattle to decreasing lucerne (*Medicago sativa*) pasture allocations within a partial mixed ration system

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The effect of pasture allocation on total dry matter intake of dairy cattle grazing pure lucerne (*Medicago sativa*) pasture was investigated in a sub-tropical Partial Mixed Ration (PMR) dairy system. The study took place at the Gatton Research Dairy, South-East Queensland, Australia, with a 28-day adaptation period followed by two eight-day measurement periods during August and September 2018. The experiment was a completely randomised design with thirty multiparous Holstein-Friesian dairy cows randomly assigned to one of 10 treatments (three cows per treatment). Treatments were two levels of PMR, high (14 kg dry matter (DM)/cow.day) or low (7 kg DM/cow.day), and five levels of pasture allocation. Pasture allocations were restricted to reach targeted residual pasture heights (Table 1). Pasture intake and pasture utilisation were measured using the pasture disappearance method (Benvenutti *et al.* 2016). PMR intake was calculated as the difference in total kg DM offered and the refused kg DM. Combined pasture and PMR intake was targeted at 21 kg DM/cow.day, and the two levels of PMR were formulated targeting an equal metabolisable energy (ME) intake of 220 MJ/cow.day when combined with the targeted pasture intake and quality.

There was no significant difference for all measurement parameters between periods (P>0.05), so cross-period results are presented. Total DM intake (DMI) was not statistically different between the two levels of PMR (P>0.05) and the DMI of PMR did not differ between pasture treatments within PMR levels, averaging 7.7 and 15.1 kg DM/cow.day for low and high groups respectively. DMI was significantly related to residual pasture height (% of initial) - for every 10% increase, DMI increased by 0.9 kg/cow.day. DMI was maximised when at least 4.7% of the allocated area remained ungrazed, irrespective of PMR level, and therefore allocating lucerne pastures to ensure an area remains ungrazed will maximise DMI in PMR dairy systems.

Table 4. Targeted and average actual pasture allocations and grazing patterns for all treatment groups across two periods (values in columns labelled * = cm, ** = % and *** = kg DM/cow.day)

Group	PMR Level	Target Residual Height*	Target Area Grazed**	Pasture Allocated***	Actual Residual Pasture Height*	Actual Area Grazed**	Pasture Intake***	Total Intake***
1	High	5	100	5.1	15.6	99.0	3.6	18.9
2	High	12	100	8.4	15.2	97.9	5.9	20.9
3	High	19	100	10.4	19.6	97.6	6.1	21.1
4	High	25	95	18.7	27.6	75.5	6.7	22.0
5	High	25	80	25.3	28.7	84.6	8.0	22.9
6	Low	5	100	12.8	13.7	98.9	9.7	17.5
7	Low	12	100	16.0	15.2	97.5	11.4	19.0
8	Low	19	100	20.0	20.0	99.2	11.5	19.2
9	Low	25	95	35.4	26.6	95.3	13.8	21.5
10	Low	25	80	49.3	30.4	78.9	13.9	21.6

Additional keywords: Grazing Management, PMR, Pasture Allocation

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We gratefully acknowledge Dairy Australia and the Queensland Department of Agriculture and Fisheries for funding this work.

Association between bodyweight changes with feed and water intake, defecation and urination of dairy cows

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Intake variability is affected by animal factors such as body weight (BW), change in BW and fat-corrected milk production. Intake prediction models based on animal characteristics as input have been developed in the past. However, high fluctuation in BW between and within animals diurnally and even hourly can affect model accuracy. These fluctuations are associated with inflows (feed and water) and outflows (urine, faeces) of material, together with heat losses. Although the latter cannot be measured in the field, we envisaged that recent and future advancements in sensor-derived animal monitoring would allow urine, faeces and water intake to be measured automatically; therefore, BW could be corrected by these factors and accuracy of grazing intake could be increased. Thus, this study aimed to quantify changes in animals' body weight (BW) due to inflow and outflow factors that contribute to BW fluctuations. Ten cull Holstein cows were offered 4 kg of lucerne cubes *as fed* (DM=88%) twice daily (morning and afternoon) for approximately one hour for five consecutive days in a scale box, while 10 kg water was given once in the afternoon. Urine and faeces were manually collected using a bucket and weighed. Continuous weight was recorded at 3.3 Hz from the time cows stepped on the scale until the end of eating and drinking. A BW change (BWC) model was developed using a linear mixed model to study the association between BWC, intake and outputs. BWC were estimated by subtracting BW before eating (average of 1-minute weight) from BW after eating (average of 1-minute weight). Results indicated that on average cows gained 1.04 and 1.02 kg of BW for every 1 kg (*as is*) of cube consumed or water drunk, and lost 0.74 and 1.14 kg of BW for every kg of urine or faeces (*as is*), respectively. The model clearly showed that inflows and outflows had significant ($P<0.05$) effect on BW changes due to changes in gutfill which 25-28% of the BW is affected by the fill. Thus, these factors have the potential to improve the estimation of daily BW and improve grazing intake estimation.

Additional keywords: intake; urination; defecation; bodyweight; dairy cows;

Microwave heat treatment can improve digestibility of lucerne hay.

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Forage quality is an important factor in livestock production, and dry matter digestibility is one of the key measures used to estimate it. Low-quality forages may limit animal production, but there is limited information about processing techniques that can be applied to enhance forage quality. This study investigated the effect of microwave (MW) heat treatment on in vitro dry matter digestibility of lucerne forage hay. An in-vitro pepsin cellulase digestion experiment was conducted with lucerne hay each treated with a 1450-W microwave oven for 0, 20, 40, 60, 80, 100, and 120 s. Genstat software 16th edition used for performing one-way ANOVA and mean comparison ($LSD_{0.05}$) on experimental data. Result revealed that dry matter percentage increased by 2.7% ($P<0.05$) when hay was treated for 120 s compared with 0s. The pepsin cellulase dry matter digestibility (PCDMD) increased by 11.3% ($P<0.05$) as microwave treatment increased from 0 to 60 s; however, PCDMD decreased as the time increased from 60 to 120 s in the results. Organic matter digestibility (OMD) and digestible organic dry matter (DOMD) increased by 14.5 and 14.4% respectively in 60 s treatment compared to 0 s ($P<0.05$). The increase in digestibility observed with up to 60 s treatment could be due to rupture of cell walls, while treatments with higher duration (i.e., 100 and 120 s) caused partial burning of the hay leading to reduced digestibility. Further research is required to understand the mechanism involved and to determine the effects on animal production, but these results suggest that MW heat treatment has the potential to improve the digestibility of hay products.

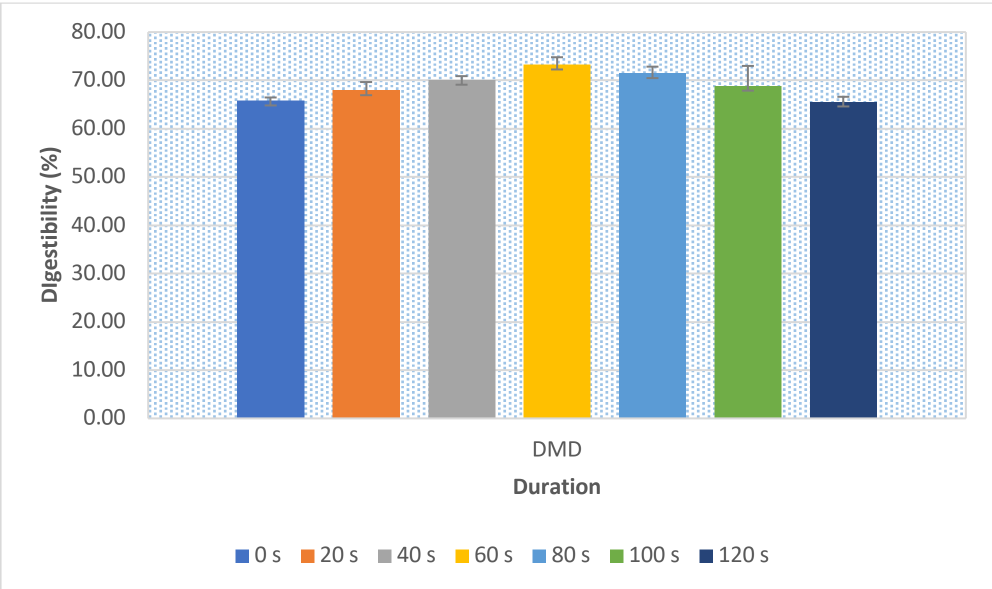

Figure 1: Effect of microwave treatment duration on dry matter digestibility lucerne hay

Additional keywords: microwave heat treatment, digestibility, lucerne hay